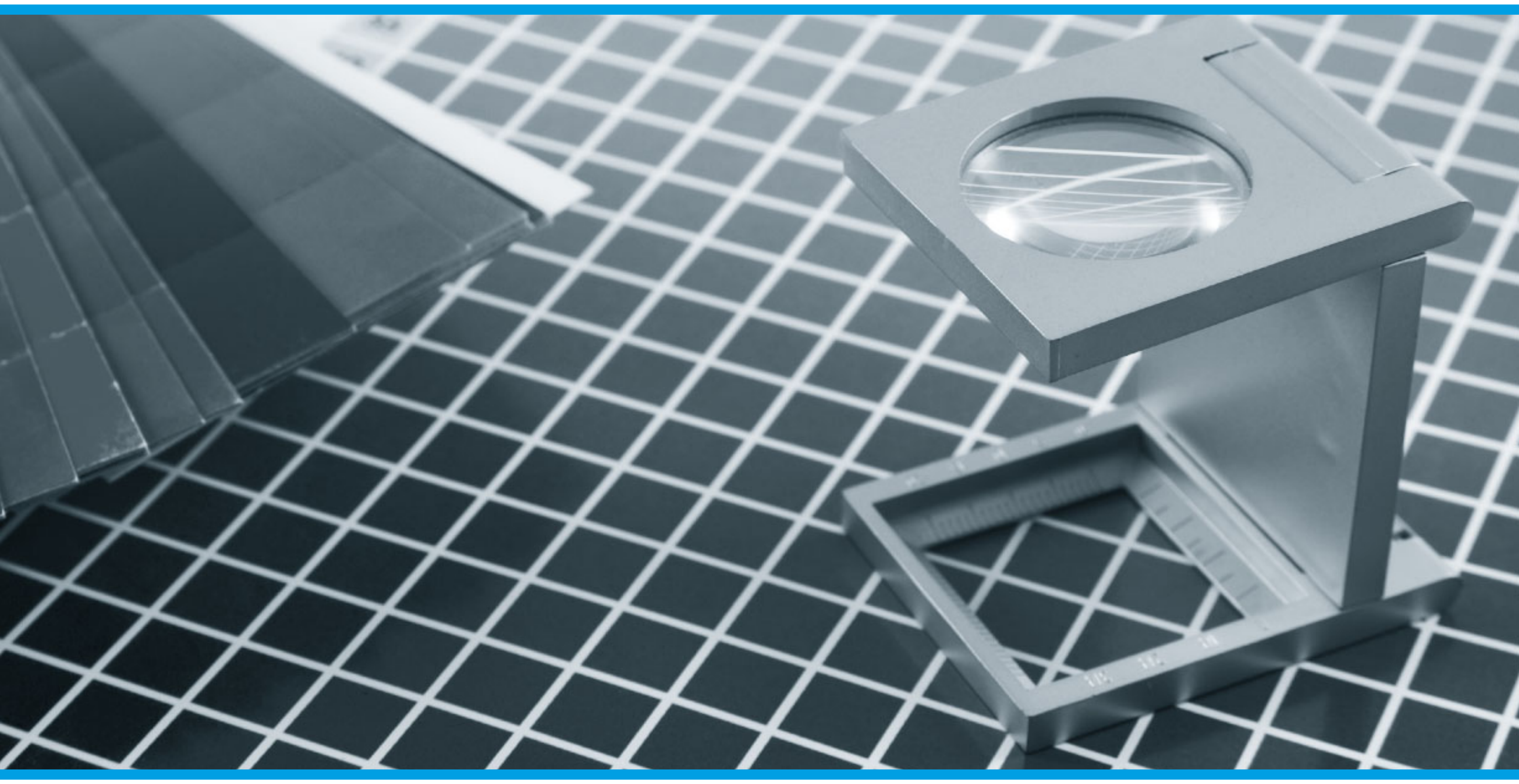
Coloristic properties of specialty carbon blacks in full tone and tinting applications for coatings

Technical Information 1464



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Contents

1. Introduction

In the paint and coatings industry the favourite black pigment in use is specialty carbon black due to its outstanding performance. Specialty carbon black is used in mass tone and tinting applications. The coloristic properties in coatings are dominated by the average primary particle size, even though specialty carbon black (SCB) do not exist as isolated primary particles. This influences the mass tone as well as the tint, for example when producing white blends based on titanium dioxide in the rutile modification. The subject of this technical information tis the theoretical basics of colorimetry involving specialty carbon black, listed as pigment black 7 in the color index.

1.1 Specialty carbon black category according to color index

Inorganic pigments

- 6- Lamp black
- 7- Specialty carbon black
- 8- Vine black
- 9- Ivory black
- 10- Graphite
- 11- Iron oxide black

Organic pigments

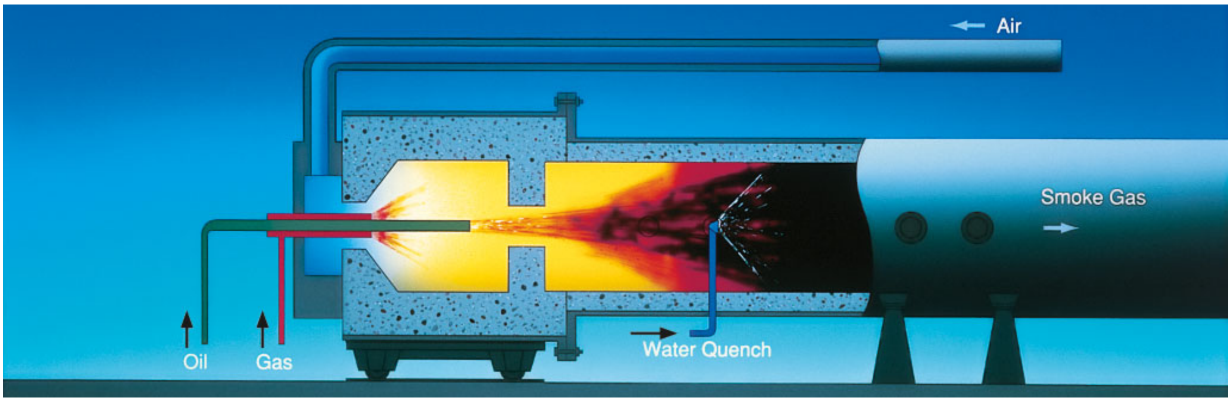
- 1- Aniline black
- 20- Anthraquinone black

1.2 Manufacturing processes

The furnace black process (figure 1) is the most common production method (95 % worldwide). In this case specialty carbon black is produced in a closed reactor (furnace) under a defined atmosphere. The temperature necessary for pyrolysis is achieved by combustion of appropriate gases; the raw material is injected into the combustion chamber through a lance. After the formation of specialty carbon black, the process mixture is quenched by injection of water; this also prevents any secondary reactions. The furnace process allows the particle sizes and structural properties of the product to be varied within wide limits.

Figure 1

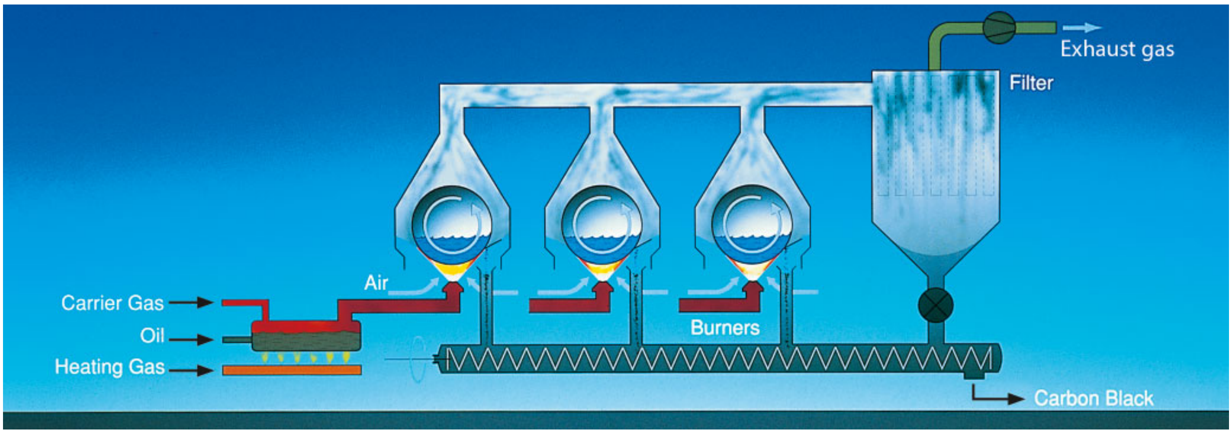
Furnace black process



In contrast to the furnace black process, during the Degussa gas black process pyrolysis occurs in the presence of atmospheric oxygen. This means that the gas black process uses an open reactor (figure 2), which is reflected in the volatile content of the resulting pigment surface. The process derives its name from the fact that the specialty carbon black feedstock is vaporized by heating and is then fed into the combustion chamber by means of a carrier gas. The specialty carbon blacks produced by this method have smaller particles. The particles' sizes can be varied in the production process, but the structure cannot be influenced.

Figure 2

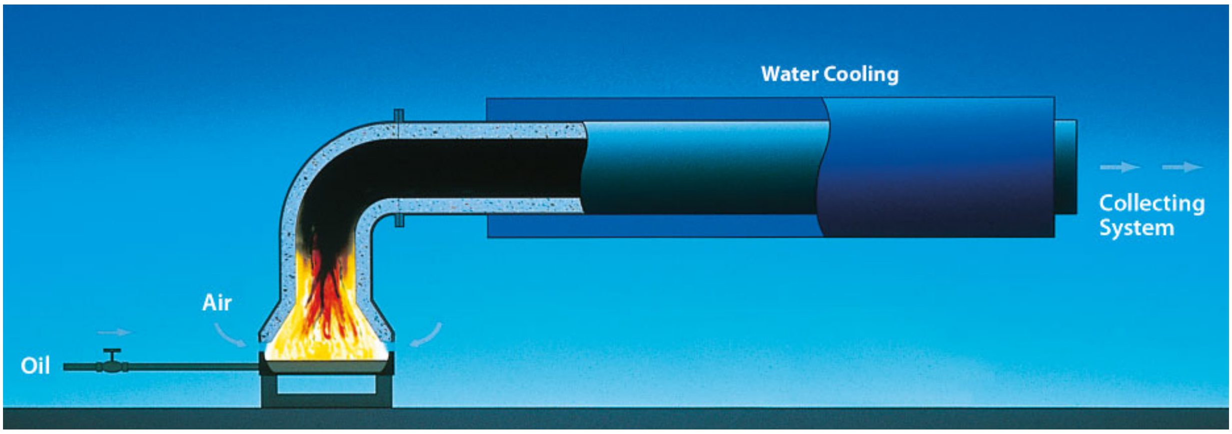
Degussa gas black process



The origin of specialty carbon black production is the lamp black process (figure 3). In this case the raw material is placed in large pans and then vaporized by the heat that is radiated from the covering hood before pyrolysis. The lamp black process is also considered as an open process with access to atmospheric oxygen, to a certain extent through a gap between the combustion pan and the exhaust hood. The particle distribution in a relatively wide range is predominated by large specialty carbon black particles.

Figure 3

Lamp black process



The particle size determines the intensity of blackness, known as jetness or optical density. Specialty carbon blacks are classified according to an internationally recognized system, which signifies the manufacturing process and the jetness. The first two letters indicate the strength of the pigment: High color (HC), medium color (MC), regular color (RC) and Low color (LC). The final letter describes the manufacturing process: The furnace (F) and the gas black (G) processes [1].

2. Basics of colorimetry

2.1 Blackness value M_Y

The blackness value M_Y of specialty carbon blacks in powder form is measured following DIN 55979. The colorimetric properties of a coating system containing specialty carbon blacks are the jetness M_Y and the absolute contribution of hue dM, which can also be named undertone [2]. The jetness determines the degree of blackness and the undertone is responsible for the optical perception in terms of hue. dM has a value for the undertone and in general corresponds to bluish if dM > 0 and to brownish if dM < 0.

$$M_Y = 100 \cdot \log\left(\frac{100}{Y}\right)$$ Blackness value

$$M_C = 100\left[\log\left(\frac{X_n}{X}\right) - \log\left(\frac{Z_n}{Z}\right) + \log\left(\frac{Y_n}{Y}\right)\right]$$ Hue-dependent blackness value

$$dM = M_C - M_Y$$ Vbsolute contribution of hue

2.2 The CIE L*a*b* color space

The norm color values are defined for the corresponding light source (D65) and observer (10°) with X_n=94,81, Z_n=107,34 and Y_n=100,0. Y is related to the observation of lightness, which can be correlated to L* in the CIE L*a*b* color space. It was designed for a better compatibility with the human color sense. The lightness L* and the color coordinates a* and b* form this color space. Their calculation is based on the trisimulus values X, Y and Z.

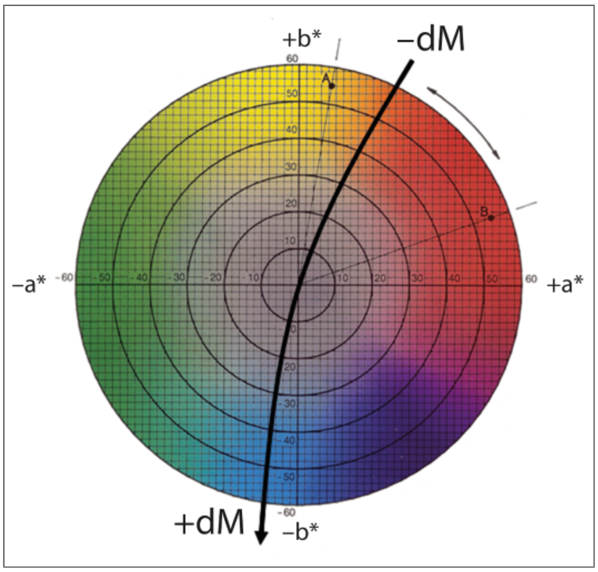
$$L^* = 116 \cdot \sqrt[3]{\frac{Y}{Y_n}} - 16$$ Lightness

$$a^* = 500\left[\sqrt[3]{\frac{X}{X_n}} - \sqrt[3]{\frac{Y}{Y_n}}\right] \quad b^* = 200\left[\sqrt[3]{\frac{Y}{Y_n}} - \sqrt[3]{\frac{Z}{Z_n}}\right]$$ Color coordinates

The correlation between the absolute contribution of hue and the color coordinate b* can be seen in figure 4. A negative b* value stands for a bluish undertone with dM > 0. For b* > 0 in the yellow (orange) region the dM value is negative.

Figure 4

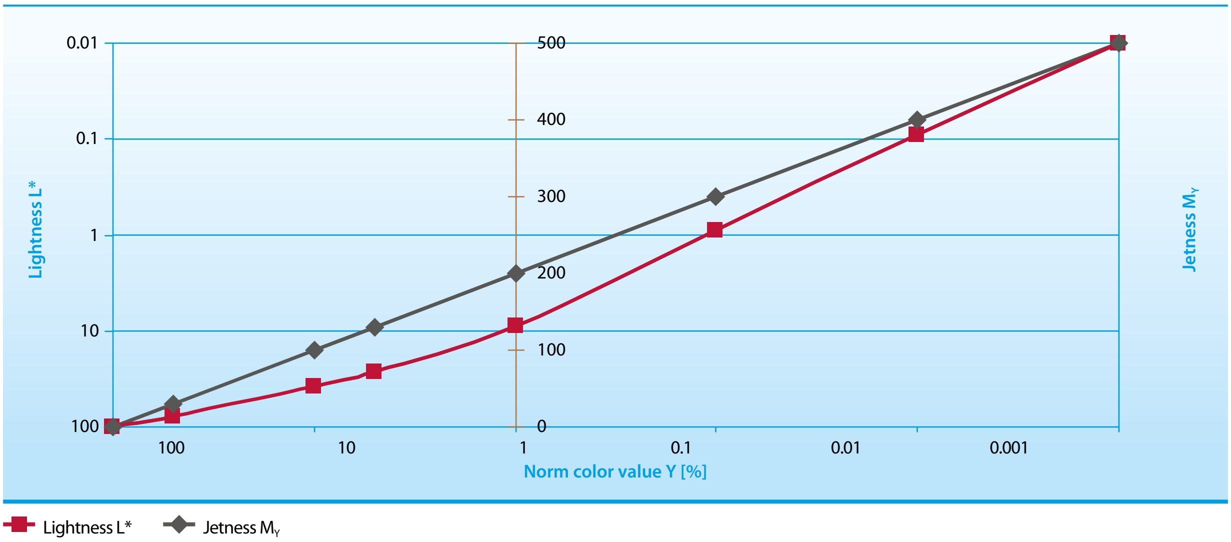
Absolute contribution of hue dM displayed in the a*b* color coordinate system



The relationship between L* and M_Y as a function of the color norm value Y (reflection) is plotted in figure 5 and can also be calculated [3].

Figure 5

Correlation between lightness L* and jetness M_Y



2.3 Degree of reflection

According to DIN 53235 and DIN 53943 the jetness is a dimension for the intensity of coloring (chroma), which rises with increasing saturation and decreasing lightness. Black pigmented systems in general are considered as not colorful, such that the concept of saturation as a degree of colorfulness cannot be applied. Therefore, the increase in jetness of black pigmented systems is defined as a decrease in lightness [4]. This correlation can be seen in figure 6.

Figure 6

Correlation of the incident light reflection with the jetness M_Y

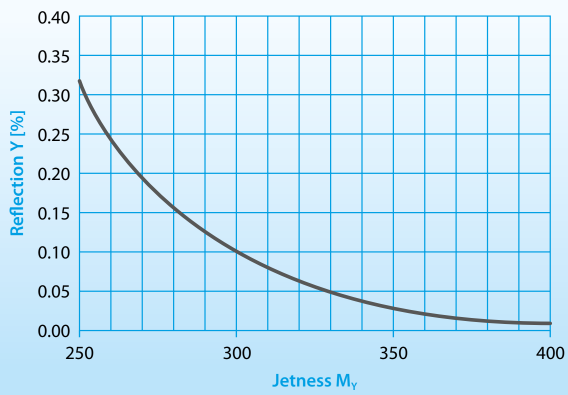


Table 1

Color depending on the absorption and reflection levels

Absorption [%]	Reflection Y [%]	Jetness M_Y	Color	CBP type
0	100	0	white	
90	10	100	grey	
99	1	200	black	
99.9	0.1	300	deep black	
99.99	0.01	400	deepest black	
99.60-99.75	0.4-0.25	240-260		RCG
99.84-99.92	0.16-0.08	280-310		MCG/HCG
99.92-99.95	0.08-0.05	310-330		HCG

2.4 Measuring geometry

The measurement method described in DIN 55797 was established for a better differentiation in the region of lowest reflection, allowing the determination of the blackness value for high jet coatings. The calibration standard in use is a black hollow body. The measuring geometry can be varied between 45°/0° or 0°/45° and d/8° or d/0°. The choice depends on the nature of the black coating and its surface texture. 45°/0° is preferred for deepest black with a glossy surface (figure 7). In case of d/8° a spherical configuration called Ulbricht-sphere is used to create diffuse light (figure 8). This spherical design contains a gloss trap that is able to eliminate 4 % of the gloss in the open state and is thus defined as the standard operating conditions (specular component excluded).

Figure 7

45°/0° geometry for measuring the blackness value and the undertone

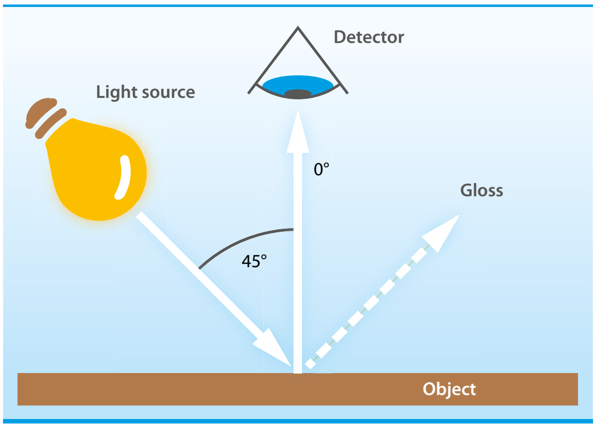
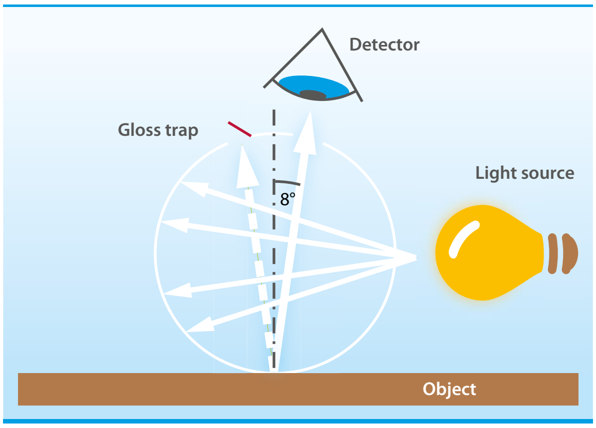


Figure 8

d/8° geometry for measuring the blackness value and the undertone

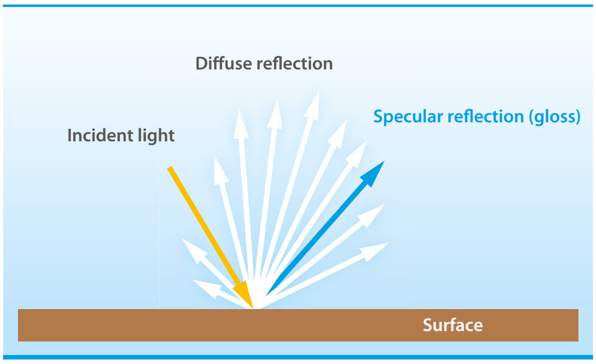


2.5 Effect of surface reflection

Gloss is an optical property that is defined as the ability of a surface to reflect light into the specular direction as described in figure 9. If the gloss trap remains closed all the reflected and scattered light would be part of the detected light. Therefore, the jetness measured in this case would be lower.

Figure 9

Diffuse and specular reflections of light on plane surfaces



3. Coloristic properties of specialty carbon blacks in full tone coating applications

The colorimetric properties concerning jetness and undertone are mainly influenced by the following physical and chemical parameters:

- Mean primary particle size
- Measuring conditions
- Form of delivery
- Functionalized pigment surface
- Pigment concentration

3.1 Mean primary particle size

The average primary particle size of each specialty carbon black is related to its jetness. In order to achieve this jetness in the final product, it is of paramount importance to stabilize the pigment within the black coating. This is also valid for the undertone, which can be blue or brown. In solvent-borne coating systems the use of post-treated specialty carbon blacks are recommended, whereas in water based formulations the non-treated pigments are more suitable. The following table shows the mill-base and let down composition for different specialty carbon blacks conducted in a PU-based coating.

Table 2

Coating formulation for an acrylate based resin system

Mill base for 2K-PU coating	
DEGALAN® VP 4157 L, 60 % (from Evonik Röhm GmbH)	68.75 g
Butyl acetate, 98 %	23 g
After-treated specialty carbon black	8.25 g
Total	**100 g**
Let down for 2K-PU coating	
Mill base	26.5 g
DEGALAN® VP 4157 L, 60 %	47.5 g
2K-diluent	20 g
Desmodur® N 75 MPA, 75 % (from Bayer Material Science)	6 g
Total	**100 g**
Total quantity of specialty carbon black	**2.2 %**

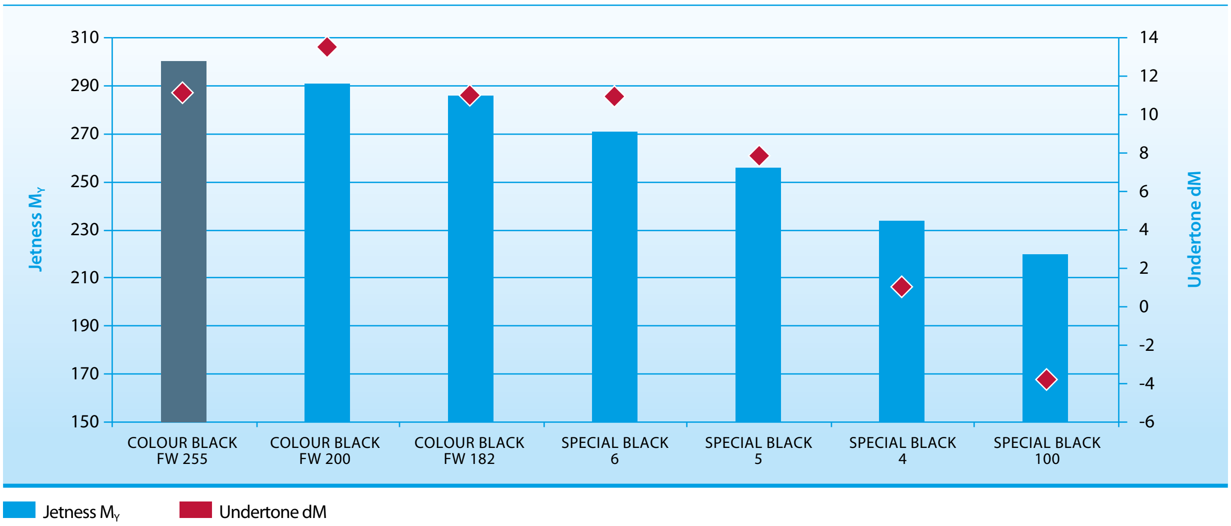
Table 3

Jetness and primary particle size of after-treated specialty carbon blacks

	Type	Jetness M_Y	Particle size [nm]
COLOUR BLACK FW 255	HCF	300	11
COLOUR BLACK FW 200	HCG	291	13
COLOUR BLACK FW 182	HCG	286	15
SPECIAL BLACK 6	HCG	271	17
SPECIAL BLACK 5	MCG	256	20
SPECIAL BLACK 4	RCG	234	25
SPECIAL BLACK 100	LCF	220	51

Figure 10

Colorimetric properties of post-treated specialty carbon blacks in solvent-borne 2K-PU coating



The after-treated furnace black COLOUR BLACK FW 255, being the finest specialty carbon black among the analyzed pigments, achieves the highest jetness with $M_Y = 300$ in this coating system. The blackness value and the undertone decrease from one pigment to another according to the rising primary particle size up to SPECIAL BLACK 100.

Table 4

Coating formulation for a water-borne Polyurethane system

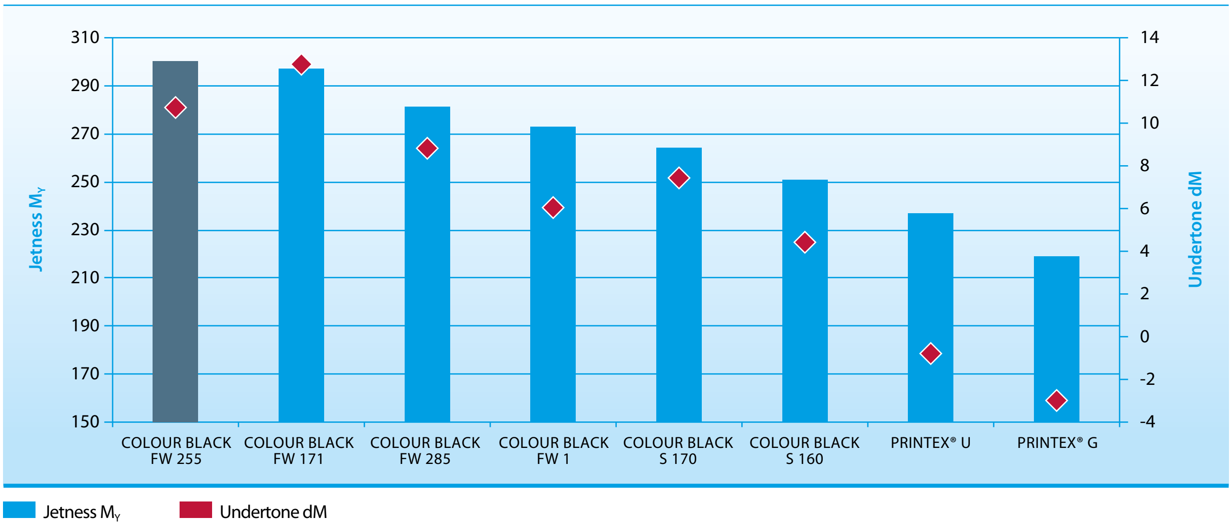
Binder free mill base	
Distilled water	44.5 g
TEGO Dispers® 760W, 35 %	36 g
TEGO Foamex® 830	1 g
DMEA (neutralization agent)	0.5 g
Specialty carbon black	18 g
Total	**100 g**

Let down with 1K-PU binder system	
Mill base	8.5 g
1K-PU binder system	91.5 g
Total	100 g
Total quantity of specialty carbon black	**1.5 %**

Formulation of 1K-PU binder system	
Alberdingk® U9800, 35 % (from Alberdingk & Boley)	75.8 g
Butyl Glycol	13 g
Distilled water	10 g
BYK® 024	0.6 g
TEGO WET® 280	0.4 g
DMEA (neutralization agent)	0.2 g
Total	**100 g**

Figure 11

Colorimetric properties of non-treated specialty carbon blacks in water-borne 1K-PU coating



The same effect on the jetness, as with after-treated specialty carbon blacks, can be observed in figure 11 with non-treated pigments in water-borne PU coatings. Additionally, the evolution of the undertone is related to the particle size. Finer pigments give a blue undertone and coarser ones appear brown in mass tone applications. The main contribution to jetness and undertone is the mean primary particle size, even though it is not possible to grind down to the particle state during dispersion. The aggregates are the smallest dispersible unit of a specialty carbon black in coating formulations. The particular advantage of COLOUR BLACK FW 255 is the universal use of this pigment in solvent- and water-borne coatings.

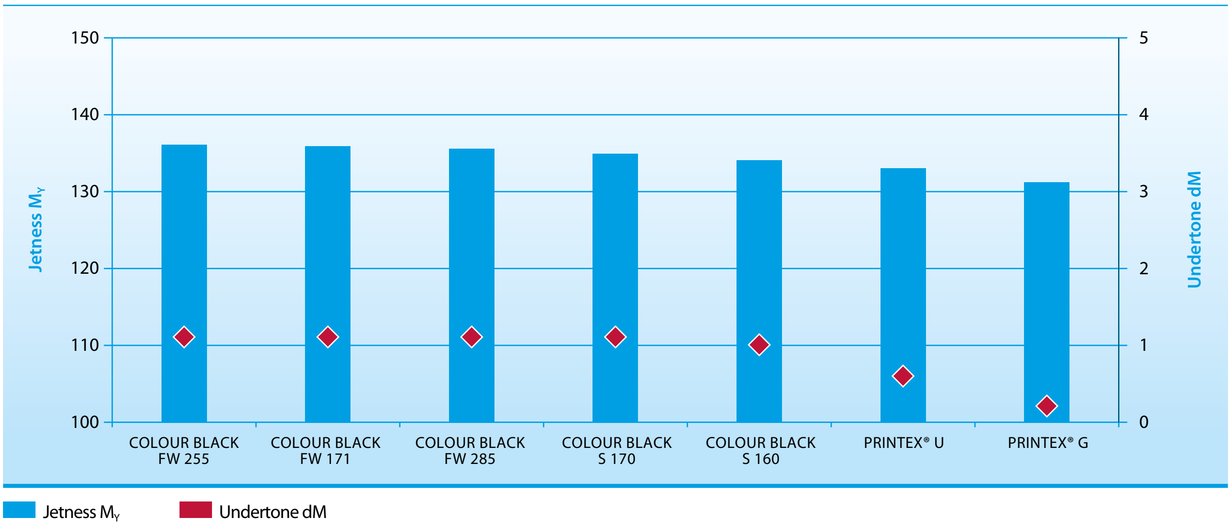
3.2 Measuring conditions

The results on jetness, including the undertone of a PU-based coating, measured with an open gloss trap are displayed in figure 11. These samples were measured again under different operating conditions (specular component included). Due to the closed gloss trap, the results changed regarding jetness and undertone (figure 12). The Y values are leveled out by 4 % of the additional gloss. Therefore, the jetness is lower and also the relative difference between the M_Y values.

The impact of gloss on the jetness is quite significant due to the trapped light inside the Ulbricht-sphere, also described in chapter 2.5.

Figure 12

Colorimetric properties of specialty carbon blacks in water-borne 1K-PU coating measured with d/8° geometry and closed gloss trap



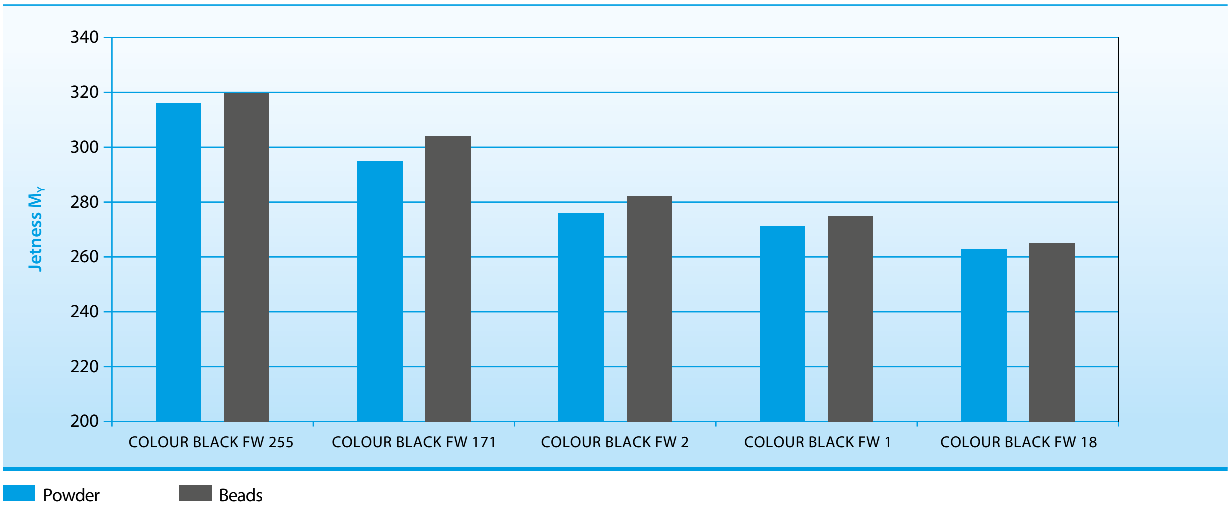
3.3 Form of delivery

Generally, specialty carbon blacks are delivered either as powder or beads. In the field of coatings both types are in use. Particularly for polymer applications, the beaded form is established. The data from an investigation, as shown in figure 13, show different coloristic properties depending on the use of powder or beads in water-borne PU coatings.

In terms of jetness the beaded material achieves a better performance than the powdered pigment. From a technical point of view the collision force during the dispersion step should be higher in case of beads. This effect leads to better dispersability of the pigment and therefore could be an explanation for higher jetness in the coating film.

Figure 13

Jetness of specialty carbon black powder and beads in water-borne 1K-PU coating



3.4 Influence of after-treatment

After the production process, specialty carbon blacks can be treated in order to obtain more functional groups on the pigment surface. Furnace and gas blacks reveal enhanced wetting and dispersing properties in solvent-borne coating systems after additional processing. This is due to enhanced interactions between the treated pigment surface and the solvent or binder molecules. Selected specialty carbon blacks and their after-treated products in figure 14 were analyzed in the alkyd-melamine based stoving enamel. Regarding the undertone dM, the surface treatment contributes to a better stabilization of the pigment within the coating which appears as bluish for the high jet and jet grades. All after-treated specialty carbon blacks show a higher dM value than without a functionalized surface. With increasing particle size the difference between the after-treated and non after-treated pigments becomes smaller. In the dM value range below zero, the undertone is considered as brown.

Figure 14

Coloristic influence of surface groups on specialty carbon black undertone in alkyd-melamine coating

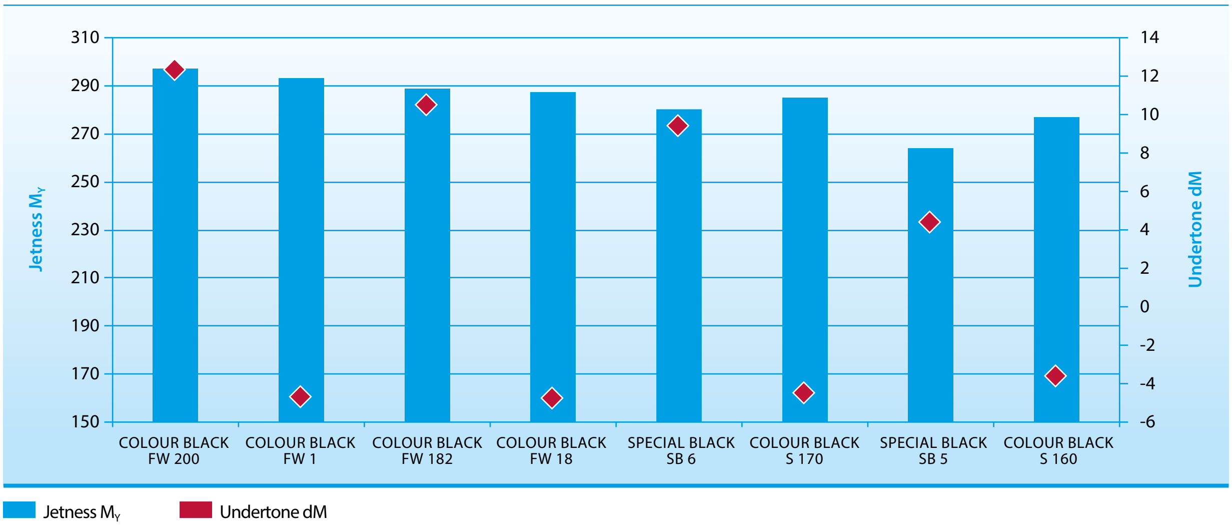


Table 5

Coating formulation for an alkyd-based resin system

Mill base for alkyd-melamine stoving enamel	
Alkydal® F 310 SN, 60 % (from Nuplex Industries)	68.75 g
Shellsol A	23 g
Specialty carbon black	8.25 g
Total	**100 g**

Let down for alkyd-melamine stoving enamel	
Mill base	26.5 g
Alkydal® F 310 SN, 60 %	33 g
MAPRENAL® MF 800/55IB, 55 % * (from Ineos Melamines)	24 g
Diluent	16.5 g
Total	**100 g**
Total quantity of specialty carbon black	**2.2 %**

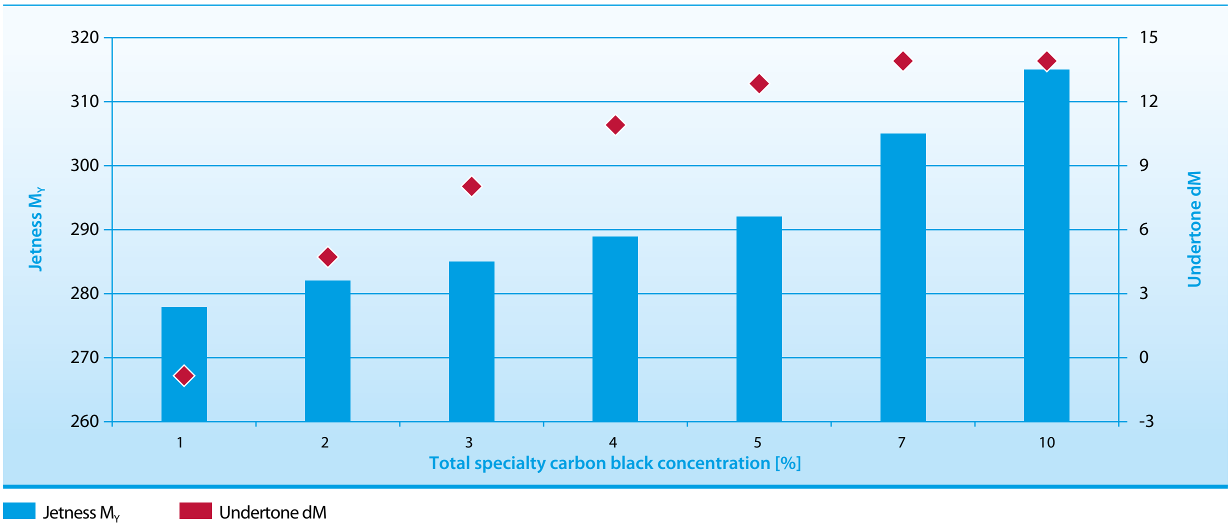
* Weight ratio Alkydal (solid): Maprenal (solid) = 70:30

3.5 Pigment concentration

In a first step the effect of pigment concentration on the colorimetry was analyzed by means of COLOUR BLACK FW 200 in the alkyd-melamine coating, followed by COLOUR BLACK FW 255 in a water-borne polyurethane coating.

Figure 15

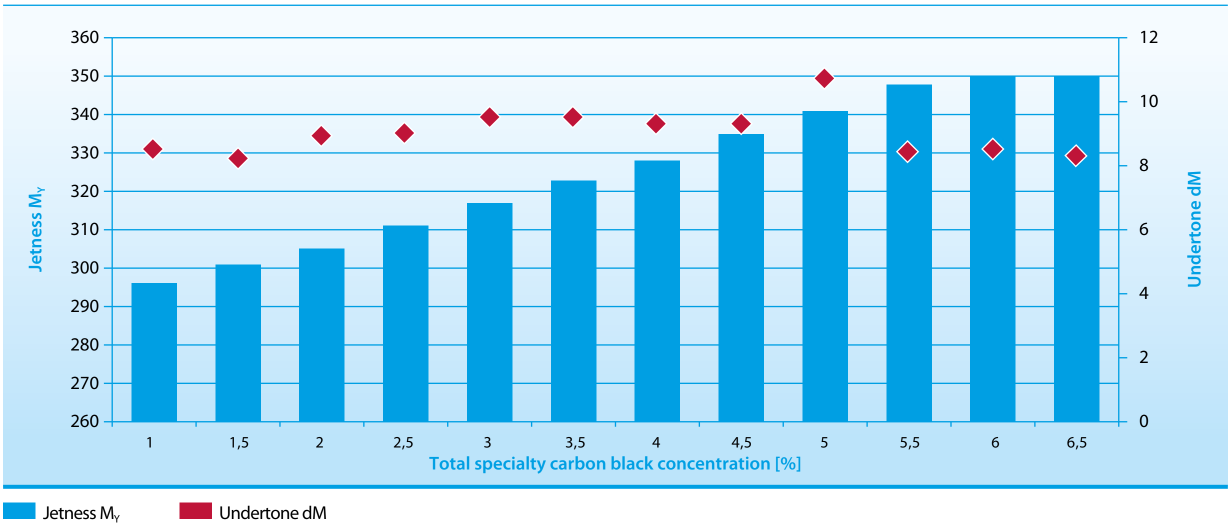
Concentration effect of COLOUR BLACK FW 200 on colorimetric properties in alkyd-melamine coating



The jetness on the one side and the undertone on the other are measured as a function of the total specialty carbon black concentration (figure 15) in the range between 1 and 10 %. COLOUR BLACK FW 200 as a high jet pigment, starts with $M_Y = 282$ at 2 % and achieves a jetness of 315 at 10 %. The undertone increases up to 7 % resulting in a dM value of 14.

Figure 16

Concentration effect of specialty carbon black COLOUR BLACK FW 255 on colorimetric properties in water-borne 1K-PU coating



For COLOUR BLACK FW 255 the same investigation has been conducted in a water-borne coating system. The concentration row of COLOUR BLACK FW 255 started with 1 % and reached 6.5 % at the end (figure 16). The highest jetness is reached at a concentration level of 6 %, due to a constant increase up to $M_Y = 350$. The medium undertone around 9 seems to be independent from the pigment loading. Even the mill base viscosity, which should be affected by higher pigment concentrations, does not show any significant changes.

Among the considered parameters listed in chapter 3, it is the mean primary particle size of the specialty carbon blacks which has the major influence on the jetness. Therefore, the mean particle size determines the level of blackness in a full tone coating. Optimized formulations with additives in form of synergists were not part of this investigation.

4. Coloristic properties of specialty carbon black in grey coatings

4.1 Tint and tinting strength

The determination of relative tinting strength is important for the use of specialty carbon blacks in grey coatings or white blends. The tinting strength results in the ability of a specialty carbon black to darken a white pigment, in this case titanium dioxide. The tinting strength is measured following ISO 787-16 and ISO 787-24 and compared to IRB3 (industrial rubber black) standard that is assumed to be 100 %.

The tint value according to ASTM D 3265 also indicates the ability to darken a white pigment, in this case zinc oxide. The same reference IRB3 is used as the standard.

$$G_Y = 100 \cdot \log\left(\frac{100}{Y}\right)$$ Greyness value

$$G_C = 100 \cdot \left[\log\left(\frac{X_n}{X}\right) - \log\left(\frac{Z_n}{Z}\right) + \log\left(\frac{Y_n}{Y}\right)\right]$$ Hue-dependent grey value

$$dG = G_C - G_Y$$ Absolute contribution of hue

4.2 Greyness value G_Y

The greyness value G_Y and the absolute contribution of hue dG are measured according to the internal method PA 1560, which is submitted for ISO standard. G_Y increases with decreasing particle size and therefore represents an indirect method for determining the mean primary particle size. Hue dG is fundamentally influenced by the scatter and absorption behaviour of small particles. Coarse specialty carbon black particles in the white mixture create a blue undertone, while fine particles produce a red or brown hue. In fact, the opposite effect is demonstrated between full shade application and white reduction.

4.3 Relative tint strength

A grey coating based on zinc oxide as the white pigment and various specialty carbon blacks was analysed regarding the relative tint (figure 17) as a function of the specialty carbon black particle size. In the formula, the terms X_n, Y_n and Z_n are known as norm color values depending on the light source and observer, also described in chapter 2.1. The lightness in case of a neutral grey tone corresponds to $L^* = 50$.

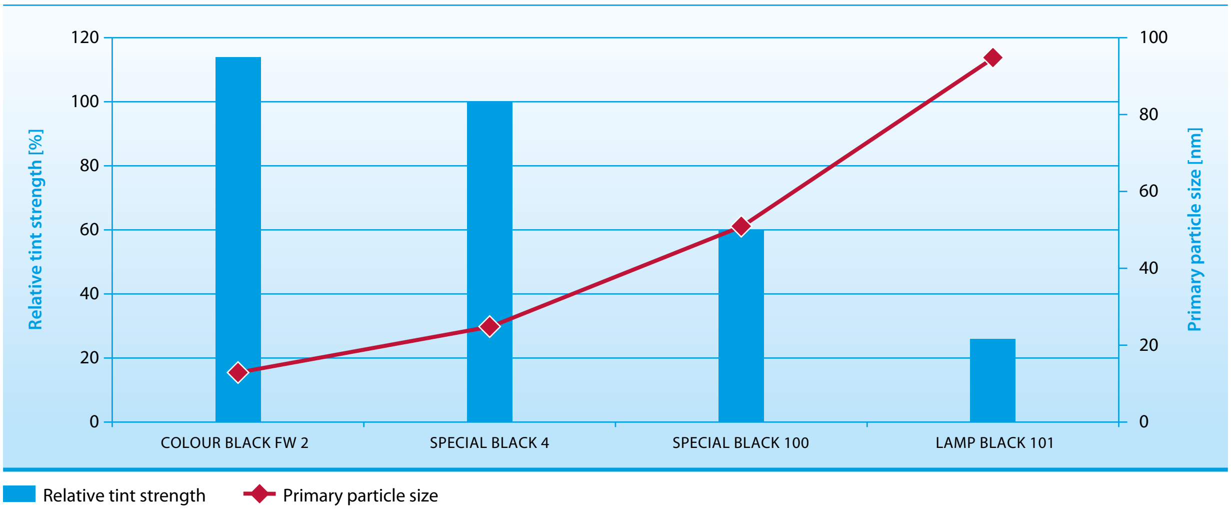
Table 6

Jetness, particle size and relative tint of various specialty carbon blacks

	Type	Jetness M_Y	Particle size [nm]	Relative tint [%]
COLOUR BLACK FW 2	HCG	283	13	114
SPECIAL BLACK 4	RCG	244	25	100
SPECIAL BLACK 100	LCF	217	51	60
LAMP BLACK 101	LB	209	95	26

Figure 17

Relative tint strength depending on the specialty carbon black primary particle size



The coloristic behavior of specialty carbon blacks that are mixed with titanium dioxide or zinc oxide in white blends mainly depends on the following parameters:

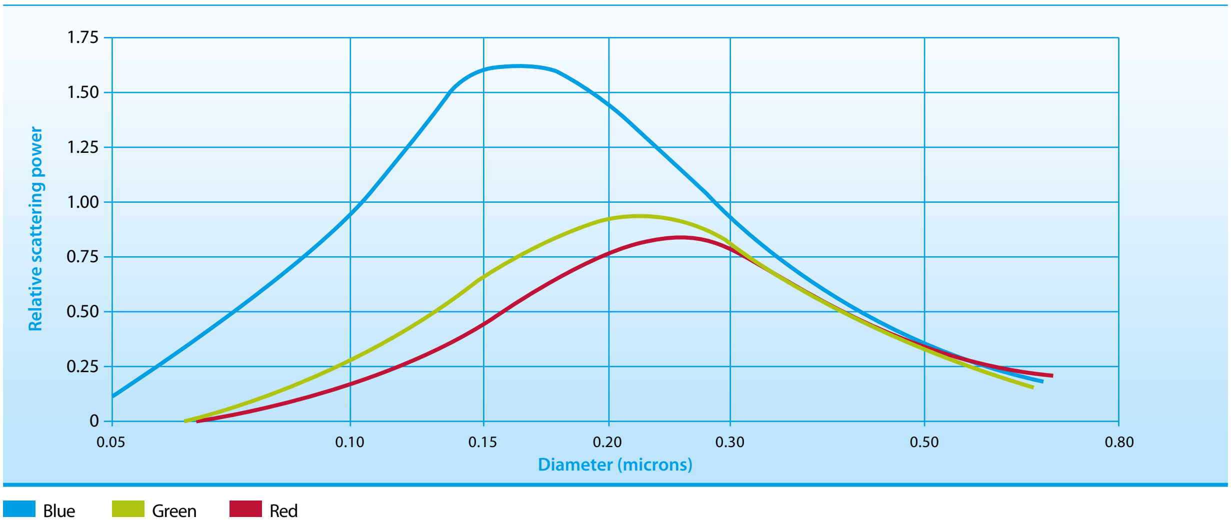
- Specialty carbon black mean primary particle size
- White pigment primary particle size
- White pigment volume concentration (PVC)

4.4 Relative light scattering of TiO_2

For the most efficient light scattering, the TiO_2 pigment diameter should be approximately one-half the wavelength of the light that is to be scattered. Since the human eye is most sensitive to yellow-green light, the theoretical optimum particle size for TiO_2 pigments applied in coatings is between 0.2 and 0.3 microns.

Figure 18

Relative light scattering power versus rutile particle size

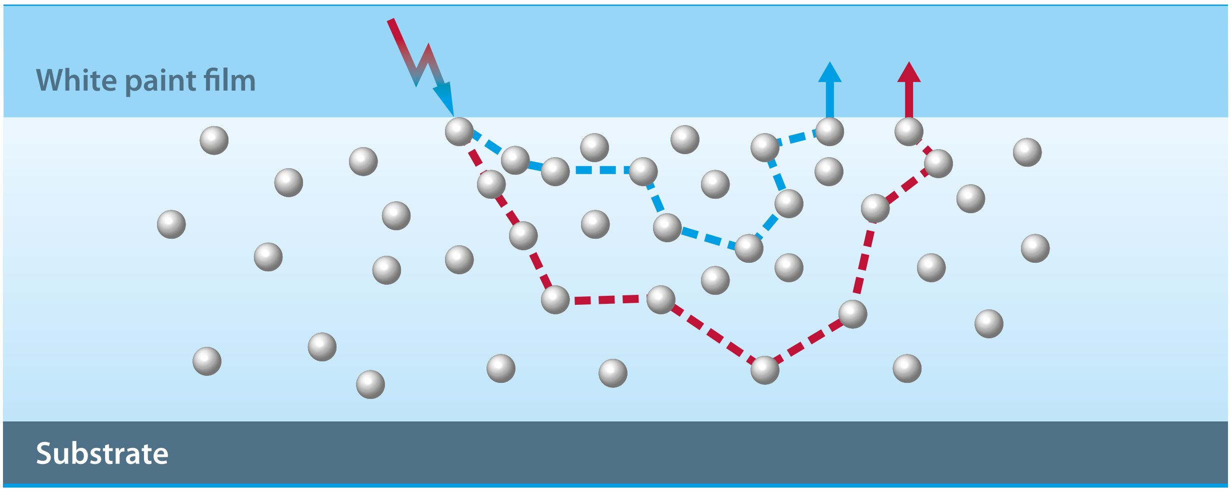


At about 0.2 microns, the sum of the light scattered at all wavelengths is maximized. When the primary particle size is increased to 0.3 microns, the scattering of blue light decreases rapidly, but the curve in the region between 0.2 and 0.3 microns for green and red light remains relatively unchanged (figure 18). The diameter of rutile corresponding to maximum scattering of blue light is 0.15 microns, whereas the light scattering for the red and green spectral color drops markedly [5].

4.5 White and grey coatings

Figure 19

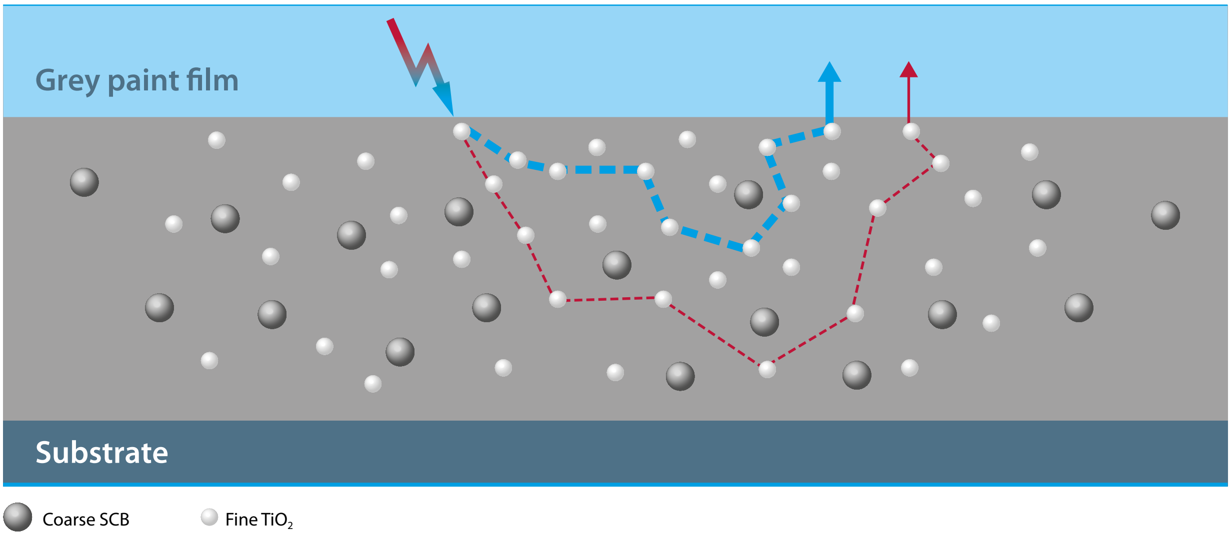
Light scattering in a white paint dilm based on rutile



In the case of an ideal white film, which is pigmented to complete hiding as shown in figure 19, the particle size has no influence on the color, since all the incident light is scattered and reflected. With addition of specialty carbon blacks to white paint, the formation of the undertone in grey coatings can be explained by considering light scattering and absorption effects. On one hand, smaller particles scatter blue light more efficiently than the red light. This means a shorter path and less absorption for the blue light. On the other hand, red light with a longer path length has a greater chance to be absorbed. As a consequence, the reflected hue appears bluer. In general, decreasing the TiO_2 particle size will intensify the blueness in terms of undertone.

Figure 20

Grey paint film based on coarse specialty carbon blacks and fine TiO_2 with a bluish undertone

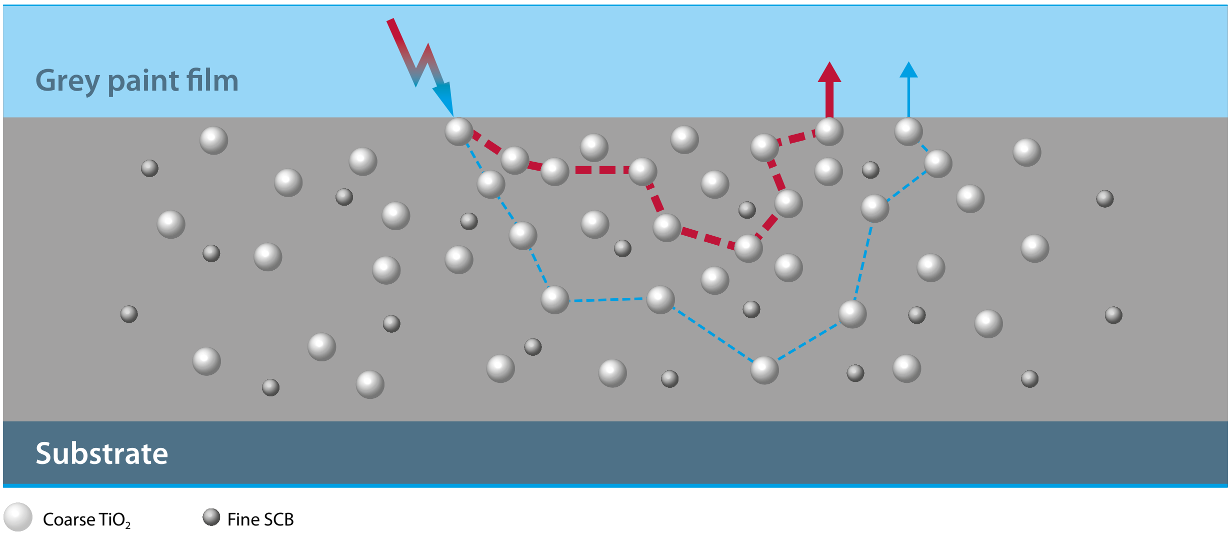


The size of the specialty carbon black also plays an important role in the formation of the undertone. In tinting applications, bigger sized particles give a bluish undertone due to the anisotropic scattering of light. This means that in grey coatings with small TiO_2 and bigger specialty carbon blacks the effect of a bluish undertone becomes very strong (figure 20).

Grey paints generating a red or brownish hue have to contain bigger TiO_2 particles and smaller specialty carbon blacks. This coloristic behavior is shown in figure 21.

Figure 21

Grey paint film based on fine specialty carbon blacks and coarse TiO_2 with brownish undertone



Due to the variation of the specialty carbon black and TiO_2 particle sizes illustrated in figure 22, a wide color range can be achieved in grey coatings. Starting from bluish (LAMP BLACK 101 + TiO_2 174 nm PVC 20 %) on the one side to brownish (COLOUR BLACK FW 2 + TiO_2 267 nm PVC 20 %) on the other side.

The main influence on the coloristic perception is given by the brightness (degree of reflection), degree of colorfulness and undertone. For a better comparison of specialty carbon blacks with different tinting values, the ratio CBP:TiO_2 is adapted in order to get the same level of apparent brightness. Two different types of titanium dioxide are used, these being a small sized (174 nm) and a bigger sized (276 nm) pigment. The description of the optical effects are based on the physical properties of specialty carbon blacks and the light scattering power of titanium dioxide as a function of the particle size.

Table 7

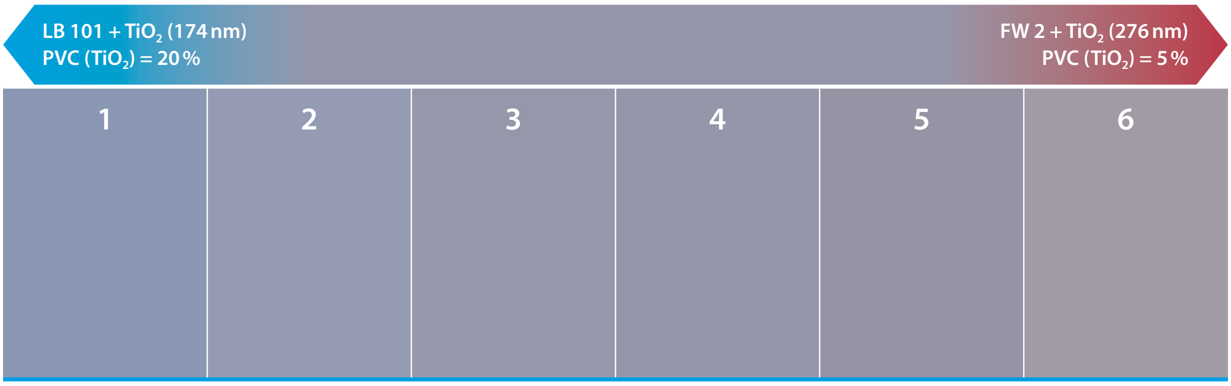
Lightness, color coordinates and greyness for different white reductions

		L*	a*	b*	G_Y
LB 101 + TiO_2 (174 nm) PVC 20 %	(1)	41.49	–1.79	–10.91	2.83
LB 101 + TiO_2 (276 nm) PVC 20 %	(2)	40.54	–1.78	–6.83	3.04
FW 2 + TiO_2 (174 nm) PVC 20 %	(3)	41.22	–1.07	–4.45	2.89
LB 101 + TiO_2 (276 nm) PVC 5 %	(4)	40.69	–1.36	–3.81	3.01
FW 2 + TiO_2 (174 nm) PVC 5 %	(5)	45.52	–0.85	–1.90	2.09
FW 2 + TiO_2 (276 nm) PVC 5 %	(6)	44.67	–0.30	1.64	2.23

The illustrated colortones 1 – 6 may differ from the real coating shades

Figure 22

Evolution of undertone in grey coatings depending on the specialty carbon black particle size, TiO_2 particle size and TiO_2 concentration



The illustrated colortones 1 – 6 may differ from the real coating shades

The various combinations of specialty carbon blacks and titanium dioxide allow grey coatings with slightly different undertones to be generated. The color intensity (chroma) of such coatings can be adjusted depending on the pigment ratio between black and white. In order to match a certain color tone it is important to know how the pigments and binder molecules interact within the final coating system. All coloristic data shown in this technical bulletin are for guidance purposes only.

5. Literature

[1] Technical Bulletin Fine Particles 79, Specialty carbon blacks in modern coating systems, Orion Engineered Carbons GmbH (2015)

[2] Lippok-Lohmer, Farbe und Lack 92 (11), 1024 (1986)

[3] Technical Bulletin Pigments 37, Coloristic Measurements of Jet-Black and Grey Coatings, Degussa (1988)

[4] Technical Information 1204, Method for Measuring Blackness of Carbon Black Pigments, Degussa (2001)

[5] DuPont™ Ti-Pure® titanium dioxide for coatings (2007)

6. Glossary of technical terms

Agglomerates
Loose clusters of aggregates which may be separated during dispersion.

Alkyd resin
Synthetic polyester resin which is manufactured by esterification of polyhydric alcohols with polybasic carboxylic acids. Alkyd resins are always modified with natural fatty acids or oils and/or synthetic fatty acids.

Binder
Defined as the non-volatile part of a coating material, excluding pigments and fillers but including plasticizers, surface driers and other non-volatile additives.

CIE LAB
Abbreviation recommended by the Commission Internationale d'Eclairage in 1976 for the color space, defined by the rectangular coordinates L*, a* and b*, and the color difference.

DIN
Deutsches Institut für Normung. The German institute responsible for standardization.

Dispersion
Uniform distribution of pigments in binders or powdered formulation components with the aid of grinding machines.

Hue
Describes the type of chromaticity of a color as red, green blue or yellow.

Hue Coordinates
Numerical measures for a three-dimensional color space used to describe the type of color in terms of hue, chromaticity and brightness. Hue coordinates are calculated from the standardized coordinates.

Illuminant
Radiation of a particular relative spectral distribution in the spectral range which influences the color of objects.

Jetness
Measure of visual perception which increases with rising saturation and generally decreases with increasing brightness.

Mass tone
Describes the color of a coating system in an optically opaque layer.

Melamine resin
Synthetic resin, which is frequently etherified with alcohols and manufactured by condensation of melamine and/or urea or such derivates with formaldehyde.

PVC
Pigment volume concentration, ratio of the volume of pigments and other solid particles in a product to the total volume of non-volatile components.

Primary particles
Smallest particles making up solids in powder form. May be recognized as single particles by means of electron microscopy.

Reflection
Sometimes termed reflectance. Reflected light intensity, measured on powder tablets in the case of pigments.

Rutile
Crystal lattice of titanium dioxide modification, the unit cell of which is in the form of a tetragonal prism.

Saturation
Degree of chromaticity of a color in comparison with something of equal brightness, but achromatic as grey.

Functional groups
Polar groups on the pigment surface of the carbon black, such as carboxyl, lactole, phenol and quinoid carbonyl groups.

Volatile content
Method of evaluation used in the characterization of carbon blacks, determined from the weight loss due to heating for 7 minutes at 950°C.

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