CARBON BLACKS

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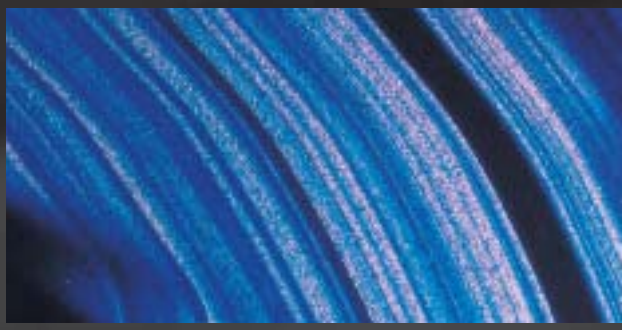
Pigment Blacks Selection Guide for Printing Ink Applications



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Introduction

Pigment Blacks Selection Guide for Printing Ink Applications

This brochure is intended to help you select the most appropriate pigment blacks for your particular printing ink application. Being such an important component of black printing inks, pigment black must be carefully selected by type and grade in order to yield optimum performance in a specific ink system.

To achieve this, the brochure is structured in three parts.

The first section relates variations in properties to variations in the physical structure of pigment black.

The second section gives some practical tips concerning the incorporation of the chosen grade of pigment black into a specific ink system.

The third section explains which pigment blacks are suitable for which applications, and why. You can go straight to this part if you choose, although we believe that applications knowledge can be easier (and more satisfying) to build and develop if there is a basic understanding of the relationship between structure and function.

At the end of the guide you will find a comprehensive reference table of the different pigment blacks with their suitability for different applications.

Cabot produces pigment blacks specially designed for printing inks applications. Cabot representatives can provide you with data reflecting test results for the grades of your interest. Please call them for further details on Cabot's product line.

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Background: the properties of pigment blacks

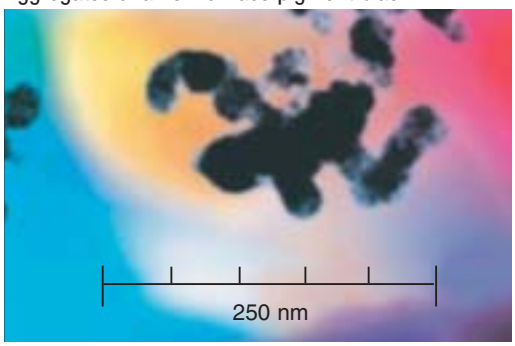
Fundamental properties

Pigment black is the particulate form of industrial carbon produced by thermal cracking of a hydrocarbon. Of the many processes historically used to produce it, the most important is now the oil furnace process. This consists of atomising a heavy oil tar fraction of petroleum distillate into a pre-heated closed furnace and then cooling and collecting the pigment particles formed.

While pigment black particles consist of layer planes, much like graphite, the layer planes are not as precisely oriented and aligned. It is therefore said to have a quasi-graphitic microstructure. Close electron microscopic inspection reveals that pigment black is composed of primary aggregates, each of which resembles a cluster of spherical prime particles fused together.

Both the primary aggregates and the spherical particles comprising them are important controlling factors in pigment black performance.

Aggregates of an oil furnace pigment black



Structure related to function

A key property of pigment black, and one which controls and influences ink performance, is the morphology of the primary aggregate. A number of attributes are highly dependent on the structure:

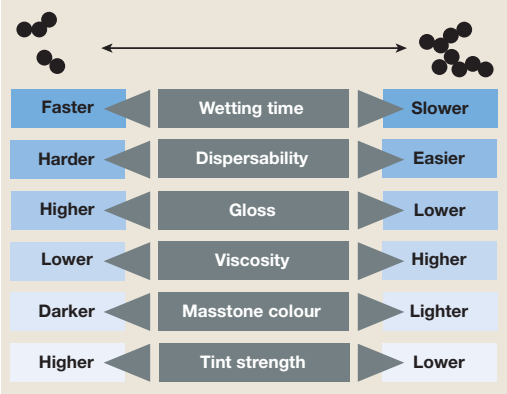
- Wetting time
- Dispersion properties
- Gloss Viscosity
- Viscosity
- Flow properties
- Colour tone
- Optical density
- Rub resistance

A pigment black characterised by primary aggregates composed of many prime particles with considerable branching and chaining is referred to as a 'high structure' pigment black. The OAN (Oil absorption number) measures the structure of the black. The level of structure determines the amount of available void space in and around primary aggregates. Thus, a very high structure black would have considerable void space and would absorb higher levels of vehicle per unit weight of black.

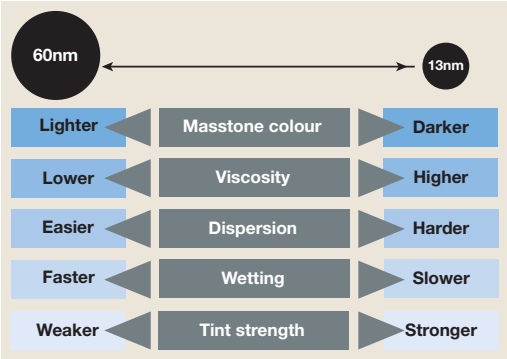
Pigment blacks for printing inks have OAN absorption values ranging between 46 and 124 cm^3 /100g.

Key properties related to structure are shown hereafter.

Performance as a function of structure



Performance as a function of particle size



The particle size of pigment black determines to a large extent its degree of blackness or "jetness" in dispersed form. This can be attributed to the effect of surface area, which continues to operate despite the fusion of the particles into aggregates. The finer the prime particle, the higher the surface area remaining exposed in the primary aggregate.

Thus, finer prime particles give jetter colour than coarser particles due to the combined effects of more available optical surface for light absorption and less light scattering.

Tint strength is higher for finer particle blacks due to greater light absorption efficiency, and tint tone is less blue due to increasingly preferential absorption of the blue end of the spectrum as particle diameter decreases. The higher surface area imparted by finer particle size requires more energy for wetting and dispersion. This ties up more liquid, so that viscosity is higher than with coarser blacks.

Pigment blacks for printing inks range from 60nm particle size, 30-Nitrogen surface area, to 22nm particle size and 138 Nitrogen surface area. Key properties related to primary particle size and surface area are shown on this page.

Performance as a function of particle size and structure

Particle size	Low structure	High structure
Large particles	Lowest viscosity Highest loading Least electrical conductivity	Easiest to disperse Weakest colour Bluest tone Least glossy
Small particles	Most difficult to disperse Strongest colour Brownest tone Most glossy	Highest viscosity Lowest loading Most electrical conductivity

Degree of structure

Surface chemistry

All pigment blacks have oxygen complexes (i.e. carboxylic, quinonic, lactonic or phenolic groups) chemisorbed on their surfaces to varying degrees, depending upon the conditions of manufacture. These surface constituents are collectively referred to as 'Volatile Content' and expressed as percentage weight loss after heating a dried pigment black to 950°C.

Some pigment blacks have surfaces that have been purposely oxidised, usually by aftertreatment with various oxidising agents, to increase their volatile content. Higher volatile content pigment blacks have some desirable rheological characteristics, including longer flow per fixed concentration and lower viscosity.

Another desirable effect of higher volatile content is enhancement of dispersability and dispersion stability. The chemisorbed oxygen complexes act like surfactants in improving the "wetting" characteristics of the pigment black when compared to lower volatile content blacks.

Electrical conductivity

Pigment blacks are all electrically conductive as a function of their structure, particle size and resulting surface area. The higher the degree of structure, the greater the conductivity of the pigment black. Due to the special nature of these pigment blacks, conductive printing inks have a relatively high viscosity. In order to achieve good electrical conductivity on the printed article, it is an advantage to have a high pigment black concentration in the printing ink, and a high ink film thickness when printing.

UV application

UV curing printing inks are becoming more and more popular. However, black UV curing printing inks can only be a compromise, since pigment black strongly absorbs incident light, in both the visible and ultraviolet ranges. It is clear that ink makers should use a black with a maximum light scattering in the UV region.

Therefore, pigment blacks with an aggregate diameter of between 100-130nm are recommended.

Food contact requirements

Cabot pigment blacks comply with a variety of European and US regulations concerning food contact. Please consult the applications table at the end of this brochure to ascertain which products meet requirements in the EU and the USA.

Where the table states that a product meets EU requirements, this refers to the Council of Europe Committee of Ministers Resolution AP (89) 1, On the use of colourants in plastic materials coming into contact with food (adopted by the Committee of Ministers on 13th September, 1989 at the 428th meeting of the Ministers' Deputies), and to the Colourants for Toys: European Toys Standard EN 71-3: 1994/A1: 2000.

Reference in the table to the USA implies that the relevant product meets all FDA requirements for use under 21CFR 178.3297: Colorants for Polymers (see Federal Register May 9, 1997, Vol. 62, No. 90, Rules and Regulations, pp. 25475-25477), Docket No. 95F-0163, and can be used at up to 2.5% loading to make articles intended for use in producing, manufacturing, packing, processing, preparing, treating, packaging, transporting or holding food under all temperatures.

Preparing and incorporating a pigment black

What is optimum dispersion of pigment black?

For a better understanding of pigment black, it is important to consider the question of dispersion. An ideal dispersion of pigment black would be the condition in which all agglomerates are broken down into primary aggregates, each primary aggregate is separated from every other aggregate, and the surface of each aggregate is completely covered by vehicle or resin. It is important to note that primary aggregates are the characteristic units of pigment black and are not broken down further under normal dispersion conditions. The process of achieving this ideal condition may be thought of as involving several steps.

Although dispersion is often thought of as one continuous process, looking at it as a number of sub-processes can lead to better understanding and control. At the end of each stage, tests can then be carried out and any corrections made before further work takes place. There are four stages during the production process. First the pigment black must be thoroughly "wet-out" or incorporated in the vehicle by displacing occluded air. Secondly, it is necessary to apply sufficient energy to break up pellets, if a pelleted form of black is being used. Thirdly, pigment black agglomerates must be broken down into their constituent primary aggregates by applying sufficient energy to overcome the attractive forces holding them together. Finally, each separated primary aggregate must absorb sufficient vehicle to completely cover its available surface. In addition, it is essential that the appropriate dispersant or other additive is used to ensure the stability of the system.

Pre-dispersion or pre-mixing

This is probably the most overlooked stage of the dispersion process, often being seen as simply the mixing of the raw materials. However, mistakes made here may be impossible to correct later. Attention to detail can provide significant rewards. It is important to understand what should be achieved during the pre-dispersion or pre-mixing phase.

- Produce a homogeneous mix of mill base raw materials;
- Displace air on the pigment black surface. This step involves the "wetting" of the pigment black by the ink vehicle. Essentially, it means displacement of occluded air and complete coverage of the surface of the agglomerates with vehicle, yielding a workable dispersion mix;
- Initiate breakdown of pigment black agglomerates. In cases where pelleted pigment black is used, incomplete pellet fracture occurs so that only very large agglomerates are wet by vehicle. The completion of pellet breakdown must therefore be accomplished by the application of additional energy after the incorporation stage.

If all of these parameters are met then the following dispersion stages will be significantly more effective.

- **Slow addition of raw materials** – slowing down the rate at which solid resins and pigments are added to the liquid portion of pre-mix will prevent any large accumulations occurring. It should be noted that, generally speaking, the highest possible pigment black loading, consistent with rheology and processing limitations, will give the best dispersion results. While pigment black can be adequately dispersed at lower loadings, the masterbatch concept should be considered in formulating mill bases, if only to realise the processing cost advantage. When using the masterbatch concept, add small quantities of pigment black at a time, allowing a few minutes between each addition. This will help to achieve many of these pre-mix objectives. Slow addition rates increase the premix viscosity slowly which in turn produces a more effective breakdown of pigment black agglomerates.

- Avoidance of incompatibility – addition of single solvents to some resin mixtures can result in incompatibility problems. It is often much safer to pre-mix solvents before they are added to the pre-mix. If a resin is forced out of solution at this stage it can remain undetected until final testing, where gloss reduction and reduced transparancy can result.

- Minimise heat production – excessive heat during mixing can cause a multitude of problems, such as vital solvent loss. If long pre-mix times are used then cooling may be necessary.

- Establishing optimum pre-mix times – it is recommended that a series of trials be undertaken to ensure the optimum time for pre-mixing. Checking dispersion levels on a Hegman or NPIRI gauge at regular intervals can indicate the point of optimum premix, however the ink residue test can prove to be a more effective method of establishing the level of dispersion. The ink residue technique, often called a “wash-out”, is widely used in the ink industry and is a reasonably good assessment of the quality of a pigment black dispersion.

Dispersion stage

Dispersion can simply be termed “the permanent particle separation of the wetted pigment particles in the liquid vehicle”. At this stage of the process, the suitably prepared pre-dispersion is subjected to large amounts of energy. Dispersion is achieved by one or more forces: shear and or impaction, resulting in attrition. Dispersion equipment uses these forces in many different ways, but it can be generally stated that either low energy is applied for long periods or high energy for short periods. To achieve a satisfactory result it is important that the mill base formulation meets the requirements of the equipment used. If this is not the case, then extended milling times will result.

It is important that the formulator has a clear understanding about what is to be achieved during this process, as the level of dispersion, gloss and opacity measurements can all be used as guides to dispersion performance. The property of "gloss" is perhaps the most sensitive to the quality of pigment black dispersion. In many cases it is possible to determine the quality of dispersion on the basis of gloss alone by recording instrumental gloss levels as a function of dispersion time. This measure has the added advantage of measuring micro-dispersion in contrast to the grind gauge and ink residue techniques.

Stabilisation and letdown stages

The objective of this stage is to reduce the dispersed mill base into a working rheology. If the masterbatch concept has been followed it is likely that the ratio of pigment to binder is high. If the letdown part of the formulation is added without the necessary precautions, pigment flocculation can occur. Additions at this stage should be made with certain considerations in mind.

- Temperatures of mill base and material to be added must be the same. Adding cold solvent or resin solution to a hot mill base will cause pigment shock;
- Add resin solutions slowly while stirring the mill base. Use a number of letdown resin concentrations if possible, so increasing the concentration of resin slowly;
- Premix solvents before adding to the mill base. The introductions of a large quantity of one solvent may cause resin instability;
- Use a number of checks to assess stabilisation. Dispersion, gloss and opacity measurements can give a better understanding than by simply using a Hegman gauge alone.

Selecting a pigment black for your application

Offset Inks

This category may be separated into three sub-categories, web offset heatset, sheet-fed offset and Web offset coldset. Web offset heatset inks are used in the printing of magazines. Sheet-fed inks are used for printing both commercial and packaging applications and web offset coldset is used for printing newspapers.

Web Offset Heatset / Sheet-fed Offset

Jetness and gloss are generally expected when coated papers are used. Depending on the color properties desired, primarily low structured pigment blacks are applied in higher quality offset ink applications.

ELFTEX 220/225 **REGAL 350A120**	Low viscosity Strong blue tone and good dispersion High gloss
ELFTEX 320/325 **REGAL® 250A117** **REGAL 250R**	Low viscosity Excellent gloss and blue tone High loading possible
ELFTEX® 410/415	Provides superior dispersability High jetness with exceptional gloss Excellent lithographic balance in IPA and non IPA fountain solutions
REGAL 400/400R	Oxidised furnace black Excellent flow and gloss Superior dispersion Good stability

Web Offset Coldset

Newspaper ink for printing by web offset dries by penetrating into the paper stock. This process utilises thin ink films and therefore ink strength is critical. This can lead to higher than ideal pigment black loading which can adversely affect ink rheology. Generally, intermediate to high structure blacks seem to be preferred due to their ease of dispersion, in addition the large aggregates associated with high structure blacks tend not to penetrate the surface of the paper, thus maximising jetness and print mileage. In cases where rheology or rub-off are more critical, lower structure blacks may be used either in blends with or in place of the higher structure blacks.

BLACK PEARLS 160 **CSX 156**	Blue tone extender pigment black with good dispersion properties Large particle size black, offering blue tone and high loading opportunities
BLACK PEARLS 430 **BLACK PEARLS 450** **ELFTEX 430**	Low structure black providing good rub resistance and flow properties
BLACK PEARLS 460 **ELFTEX 460**	Series of pigment blacks with varying OAN values at essentially equal surface area. Suitable for aqueous ink newspaper applications, helping to provide minimal set-off and halftone filling in

Publication gravure applications

Gravure inks require low viscosity to accomplish the transfer to the substrate from the engraved cells on the cylinder's surface. Low structure pigment blacks provide this required low viscosity for publication gravure applications. Cabot provides a number of products that offer the ink maker high jetness, gloss and blue tone.

BLACK PEARLS 280 **MONARCH 280**	Excellent dispersability Provides blue undertone Suitable for matt applications Excellent hold out and lay on absorbent stocks
BLACK PEARLS 450	High jetness Low abrasion
REGAL 250R	Low viscosity with excellent flow properties – high loading possible Excellent gloss and blue tone
REGAL 350A120 **REGAL 350R**	Low viscosity with excellent flow properties Courser particle size than REGAL 250R, providing good dispersion, strong blue tone and high gloss

BLACK PEARLS E **MOGUL E**	Oxidised furnace black Excellent viscosity with excellent flow properties in flexographic applications Excellent gloss and strong blue tone
REGAL 250R	Low viscosity with excellent flow properties in flexographic applications – high loading possible Excellent gloss and strong blue tone
REGAL 400/400R	Oxidised furnace black Excellent flow and gloss in paste ink applications Superior dispersion with good stability

Energy curing printing inks

In recent years the use of ultra-violet radiation to polymerise ink films and provide an extremely rapid dry has gained in popularity. The mechanism of cure is generally a “free radical” process started by photo initiators in the presence of UV radiation. Pigment black as a function of its particle size and surface area absorbs UV light thus causing unique problems to the ink formulator. In addition, as press speeds increase, the need for even faster cure times also increases. Cabot provides three product types designed for the different needs of both paste and flexographic inks. Both products provide low levels of UV absorption and good dispersability even in the poorly wetting binders used in UV printing inks.

BLACK PEARLS E **MOGUL E**	Oxidised furnace black Excellent viscosity with excellent flow properties in flexographic applications Strong blue tone
BLACK PEARLS L **MOGUL L**	Oxidised furnace black with excellent flow, gloss and strength in high quality inks. Particularly suitable for NC and polyamide-based inks
BLACK PEARLS 490 **MONARCH 490**	Series of pigment blacks with varying OAN values at essentially equal surface areas. Well suited for use in water-based flexographic inks
BLACK PEARLS 800 **MONARCH 800**	Particularly suitable for point of purchase applications Highest jetness
ELFTEX 220/225 **REGAL 350A120**	Low viscosity with excellent flow properties. Courser particle size than ELFTEX 320/325, providing good dispersion, strong blue tone and high gloss.
ELFTEX 320/325 **REGAL 250R** **REGAL 250A117**	Low viscosity with excellent flow properties in flexographic applications – high loading possible Strong blue tone
ELFTEX 410/415	Provides superior dispersability, with high jetness and exceptional gloss. Well suited for use in PVC copolymerisates
ELFTEX 430 **MONARCH 430**	Lower structure black, providing good rub resistance and flow properties
ELFTEX 570 **ELFTEX 460** **MONARCH 570** **MONARCH 460**	Medium structure black, suitable for a broad field of liquid ink applications
REGAL 400/400R	Oxidised furnace black with excellent flow and gloss providing superior dispersion with good stability
REGAL 660 **REGAL 660R**	Excellent jetness Good flow High gloss

Packaging applications

Within this application of printing, great variation in both substrate type and quality is encountered. Therefore pigment blacks in both oxidised and non-oxidised form are required to fully optimise this extremely varied section of the printing inks market. Packaging inks are produced in both aqueous and solvent form. For aqueous inks the required levels of jetness and dispersion are generally achieved with pigment blacks of relatively high surface area (>85 m^2/g) and high structure (>114 $cm^3/100g$). These types of pigment black perform particularly well as a majority of aqueous inks are printed on the more absorbent uncoated papers.

Many packaging applications print on foil, film or other non-absorbent stocks, and it is clear the requirements for pigment black are very different. The need for low viscosity and high fluidity dictates a low structure pigment black. This also helps the need for high gloss. The properties of blue tone and good dispersion can be accommodated by choosing blacks with an oxidised surface or low area, low structure properties. Aftertreated grades minimise viscosity and maximise flow at a given pigment black loading.

Printing ink applications of Cabot pigment blacks

	Gloss ink Application		Newspaper Applications		Liquid Ink Applications		Speciality Applications	
	Heatset	Sheetfed	Oil Based	Aqueous	Gravure	Flexo	UV	Food Packaging
BLACK PEARLS E	●●	●				●●		EU
BLACK PEARLS L		●			●●			EU
BLACK PEARLS 160	●●		●●●					EU
BLACK PEARLS 280					●●●			EU
BLACK PEARLS 430			●●		●			EU
BLACK PEARLS 450			●●		●			EU
BLACK PEARLS 460			●●	●	●			EU
BLACK PEARLS 490			●●	●●●		●●●		EU
BLACK PEARLS 800						●●●		EU
BLACK PEARLS 4350	●●	●				●●●		EU US
CSX 156	●●		●●●					
ELFTEX 220	●●●	●●				●●●		EU
ELFTEX 225	●●●	●●				●●●	●●●	EU
ELFTEX 320	●●	●●				●●●		EU
ELFTEX 325	●●	●●				●●●	●●●	EU
ELFTEX 410	●●●	●●●				●●●		EU
ELFTEX 415	●●●	●●●				●●●		EU
ELFTEX 430	●●	●●	●●●		●●			
ELFTEX 460			●●●	●●	●●	●		
ELFTEX 570				●●		●●		EU
MOGUL E	●●	●●				●●	●●●	EU
MOGUL L		●●			●●●		●●●	EU
MONARCH 280					●●●			
MONARCH 430	●●	●●			●●			EU
MONARCH 460					●●	●●		EU
MONARCH 490						●●●		EU
MONARCH 570						●●●		EU
MONARCH 800						●●●		EU
REGAL 250A117	●●●	●●			●●●	●●●		EU
REGAL 250R	●●●	●●			●●●		●●●	EU
REGAL 350A120	●●●	●●			●●●	●●●		EU
REGAL 350R	●●●	●●			●●●		●●●	EU
REGAL 400	●●	●●●			●●●	●●●		EU
REGAL 400R	●●	●●●			●●●	●●●	●●●	EU
REGAL 660						●●●		EU
REGAL 660R		●●				●●●		

●●● = *Especially suitable* ●● = *Well suited* ● = *Suitable for special application*

Food packaging compliance (see page 5) EU = *EU* US = *United States (FDA)*

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