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Paints and Other Coatings

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Please note

Paints and other coatings involve three main constituents - binder, pigment and solvent. This Digest describes the different kinds of coatings made from these three components. Although it is true that there is no pigment in most clear coatings and no solvent in some coatings designed to produce thick films, all three constituents are commonly present in the different types of organic coatings.

Classifications

Because of their great variety, it is desirable to classify coatings in groups. This may be done in several ways according to:

- composition - oil, latex, alkyd, zinc-rich, etc;
- end use - interior, exterior, industrial, particular substrate (for wood, for metal), particular exposure (water immersion), etc;
- method of cure - air dry, bake, cold cure, etc;
- appearance - clear, stain, pigmented, metallic, flat, high gloss, etc.

Users tend to classify coatings by one of the latter three groupings, but coatings technologists prefer to classify them according to composition, because it usually determines the other three - end use, method of cure, and appearance. This series of Digests will group coatings according to their composition and relate their end use to their properties.

In classifying coatings according to composition there are two main categories:

- solvent-based coatings - materials that contain or are soluble in organic solvents;
- water-based coatings - materials that dissolve in or are dispersed in water.

Solvent-Based Coatings

Oils and oil paints, varnishes, enamels and lacquers are classed as solvent-based coatings. Too often, any solvent-based coating is called an oil paint or oil-based paint to distinguish it from a water-based coating, but this is not correct; many types do not contain oil and technically are not paints. In solvent-based coatings the pigment is dispersed throughout the vehicle (i.e.

binder and solvent), except in a few isolated cases. As the solvent evaporates during the drying process, the binder continues to wet, or hold, the pigment. There is therefore little danger that the pigment particles will group together in flocculates, causing loss of hiding power; and all degrees of gloss are feasible with most of these binders because sufficient quantities of pigment can be dispersed in the complete vehicle.

Solvent-based coatings provide a wide range of times for initial, intermediate, and final drying stages, for many different solvents suiting individual requirements can be used. The final hard-dry time is chiefly dependent upon the binder, although it can be influenced by the solvent. These coatings readily wet surfaces that resist wetting by water, and thus reduce the possibility of such defects as pin-holes.

Oils and Oil Paints. The simplest solvent-based coatings are drying oils and their pigmented versions, paints. The specific definition of a paint is "a pigment or pigment mixture dispersed in a drying oil". The word "paint" will be used for solvent-based coatings in this limited sense. Drying oils, obtained chiefly from vegetable sources, are those oils that absorb oxygen and solidify within a usable time when exposed to the air in thin films. Linseed oil is the most common. Drying oils do not usually contain solvents if used without pigment, but they are solvent-soluble.

Because the polymer is formed from small liquid molecules after application, paints take a long time to dry and to cure completely. The process can be somewhat speeded up by pre-polymerizing part of the oil by heating it to produce what is called "bodied" oil. Because of the increased viscosity some solvent can then be added to help decrease the setting time of the film through evaporation.

Oils dry by reacting with the oxygen in the air to form a chemically linked network of molecules. Since oxygen is always available, the reaction can continue past the optimum point so that the film eventually becomes quite brittle. The type of pigment used in the paint can alter this to a limited degree. Because the types of oils that dry best produce quite yellow films, paints are not used where colour retention is important. The original adhesion of oil paints is good owing to the many points of chemical attraction offered by the molecules making up the vehicle. As the chemical groups are of the type easily attacked by water and alkali, however, the films have no chemical and little water resistance. Where conditions are critical, paints fail rather badly, usually by blistering, cracking or peeling.

In addition to the fact that little solvent is needed in paints, another consequence of the small initial molecular size of the binder is that paints have poor flow and tend to show brush marks. At one time they were used on practically all surfaces, both interior and exterior, because they were almost the only solvent-based coatings available. Due to their limitations they have largely been replaced over the last 30 years for all interior uses, except for flat wall paints, which are still employed to a limited extent. Paints have continued to be used for exterior wood surfaces, although this field also has been invaded by other coatings. Drying oils are used by themselves only in a few specialty areas, such as for oiled furniture, where the user will tolerate the excessive application or maintenance procedures required.

Varnishes. Varnishes are clear resin-containing finishes that dry by reaction of the binder in combination, usually, with solvent evaporation. They were developed to provide harder, more abrasion-resistant finishes than drying oil films can offer. As discussed in **CBD 76**, when partially polymerized molecules are included in a vehicle, the resultant film dries faster and is more resistant to some, if not all, destructive elements. Chronologically, the first development after drying oils was oleoresinous varnish, made by cooking oil and hard resin together. One of the original resins used was rosin, the natural resin obtained from pine trees. Rosin itself causes yellowing, however, and today it is used in manufacturing synthetic resins that have better colour retention. Other natural resins were replaced by the synthetic hard resins, which are dependably uniform. Resin contributes hardness and speed of drying and may, depending upon its type, confer chemical resistance.

The proportion of oil and resin can vary from equal parts resin and oil to almost all oil; whether the material is more like an oil or a varnish depends upon the relative amounts. With most resins exterior durability reaches a maximum with a fairly high oil content. With pure phenolic resins, however, the greater the resin content the more durable the varnish, until a point is reached at which the film becomes too brittle. Varnishes with low oil content are called "short oil" varnishes; those with more oil are "long oil" varnishes, the amount being expressed in gallons of oil per 100 pounds of resin.

Varnishes are also produced with vehicles other than oleoresinous binders. Solutions of alkyd resins and urethane resins, which will be described in detail in a later Digest, are often called "synthetic" varnishes. Alkyds are used on interior wood surfaces because of their light colour and good colour retention. Urethanes do not have the tendency toward brittleness of hard oleoresinous varnishes. Because they are hard but flexible, urethanes have outstanding abrasion resistance and are used on floors.

As with other unpigmented finishes, varnishes do not give satisfactory performance on exterior wood. Their high transmission of ultra-violet light, the destructive component of sunlight, leads to degradation of either the binder or the wood substrate.

Enamels. Just as varnishes were introduced to overcome some of the defects of drying oils, so enamels were developed as improvements on paints. Enamels are pigments dispersed in varnishes or resins that dry by reaction and not by solvent evaporation alone. They are characterized by the ability to form smooth, hard films. There is a strong tendency to call a material with a high gloss an enamel and one with a low gloss a paint, but strictly speaking both paints and enamels can be prepared with high or low gloss. As there is no definite line between an oil and a very long-oil varnish, the latter, when pigmented, is generally referred to as a paint.

The first enamels were based on oleoresinous binders and for many years were the only type available. Interior oleoresinous enamels have better colour and gloss retention than oil paints, but the type of resin needed for exterior durability promotes yellowing. Because the binder is already partly polymerized, solvent is required to thin it for application. Oleoresinous varnishes and enamels usually contain about 50 per cent solvent.

In recent years many more resins have been developed and applied to the production of enamels for particular purposes. Some of the more important ones are the alkyds, the epoxies, the polyurethanes and the acrylics. Because there are now so many different binders they will be the subject of a separate Digest.

Lacquers. Lacquers are coatings in which the binder is dissolved in organic solvents and drying occurs solely by evaporation of the solvents. On this continent the term has generally been restricted to coatings based on cellulose nitrate, except where qualified, e.g., acrylic lacquers. Alcoholic solutions of natural resins, such as shellac, that were in use before the advent of lacquer are still called spirit varnishes, although by definition they are lacquers.

Cellulose lacquers were introduced to speed up drying for production line finishing. The polymer is already formed and is dissolved in fast-evaporating solvents to provide very fast drying. As there is no chemical reaction in drying, the binder is permanently soluble. Consequently, brushing lacquers are not very satisfactory because the action of the brush tends to re-dissolve previous coats. In spray application this is not a factor owing to the fast evaporation of the solvents. Because of the large molecule, the solids content of cellulose nitrate solutions is low, requiring more coats of lacquer than enamel for the same film thickness. In recent years attempts have been made to overcome this defect by changing solvents to get higher solids and by thinning with heat (hot spray). Although there bas been some improvement, lacquers are now used mostly in furniture finishing where fast drying is their chief asset.

Some years after the original lacquers were developed, vinyl lacquers were produced for use where extreme chemical resistance is required. More recently acrylic lacquers have been used where superior gloss and colour retention are desired for exterior service.

Water-Based Coatings

The distinction between different types has not been so great in this category as in solvent-based coatings. All are generally referred to as "water paints" because the binders are either soluble in or dispersed in water. As the solvent in a coating is present only to reduce viscosity until after the material bas been applied and then evaporates and is lost, one may as well use the cheapest and most readily available solvent - water. Another advantage is that damp surfaces are not detrimental during application, providing the water can subsequently evaporate.

Soluble Coatings. The use of water does introduce some problems. If the binder is water soluble, some method must be found to make it insoluble in its dried film form if any degree of washability or exterior durability is to be attained. The first water-based coatings did not overcome this problem very successfully, and could only compete with solvent-based coatings because of relatively low price.

Calcimine was the first commercial material in the water soluble group. Its chief ingredient was whiting (powdered chalk), with a small amount of glue to act as binder. Next came powdered casein paint, with a binder of casein, the protein from milk, and some lime to give better water resistance. Casein paints were also sold as a paste requiring addition of water before use. These materials are now used only where initial economy is extremely important.

Cement powder paint is one of the earlier water paints that is still used. As is indicated by its name, the binder is cement, which reacts with water added just before application. Cement paints also contain pigment to supply hiding power and colour.

Dispersed Coatings. The development of casein paste paints led to water-dispersed as opposed to water-soluble binders. With a dispersion, water resistance of the dry film is not such a problem because the binder is not soluble. The chief difficulty is in achieving a balance between dispersion stability in the container and water resistance in the film. At first, emulsified oils were used, but more success was obtained with emulsified alkyds. Although these coatings were not as durable as solution alkyds, they were a great improvement over the older water soluble materials.

Finally, the resin emulsion paints led to the latex paints, a group that now completely dominates the water-based field and has in some cases displaced solvent-based coatings. Other names for this class are "emulsion" paint and "rubber-base" paint. The latter is not too satisfactory as a class name, however; it causes confusion with chlorinated rubber and other solvent-based coatings, which. are also known as rubber-base. The name originates from the fact that the same chemicals used to manufacture synthetic rubber are used, although in very different proportions, to make the binder that produced the first latex paint. Although not strictly correct, the name 'emulsion' paint, which derives from the alkyd resin emulsion paints, is better. In manufacturing the binder, the small molecules start out as emulsions, but the resultant large molecules, being solids, are technically dispersions.

One of the chief advantages of latexes is that the molecules can be large without attendant high viscosity. It was stated in **CBD 76** that with lacquers the more soluble resins, which give good film thickness, have inferior physical properties and chemical resistance, and that resins with better properties are less soluble and produce highly viscous solutions. If the resin, however, is dispersed in a volatile non-solvent, in this case water, the viscosity of the dispersing medium is the controlling factor. It is thus possible to use high polymers (large molecules) and still get high solids content.

For air-drying coatings the technique is limited to those resins that will flow sufficiently while the water evaporates to coalesce into a continuous film at normal temperatures. The resin must not be too soft or the film will remain tacky. As the softness and flow of the resin is affected by temperature, latex paints cannot be applied at too low a temperature because the resin particles will be too hard to flow when the water evaporates. Even if the temperature should later increase there will be no capillary force to cause coalescence and the final film will be powdery.

Another disadvantage of latex paints is that both the pigment and the binder have to be dispersed in water, while in solvent- or water-soluble coatings the pigment is dispersed in the complete vehicle. Consequently, it is not generally possible to use as much pigment in a latex paint as in the soluble types. There is the added fact that when about 50 per cent of the water has evaporated, the resin dispersion breaks and the pigment and resin particles form a film. Since the pigment was previously wet with water and now has to be wet with resin, there is a tendency for the pigment to flocculate, thus losing hiding power. For both these reasons latex finishes do not cover as well as solution finishes of the same degree of gloss. At the time of writing there are no gloss latex finishes, although there is much development work in this field.

Chemically there are three types of latex binders. Styrene-butadiene was used in the first latex paints and is still present in interior finishes. Because there are some reactive sites in the molecules, the resin slowly oxidizes on exterior exposure, leading to yellowing and brittleness. Styrene-butadiene latex paints are therefore not used to make exterior paints. The other two types are polyvinyl acetate (PVA) and acrylic, both of which can be used on interior or exterior surfaces. They have given excellent service on exterior masonry and in recent years have been adapted for use on wood. Because latex resins have to be soft enough to flow during film formation, the resultant films have very great extensibility. Both PVA and acrylics have no reactive sites, so that they remain very flexible and do not change colour. Combinations of the two in one resin have also been produced.

In an attempt to overcome the disadvantages of latex dispersions, much work bas recently been devoted to new types of water-soluble coatings. Included in this group are water-soluble oils and water-soluble alkyds. Because the vehicles are solutions and not dispersions, the pigment is wetted by the binder before drying. It is therefore possible to obtain good coverage and high gloss. As with the original water-soluble paints, however, it is necessary to develop a means of making the binder insoluble. So far the most successful newer coatings are those that are baked to cure the film.

Summary

This Digest has described the different types of coatings and tried to show why they behave as they do. As in many other fields, the technology is constantly changing and what is accepted today may well have been replaced by tomorrow. With some idea of the principles of coatings, it may be easier for those not directly involved in the industry to keep informed on trends in their continuing development.