European Coatings Tech Files

VINCENTZ

Adrie Winkelaar

Coatings Basics

Adrie Winkelaar

Coatings Basics

Adrie Winkelaar: Coatings Basics

ISBN 978-3-86630-851-0

Cover: Evonik Degussa Coatings & Colorants – Dieter Debo, Infracor, Marl/Germany

Bibliographische Information der Deutschen Bibliothek
Die Deutsche Bibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliographie; detaillierte bibliographische Daten sind im Internet über http://dnb.ddb.de abrufbar.

Adrie Winkelaar
Coatings Basics
Hannover: Vincentz Network, 2009
(European Coatings Tech Files)
ISBN 3-86630-851-5
ISBN 978-3-86630-851-0

Please ask for our book catalogue
Vincentz Network, Plathnerstr. 4c, 30175 Hannover, Germany
Tel. +49 511 9910-033, Fax +49 511 9910-029
E-mail: books@european-coatings.com, www.european-coatings.com

Layout: Maxbauer & Maxbauer, Hannover, Germany
Printed by Quensen Druck + Verlag GmbH & Co. KG, Lamspringe, Germany
ISBN 3-86630-851-5
ISBN 978-3-86630-851-0

European Coatings Tech Files

Adrie Winkelaar

Coatings Basics

Adrie Winkelaar: Coatings Basics

ISBN 978-3-86630-851-0

Preface

The purpose of this book is to provide an insight to the development, manufacture and application of paint products for those who have little or no education in coating technologies. Paint is considered to be a straightforward product and simple to apply, however, all paints contain a variety of risk-involved chemicals that are in accordance with physical and chemical laws. Increasingly more safety, health and environment legislations have been and are being passed in order to protect paint users, such as professional painters, do-it-yourselfers and industrial applicators.

The physical and chemical processes when applying paint products are extremely important, it is therefore necessary for the user to understand what the properties are and what to expect so that the best possible protection is provided and disappointments of substrate decoration results are avoided. This book, comprising ten chapters, offers important and useful explanations and guidelines to understanding what happens and what to expect when paints are developed, manufactured and applied.

The following chapters have been divided into various topics, starting in Chapter 1 with a short summary of the lengthy history of paint, worldwide differences and definitions. Because paint products contain chemicals that are in accordance to physical and chemical laws some basic chemistry information is necessary for understanding the background and basics of paint. The book continues with information on ingredients and properties of paint. It is important to know something about the various paint formulas and the differences between wall paint, wood paint, and metal paint etc. Paint manufacture and paint application are steps in the process of understanding how sensitive paint can react. The final two chapters of this book are concerned with test methods and regulations for health, safety and

Adrie Winkelaar: Coatings Basics

ISBN 978-3-86630-851-0

environment. Solvents in paints are harmful to health, safety and to the environment and are gradually being reduced and replaced with water. Increasingly new technologies are being introduced in the paint industry. Hopefully this book will provide an insight, not only to the present properties and use of paint but also to future new developments.

This book has been written with very few references so that newcomers are able to read it through freely and easily. Many illustrations and figures have been inserted to show the various manufacturing machinery and test methods equipment. The appendix contains a list of reference books that provide more specific, extensive knowledge about organic chemical science. It is always possible to provide more detailed information regarding ingredients, formulations, manufacturing, application and legislation, however, this book offers concise information and guidelines for understanding the paint and coatings phenomena.

Adrie Winkelaar
Heemskerk, Netherlands, May 2009

Contents

Adrie Winkelaar: Coatings Basics

ISBN 978-3-86630-851-0

1 What is paint or coating?

To explain the many varieties of paint applications that are worldwide available, it is important to understand the rich and extensive history of paint. Paint is a personal experience to which emotions and feelings are linked and which vary worldwide. Architectural paint provides a new fresh appearance to many used things and because the question of what is beautiful is different for each and every one of us, it is a personal issue. Looking back through the ages we have learned that throughout the world of paint has varied. It is now possible to see how paint differs from country to country and perhaps we are gradually moving towards a common worldwide feeling towards paint by using the same compositions.

The first history questions are: When was the first paint made? How was the first composition devised? What was the first application?

Through ages paint has been more and more developed with the use of new experience which resulted in making new applications possible. The increasing introduction of different pigments, different dyes and different binders has resulted in an increase of paint applications that have provided even more possibilities to communicate worldwide. It is very important to communicate durability and sustainability to all cultures and future generations throughout the world.

Present-day coatings appear on all objects in our environment. Knowing something about paint makes for being an authority on our ‘painted = coated’ surroundings. Coatings are applied to houses, cars, aeroplanes, furniture, and computers – paint is, in fact, applied to so many objects and in so many different ways. There are also many similarities between paint and cosmetics, paint and wallpaper, paint and glazing and between paint and foil. Basic knowledge about these substances will open up a new, wonderful and colourful world. Colour is coating and coating is colour.

Adrie Winkelaar: Coatings Basics

ISBN 978-3-86630-851-0

Differences between paint and coating

When the substance is wet – it is paint and when it is a dried layer – it is a coating. People sometimes call thick layers “coatings” and thin layers “paint”, such as paint on wood. Wet paint products for thick layers (for metal protection) are also called “coatings”. Generally speaking – wet paints are in a tin or layer and “coatings” are dried layers on substrates.

1.1 History

Paint goes far back in history. According to neuropsychologists, human beings developed their language between 50,000 and 70,000 years ago and the first paintings were discovered after that period. A language had been developed to enable communication and paint is in that case the first visual expression of communication. It is estimated that the first paint was composed between 30,000 to 40,000 years ago. The oldest cultures used carbonized wood to illustrate expressions of what they saw, such as animals and landscapes. The Cro-Magnon men painted on the walls in caves in France (Lascaux) and Spain (Altamira) between 15,000 and 10,000 B.C. Ferrous earth was also used as pigment and blood and milk as binders.

Throughout Europe many cave paintings have been found – from Spain and right across to The Ural. The oldest painting which was found in the Lions Cave, South Africa dates back to 40,000 years ago.

Figure 1.1: Cave paintings in Lascaux

Paint was later used to identify and decorate objects, clothes and the body. The natural substances used are still being applied for re-usable binding substances in the modern paint industry, such as casein, grease, waxes and resins from milk, plants and trees.

The advanced civilisation of the Egyptians, Chinese, Greeks and Romans used painting techniques to identify and decorate vessels, statues, tools and buildings. Paint was also increasingly being used to provide protection against the influences of weather. Wooden ships were made watertight with mixtures of natural bitumen and asphalt. The old Greeks used the first anti-fouling application to protect their ships against under water fouling, which increased the speed of their vessels compared to enemy ships.

Figure 1.2: Vessels in original colours from the Ancient Greece period

Approximately 2000 years before Christ marks an important period in the development of paint which is illustrated by the decoration techniques of the Ancient Chinese who produced smooth and glossy objects. Varnishes offered a new dimension to paintwork and the new raw materials such as balsams and natural resins provided many possibilities. The most famous resin is shellac, produced by certain insects called 'lac insects' that produce sap in Indian fig trees.

In the 11^{th} century, monks made a spectacular step forward in the history of paint when they boiled linseed oil with molten amber and acquired a more durable coating. From that period coatings were used to maintain paintings, the shields of knights and as durable protection of wood, in addition to the old fashion bitumen and asphalt. This resulted in a unity of decoration and protection and thus the manufacture of paint as a trade was born. The famous painters in the 15^{th}, 16^{th} and 17^{th} centuries made their own paints. At that time each part of the world had its own local artist who made paint and applied the colours to the inside and outside of houses and public buildings.

In the 18^{th} century the industrial revolution caused a huge demand for paint for all objects, houses and ships. The world population increased and many cities and villages evolved. At that time the first paint factories were opened in England, Holland and Germany. At these factories investigations were carried out using brewing kettles for the manufacturing of linseed oil binders and machines for milling the pigments.

The final mega development came in the 20^{th} century, when the industry produced new such as

- nitrocellulose,
- alkyds,
- acrylics,
- polyurethanes and
- epoxies

as binders for use in the paint industry. New production lines were opened for the manufacture of numerous consumer goods such as cars, buses and trains, but also for furniture, beds and paint for the decorative market. For all these applications the paint industry used micro-technology with of 1 to 10 micron. One micron is a one thousand part of a millimetre. At the beginning of the 21^{st} century new technology introduced nano-particles consisting of new properties. A nanometre is a one thousand part of a micron. It is possible to introduce nano-particles into micro-particles for 'self healing' paints. The nano-particles open when a scratch occurs. "Smart coatings" have also been developed as structured coating systems that provide an optimum response to certain external stimuli, and react to outside conditions, such as temperature, stress, strain or the environment, in selective ways.

The production and the use of paint has developed together with humans and dates back from prehistoric times when it was used as an experimental communication tool, through the Middle Ages when it became a trade that introduced durable properties and right up to Modern Times resulting in an ever growing multi-disciplinary high coating technology.

1.2 Worldwide differences

Paint is used on a large scale throughout the world. The paint quantity per population head varies for each country. Worldwide – Ger-

Table 1.1: European paint production and consumption in 1996, source: CEPE, the European Paint Makers Association in Brussels, www.cepe.org

	Inhabitant in millions	Paints in 1000 tonnes	kg/ inhabitant
Germany	80.4	1,350	16.8
Spain	40.4	630	15.6
France	63.7	690	10.8
Italy	58.1	730	12.6
United Kingdom	60.7	410	6.7
The Netherlands	15.5	310	20.0
Denmark	5.4	130	24.0
Belgium	10.4	140	13.5

Table 1.2: European Decorative market in 2006

	kt deco	kg/ inhabitant
Germany	800	9.7
Spain	700	17.3
France	500	7.8
Italy	400	6.9
United Kingdom	400	6.5
The Netherlands	150	9.1
Denmark	70	13.0
Belgium	50	4.8

many, Denmark and The Netherlands use the highest quantities with approximately 20 kg per inhabitant, see Table 1.1. For example: Egypt = 3 kg per inhabitant and Russia = 4,5 kg per inhabitant. The quantities of paint applications used provide an indication of the prosperity and hygiene of a certain country. The figures also include consumption and provide a total impression of welfare and economics.

In Europe the decorative market also varies for each country. This market offers an impression of habitation and public buildings in each country. The paint quantity per population head provides

Table 1.3: Decorative consumption in tonnes in 2004 in The Netherlands, source: Dutch Paint Makers Association in The Hague, The Netherlands, www.vvvf.nl

	Professional painters	Do-it-yourself	Total
Lacquers and varnishes	13,700	13,100	26,800
Wall paints	22,900	40,800	63,700
Plaster	48,500	12,700	61,200
Wood stains		1,300	1,300
Concrete repair	2,200		2,200
Fillers	2,000	850	2,850
Total	89,300	68,750	158,050

another impression. Spain and Denmark show the highest figures and provide an impression of building and maintenance activities at a specific moment, see Table 1.2.

The different habits and cultures of each country are also illustrated by the figures of the various paint types sold on the decorative market. Wall paints are applied more in Germany and in southern countries than in other countries. In northern countries a lot of wood paint and wood stains are applied.

In The Netherlands many different products, such as wood stains, lacquers, varnishes, wall paints for ceilings, interior walls, kitchens and exterior walls, etc are applied. In this country there is a difference between the professional decorative market and the do-it-yourself decorative market, see Table 1.3. The decorative market is 80 % of the total volume in The Netherlands.

The European paint makers association, CEPE, represents 85% of the European paint volume. CEPE represents 900 members; however there are approximately 3,300 paint manufactures in Europe. In the European paint industry in 2006, 120,000 people worked together and produced more than 4,000 kt of products with a total value of 17 billion Euros. The European decorative paint market is approximately 60% of the total volume and represents about 7 billion Euros divided under 2.5 million professional painters and about 100 million do-it-yourselves. The paint impact on daily life is enormous and a world without paint is unimaginable.

1.3 Definitions and standardization

A coating is a dried paint on a substrate. Our environment is full of coatings – it is the most ‘looked-at’ product in the world. Paint definitions are described in EN/ISO 4618 and paints are applied as coatings on substrates for identification, decoration and protection purposes.

In addition, an important property of a coating is indicated with information using colours in the design and the printing trades.

There is an increasing global harmonization regarding definitions, test methods and regulations. The International Organization of Standardization (ISO) is the world’s largest developer of international standards. ISO is a network of the national standards institutes of 160 countries, one member per country, with a Central Office in Geneva, Switzerland, that coordinates the systems. ISO is a non-governmental organization that forms a bridge between the public and private sectors. The ISO 9000 is a standard quality system and the ISO 14000 is a standard environment system.

In the middle of the 1990’s the paint industry introduced a worldwide responsible care system based on the ISO system, called Coatings Care®. The Coatings Care® program was conceived as a voluntary initiative aimed at assisting industry professionals in their efforts to protect the health and environment of the worker and the community, as well as promote product safety. Coatings Care® is designed to foster best management practices, and promote the development of new technologies that improve product performance. The framework and resources for the program deliver comprehensive guidance for manufacturing operations as well as critical support for customers and business partners throughout the supply and distribution chain. Coatings Care® is tailor-made to be the most effective and practical system for the coatings industry to sustain safe and environmentally friendly operations around the globe.

2 Basic principles of chemistry

Chemistry originated in Ancient Egypt. The name chemistry derives from the Egyptian word “kēme” (chem), meaning “earth”. Chemistry is the science concerned, not only with the composition, structure and properties of substances, but also the changes that substances undergo during chemical reactions. Modern chemistry results from alchemy practiced during the chemical revolution in the 18th and 19th century.

2.1 Substances

The concept of a chemical element is related to that of a chemical. A chemical element is characterized by its atom – the basic unit of an element. A collection of matter consisting of a positively charged core (the atomic nucleus) made up of protons and neutrons. A number of electrons, surrounding the atomic nucleus, are maintained in order to balance the positive charge within the nucleus. An electron has a negative charge. An atom is also the smallest entity that can be envisaged and retains some of the chemical properties of the element, such as ionization potential and a preferred oxidation state. Each element has a characterized element value with a number of protons.

A presentation of the chemical elements is illustrated in the “periodic table” (see Appendix 1), which groups elements by atomic values. *Dmitri Mendeleev* (1869) was the first scientist to create a periodic table of elements. This table shows that when elements were ordered by an increasing atom weight (protons and neutrons), a pattern appeared when the properties of the elements were periodically repeated. There are more than 103 elements, many of which are important to daily life, such as, number 1 (H = Hydrogen), number 6 (C = Carbon), number 8 (O = Oxygen), number 26 (Fe = Iron), number 47 (Ag = Silver) and number 79 (Au = Gold).

Adrie Winkelaar: Coatings Basics

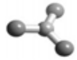
ISBN 978-3-86630-851-0

Apart from an atom, a molecule is the smallest indivisible portion of a pure chemical substance that has a unique collection of chemical properties. Molecules are a typical set of atoms bound together by covalent bonds, such that, the structure is electrically neutral and all of the valence electrons are paired with other electrons either in bonds or in lone pairs.

A molecule may consist of atoms of the same chemical element, such as with oxygen (O_2), or of different elements, such as with water (H_2O). Atoms and complexes connected by non-covalent bonds such as hydrogen bonds or ionic bonds are not generally considered as single molecules.

One of the main characteristics of a molecule is its geometry – often called its ‘structure’. No typical molecule can be defined in ionic crystals (salts) and covalent crystals (network solids), although these are often composed of repetitive unit cells that extend either in a plane (such as in graphite) or three-dimensionally (such as in diamonds or sodium chloride). The theme of the repetitive unit-cellular-structure also applies to the most condensed phases of metallic bonding. In glass (solids that exist in a vitreous disordered state), atoms may also

Table 2.1: Chemical description of some substances

Structure	Angle of atoms	Formula	Visualisation
Linear	180°	beryllium-chlorine: $BeCl_2$	
Trigonal planar	120°	boron-fluorine: BF_3	
Bent	120°	sulphur dioxide: SO_2	
Tetrahedral	109.5°	methane: CH_4	
Trigonal pyramidal	109.5°	ammonia: NH_3	
Bent	109.5°	water: H_2O	

be held together, not only by chemical bonds without any definable molecule, but also without any of the regularity of repetitive units that characterize crystals.

In each molecule structure the elements are bonded with other elements in a specific geometry, such as linear, pyramidal or rings. The chemical formula provides the letters of the elements and each formula can be visualised.

In the following Table 2.1 the chemical structures of some substances are described by name, formula, and angles of the atoms and the visualisation of the structure.

2.2 Organic (carbon) chemistry

Carbon is found in many different compounds. It is in the food we eat, the clothes we wear, the cosmetics we use and the gasoline that fuels our car. Carbon is the sixth most common element in the universe. In addition, carbon is a very special element because it plays a dominant role in the chemistry of life.

The simplest organic compounds contain molecules composed of carbon and hydrogen. The compound methane contains one carbon bonded to four hydrogens. Ethane is another example of a simple hydrocarbon. Ethane contains two carbon atoms and six hydrogen atoms. In chemistry we use a molecular formula to show how many atoms of each element are present in a molecule. However, a molecular formula does not show the structure of the molecule. Scientists often use structural formulas to illustrate the number and arrangement of atoms in compounds. In Figure 2.1 the molecular formula for methane (CH_4) and ethane (C_2H_6) are illustrated.

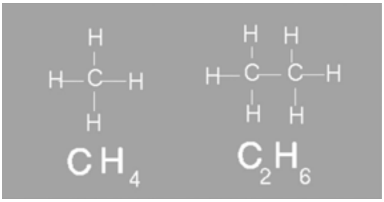


Figure 2.1: Molecular formula methane (left) and ethane (right)

Although structural formulas can be very helpful they do not present a complete picture of a molecule. Structural formulas tell us nothing about the distances

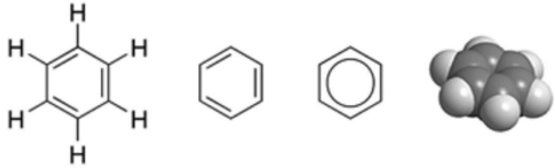


Figure 2.2: Chemical figures of benzene

between bonds, the angles formed by these bonds, or the size and shape of the molecule.

In chemical books the formula of alcohol is written: C-C-OH (ethanol), which means two carbon atoms (ethane) and a hydrogen-oxygen group (alcohol). An organic acid molecule is bonded on two carbon atoms with double bonds (ethylene): C=C-COOH. The acid-group is COOH and can be written as CO_2H. In some cases it is noted as $-\underset{\overset{|}{OH}}{C} = O$ because the bond “=” is a double bond and “–“ is a single bond.

This chemical acid C=C-COOH is called acrylic-acid and is the raw material for the binder poly-acrylics for acrylic paint.

All aliphatic hydrocarbons are linear carbon chains. The aromatic hydrocarbons are ring structures of six carbon atoms, such as benzene or toluene, with double bonds, also noted with three stripes or a circle in the middle.

In the following Figure 2.2 the six-aromatic ring of benzene has been sketched in three different ways. The fourth structure illustrates the visualisations of benzene with six carbon and six hydrogen atoms.

2.3 Chemical reactions

A chemical reaction is a process that always results in a change in chemical substances. The substance or substances initially involved in a chemical reaction are called reactants. Chemical reactions are usually characterized by chemical changes that yield one or more products, which usually have different properties to the reactants. Chemical reactions encompass changes that strictly involve the motion of electrons in the forming and breaking of chemical bonds.

Different chemical reactions are used in combination with chemical synthesis in order to obtain a desired product. The large diversity of chemical reactions and approaches to their study results in the existence of several concurring, often overlapping ways of classifying them. Below are examples of widely used terms for describing common kinds of reactions.

Direct combination or synthesis, in which 2 or more chemical elements or compounds unite to form a more complex product: $N_2 + 3H_2 \rightarrow 2\ NH_3$ (ammonia)

Chemical decomposition or analysis, in which a compound is decomposed into smaller compounds or elements: water: $2\ H_2O \rightarrow 2\ H_2 + O_2$

Displacement or substitution, characterized by an element being displaced out of a compound by a more reactive element: $2\ Na + 2\ HCl \rightarrow 2\ NaCl$ (salt) $+ H_2$

Acid-base reactions, broadly characterized as reactions between an acid and a base, such as HCl (hydrochloric acid) + NaOH (lye) $\rightarrow NaCl + H_2O$

Oxidation reaction of metals with oxygen from the atmosphere: $Fe + O_2 \rightarrow FeO_2$

The rate of a chemical reaction is a measurement of how the concentration or pressure of the involved substances changes with time. Rates of reaction depend basically on:

- **Reactant concentrations**, which usually make the reaction happen at a faster rate if raised through increased collisions per unit time.
- **Surface area** available for contact between the reactants, in particular solid ones in heterogeneous systems. A larger surface area leads to a higher reaction rate.
- **Pressure**: by increasing the pressure, the volume between molecules is decreased. This increases the frequency of molecule collisions.
- **Activation energy** is defined as the amount of energy required to make a reaction start and continue spontaneously. Higher activa-

tion energy implies that the reactants need more energy, than a reaction with lower activation energy, to start with.

- **Temperature**, which, if raised, speeds up reactions, since a higher temperature increases the energy of the molecules, creating more collisions per unit time,
- The presence or **absence of a catalyst**. Catalysts are substances which change the pathway (mechanism) of a reaction which in turn increases the speed of a reaction by lowering the activation energy needed for the reaction to take place. A catalyst is not destroyed or changed during a reaction, so it can be used again.
- For some reactions, the presence of **electromagnetic radiation**, most notably ultraviolet, is needed to promote the breaking up of bonds to start the reaction – this is particularly true for reactions involving radicals.

Chemical energy is part of all chemical reactions. Energy is needed to break chemical bonds within the starting substances. As new bonds form in the final substances, energy is released. The comparison of the chemical energy of the original substances and the chemical energy of the final substances can be decisive, if the energy has been released or absorbed in the overall reaction. A chemical reaction in which energy is released is called an ‘exothermic’ reaction. Exo means “go out” or “exit”. Thermic means “heat” or “energy”. Exothermic reactions can produce energy in several forms. If heat is released in an exothermic reaction, the nearby matter will become warmer.

In organic synthesis, organic reactions are used in the construction of new organic molecules. The production of many man-made chemicals such as plastics, polymers and additives depend on organic reactions. The oldest organic reactions are combustion of organic fuels and saponification of fats to make soap.

3 *Paint ingredients*

Almost all types of paint consist of viscous binders that enable the application of a thin layer (a coating) for adhesion and protection. Pigments are also necessary in order to provide colours in the paint. Many additives and solvents are added to enable good application and stability properties. Additives, such as driers, surface-active additives, biocides etc. are necessary for improving various such as the flow, smoothness, hardness, fouling etc.

Developing and manufacturing paint can be compared with cooking a good meal. The cook invents his own formulas and recipes with his selected ingredients: vegetables, rice, potatoes, meat or fish and various chosen additives: herbs, pepper, salt, garlic etc. There are no two cooks in the world who have the exact same formula or recipe and presentation. Everyone cooks in a different way, using different methods and yet all eaters enjoy the different meals, whether it is an exquisite dinner in a small bistro or a grand buffet in a large renowned restaurant. The atmosphere and surroundings are also very important to making a meal a success. The same comments can be applied to paint. The colour choice and the application conditions influence the paint result: the coating experience. Also the discussion regarding the best paint in the world is the similar to discussing the best cook in the world. Your mother is the best cook in the world and you can eat just as well in both small and large restaurants. The big paint companies can be just as good as smaller paint companies. Smaller paint companies sometimes specialize and make their own special products similar to the comparison we make between a Chinese restaurant and an Argentine restaurant – both different but both just as good! The differences between big and small companies are the logistics, the distribution and the size of the budget for marketing and advertising. The discussion on the quality of paint is all about good ingredients and good formulas.

Adrie Winkelaar: Coatings Basics

ISBN 978-3-86630-851-0

3.1 Binders

Binders are film formers that enable bonding between the pigments and between the surface and the pigments. A coating is a dried layer like a film. The most important binders are

- oil,
- alkyds,
- acrylics,
- epoxies and
- polyurethanes.

All these substances have different properties in adhesion, hardness, flexibility, gloss retention, water resistance and UV-resistance. The question is, how it is possible and what causes these differences?

There are natural binders, such as linseed oil and resins, and also modified natural substances such as nitrocellulose, alkyd and synthetic substances such as acrylics, epoxies and polyurethanes.

In each coating of applied paint a transition from liquid to a solid state takes place. A distinction is made between **physical drying** and **chemical curing**. This can occur simultaneously or in sequence.

During the physical drying of an applied paint, the transition from liquid to a solid state is the result of evaporation of solvents, including water. An example is the old-fashioned cellulose lacquer used in former days. Another form of physical drying is coalescing drying of waterbased dispersion paints. The binder particles flow together after the evaporation of the water. During the chemical curing of an applied paint, the transition from liquid to a solid state is accompanied by an increase in molecular mass. Examples are two-component paints, which must be mixed together before application. The oxidative drying paints such as the well-known oil or alkyd resin have oxidative drying by oxygen from the air. See Chapter 4 for drying mechanisms of binders.

3.1.1 Natural binders

In the present paint industry natural substances such as resins, plant oil and bitumen are still used. They must be diluted with solvents such as white spirit, xylene, alcohol or acetone.

Resins

The most important natural resins are colophony, copal, dammar and shellac. Colophony is extracted from pine trees and is diluted in white spirit. This resin has a high acid value and has to be combined with oxides of zinc, magnesium or calcium to neutralise it. Shellac is the product of the sap of certain trees and is produced by the insect called Laccifer lacca commonly known as the 'lac insect'. This amber coloured resin is soluble in alcohol and can be made water-soluble in combination with amines or ammonia. Resins provide a hard film and are combined with other binders.

Plant oils

Important oils in paint chemistry are linseed oil, soya bean oil, safflower oil and castor oil. Linseed and soya bean oil are drying oils, safflower oil is semi drying and castor oil is non-drying. The fatty acids in the oil are, together with other reactive groups, responsible for drying properties. Through an oxidative reaction the oil changes into a soft and sticky substance. The drying oils play an important part in modified binders such as alkyds. In Table 3.1 the compositions of some plant oils are described.

Table 3.1: Composition of some plant oils

	Linseed oil	Safflower oil	Wood oil	Soya oil
Palmitin acid	6.0	6.0	4.0	10.0
Stearin acid	4.0	2.0	1.0	3.0
Oil acid	19.0	19.0	4.0	29.0
Lineic acid	24.0	70.0	-	51.0
Linoleic acid	47.0	3.0	1.0	7.0
Eleostearin acid	-	-	90.0	-
Total weight %	100.0	100.0	100.0	100.0

Bitumen

Bitumen, asphalt and pitch are dark, hard substances that contain excellent water resistant properties and are used for corrosion protection, roof coatings and vehicle under seals. They are combined with other binders into one and two component products. The use of coal tar is forbidden because it contains toxic polycyclic aromatic hydrocarbons (PAC).

3.1.2 Modified natural binders

Modified binders play a big part in natural substances. Cellulose, rubber and fatty acids (plant oils) can be modified to become good binders.

Fatty acids: alkyds

A combination of "alcohol" and "acid" is called **alkyd**. In chemical terms this reactive product is called **polyester**. The structure of an alkyd consists of oil, alcohol (glycerol) and phtalic acid. More phtalic acid in the alkyd presents a harder and faster drying binder. Increased plant oil in the alkyd results in a weaker and slower drying binder. A high fat-content binder is for exterior application and a low fat-content binder is for interior application.

An alkyd is formed in three steps by

- phtalicacid: $C_6H_4(COOH)_2$, a benzene ring with two acid-groups,
- glycerol: $C_3H_5(OH)_3$, an alcohol with three OH-groups
- carboxylic acid: R-COOH, which R is a long chain of linseed oil, that is a mix of linolenic acid, linoleic acid and oleic acid.

There are fatty alkyds containing more than 55 % of plant oil and lean alkyds containing less than 45 % of plant oil. If the alkyd is fatty, the phtalic acid is much less. See Table 3.2.

Figure 3.1: Alkyd molecule structure

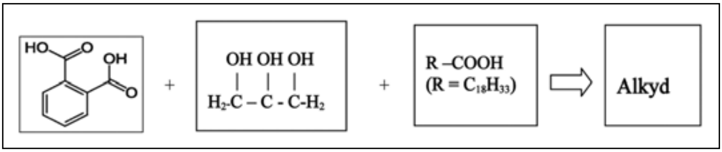


Table 3.2: Types of alkyds

Types of alkyds	Oil content (%)	PA content (%)
Oil free	0	77
Lean	<45	>40
Medium fatty	45 to 55	30 to 40
Fatty	>55	15 to 30

If the oil content is high, then the alkyd viscosity is low and the brush ability is good. If the viscosity of a lean alkyd is too high then the brush ability is bad. The thickness of a dried layer from a fatty alkyd is more than the thickness of dried layer from a lean alkyd. The flexibility of a fatty alkyd is higher than that of a lean alkyd. The wet paint film-flow is much better from a fatty alkyd. The yellowing of a dried fatty alkyd paint film is increased compared to a lean alkyd paint film. The durability of a medium fatty alkyd is the best.

Alkyds conforming to the Directive 2004/42/EC (see Chapter 10) have to be composed of more less-solvents. The glycerol changes through an organic alcohol with four or five reactive groups that provide more branching alkyds and better drying time. The low viscosity is attained with shorter oil chains.

3.1.3 Synthetic binders

The most famous synthetic binder is acrylic which is obtained through a polymerisation process of raw materials from crude oil. This means that a long chain of carbon molecules is built up from the reaction of each molecule together with another molecule. In addition, epoxy and polyurethane binders are now being manufactured.

Acrylic

The acrylic “monomer”, one molecule of pure **acrylate**, comes from the petrochemical industry and can be combined with other monomers. The chemical structure is based on two carbon atoms and carbon acid. A double connection between two carbon atoms is very reactive and can react with other monomers to a polyacrylic

$C = C - COOH$