CHAPTER 7

PAINTS, PIGMENTS, AND INDUSTRIAL COATINGS

CHAPTER 7 OBJECTIVES

- CONSTITUENTS OF PAINTS
  - Pigments
  - Binders
  - Solvents
  - Additives
- PAINT FORMULATION
  - Classification and Types of Paints
    - Architectural Coatings
    - Industrial Coatings (OEM Paints)
    - Special Purpose Coatings
    - Varnishes
    - Lacquers

CONSTITUENTS OF PAINTS

- All paints are basically similar in composition in that they contain a suspension of finely ground solids (pigments) in a liquid medium (vehicle) consisting of a polymeric or resinous material (binder) and a volatile solvent.
- During the drying of paint, the binder forms the continuous film with the necessary attributes of adhesion, flexibility, toughness and durability to the substrate (the surface being coated).
- Paints also contain additives, which are added in small quantities to modify some property of the pigments and binder constituents.
- The four broad fundamental constituents are: (1) pigments, (2) binders, (3) solvents and (4) additives.

CONSTITUENTS OF PAINTS
Pigments

- Pigments are insoluble, fine particle size materials which confer on a paint its color and opacity.
- The pigments are used in paint formulation to carry out one or more of the following tasks:
  i. to provide color,
  ii. to hide substrates and obliterate previous colors ,
  iii. to improve the strength of the paint film,
  iv. to improve the adhesion of the paint film,
  v. to reduce gloss,
  vi. to reduce cost,

CONSTITUENTS OF PAINTS
Pigments

- All Pigments should be insoluble in the medium in which they are used, chemically inert, free of soluble salts and unaffected by normal temperatures.
- It should be easily wetted for proper dispersion, nontoxic, non-corrosive and have low oil-absorption characteristics.
- They should be durable and fast to light as possible.

CONSTITUENTS OF PAINTS
Pigments

- In general the following properties of the pigments are important in selecting a pigment for any particular product.
  a) Hiding power
  b) Tinting strength
  c) Refractive index
  d) Light fastness
  e) Bleeding Characteristics
  f) Particle size and shape

CONSTITUENTS OF PAINTS
Pigments

Hiding Power

- Hiding Power is the ability of paint to completely obliterate any underlying color and usually expressed as the number of square meters of a surface covered by one liter of paint.
- The pigments used must prevent light from passing through the film to the previous colored layer and back to the eye of an observer.
- Hiding power depends upon the wavelength and the total amount of light that a pigment will absorb, on its refractive index and also on particle size and shape.

CONSTITUENTS OF PAINTS
Pigments

Hiding Power

- Hiding The difference between the index (RI) of refraction of the vehicle and that of the pigment is used by the paint formulators as an indicator for the hiding power.
- *The greater the difference indicates the greater hiding power for the paint.*
- The pigment rutile (TiO_2) with the highest RI is the most effective white pigment for hiding power.

CONSTITUENTS OF PAINTS
Pigments

Tinting Strength

- Tenting Strength is the amount of a colored pigment required to tint (color) a given weight of a white pigment to produce a given shade.
- Tinting strengths are always relative to a standard sample of the pigment under test, and for two samples of the same pigment, the tinting strength is a measure of the difference in particle size and distribution.

CONSTITUENTS OF PAINTS
Pigments

Tinting Strength

- Comparative tinting strengths of white pigments in a standard blue pigment show that the tinting strength of rutile titanium pigment exceeds that of all other listed pigments.
- The tinting strength of a pigment is independent of its hiding power. Relatively transparent pigments can have a high tinting strength.

CONSTITUENTS OF PAINTS
Pigments

Table 7.1 Indices of Refraction of Some Common Paint Materials

Material	Refractive Index
Rutile titanium dioxide	2.76
Anatase titanium dioxide	2.55
Zinc sulfide	2.37
Antimony oxide	2.09
Zinc oxide	2.02
Basic lead carbonate	2.00
Basic lead sulfate	1.93

CONSTITUENTS OF PAINTS
Pigments

Table 7.1 Indices of Refraction of Some Common Paint Materials

Material	Refractive Index
Barytes	1.64
Calcium sulfate (anhydrite)	1.59
Magnesium silicate	1.59
Calcium carbonate	1.57
China clay	1.56
Silica	1.55

CONSTITUENTS OF PAINTS
Pigments

Table 7.1 Indices of Refraction of Some Common Paint Materials

Material	Refractive Index
Phenolic resins	1.55-1.68
Malamine resins	1.55-1.68
Urea-formaldehyde resins	1.55-1.60
Alkyd resins	1.50-1.60
Natural resins	1.50-1.55
China wood oil	1.52
Linseed oil	1.48
Soya bean oil	1.48

CONSTITUENTS OF PAINTS
Pigments

Table 7.2 Comparative Tinting Strengths of Common Pigments

Material	Tinting Strength
Rutile titanium pigment	1850
Anatase titanium pigment	1350
Zinc sulfide	900
Antimony oxide	400
Lithopone	300
Zinc oxide	200
White lead	100

CONSTITUENTS OF PAINTS
Pigments

Refractive Index

- When light falls on a pigmented paint film, part is reflected back whilst some enters the film.
- The light, which is reflected back, interacts with the pigment on the way back through the film.
- The black and strongly colored pigments absorb the light to obliterate any surface, whereas the white pigments confer opacity solely by scattering of light.

CONSTITUENTS OF PAINTS
Pigments

Refractive Index

- White pigments have a higher refractive index than most colored pigments, with consequently greater scattering power.
- In particular, the refractive index of titanium dioxide pigments is so much higher than those of film-formers (binders) that they possess excellent hiding power.

CONSTITUENTS OF PAINTS
Pigments

Light Fastness

- Light fastness of a paint is its ability to resist deterioration under the action of sunlight and industrial fumes.
- Pigment stability during exposure to sunlight and environment is of considerable importance. Many pigments fade or darken or change shade badly in the light.
- This is because the ultra-violet rays in the sunlight are sufficiently energetic to break certain chemical bonds and thus change molecules.

CONSTITUENTS OF PAINTS
Pigments

Light Fastness

- This change in chemical structure leads to an absorption of light in the visible region of the spectrum resulting in a loss of color or variation of hue.
- On the other hand, if the pigment can absorb ultra violet rays without breakdown, it will protect the binder. Color changes can also occur in pigments by a chemical attack of the environment.
- The chemical composition of the pigment is therefore an important factor in determining its chemical resistance and color or light fastness.

CONSTITUENTS OF PAINTS
Pigments

Bleeding Characteristics

- Some pigments (organic type) are soluble in aromatic solvents and slightly soluble in alcohols and other aliphatic solvents.
- This solvent solubility results in the phenomenon of bleeding, whereby organic pigments in paint films can be solubilized.
- The bleeding results in discoloration of paint films.

CONSTITUENTS OF PAINTS
Pigments

Particle Size and Shape

- The particle size, shape and distribution of a pigment influence the rheological properties, shade, gloss, weathering characteristics and ease of dispersion.
- Pigment particles can occur in three different forms: primary particles, aggregates and agglomerates.
- ***Primary particles*** in a single 'piece' of pigment can be identified as an individual by microscopic examination.
- ***Aggregates*** are primary particles that are firmly 'cemented' together at crystalline areas.

CONSTITUENTS OF PAINTS
Pigments

Particle Size and Shape

- ***Agglomerates*** are comparatively loosely bound primary particles and aggregates that are joined at crystal corners and edges.
- The particle size of the dispersed pigment agglomerates or primary particles is of great importance in determining the performance of paint systems.
- The size of particles of pigments may range between 1 μ and 60 μ diameters.
- Most pigments and extenders used in paints are crystalline in nature. Non-crystalline pigments such as the carbon blacks are also used in the paint industry.

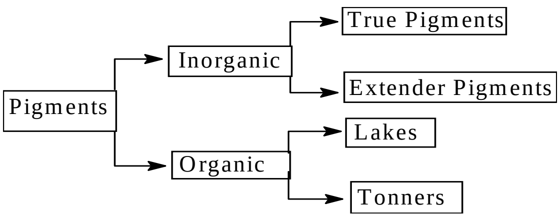
CONSTITUENTS OF PAINTS
The Classification of Pigments

- The materials used to impart color may either be pigments or dyestuffs.
- The difference between pigments and dyes is their relative solubility in the liquid media (solvent + binder) in which they are dispersed.
- Dyes are soluble, while pigments are insoluble. This solubility or insolubility is the reason a surface colored with an insoluble pigment is opaque with their good light fastness.
- A dye, on the other hand, may impart an intense color to the surface but remain transparent and generally their light fastness is fairly poor.

CONSTITUENTS OF PAINTS
The Classification of Pigments

- Pigments, which can be organic or inorganic in origin, have been classified in a variety of ways, such as: color, natural or synthetic, and by chemical types.
- Extenders are solid materials insoluble in the paint medium but which impart little or no opacity or color to the film into which they are incorporated.
- Extenders are incorporated into paints to modify the flow properties, gloss, surface topography and the mechanical and permeability characteristics of the film.

CONSTITUENTS OF PAINTS
The Classification of Pigments



CONSTITUENTS OF PAINTS
The Classification of Pigments

- Many ***inorganic pigments*** are found in nature as minerals.
- The light stability, degree of opacity and chemical resistance of natural inorganic pigment is normally very high.
- Frequently, inorganic pigments are chemically prepared from inorganic raw materials.
- The synthetic inorganic pigments are apparently the same chemically as the naturally occurring pigments, but often quite different in properties.

CONSTITUENTS OF PAINTS
The Classification of Pigments

- The natural pigment may be contaminated by some impurity, such as silica, which is uneconomical to remove; the synthetic products are pure.
- The naturally occurring ***organic pigments*** are mainly of historical interest and are no longer used.
- There are now far more synthetic organic pigments and dyes than inorganic ones.
- In the manufacture of organic pigments certain materials become insoluble in the pure form, whereas, others require a metal or an inorganic base to precipitate them.

CONSTITUENTS OF PAINTS
The Classification of Pigments

- The coloring materials, which are insoluble in the pure form, are known as *toners* and those, which require a base, are called *lakes*.
- Synthetic organic pigments are very finely textured and they provide clean, intense colors.
- However, both light fastness and heat stability of organic pigments are generally lower than that of inorganic pigments.
- The brilliance and clarity of hue for organic pigments is much superior. The most attractive, cleanest colors can only be obtained with organic pigments.

CONSTITUENTS OF PAINTS

Inorganic Pigments

CLASSIFICATION OF INORGANIC PIGMENTS

INORGANIC PIGMENTS

White	Colored	Metallic	Extenders
* Titanium dioxide	* Iron oxide	* Aluminum	* Blanc fixe
* Zinc oxide	* Red lead	* Zinc	* Paris white
* Antimony oxide	* Cadmium red	* Lead	* Barytes whiting
* White lead	* Lead silicochromate		* China clay
* Lead sulfate	* Lead chromates		* Mica
	* Zinc chromates		* Talc
	* Cadmium yellow		
	* Calcium plumbate		
	* Chromium oxide		
	* Prussian blue		
	* Ultramarine blue		

CONSTITUENTS OF PAINTS

White Pigments

- White pigments are the major contributors in paint formulation.
- White pigments are used not only in white paints, but also in a substantial fraction of other pigmented paints to give lighter colors than would be obtained using color pigments alone.
- All white pigments are inorganic compounds of ***titanium, zinc, antimony, or lead***. Presently, the most important white pigment used in paints is titanium dioxide. Formerly, white lead and zinc oxide were widely used.

CONSTITUENTS OF PAINTS

Other White Pigments

- The range of available white pigment is wide and includes white lead (basic lead carbonate, $2PbCO_3.Pb(OH)_2$; lithopone (mixed $ZnS/BaSO_4$); zinc oxide (ZnO); antimony oxide (Sb_2O_3); and titanium dioxide (TiO_2).
- White lead used to be the most widely used pigment until the late 1930s.
- Due to high toxicity of lead salts and because of this restriction and also easy availability of titanium dioxide pigments, usage of white lead dropped rapidly and is no longer permitted as a constituent of most paints.

CONSTITUENTS OF PAINTS
Other White Pigments

- Lithopone is a mixed zinc sulfide-barium sulfate pigment available in two types; one containing 30 % zinc sulfide and one containing 60 % zinc sulfide.
- Coprecipitation is achieved by reacting an aqueous solution of zinc sulfate with barium sulfide. The barium sulfide solution is prepared by reducing barite ore ($BaSO_4$) with carbon.

$$BaSO_4 + 4C \longrightarrow BaS + 4CO$$
$$ZnSO_4 + BaS \longrightarrow BaSO_4\downarrow + ZnS\downarrow$$

- After TiO_2, zinc sulfide is the strongest white pigment due to its brilliant white color, extremely fine texture and relative cheaper cost.

CONSTITUENTS OF PAINTS
Other White Pigments

- Zinc oxide, ZnO, is a reactive white pigment prepared by vaporizing metallic zinc at a temperature of about 900°C in the presence of oxygen.
- Because of its low refractive index, 2.02, ZnO cannot compete for the hiding power of TiO_2.
- Consequently, ZnO is rarely used as the sole pigment in modern coatings.
- ZnO is used in exterior house paints as a fungicide and in some can linings as a sulfide scavenger.

CONSTITUENTS OF PAINTS
Other White Pigments

- Antimony oxide, Sb_2O_3, is a non-reactive white pigment prepared from metallic antimony and oxygen.
- Antimony oxide is widely used in the preparation of fire retardant paint in conjunction with chlorine containing resins.
- On exposure to fire, the chlorine gas liberated by decomposition of the resin component of the paint film reacts with the antimony oxide to produce a vapor of antimony chloride which blankets the flames.
- Antimony oxide is also used to modify the heavy chalking characteristics of anatase form of titanium oxide.

CONSTITUENTS OF PAINTS
Color Pigments

- Color pigments can be divided into inorganic and organic products.
- The inorganic pigments are chemically inert, very light-fast products based on oxides and sulfides of the elements iron and chromium in particular, and of zinc, molybdenum and cadmium to a smaller level.
- The color pigments may be either of natural or synthetic origin. Synthetically produced pigments are preferred by the paint formulators, since only they fulfill for today's requirements for color consistency and uniformity.

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- The most important organic color pigments include azo compounds, carbonyl colorants and phthalocyanius, as well as their salts and metal complexes.

CONSTITUENTS OF PAINTS
Yellow and Orange Pigments

- Yellow Iron Oxide, FeO(OH), lead chromates, $PbCrO_4$, zinc chromates, $ZnCrO_4$ and cadmium yellow, CdS belong to standard pigments among the yellow pigments.
- Yellow iron oxides are of both natural and synthetic origin.
- The synthetic iron oxides are available in a wider range of shades than the naturally occurring varieties.
- Yellow iron oxides give opaque films with good hiding and high exterior durability; chemical and solvent resistance is excellent.

CONSTITUENTS OF PAINTS
Yellow and Orange Pigments

- The lead chromate ($PbCrO_4$) is medium yellow in color.
- The crystals of lead chromate with lead oxide (chrome oranges) are redder yellow in color.
- Chrome yellows are relatively low cost pigments with good light fastness, high tinting strength and opacity.
- Despite the good light fastness of this class of pigments, bleaching by sulfur dioxide results in a gradual loss of color in films containing lead chromates on prolonged exposure in an industrial atmosphere.

CONSTITUENTS OF PAINTS
Yellow and Orange Pigments

- ***Zinc chromates*** are used for decorative and as anticorrosive yellow paints.
- This pigment has the advantage of being non-toxic and, furthermore, its color does not change by exposure to sulfur containing atmospheres.
- It is characterized by excellent light fastness, but its use is restricted due to poor opacity and poor tinting strength.
- The color stability of zinc chromate when exposed to lime permits its use as a pigment in paints for plaster and concrete.
- Zinc yellow has the composition $4ZnCrO_4.K_2O.H_2O$.
- Two other yellow chromate pigments are strontium chromate and barium chromate, both used as corrosion inhibitors.

CONSTITUENTS OF PAINTS
Red Pigments

- Red iron oxide (Fe_2O_3) is an inorganic pigment of either natural or synthetic origin.
- Synthetic pigment is made by heating iron sulfate with quicklime in a furnace.
- Indian red is a naturally occurring mineral whose ferric oxide content may vary from 80 to 95%, the remainder being clay and silica.
- It is made by grinding hematite and floating off the fines for use.
- Red lead (Pb_3O_4) is a brilliant red-orange colored synthetic inorganic pigment used mainly as a protective priming coat for steel work rather than a coloring pigment in paints.

CONSTITUENTS OF PAINTS

Blue and Green Pigments

- *Ultramarine blue* is a complex sodium aluminum silicate and sulfide, made by calcining an intimate mixture of sodium carbonate, china clay, sulfur and silica together with some organic resinous material such as rosin.
- The color of the pigment is attributed to the presence of sulfur.
- Ultramarine is widely used as bluing in laundering to neutralize the yellowish tone in cotton and linen fabrics.
- *Prussian blue*, $KFe(Fe(CN)_6)$, is an intense reddish shade blue pigment with fairly good properties. It is used as a coloring pigment in many types of paint systems and is also used in the production of lead chrome greens.

CONSTITUENTS OF PAINTS

Blue and Green Pigments

- *Lead chrome greens*, $PbCrO_4$: $KFe(Fe(CN)_6)$, are synthetic inorganic pigments varying in shades from grass green to deep green. The use of lead chrome greens is, however, limited due to the toxicity of lead.
- *Chromium oxide*, Cr_2O_3 is a dull green synthetic inorganic pigment, which can be used in all types of paint systems where high chemical resistance and outstanding light fastness are required.
- Inorganic blues and greens are increasingly supplanted by phthalocyanine blues and greens, which have greater color strength.

CONSTITUENTS OF PAINTS

Black and Metallic Pigments

- Black iron oxide, Fe_3O_4, is a synthetic inorganic pigment, produced by oxidation of iron (II) hydroxide obtained from the action of alkali on iron (II) sulfate solution.
- Metallic pigments are used on the surfaces for luster and brilliance finishes which are normally not produced by conventional pigments.
- For many applications, a metallic effect is highly desirable and can be achieved by adding aluminum, zinc, bronze, stainless steel or pearlescent pigments.

CONSTITUENTS OF PAINTS
Aluminum Powder

- Aluminum powder is available in two forms: Leafing grade and non-leafing grade. Both grades are manufactured from pure aluminum (99.3-99.7% purity) and the particle is lamellar in shape (0.1-2 µm in thickness and 0.5-200 µm in diameter).
- In the milling process stearic acid is used to give the leafing grade having a bright silvery appearance.
- The non-leafing grade aluminum types are manufactured using oleic acid. The non-leafing grade is primarily used in automotive topcoats where they impart an aesthetically pleasing sparkle to the finish.

CONSTITUENTS OF PAINTS
Zinc Dust

- There are two forms of zinc, namely powder and dust. Only the zinc dust is used in coatings.
- Zinc dust is prepared by distilling zinc oxide, ZnO, in the presence of carbon.
- Zinc dust primers provide a high degree of corrosion protection to the steel substrate due to the tendency of the metallic zinc to corrode preferentially to steel.

CONSTITUENTS OF PAINTS
Extender Pigments

- Extenders or extender pigments are white inorganic minerals that are relatively deficient in both color and opacity and are commonly to replace the more expensive prime pigments.
- These pigments are also referred to as *inert pigments* because of their optically inert behavior in surface coatings.
- The extenders commonly used by the surface coatings industry include, for the most part, the following: Calcite (Whiting), Silica, Kaolin (Clay), Talc and Barytes.
- Calcite and whitings (refractive index: 1.5-1.7) are naturally occurring calcium carbonate deposits. The lowest cost grades are ground limestone or the mixed calcium magnesium carbonate ore, dolomite.

CONSTITUENTS OF PAINTS
Extender Pigments

- Calcium carbonate is the most widely used of the extender pigments. It is used throughout the range of water and solvent based paints for both interior and exterior application.
- In some applications, the reactivity of calcium carbonate with acids makes carbonate pigments undesirable, especially in exterior applications.
- Silica (SiO_2) (refractive index: 1.48) is mined from deposits of diatomaceous soft chalk-like rock (keiselghur).

CONSTITUENTS OF PAINTS
Extender Pigments

- This is an important group of extender pigments, which is used in a variety of particle sizes. They are used as a flatting agent to reduce gloss of clear coatings and to impart shear thinning flow properties to coatings. They are relatively expensive.
- Kaolin or china clay (refractive index: 1.56) is hydrated aluminum silicates of very fine colloidal dimensions in the natural state.
- Clays are used in the paints due to their extremely good dispersibility in water-based systems, good suspension properties and good brushability and opacity. However, they have poor weather resistance.

CONSTITUENTS OF PAINTS
Organic Pigments

- The organic coloring materials, which are insoluble in the pure form, are known as *toner pigments* and those, which require a base, are referred to as *lakes*.
- Compared with inorganic pigments, organic pigments in general are brighter in color, more transparent (lower hiding power), considerably greater in tinting strength, and poorer in heat and light-fastness.
- A large number of organic pigments are available in the market.

CONSTITUENTS OF PAINTS

Red Pigments

- Toluidine red, barium lithol red and BON red are the three widely used organic red pigments.
- The toluidine reds are a class of organic compound known as insoluble azo dyes. It is an azo derivative of B-naphthol (Figure 7.3).
- Toluidine red is bright red of moderate light-fastness, good chemical resistance and good hiding power.
- Toluidine red is soluble in some solvents and gives coatings that are likely to bleed.

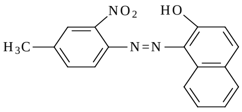

Figure 7.3 Structure of Toluidine Red

CONSTITUENTS OF PAINTS

Red Pigments

- Barium lithol red (Figure 7.4) is bright red in color and is suitable for interior use only due to its relatively poor light-fastness and poor chemical resistance.

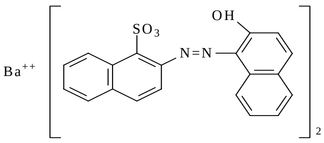

Figure 7.4 Structure of Barium Lithol Red

CONSTITUENTS OF PAINTS

Red Pigments

- 2-Hydroxy-3-naphthoic acid (BON) is coupled with diazo compounds and their calcium salts (Figure 7.5) are bright red bleed resistance pigments.
- The higher cost, manganese salt shows better exterior durability than the calcium or barium salts.
- The BON red pigments are characterized by an extremely high degree of color stability, resistance to acids and alkalies and are non-toxic

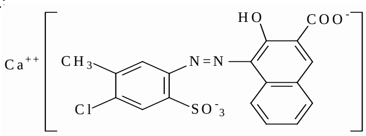

Figure 7.5 Structure of Calcium BON Red

CONSTITUENTS OF PAINTS
Yellow Pigments

- The most common organic yellow pigments are members of the insoluble azo class of pigments and they belong to the four main classes: monoarylide yellows, diarylide yellows, benzimidiazolone yellows and heterocyclic yellows.
- The Hansa yellow (Figure 7.6) is a bright monoarylide often used in trade sales and emulsion paints. They have low opacity in paint films and are soluble in aromatic solvents.

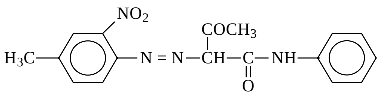

Figure 7.6 Structure of Pigment Yellow 1

CONSTITUENTS OF PAINTS
Yellow Pigments

- Benzimidiazolone yellows have good opacity, very good heat resistance, good solvent resistance (little tendency to bleed) and very good light-fastness.
- Pigment Yellow 151 (Figure 7.8) is an example, which is used as replacements for the lead chrome pigments.

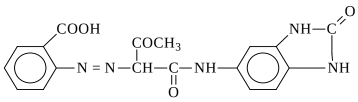

Figure 7.8 Structure of Pigment Yellow 151

CONSTITUENTS OF PAINTS
Yellow Pigments

- There are numerous heterocyclic yellow pigments such as nickel azo yellow (Figure 7.9). They are high-cost, high performance yellow pigments with excellent light-fastness.

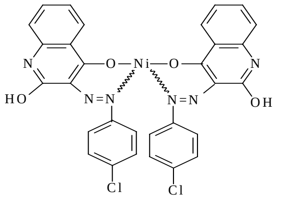

Figure 7.9 Structure of a Nickel Azo Yellow

CONSTITUENTS OF PAINTS
Green Pigments

- The most common organic green pigments are phthalocyanine greens.
- Phthalogreens are made by halogenating copper phthalocyanine (CPC) to produce mixtures of isomers in which many of the 16 hydrogen atoms of CPC have been replaced with chlorine or mixtures of chlorine and bromine (Figure 7.10).
- The pigments vary from a blue green to yellow green, depending on the ratio of bromine to chlorine.

CONSTITUENTS OF PAINTS
Green Pigments

- The yellowish green are obtained with nine to ten bromine atoms per molecule.
- The phthalocyanine greens are economical and have good light-fastness.
- The excellent stability of these pigments permits their use as colorants in all forms of decorative and industrial coating systems.

CONSTITUENTS OF PAINTS
Green Pigments

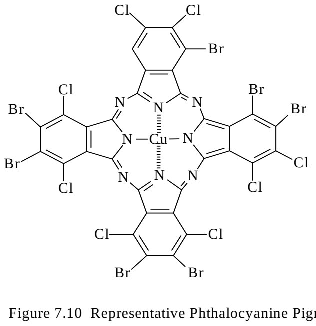

Figure 7.10 Representative Phthalocyanine Pigments

CONSTITUENTS OF PAINTS
Blue Pigments

- The most common organic blue pigments in the coatings industry is copper phthalocyanine (Figure 7.11).
- This is a bright, versatile pigment of outstanding light fastness. Phthaloblues are available commercially in three crystal forms: alpha, beta and the seldom-used epsilon.
- The beta form is the most stable. Phthalocyanine pigments are characterized by a high tinting strength and opacity together with excellent color stability on exposure to light.

CONSTITUENTS OF PAINTS
Blue Pigments

- These pigments are also insoluble in most solvents used in paints and hence are not prone to bleeding.

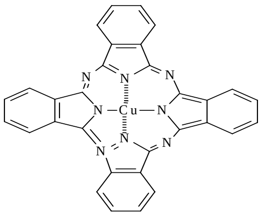

Figure 7.11 Structure of Copper Phthalocyanine Blue

CONSTITUENTS OF PAINTS
Black Pigments

- Carbon blacks are organic pigments produced by partial combustion of petroleum products or natural gas.
- The particle size and intensity of blackness depends on the process and the raw materials used.
- As a class, carbon blacks are insoluble in solvents, stable to acids and alkalies and have excellent light-fastness. They are used as coloring pigments in all types of decorative and industrial paints.

CONSTITUENTS OF PAINTS
Binders

- The second basic constituent of a paint is a “binder”, which binds together the pigment particles and holds them on to the surface.
- There are numerous types of binders currently available to the paint industry for various applications such as alkyds, polyesters, acrylics, vinyls, natural resins and oils.

CONSTITUENTS OF PAINTS
Alkyds

- Alkyd resins represent the single largest quantity of solvent-soluble resin produced for use in the surface coating industry.
- They are relatively low molecular weight oil-modified polyesters prepared by reacting together polyols, dibasic acids and oil (linseed or soya fatty acids).
- According to the oil or fatty acid content, the alkyds are divided into three broad categories:
  - Short oil (to 40%)
  - Medium oil (40-60%) and
  - Long oil (more than 60%) alkyd resins

CONSTITUENTS OF PAINTS
Alkyds

- Alkyd They are further divided into drying (oxidizing) and non-drying (non-oxidizing) types.
- Non-drying oil alkyds do not readily form films and, as such, they are mainly used as plasticizers for other binders.
- Drying oil alkyds can form films (coatings) through oxidative polymerization in a similar manner to that of the natural oils (linseed or soya) from which they are made.
- Short drying oil alkyds are typically made of linseed, soya or dehydrated castor oils. The linseed based alkyds are used in automotive refining enamels and in general purpose air drying enamels.

CONSTITUENTS OF PAINTS
Polyesters

- Polyesters are polymers obtained by reacting monomeric polycarboxylic acid and polyalcohols.
- They are practically free of fatty acids (oils) and have a much simpler structure than that of alkyd.
- Saturated polyesters are produced from a large number of polyfunctional alcohols, e.g., 1-6-hexanediol, neopentyl glycol, and polycarboxylic acids (phthalic acid and adipic acid).
- Most saturated polyester resins have relatively low molecular weights, ranging from 5000 g/mol to 10,000 g/mol.

CONSTITUENTS OF PAINTS
Polyesters

- Coatings prepared from these polyester resins utilize cross-linking resins such as melamine-formaldehyde (MF) resin, benzoguanimine-formaldehyde (BF) resin, or epoxy resin.
- Polyester resins possess premium performance properties such as exterior durability, gloss, flexibility hardness, color stability and versatility of cure.
- Polyesters are used in product finishes for household appliances, food and beverage containers, aircraft and equipment, automotive primers and bake coats, metal furniture and fixtures.

CONSTITUENTS OF PAINTS
Acrylics

- Acrylic resins are the most widely used polymers in the paint and coatings industry.
- The two principal forms of acrylic used in surface coatings are ***thermoplastic and thermoset***.
- Thermoplastics form a film by the evaporation of the solvent present in the coating formation.
- Thermoset are cured at ambient or elevated temperatures by reacting them with other polymers.

CONSTITUENTS OF PAINTS
Acrylics

Thermoplastic Acrylic:

- Thermoplastic acrylic resins belong to the two subgroups, namely ***solution acrylics*** and ***acrylic latex*** coatings.
- ***Solution acrylics*** (acrylic lacquers) are single component, thermoplastic coatings that dry and cure by solvent evaporation.
- They are used for wood furniture, automotive topcoats, aerosol paints and maintenance coatings.
- They have relatively high molecular weights and are rather low in solid contents to achieve workable viscosities.

CONSTITUENTS OF PAINTS
Acrylics

- They exhibit good resistance to hydrolysis and ultraviolet degradation, which accounts for their outstanding durability. The demand for acrylic lacquers is declining due to VOC restrictions.
- Acrylic latex coatings are a stable, fine dispersion of polymer in water. They are used in a very large amount in the coatings industry.
- Because of very low VOC, easy application, cleanability with soap and good service, the acrylic latex make up the bulk of the house-paint and architectural coatings.

CONSTITUENTS OF PAINTS
Acrylics

- A latex has basically two parts, a dispersed phase (polymer particles) and the continuous phase (the water the liquid in which the polymer droplets are dispersed), the process is usually referred as ***emulsion polymerization***.
- Surfactants are used in large amounts to stabilize the latexes.
- Acrylic latex coatings are ideal for the house-paint and architectural coatings because of their two big advantages to the consumer: low odor and an easy cleanup with water.
- Acrylic latex coatings can be formulated to meet the extremely low VOC requirements being mandated by the EPA.

CONSTITUENTS OF PAINTS
Thermoset Acrylics

- ***Thermoset acrylics*** are used in product finishes for metal furniture coatings, automotive topcoats, maintenance coatings, appliance and other original equipment manufacture finishes.
- They have major performance advantages for gloss, exterior durability, corrosion resistance, chemical resistance, solvent resistance and hardness.
- The monomers such as hydroxylethyl methacrylate, styrene and n-butylacrylate are often cross-linked with melamine-formaldehyde (MF) or benzoguanimine-formaldehyde (BF) resins.

CONSTITUENTS OF PAINTS
Vinyls

- Vinyl esters are usually used in waterborne coatings in the form of copolymer dispersions. Typical vinyl esters are for example, vinyl acetate, vinyl propionate, and vinyl laurate.
- Acrylic, maleic and fumaric acid esters are used as copolymers. Vinyl acetate is lower in cost relative to acrylic esters.
- Vinyl acetate coatings are primarily used as interior coatings. Most flat interior wall paints are vinyl latexes.

CONSTITUENTS OF PAINTS
Solvents

- Vinyl The solvents generally used in the paint industry may be divided into three classes:
  - hydrocarbon solvents;
  - oxygenated solvents;
  - water.
- Hydrocarbon solvents are the most commonly used solvents in paints to carry the pigment and binder.
- They are divided into three groups; aliphatic, naphthenic and aromatic.

CONSTITUENTS OF PAINTS

Solvents

- The preferred type of solvent is an odorless aliphatic hydrocarbon (mineral spirits), which can be used in all areas including the home.
- Aromatic solvents provide stronger solvency, but with a greater odor. The most common are toluene, xylene and naphthas.
- The principal oxygenated solvents are ketones, esters, glycol esters and alcohols. They offer much stronger solvency and are widely used as active solvents for synthetic binders.

CONSTITUENTS OF PAINTS

Solvents

- Ketones are characterized by their strong odor, range of water solubility and evaporation rate. Esters provide solvency nearly equal to ketones but with more pleasing odors.
- Glycol ethers possess both alcoholic and ether functional groups and are milder in odor. They display water miscibility, strong solvency and slow evaporation.
- n-Butanol is the most commonly used oxygenated solvents.

CONSTITUENTS OF PAINTS

Solvents

- Water is the main ingredient of the continuous phase of most emulsion paints.
- It is also used alone, or blended with alcohols or ether-alcohols, to dissolve water-soluble resins.
- Any type of resin can be made water-soluble by incorporating sufficient carboxylic groups into the polymer.
- The advantages of water as a solvent are its availability, cheapness, lack of smell, non-toxicity and non-flammability.

CONSTITUENTS OF PAINTS
Additives

- The major components of paints are
  - binders
  - pigments and extenders
  - solvents
  - additives
- ***Additives*** are any substances that are added in small quantities to a paint to improve or to modify certain properties of the finished paint coatings or of the paint during its manufacture, storage, transport, or application.
- The amount of additives in a paint can be as little as ***0.001 percent*** and seldom more than 5 percent.

CONSTITUENTS OF PAINTS
Additives

- The average proportion of a single additive in a formulation is usually around 1.5% of the total quantity of the paint formulation.
- The additives have a profound influence on the physical and chemical properties of the paint.
- They are classified according to their function as follows:

CONSTITUENTS OF PAINTS
Additives

(a) Thickening agents – These additives influence the rheological properties of paint by increasing the viscosity.

- Organoclays, organically modified laminar silicates, are the most widely used inorganic thickeners in the paint industry.
- There are a number of organic thickeners, notably hydrogenated castor oil and its derivatives, polyamides, and polyamide-oil or polyamide-alkyd reaction products.

CONSTITUENTS OF PAINTS
Additives

(b) Surface active agents – This group consists of three types of additives: wetting and dispersing agents, anti-foam agents, and adhesion promoters.

- *Wetting and dispersing agents* are additives that belong to the group of surfactants. They consist of amphiphilic molecules, which facilitate the very important process for pigment and extender dispersion and stabilization in paints and coatings.
- *Defoamers* consist of water-insoluble, hydrophobic, organic liquids such as mineral, vegetable and animal oils as well as polydimethyl siloxanes or mixtures thereof.

CONSTITUENTS OF PAINTS
Additives

- The necessary dosage, or effectiveness of a defoamer depends on the formulation.
- *Adhesion promoters* are the substances that improve adhesive strength of paints in terms of its resistance against mechanical separation from the painted surface.
- A large number of different chemical types of adhesion promoters include silanes, silicones, titanium compounds, zirconates, amides, imines, phosphates and specially modified polymers.

CONSTITUENTS OF PAINTS
Additives

(c) Surface Modifiers – These additives control the mechanical (e.g., surface slip, scratch resistance) and optical properties (e.g., gloss) of a coated surface.

- Polysiloxane-based and wax-based additives are used to control these surface characteristics. Matt surfaces (low gloss) are often preferred for many different reasons.
- Matting agents are used to reduce gloss. Natural silicas (sand) are used together with pigments and fillers in wall paints as matting agents.
- Waxes are also used as matting agents but they possess inferior matting efficiency compared to silica. Very often waxes and silica in combination are used if special surface characteristics are required.

CONSTITUENTS OF PAINTS
Additives

(d) Leveling Agents and Coalescing Agents – These additives are used to control flow and leveling of a paint during and after the application and before the film is formed.

- It influences, to a large extent, the appearance of the coating.
- Coalescing refers to the film formation of emulsion paints.
- Polyacrylates, cellulose acetobutyrate and other specialty polymers are used as leveling additives.

CONSTITUENTS OF PAINTS
Additives

(e) *Catalytically Active Additives* – This group includes paint driers and other catalysts that are used to accelerate a chemical reaction occurring during the film-forming process.

- Driers are organometallic compounds, soluble in organic solvents and binders.
- They belong to two types: primary (or active driers), and secondary (or auxiliary driers).
- The primary driers are compounds of cobalt and manganese, which have the highest catalytic activity and most pronounced accelerating effect on film formation.
- Secondary driers are compounds of lead, calcium, zinc or zirconium; they possess a lower level of catalytic activity.

CONSTITUENTS OF PAINTS
Additives

(e) Special-Effects Additives – This group of additives include a number of other substances which are added to paint formulation, e.g.:

- anti-skinning agents
- light stabilizers
- corrosion inhibitors
- biocides
- flame retardants

CHAPTER 7 OBJECTIVES

- CONSTITUENTS OF PAINTS
  - Pigments
  - Binders
  - Solvents
  - Additives
- PAINT FORMULATION
  - Classification and Types of Paints
    - Architectural Coatings
    - Industrial Coatings (OEM Paints)
    - Special Purpose Coatings
    - Varnishes
    - Lacquers

PAINT FORMULATION

- The formulation of a paint is largely determined by the ratios of the constituents in paints and to the nature of substrate to which the paint is to be applied.
- The fundamental parameters used in the formulation of a paint are:

  (a) pigment to binder ratio; (b) solid contents;

  (c) pigment volume concentration; and (e) cost.
- The performance capability of a paint depends largely on the capability of a binder in the film to provide a *completely continuous matrix* for the pigment.

PAINT FORMULATION

- The weight ratio of the pigment and extender content to that of binder solids content can be usefully correlated with the performance properties of a paint.
- In general, paints with a pigment to binder ratio of greater than 4:1 are low gloss, suitable only for some interior applications.
- The solids content of some paints provide useful information to paint formulators.

PAINT FORMULATION

- The concept of pigment volume concentration (PVC) is defined as the percentage of pigment volume in the total volume solids of the paint.

$$PVC\ \% = \frac{\text{Volume of Pigment X 100}}{\text{Volume of Pigment + Volume of Non-Volatile Binder}}$$

- In the above formula, since the amounts of the pigment and the binder are on volume basis.
- Two paints can have an identical pigment-binder (wt %) ratio, but very different PVC values, simply by using pigments of different densities.

PAINT FORMULATION

- Maximum gloss and durability are achieved at low PVC, and maximum opacity at either moderate or very high PVC.

Flat Paints	**50-75%**	**Exterior House Paints**	**28-36%**
Semigloss Paints	**35-35%**	**Metal primers**	**25-40%**
Gloss Paints	**25-35%**	**Wood Primers**	**35-40%**

- The paints formulated with low PVC, shows an excess of binder present which results in a well bound film giving a high gloss level, and good chemical, water and abrasion resistance.

PAINT FORMULATION

- At extremely high PVCs, paints would be flat with a poor degree of wash and abrasion resistance.
- The level of pigmentation is known as the critical pigment volume concentration (CPVC).
- CPVC is usually described as the PVC at which there is precisely the right amount of binder to wet the pigment particles and to fill the voids between them.
- At levels above the CPVC, there is insufficient binder to wet all of the pigment and the air-filled voids will form in dry film.

PAINT FORMULATION

- When the PVC is equal or below the CPVC, the binder forms a continuous film, which is relatively impermeable.
- A good quality paint should be formulated at a PVC at least 5 percent above or below the CPVC, depending on the properties required.
- The CPVC of a paint system is variable and depends on the nature of vehicles used in the formulation.

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Classification and Types of Paints

- Paints are classified by its proposed function or service application such as architectural coatings, industrial coatings, special purpose coatings, varnishes, lacquers, etc.

Architectural Coatings (house paints)

- This class includes paints and coatings, which are used for the decoration and protection of exterior and interior of buildings. They are divided into (a) *solvent-based*, and (b) *water-based paints*.
- The normal materials used in the painting of building include *primers*, *undercoats*, and *finish coats (top coats)*.

Classification and Types of Paints

- Primers are pigmented coatings that are applied to new surfaces or to old cleaned surfaces, prior to the application of undercoats or top coats.
- Its main functions are to achieve adequate adhesion to the substrate and to provide good intercoat adhesion for subsequent coats.
- They are specifically formulated for particular substrates such as wood, metals, and concrete and other masonry surfaces. Concrete and other masonry surfaces are alkaline and often require special surface treatments.

Classification and Types of Paints

- For etching and neutralization of these alkaline surfaces, hydrochloric or phosphoric acid washing is usually done.
- The *undercoats* are pigmented paints that are applied to primed surfaces prior to the application of finished coats. The undercoats are high pigment paints with a matt finish and a color to complement that of the ultimate finishing coats.
- The *finish coats* or the *top coats* are the final coats for use as both over primers or undercoats, and directly on a substrate.
- They are formulated to provide good adherence to the undercoat, high durability, the desired appearance, and other properties.

Classification and Types of Paints

Exterior Building Paints:

- The exterior paints are formulated to meet more hostile atmospheric conditions, such as rain, dew, temperature extremes, UV radiation and other pollutants.
- The paint film must be able to resist mildew growth, cracking and checking.
- In addition, the nature and condition of the substrate to which paint is applied is one of the major factors determining the durability of a paint.
- Generally, the paints that are used on building exteriors are 25 percent oil or alkyd and about 75 percent latex.

Classification and Types of Paints

- The cementitious substrates include concrete, masonry, sand-cement and gypsum plasters. All these substrates retain moisture and are alkaline in nature.
- The surface alkalinity can result in a chemical attack or saponification of certain types of binders used in paints, notably oils and alkyds.
- Alkyd paints are, therefore, not used on fresh concrete, masonry and plaster surfaces.
- The majority of timber used externally is in the form of solid timber, as opposed to laminates, veneers and panel products such as plywood. Both softwood and hardwoods are used.

Classification and Types of Paints

- The moisture and ultra-violet (UV) light (sunlight) are particularly harmful to timber.
- A coating system having an ability to protect the substrate from water and damaging effects of UV light is used.
- Pigmented paints, normally based on drying oil alkyd resins are normally used. The use of clear varnishes is, however, common on many timbers.
- Latex paints are found to be more resistant than varnish or alkyd paints in performance.

Classification and Types of Paints

Interior Flat Paints:

- The interior flat wall paints are the largest volume of trade sales paints.
- In the retail market, water-based latex paint has almost entirely taken over the market from their oil-based counterparts.
- The major advantages of latex paints over oil-based paints are (a) fast drying and less sagging; (b) low odor; (c) ease of cleanup; (d) low VOC emission; and (e) less yellowing and embrittlement.

Classification and Types of Paints

Industrial Coatings (OEM Paints)

- Industrial coatings include paints and finishes used in factories on products such as automobiles magnet wire, aircraft, furniture, appliance finishes, metal cans, chewing gum wrappers and various other products.
- Powder coatings and radiation-cured coatings are also included.
- They are commonly called OEM coatings, that is, *original equipment manufacturer* coatings.
- In 2001 in the United States, the OEM coatings were about 33% of the value of all coatings.

Classification and Types of Paints

- Primers are used to aid adhesion of the top coat to a surface and to provide a relatively uniform film thickness on all metal surfaces.
- Primers can also be used to prevent corrosion of a metal surface.
- Paints used as the final coats are referred to as finishes or top coats. They are based on binders selected to withstand the conditions likely to be experienced in the proposed service environment.
- Alkyd resins are used extensively for exterior exposure under mild conditions.

Classification and Types of Paints

Powder Coatings:

- Powder coatings are used by the paint industry usually for metal substrates.
- The powder is applied to the substrate and fused to a continuous film by baking. The formulation of a powder coating is based on pulverizing solid components, resins, pigments and a hardener.
- Thermosetting, thermoplastic and vitreous enamel powders are available; the major portion of the market is for thermosetting types.
- Binders for thermosetting powder coatings are often called a *hardener*.

Classification and Types of Paints

- The hardeners are a mixture of a primary resin and a cross-linker. The major types of binders can be limited to polyester, epoxy, hybrid epoxy-polyester, acrylic and UV cure types.
- Polyester binders are used for good exterior durability, retention of gloss and resistance to chalking.
- Vinyl chloride copolymer (PVC), polyamides and thermoplastic polyesters are used as binders for thermoplastic powder coatings.

Classification and Types of Paints

- They are difficult to pulverize to small particle sizes. They are more viscous and give poor flow and leveling, even at high baking temperatures.
- Ultraviolet-cured powder coatings are used for rapid curing at low temperatures. The curing process is based on both free radical and cationic cure coatings.
- Free radical cure coatings use acrylated epoxy resins as binders. Cationic UV cure coatings use BP epoxy resins as binders.

Classification and Types of Paints

Special Purpose Coatings:

- Special purpose coatings represent approximately 14% of market, which includes specific paint, such as highway marking paint, automotive refinishing and high performance maintenance paints.
- The term maintenance paints is generally taken to mean paints for field application, including highway bridges, refineries, factories, power plants, and tank forms.
- A major requirement of maintenance paints is corrosion protection. Another important requirement is the time interval to be expected between repainting.

Classification and Types of Paints

- The pigments used in the formulation of industrial paints are mainly zinc meal, zinc oxide, molybdates and phosphates.
- For severe environments, chlorinated rubber, vinyl solutions, epoxies and cross-linked epoxies are used.
- Special paints are used for protecting flammable substrates by retarding flame spread.
- Polyammonium phosphate emits a gas at elevated temperatures but lower than charring temperatures.

Classification and Types of Paints

Varnishes:

- Varnishes are non-pigmented paints, which dry to a hard-gloss, semi-gloss or flat transparent film by a process comprising evaporation of solvent, followed by oxidation and polymerization of the drying oils and resins.
- The varnish is manufactured by cooking the drying oil (usually linseed oil, tung oil or mixture of the two) and resin together to a high temperature to obtain a homogeneous solution of the proper viscosity.
- The varnish is then thinned with hydrocarbon solvents to application viscosity.

Classification and Types of Paints

- The types of oils and resins and the ratio of oil to resins are the principal factors, which determine the properties of a varnish.
- The bulk of the market for these traditional types of varnishes have been almost completely replaced by a variety of other products, especially to uralkyds which provide greater abrasion and water resistance.

Classification and Types of Paints

- Uralkyds are also called urethane alkyds or urethane oils. They are alkyd resins in which a diisocyanate, usually toluene diisocyanate, has fully or partly replaced the phthalic anhydride usually used in the preparation of alkyds.
- Uralkyds are superior in performance over alkyds or epoxy esters. The term varnish these days refers generally to the transparent coatings, even though few of them today are varnishes in the original meaning of the word.

Classification and Types of Paints

Lacquers

- A lacquer is a solution of a hard linear polymer in an organic solvent. It dries by simple evaporation of the solvent.
- The film forming polymers usually used are chlorinated rubber, nitro cellulose, acrylics, vinyl resins, or other high molecular weight linear polymers.
- The properties of lacquers vary with the main type of film forming resin used, and their main advantage is rapid drying speed.
- Cellulose nitrate is the most widely used film-former for the manufacture of lacquers.

Classification and Types of Paints

- Plasticizers (such as vegetable oils, monomeric and polymeric esters) are added to impart necessary flexibility to nitrocellulose films.
- The lacquers may be formulated for application by most of the conventional methods cold spraying, hot spraying, dipping, squeeze coatings and electrostatic application.
- The lacquers are largely used in automobile finishes, furniture finishes, metal finishes, and plastic, rubber, paper, and textile finishes.

CHAPTER 7 OBJECTIVES

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