

# Materials for Automobiles 10

Paints

Lecture 10

14 September 2011

# Plan

|   | <b>Paints</b>         |
|---|-----------------------|
| 1 | Paints - Introduction |
| 2 | Paints - composition  |
| 3 | Paints - Types        |
| 4 | Paints - Tests        |

# Painting - Introduction

PAINTING is a generic term for the application of a thin organic coating to the surface of a material for decorative, protective, or functional purposes.

Most organic coatings are based on:

- (1) **a film former** or binder that is dissolved or dispersed in a
- (2) **solvent or water.**

This film-forming liquid constitutes the vehicle in which

(3) **pigments** are dispersed to give ***color, opacity, and other properties to the dried film.***

Many other ingredients can be added to the vehicle to achieve specific film properties. These would include such things as :

- driers to aid curing,
- plasticizers to impart flexibility and other properties, and
- stabilizers to lessen the deleterious effects of heat or sunlight.

- (1) A wide variety of film-forming materials is available and includes:
- oils,
  - varnishes,
  - synthetic resins and polymers such as cellulose, vinyl, epoxy, and polyester.

***In general, major performance characteristics depend on the binder used.***

# Painting - Introduction

## Advantages of Organic Coatings

- The equipment required for applying paint is usually less expensive to buy and install, is simpler to operate, and requires less control.
- Material and labor costs per unit area of surface coated often are much lower.
- Organic coatings are available in a wide range of pigments and vehicles and can meet practically any coating requirement for color, gloss, or surface texture.

Paints have been developed that can withstand most corrosive conditions, and unlike many metallic protective coatings, organic films can simultaneously resist more than one corrosive condition, such as combinations of marine atmosphere and acid fumes.

Conventional paint films have good dielectric properties, which enable them to inhibit galvanic action between dissimilar metals. Conversely, paints are available that contain special pigments to provide conductivity suitable for grounding induced or static electricity.

Paints have been developed to meet newer environmental regulations

# Typical Resins

---

**TABLE 3.1**  
**Comparative Properties of Common Paint Resins**

| <b>Resin</b> | <b>Moisture Resistance</b> | <b>Chip Resistance</b> | <b>Temperature Resistance</b> | <b>Light Stability</b> | <b>Cost</b> |
|--------------|----------------------------|------------------------|-------------------------------|------------------------|-------------|
| Acrylic      | Medium                     | Low                    | Medium                        | High                   | Medium      |
| Alkyd        | Medium                     | Medium                 | Medium                        | Medium                 | Medium      |
| Asphaltic    | High                       | High                   | Low                           | Low                    | Low         |
| Epoxies      | High                       | High                   | High                          | Low                    | High        |
| Urethanes    | Medium                     | High                   | Variable                      | Medium                 | High        |
| Polyester    | Medium                     | Medium                 | Medium                        | Medium                 | Medium      |

---

**TABLE 2.5**  
**Properties of Some Solvents**

| <b>Solvent</b>                                    | <b>Specific Gravity</b> | <b>Boiling Point (°C)</b> | <b>Evaporation Rate<sup>a</sup></b> | <b>Flash Point (°C)</b> |
|---|-------------------------|---------------------------|-------------------------------------|-------------------------|
| Acetone   | 0.79                    | 56                        | 944                                 | -18                     |
| Butyl acetate                                     | 0.88                    | 125                       | 100                                 | 23                      |
| Butyl alcohol                                     | 0.881                   | 118                       | 36                                  | 35                      |
| Ethyl acetate                                     | 0.90                    | 77                        | 480                                 | -4.4                    |
| Ethyl alcohol                                     | 0.79                    | 79                        | 253                                 | 12                      |
| Ethylene glycol monoethyl ether (2 ethoxyethanol) | 0.93                    | 135                       | 24                                  | 49                      |
| Methyl ethyl ketone                               | 0.81                    | 80                        | 572                                 | -7                      |
| Methyl isobutyl ketone                            | 0.83                    | 116                       | 164                                 | 13                      |
| Toluene   | 0.87                    | 111                       | 214                                 | 4.4                     |
| Mineral spirits                                   | 0.80                    | 150-200                   | -18                                 | 38 (min)                |
| Xylene  | 0.87                    | 138-144                   | 73                                  | 17-25                   |

<sup>a</sup> Evaporation rate values based on butyl acetate = 100; these values relate to pure solvents and will be lower where dissolved solids or diluents are present.

|         |                            |
|---------|----------------------------|
| 2.2     | Pigments .....             |
| 2.2.1   | White Pigments .....       |
| 2.2.1.1 | Titanium Dioxide .....     |
| 2.2.1.2 | Zinc Oxide .....           |
| 2.2.1.3 | Antimony Oxide .....       |
| 2.2.1.4 | White Lead .....           |
| 2.2.2   | Yellow Pigments .....      |
| 2.2.2.1 | Yellow Dyes .....          |
| 2.2.2.2 | Benzidine Yellows .....    |
| 2.2.2.3 | Lead Chromates .....       |
| 2.2.2.4 | Zinc Chromate .....        |
| 2.2.2.5 | Yellow Iron Oxides .....   |
| 2.2.2.6 | Cadmium Yellow .....       |
| 2.2.3   | Green Pigments .....       |
| 2.2.3.1 | Phthalo Green .....        |
| 2.2.3.2 | Chromium Oxide .....       |
| 2.2.3.3 | Lead Chrome Greens .....   |
| 2.2.4   | Blue Pigments .....        |
| 2.2.4.1 | Phthalocyanine Blues ..... |
| 2.2.4.2 | Prussian Blue .....        |
| 2.2.4.3 | Ultramarine Blue .....     |
| 2.2.5   | Red Pigments .....         |
| 2.2.5.1 | Toluidine Reds .....       |
| 2.2.5.2 | Arylamide Reds .....       |
| 2.2.5.3 | Red Iron Oxide .....       |
| 2.2.6   | Black Pigments .....       |
| 2.2.6.1 | Black Iron Oxide .....     |
| 2.2.6.2 | Carbon Blacks .....        |

# Effect of prepainting surface treatments on performance of paint films :

- Alkyd-melamine finish, baked 30 mins @ 150°C , cured 72 hrs @ 49 °C, DFT 38 - 46µm, gloss (60°) = 82

|                                    | Results for Prepainting treatments |                  |                |
|------------------------------------|------------------------------------|------------------|----------------|
|                                    | Cleaning only                      | Cleaning Plus    |                |
|                                    |                                    | Iron Phosphating | Zn Phosphating |
| Pencil Hardness                    | HB(a)                              | HB-F             | HB-F           |
| Adhesion                           | Poor                               | Excellent        | Excellent      |
| Bend( c)                           | Fair to Good                       | Excellent        |                |
| Impact resistance(b)(face & back)  | 7.2 Nm                             | 7.2 Nm           | 7.2 Nm         |
| crimp                              | 100%failure                        | Excellent        | Excellent      |
| 100% Relative Humidity @ 43°C, Hrs | 300 max                            | 1000             | 1000           |
| 5% Salt spray hrs (d)              | 72 max                             | 500 max          | 750            |

(a) Pencil of this hardness cut through and removed paint cleanly; when cut, paint scratched cleanly with fingernail.

(b) Impacting surface 1.59 mm (0.0625 in.) in diameter tested with 0.9 kg (2 lb) weight.

(c) 180° bend over 6.4 mm (4in.) mandrel.

(d) Hours to 65 mm (2.6 in.) creepage from scribe or to blistering, or both  
It is important to note that phosphate coatings may not be suitable for all substrates

# Types of Paints 1

1

**Water-borne paints are dilutable with water.**

There are three principal types: solutions, colloidal dispersions, and emulsions.

- **Solution coatings** are based on water-soluble binders. Many conventional binders (alkyds, acrylics, and epoxies) can be made water soluble by chemically attracting polar groups such as carboxyl, hydroxyl, and amide, which are strongly hydrophilic. Some hydrocarbon solvents are usually necessary, up to 20% of the total, to improve solubility.
- **Colloidal dispersions** are very small particles of binder, less than 0.1  $\mu\text{m}$  in diameter, dispersed in water. Normally, these dispersions contain water-soluble polar groups to partially solubilize a portion of the resin.
- **Emulsions, or latexes**, are water dispersions that differ from colloidal dispersion by having much larger particle size on the order of 0.1  $\mu\text{m}$  or larger. They are made by precipitation in water and therefore do not need to be dispersed.

Water-reducible paints have a low volatile organic content (VOC) and comply with most environmental regulations.

# Types of Paints 1

1

## Water borne paints

The **advantages** of water-borne paints include:

- Low flammability
- Reduced toxicity and odor
- Easy cleanup with water
- Good film continuity, with continuous film similar to conventional solvent systems
- Good mechanical stability; can be pumped in all types of equipment similar to conventional solvent paints
- Application by air spraying, dipping, flow coating, electrodeposition, and roller coating

The **disadvantages** of water-borne paints include:

- Application by electrostatic spraying requires complete electrical isolation because of the water conductivity.
- Coatings require a longer flash tunnel before curing.
- Temperature must be raised more slowly to evaporate water at a slow enough rate to prevent the coating from blistering.
- Coatings are more susceptible to dirt pickup.
- Proper temperature and humidity control are vital. If the humidity is too high or the temperature too low, coating can sag or run

# Types of Paints 1

---

**TABLE 3.2**  
**Characteristics of Waterborne Formulations**

| Property            | True Solutions              | Colloidal Dispersions       | Emulsions                       |
|---------------------|-----------------------------|-----------------------------|---------------------------------|
| Molecular weight    | 15–50,000                   | 20–200,000                  | Up to 1 million                 |
| Viscosity           | Depends on molecular weight | Depends on molecular weight | Independent of molecular weight |
| Particle size       | Molecules                   | Less than 0.1 $\mu\text{m}$ | Greater than 0.1 $\mu\text{m}$  |
| % Solids            | Low                         | Medium                      | High                            |
| Physical appearance | Clear                       | Hazy                        | Milky                           |
| Pigment stability   | Good                        | Variable                    | Variable                        |

---

# Types of paints

| 2 | <p><b>Conventional paints :</b></p> <p>These contain organic solvent , binder and pigment. The following are common :</p> <p>Enamels are topcoats characterized by their ability to form a smooth surface that is typically of high gloss, but may also include lower degrees of gloss such as flat enamels. Enamels may air dry or bake.</p> <p>Air-dry enamels are cured essentially by a combination of solvent evaporation and oxidation.</p> <p>Baking enamels incorporate catalysts and cross-linking agents that require heat for polymerization.</p> |
|---|--|
| 3 | <p><b>Lacquers</b> are compositions based on natural or synthetic thermoplastic film-forming materials dissolved in organic solvent. These dry primarily by solvent evaporation. Lacquers are generally characterized by fast drying properties. Typical lacquers include those based on nitrocellulose, other cellulose derivatives, vinyl resins, and acrylic resins. A natural lacquer resin, based on secretions of the lac beetle, is called shellac.</p>   |
|   |  |

# Types of Paints 1

4

## Electrophoretic paints

**Electrophoretic paints** are special water-reducible ( water soluble) paints. Resin and pigment materials are shipped and stored as concentrates to be added to the production tank as needed.

- Electrophoretic films are always deposited from a dip tank.
- The concentration of nonvolatile solids in the bath varies from about 10 to 20%, depending on type and composition.
- Paint films are deposited on the work by electrophoretic action. Paints can be prepared to deposit films on either the anode or cathode. The resins used most frequently are epoxies and acrylics, including numerous modifications and hybrids.
- Immediately after the film has been deposited, the work is removed from the bath and rinsed with water to remove the excess paint bath, leaving a uniform, tightly adhering film of paint on the workpiece.
- The workpiece is then baked.

# Types of Paint 1

|   |  |
|---|--|
| 5 | <b>High-solids paints</b>  |
|   | <ul style="list-style-type: none"><li>• <b>High-solids paints</b> contain 70% or more solids by volume.</li><li>• Many two-component systems use a catalyst to increase the rate of the curing reaction. Two-component resins may be urethanes, acrylic-urethane, or epoxy-amine. Fast-reacting two-component systems are usually applied with special spray guns that mix the two components at the spray nozzle.</li><li>• Single-component resins in high-solids paints include epoxy, acrylic, polyester, and alkyd;</li></ul>   |
|   | <b>Advantages</b> <ul style="list-style-type: none"><li>• Color control and matching is like conventional solvent paints.</li><li>• These paints can be applied by higher speed (6000 to 30,000 rev/min) electrostatic bells and disks with minimum facility conversion from existing bell or disk systems.</li><li>• Performance properties are equivalent to conventional solvent paints.</li><li>• Applied cost per square foot is lower than conventional solvent paints.</li><li>• Require less energy for curing than conventional solvent paints.</li><li>• VOC compliance is more readily attained because of reduced solvent use.</li></ul> |
|   | <b>Disadvantages</b> <ul style="list-style-type: none"><li>• High-solids paints require specialized pumping and transport equipment.</li><li>• Cleanup of overspray is much more difficult</li><li>• Toxicity of isocyanates used with urethanes /amines used with epoxies</li><li>• Drying and/or curing times may be longer than for solvent paints .</li></ul>  |

## Types of Paint 1

- 6 **Powder paint** consists of plastic resins, color pigments, and additives. In a mixing and grinding unit, the ingredients are combined in a homogeneous mixture that is heated to the melting point. The molten material is extruded into a thin sheet, which is cooled and crushed. The chips are pulverized to a fine powder of carefully controlled particle size, ensuring optimum fluidity and efficient flow through the finishing system.
- 7 **Autophoretic paints** are water-reducible paints deposited on metal surfaces by the catalytic action of the metal on the paint materials in the bath. Currently, only ferrous surfaces activate the autophoretic paints available commercially. Tubular automotive frames are coated with this method, because the entire length of the tubing can be coated inside and outside with equal ease.

# Layers of paint-

| 1 | Primer ( Base Coat)  |
|---|--|
|   | <p>A primer is the first coat applied to a surface. Its usual job is to :</p> <ul style="list-style-type: none"><li>• fight corrosion and</li><li>• enhance the adhesion of subsequent coatings applied over the primed surface.</li></ul>   |
|   | <ul style="list-style-type: none"><li>• Most industrial primers are cross-linking or thermosetting type</li></ul>  |
|   | <p>The binder used in the primer must be compatible with the substrate and the second coat. Primers must be able to tolerate the differences in thermal expansion between substrate and paint.</p>   |
|   | <p>Primers are used for protection against corrosion, are usually highly pigmented. They usually have relatively low gloss, because the primer particles extend up to the surface of the film and give it a rough, pebbled texture</p>   |
|   | <ul style="list-style-type: none"><li>• Primer film thickness is typically 25 to 75 <math>\mu\text{m}</math>.</li></ul>  |
|   | <p>Primers for metal are frequently alkyd based. A typical industrial primer might have the following approximate composition, as sprayed:<br/>Alkyd resin: 20%—binder/ Pigment: 15%—for corrosion protection/ Solvent: 60%—to liquefy / Additives: 5%—viscosity control, antifoam, and so forth<br/>In recent years, there has been a trend toward using epoxy-modified alkyd binders for primers. These resins have better adhesion and corrosion resistance than conventional alkyds.</p> |

## Layers of paint-

2

### Sealers and Surfacer ( Also called Primer – surfacer)

Sealers are paint films applied between a primer and a topcoat to

- Improve adhesion. This is often necessary if the primer and topcoat have different adhesive, thermal expansion, or impact resistance properties.
- Prevent top coat chipping. When the interface between these films is stressed, the layers sometimes separate, and the topcoat can then chip.
- to provide a barrier coat between a paint film and the solvent in a subsequent coat. This may be necessary if the pigment in the lower coat has a tendency to bleed into the solvent of the upper coat.

Sealers have special binders that stick well to both the primer and the topcoat. In addition, they are slightly elastic, acting as flexible glue to hold the primer and the topcoat together during periods of mechanical or thermal stress. Sealers are usually low in pigment. Typically, sealers are applied as thin films less than 12  $\mu\text{m}$  thick when dry.

A surfacer is a coating used to:

- fill irregularities in the primer. and
- provide a smooth surface before topcoat application. Since primers are often heavily loaded with pigment, they sometimes bake out with rough surfaces that are difficult to sand. A surfacer is designed to be sanded
- The typical film thickness for a surfacer is 25 to 75  $\mu\text{m}$ .

# Layers of Paint

## 3 Topcoat

The topcoat provides the surface with the

- desired color, gloss,
- abrasion resistance, and
- weatherability.

Usually, the corrosion resistance of the topcoat is minimal. The highly pigmented primer is expected to provide most of the paint's corrosion resistance.

Many binders are used for topcoats. The final choice of a topcoat usually requires a trade-off among several properties (Table 3.1). In the automotive industry, for example, it may be necessary to sacrifice some impact resistance to achieve the desired gloss

Topcoat may be applied as a single coat, or it may be applied as more than one thin coat to achieve the final film build. When several coats are applied, it is not always necessary to completely dry each coat. The first coat is allowed to flash off before receiving the next coat. This is referred to as wet-on-wet application.

## Stages in the Painting Process

|    |  |
|----|--|
| 1  | <p>Film formation:</p> <p>The resin is the primary ingredient of the film formed after the paint coat has dried. As the coating is applied, it flows and stabilizes in a relative uniform film, this process is called stabilization. The curing process starts after this.</p>  |
| 2a | <p>Cure</p> <p><b>Air Dry</b></p> <p>The period of cure is adjusted with the proper blend of drier catalysts. The process does not start as soon as the paint is spread and exposed to the air. An introduction period is involved, then curing starts to result in a paint film. Actually, the drying process never stops. It slows down greatly and must be controlled to avoid the ultimate formation of an excessively brittle film. An increase in temperature will increase the rate of the chemical reaction.</p> |
| 2b | <p><b>Catalyzed Materials</b></p> <p>Catalyzed materials have two major or more constituents that will begin a curing reaction when they are mixed together. The cure time varies and temperature may vary, but is possible to reach full film properties, even at room temperature. Application of heat will accelerate the cure cycle. Catalyzed materials are typically very durable coatings.</p> <p>One example of a two-component coating is the epoxy-polyamide system.</p>                                       |

2c

## Baking Enamels

Some coatings do not cure at room temperature and fortunately remain stable in the paint container for extended periods.

They cure rapidly (in a fraction of an hour) when exposed to heat. Typical temperatures for baking enamels range from 280 to 350°F (135–175°C) for 10–30 min.

Amine resins are one of the many convertible coatings of this type. Broadly speaking, they divide into urea–formaldehyde derivatives and melamine–formaldehyde derivatives.

When heated, these products can become brittle, so many common baking enamels are formulated with plasticizers, such as alkyd resins.

.

# DRY FILM PROPERTIES

## DRY FILM PROPERTIES

Once the paint is cured, the concern switches to dry film properties. In some respects, the properties of a dry paint film are important since it is exposed to the service environment and to the customer's inspection.

### **3.3.4.1 Gloss**

A high-gloss surface reflects nearly all of the light that falls upon it. Reflection of more than 90% of the incident light is possible with modern industrial finishes. High gloss requires a smooth surface. Surface roughness results in scattering of incident light and low gloss. Smoothness can be obtained by polishing or by using processes that allow the paint to dry smoothly without cracks, wrinkles, pinholes, or protrusions. Highly pigmented paints often have low gloss, because pigment particles extend through the surface and reduce smoothness. Gloss can be manipulated by addition of ingredients that provide hazing to reduce reflection or smoothness to increase reflection.

### **3.3.4.2 Hiding Power (Opacity)**

The ability of a paint to cover a surface and mask it from view is referred to as hiding power. Since most paint binders are transparent, the job of hiding the surface falls primarily to the pigment. Pigments contribute to hiding power in three ways. They may reflect, refract, or absorb the light that enters the paint film.

# DRY FILM PROPERTIES

## **Color**

The color of a paint material is primarily due to the pigment interaction with light. Ordinarily, white light is composed of all the colors visible to the human eye. Pigments have the ability to absorb some of these colors and reflect or transmit others. Therefore, the pigment in a red paint absorbs all colors except red.

## **Strength, Hardness, and Brittleness**

These terms describe important properties of a dry paint film. They depend on how effectively the binder molecules, pigment particles, and additive materials attract one another.

Very strong, hard films may not be able to bend or stretch and recover under ordinary use conditions. The paint must have some resiliency or stretchiness, because the solid surface under the film may shrink and expand due to temperature.

Paint binders may be linear (thermoplastic) or cross-linked (thermosetting). Linear binders are generally softer, more flexible, less brittle, more soluble, more water permeable, and less heat resistant than cross-linked binders. Cross-linking means that the linear, threadlike binder molecules have become laterally bonded together at various positions along their length. The resulting 3-D networks are usually stiffer, harder, more brittle, less soluble, less water permeable, and more heat resistant than linear binders are.

Most primers and many industrial topcoats have thermosetting binders while sealers and some topcoats are linear binders.

# DRY FILM PROPERTIES

## **Strength, Hardness, and Brittleness (continued)**

Another means of controlling strength, hardness, and brittleness is by the use of additives. Plasticizers weaken, soften, and decrease the brittleness of a paint film. Because plasticizers are small molecules, they have a tendency to slowly evaporate from the film over a period of months or years. The result is that many paints tend to become harder and more brittle with age.

## HOW PAINT WEARS OUT

All paint films are semipermeable layers that are susceptible to degradation. Exposure to the atmosphere, physical abuse, sunlight, water, corrosives, and general wear will cause discoloration, loss of gloss, cracking, chipping, or peeling from their substrate. The three greatest natural enemies of a paint film are sunlight, moisture, and temperature changes.

1. Ultraviolet radiation degrades the binder molecules by breaking bonds.
2. As binder molecules shrink, film strength declines and moisture penetration increases.
3. With temperature cycling, the moist paint film is first heated and then cooled. The accompanying expansions and contractions put a strain on the film that is poorly resisted, because the binder molecules are now smaller and mechanically weakened.
4. The weakened film surface is now subject to mechanical rub-off and water wash-off.
5. As the unpigmented surface film wears away, the pigment particles become exposed to the elements. Continued degradation of the binder may actually set the pigment mechanically free, at which point the paint begins to chalk.
6. These changes occur because of a gradual loss of plasticizer from the film that makes it more brittle. The stiffening film is less able to resist the strain of thermal expansion and contraction. Microcracks form and allow moisture to penetrate.

# Paint Properties

## 10.2 PAINT VISCOSITY

Viscosity is a very important paint property, usually determined by measuring the time required for a given quantity of paint to flow through a hole in the bottom of a metal cup. A number of cup sizes and drain hole diameters are available for use with different viscosity paints. Three widely used viscosity cups are the Fisher, Ford, and Zahn viscometer. Table 10.1 gives conversion values for use with these cups. It is important to correct the viscosity cup flow-out times for the temperature of the paint. The recommended spray viscosity is typically based on a temperature of 70°F. If the viscosity is measured at a colder or warmer temperature, the actual viscosity could be too low or too high. A paint supplier can provide the appropriate corrections for their product. Be sure that the type of Zahn cup or other viscosity cup used is consistent. In addition, be sure that the method of measurement is consistent. Some operators consider the first break in the paint to be the stop point, while others may wait until the cup is virtually empty.

**Wet-film thickness** is measured for process control. It can be measured with a handheld immersion gauge that has a series of teeth along the edge of different lengths. The gauge is placed on the freshly painted surface, and the edge of the gauge is supported by two teeth of the same length for measurement control. All the other teeth are different in length and shorter than the control teeth. The wet thickness is measured as the last tooth that leaves a mark in the paint film. This method of measuring leaves marks in the paint, requiring the part to be reworked.

# Ford Cup for viscosity



---

**TABLE 10.1****Conversion Chart for Commonly Used Viscosity Cups**

| Fisher #2 | Ford #3 | Ford #4 | Zahn #1 | Zahn #2 | Zahn #3 |
|-----------|---------|---------|---------|---------|---------|
|           |         | 5 s     | 30 s    | 16 s    |         |
|           |         | 8       | 34      | 17      |         |
| 15 s      | 12 s    | 10      | 37      | 18      |         |
| 17        | 15      | 12      | 41      | 19      |         |
| 18        | 19      | 14      | 44      | 20      |         |
| 21        | 25      | 18      | 52      | 22      |         |
| 29        | 33      | 25      | 68      | 24      |         |
| 33        | 36      | 28      |         | 30      |         |
| 39        | 41      | 31      |         | 34      |         |
| 44        | 45      | 32      |         | 37      | 10 s    |
| 50        | 50      | 34      |         | 41      | 12      |
| 62        | 58      | 41      |         | 49      | 14      |
|           | 66      | 45      |         | 58      | 16      |
|           |         | 50      |         | 66      | 18      |
|           |         | 54      |         | 74      | 20      |
|           |         | 58      |         | 82      | 23      |

---

# Wet paint film thickness Gauge



## FINISHED FILM TESTING

Finished film testing is used to confirm physical properties of the coating after it is applied and cured. Daily tests might include such things as gloss, color, hardness, and adhesion. The particular tests used depend on the properties that the coating is supposed to provide and the established quality standards.

**The dry film thickness of paint on iron or steel surfaces** is easily determined with a pull-off gauge. Pull-off gauges reflect the force required to pull a magnet suspended on a spring inside a metal case away from the painted surface. Pull-off gauges may be graduated in microns, mil (thousandths of an inch), or arbitrary units. They are direct measurement devices.

Alternatively electronic dry film thickness gauges are available.

### **10.3.2.3 Impact Resistance**

Resistance to impact damage (chipping and cracking) is an important property for nearly every paint film.

The most common way to measure impact resistance is ASTM D 2794-93. A standard weight is dropped from a height onto a coated panel. The indentation is inspected to detect if the coating has cracked. The weight can be dropped from different heights, and the results are then measured in inch-pounds. The goal is to see how many inch-pounds the coating can take without cracking. . Another test (Society of Automotive Engineers Test Procedure V400) is called a gravel damage test. The gravel damage test uses stones hurled against the panel to inflict damage.

## FINISHED FILM TESTING

### **Tape Adhesion**

Adhesion of a paint film to its substrate is often measured by jerking the paint away from a scribed "X" or grid with a strip of tape. Three M Company's #600 Crystal brand transparent tape or another tape with strong adhesive properties will work for this test. The tape is jerked back upon itself as nearly in the plane of the painted surface as possible. A numerical rating system from a 0 for total failure to a 5 for 100% adhesion with no loss may be used to evaluate tape adhesion test results. If a scribed grid has been used, the failure of adhesion may be expressed as the percentage of squares that have some loss of paint (D 3359-97).

### **Humidity Testing**

Water vapor is one of the most severe agents to which a paint film is exposed. Because water molecules are small and binder molecules are constantly vibrating, moisture can easily penetrate lightly pigmented paints. When warmed, it will tend to vaporize and exert a pressure that causes the film to swell.

The condensing humidity test is widely used to measure humidity resistance. In this test, water vapor is allowed to condense on sample panels. The condensed water drips off the panel and is revaporized by means of an evaporative heater in the bottom of the test chamber. A typical test involves water at 60°C (140°F) for 24 h. After testing, panels are checked for blistering, color changes, and loss of gloss. Another humidity test involves exposing the panels to 100% relative humidity at 38°C (100°F) for 24 h.

## FINISHED FILM TESTING

### Salt Spray Testing

The use of salt solution spray testing is an attempt to accelerate the corrosion process and cause early paint failure. Panels are usually exposed for up to 14 days to a mist of 5% (w/v) sodium chloride solution at 33–36°C (92–97°F). The mist is produced by blowing hot saturated air through a 5% salt solution.

The panels are evaluated for two types of corrosion:

1. *Rust-through*—the percentage of the surface, which has rust visible through the paint
2. *“Creep”*—the distance in 1/32 of an inch (0.8 mm) from the center of the scribe line that the paint film breaks down and separates from the substrate. The results are measured on scale with a predetermined point described as failure in number of hours of exposure. Sometimes, acetic acid is added to the salt spray solution to accelerate the corrosion.

Salt spray testing has been used as a standard for performance by many coaters from all different types of industry. It is poorly understood and not necessarily reliable as a predictor of field service. The most important value of salt spray testing is comparison of different pretreatment methods and coatings to see what appears to be the best combination for corrosion resistance. In all cases, the salt spray comparison should be done with the same steel panels and the same test cabinet.

## FINISHED FILM TESTING

### **10.3.2.7 QUV Testing**

AQ-LAB Ultraviolet (QUV) test chamber reproduces the damage caused by sunlight, rain, and dew. Coated parts or test panels are placed inside the chamber and subjected to alternating cycles of light and moisture at controlled, elevated temperatures.

Parts can be measured for resistance to chalking, fading, color fastness, cracking, blistering, embrittlement, strength loss, and oxidation.

The QUV test chamber provides a more accurate comparison of different processes and materials than salt spray testing alone. It is more helpful in evaluating the affect of outdoor exposure on different coating materials and a somewhat better predictor of actual field life.

### **Outdoor Exposure**

Outdoor exposure tests are slow, but they are the best way to predict weatherability. Three months of exposure takes a while, but it does provide good information about how well the paint film will last in an outdoor environment. The most common defects turned up by exposure testing are fading, cracking, checking, chalking, blistering, and peeling. Often a portion of the panel is buffed after testing to see to what extent the original appearance can be restored.

Exposure tests are usually conducted in a sunny climate such as Florida or Arizona to get the maximum ultraviolet radiation effect. Panels are usually exposed 5° from the horizontal, facing south. Florida is a preferred location in this country because of the sudden and frequent humidity changes that occur there. The test panel is held in a clamp that shields the top portion of the panel from exposure.

## FINISHED FILM TESTING

### **Corrosion Cycling**

Paint films in use are always exposed to a number of cyclic environmental factors. A corrosion cycle test measures the behavior of a film under a combination of test conditions. Usually, a combination of salt, humidity, and changing temperature is used for corrosion cycle testing. A typical sequence is listed below:

- 4 h at 5% neutral salt spray
- 18 h at 38°C (100°F) 100% relative humidity
- 2 h at -23°C (-10°F)

The resulting panels are rated against a control on the basis of the percent of rusted area. Cycle testing can be a more accurate way of predicting comparative qualities of coatings than salt spray alone

# Paints Test- specification

| S.No. | Level    | Position  | Degree of corrosion protection required     | Degree of Weathering Resistance required  | List of Parts  |
|-------|----------|---|---|---|--|
| 1     | CLASS A  | Directly Exposed & Aesthetically appealing  | <b>High</b> (Min 1000h as per ASTM B117)    | <b>High</b> (Min 250h – Gloss Retention = 85%, No Chalking, No film cracking)   | Cab BIW panels & Exterior Parts, Loadbody                                      |
| 2     | CLASS B  | Interior parts that will be visible to customers after opening of closures. Eg. Glove Box | <b>High</b> (Min 800h as per ASTM B117)     | <b>Low</b> (Min 200h – No Chalking, No film Cracking)                           | Cab Interior Surface items, Cab Threaded parts & metallic trims                |
| 3     | *CLASS C | Direct Exposure & aesthetically less appealing  | <b>Moderate</b> (Min 300h as per ASTM B117) | <b>Medium</b> (Min 200h – Gloss Retention = 85%, No Chalking, No film cracking) | Chassis FSM, Underbody Parts   |
| 4     | CLASS D  | Indirect Exposure & No UV resistance requirement  | <b>Moderate</b> (Min 300h) as per ASTM B117 | <b>Low</b> (Min 200h – No Chalking, No film Cracking)                           | Pipings, Adaptors, Clamps, Chassis & Cab Fasteners, Exhaust Pipes Engine Parts |

| S.No | Property   | Test Acceptance Criteria  | Test Method            |
|------|--|---|------------------------|
| 1    | Coated Surface Appearance  | The coated surface shall be free from running, crawling, solvent popping, pin holes and water drop traces   | 5.3.1                  |
| 2    | Dry Film Thickness (DFT)   | As agreed between AL & Vendor   | 5.3.2                  |
| 3    | Gloss  | As per master sample  | Visual Observation     |
| 4    | * Instrumented Gloss @ 60°   | Mutual agreement between AL & Customer  | Glossmeter             |
| 5    | Color Difference   | As per master sample  | Visual Observation     |
| 6    | *Instrumented Color Difference   | dE < 1  | SAE J1545              |
| 7    | Adhesion   | No film notches or liftings in the square (10 x 10 squares) lattice are allowed   | 5.3.3                  |
| 8    | Resistance to Solvents (30% Toluene & 70% Isooctane)   | No Surface Alterations are allowed  | 5.3.4                  |
| 9    | Corrosion Resistance (Hrs as per Component Classification)   | Edge Masked & Dent Free Panel <ul style="list-style-type: none"> <li>- No Corrosion / Red Rust</li> <li>- No Blistering</li> <li>- Underpellicular Corrosion = 2mm</li> </ul> Edge masked and damage free component, the following are not allowed: <ul style="list-style-type: none"> <li>- Slight Corrosion focuses on weld junctions and surfaces in general</li> <li>- Slight Blistering.</li> <li>- Underpellicular corrosion = 2mm</li> </ul> On Box-type surfaces:<br>No ferrous corrosion focuses on the walls. | ASTM B117              |
| 10   | Resistance to UV light alternating with Humidity (Hrs as per Component Classification)<br>Irradiance: 0.47 Watt/m <sup>2</sup> /mm | <ul style="list-style-type: none"> <li>- Chalking &amp; Film Cracking not allowed.</li> <li>- Gloss Variation ? 15%</li> <li>- No Color Variations are allowed.</li> </ul>  | 5.3.5                  |
| 11   | Resistance to Humidity (168h at 40°C)  | No Film removal and blistering is allowed. Min 80% of Adhesion should be retained   | 5.3.6                  |
| 12   | Pencil Hardness  | Min HB  | Pencil Hardness Tester |
| 13   | *Surface Flow (DOI) measured on vertical surfaces  | = 0.6   | 5.3.7                  |
| 14   | *Erichsen Cupping  | No cracks upto 5mm indentation.   | 5.3.8                  |

## E coat line

### **Pretreatment**

Pretreatment consists of the steps of precleaning, degreasing, purging, and phosphating. Precleaning removes the rough contaminations. Phosphating following after a purging process, serves as a temporary corrosion protection, and improves the adhesiveness of the paint film when it is applied.

### **Electrocoating (EC)**

Electrocoat paints are water soluble (suspensions of binders and pigments in d.i. (deionized) water) with only low proportions of organic solvents (approximately 3%). Electrocoating covers all dip painting processes, where the paint precipitates on the workpiece owing to chemical conversion and associated coagulation of the binder. These conversions are caused by an electric current flow from an external electrode via the conductive paint, to the workpiece.

The advantages of the electrocoating process are as follows:

- complete and uniform coating, also in cavities;
- very good corrosion protection;
- no formation of drops and runners;
- very low paint losses with the corresponding purging techniques;
- very good possibilities of process and quality control;
- electrocoat installations are fully automatic, and are continuously operated.

The process is faced with some disadvantages, namely,

- high installation-specific expenditure with correspondingly high investment cost;
- relatively high material cost;

## Electrodeposition Principles

Epoxy resins are used as a binder for the cathodic electrodeposition paints because of their known characteristics, such as good corrosion protection and good adhesion to the underground and to further coatings.

Normally, the epoxy resins are not water soluble and must therefore be modified to be able to convey into a 'water-soluble' state in a so-called neutralization reaction with organic acids like acetic acid. At the electrodes, and at the workpiece, the water is electrolyzed by the electric current, and gases ( $H_2$  and  $O_2$ ) as well as ions are released .

The hydroxyl ions ( $OH^-$ ) created at the interface to the cathodically poled workpiece cause a reversal of the neutralization reaction and lead to a coagulation of the binder .

The layer of coagulated paint particles that is loose in the beginning is pushed toward the electrode by the paint particles which are wandering because they are still electrically charged. At the electrode, the coagulated material with high water content, is fixed and compressed by the material that follows later. At the same time, the electric field causes removal of ions that carry along hydrate shells.

This leads additionally to a dehydration and solidification of the film by means of electro-osmosis. Within a short time, the nonvolatile portion of the film increases to more than 90%, although the paint bath itself only has about 20%.

## Sealing and Underbody Protection

### **Sealing**

The overlapping, spot-welded metal sheets must be sealed in such a way that no humidity can penetrate between the metal sheets and water in the vehicle interior, which may lead to corrosion there. Special sealants are available for this.

### **Underbody Protection**

High viscous polyvinylchloride (PVC) material is mostly sprayed as paths with airless application or extruded by flat stream nozzles. The underbody protection also serves as protection from corrosion, mostly for areas exposed to a high strain because of stone chips. It is applied partially two-dimensionally, for instance, in wheel arches and in the rocker panel area

## Electrochemical Potential of select Metals vs SHE (mV)

|          |       |           |        |
|----------|-------|-----------|--------|
| Gold     | +1360 | iron      | - 440  |
| Silver   | +800  | Chromium  | - 560  |
| Copper   | +350  | Zinc      | - 760  |
| Hydrogen | 0     | Aluminium | - 1670 |
| Tin      | -140  |           |        |
| Nickel   | -230  |           |        |

**Corrosion Processes.** Corrosion is based on the reaction of a metallic material or layer with its environment. The metal atoms of a component change from the metallic state into an oxidized state.

Corrosion in aqueous media is a surface reaction that takes place as an electrochemical process. In terms of electrochemistry, the metal and the corrosive medium are the electrode and the electrolyte, respectively.

Corrosion results from a direct electrical contact between the metal and the electrolyte. In the case of the formation of a nonconducting, pinhole-free surface layer (e.g., aluminum oxide on aluminum), no corrosion current is possible.

In the case of a very low metal ion concentration in the electrolyte, the corrosion current is anodic to its major part (i.e., the metal is corroded by its dissolution in the electrolyte).

For corrosion processes, such tables indicate which metal of a pair in contact is more noble or less noble. Factors influencing the actual potential values are temperature, concentration of the electrolyte, and alloy composition of the metal.

# Typical Cathodic Electrocoat Line

|   | <b>Cab Paint Shop</b>            |
|---|----------------------------------|
| 1 | Phosphate treatment              |
| 2 | Electrodeposition Primer Coating |
| 3 | Sealant Application              |
| 4 | Masking                          |
| 5 | PVC Underbody coating            |
| 6 | Demasking                        |
| 7 | Painting Top Coat                |
| 8 | Baking                           |
| 9 | Wax application                  |

# Phosphate Treatment

| 11 Tank Phosphating line |   |  |
|--------------------------|---|--|
| 1                        | Town water spray                                | Room temperature , t : 30 secs                                 |
| 2                        | Knock off degreasing spray                      | Medium :soap solution, T= 55-65°C, t = 3 min.                  |
| 3                        | Degrease Dip                                    | Medium :soap solution, T= 55-65°C, t = 3 min.                  |
| 4                        | Rinse 1- Dip process<br>Rinse 2 – Spray process | Medium : soft water, T both RT,<br>T= 1 min each dip and spray |
| 5                        | Surface activation - dip                        | Medium :Ti salt solution, T= RT., t = 1 min.                   |
| 6                        | Phosphating - dip                               | Medium :Tri cationic (Zn, Ni, Mn), T= 44 - 48 °C, t = 3 min.   |
| 7                        | Rinse 3 - dip<br>Rinse 4 - spray                | Medium :soft water ( 100 ppm max.), T= RT, t = 1 min each      |
| 8                        | Passivation- spray                              | Medium :Chrome free passivation, T= RT, t = 1 min.             |
| 9                        | Recirculated DM water spray                     | T= RT, t = 1 min.  |

# Electrodeposition

| Electrodeposition of Primer |   |  |
|-----------------------------|---|--|
| 10                          | ED- dip                                 | T= 26 - 29°C / Voltage = 300V/ pH= 5.7 -6.3<br>CED nonvolatile = 18 – 22%, t = 3.5 min,<br>thickness = 20 μm   |
| 11                          |   | Constituents of ED Paint<br>77 – 84% - Deionized Water<br>18 – 22% - Paint Solids<br><2% Butyl Cellulose Solvent + others<br>Paint Solids:<br>Resin Concentrate: Epoxy system<br>Pigment: Inorganic Grey<br>Mixing Ratio of Pigment: Resin:: 1:3 |
|                             |   | Following ED, a paint film containing 95% solids is deposited  |
| 12                          | UF Module Rinse 1:<br>UF Module Rinse 2 | UF Module Rinse 1: Filters extra paint and sends to ED tank; Permeate will go to UF → UF1<br>→ UF2 → ED<br>(T = RT, t= 1 min in each rinse)  |
| 13                          | Deionized water spray                   |  |

# Electrocoat Line

| Operations after Electrodeposition |  |   |
|------------------------------------|--|---|
| 14                                 | Baking in oven   | Oven T = 160°C ; time in Oven: 38 min<br>Effective Metal T = 150°C, t = 20 min                                  |
| 15                                 | Inspection   |   |
| 16                                 | Sealant application  | Anabond Sealant applied to roof, liner & Joints,<br>Sealant Application → Brushing →<br>Wiping-off with a cloth |
| 17                                 | Masking  |   |
| 18                                 | PVC Underbody Coating  |   |
| 19                                 | Demasking  |   |
| 20                                 | Tack Rag Application (a chemical cloth) to absorb dust on cab to ensure dust free cab to paint booth |   |
| 21                                 | <u>Sealant Appln. System</u>   | Graco Dispensing System (Appln. pressure: 30 – 80kg/cm <sup>2</sup> )   |

# Electrodeposition line

| 22 | Top coat painting | <p>Stage 1: Mist Spray Application using 2 guns<br/>Stage 2: Roof &amp; Inside using 2 guns<br/>Stage 3: Complete Painting using 2 guns</p> <p>Paint Booth Parameters:<br/>Paint Pressure: 1.5 – 2.5 bar<br/>Air Pressure: &gt; 4 bar<br/>Application Viscosity: 22 ± 2 second (for Normal solid shades)<br/>Total Time: 3 x 8 min = 24 min</p> |
|----|-------------------|---|
|    |                   | <p>Coating Thickness: min 30 microns<br/>Alkyd Amino &amp; Polyester (Stoving type)</p>   |
| 24 | Top flash off     | <p>T = 150 °C, t = 40 min. (effective metal T = 140°C, t = 30 min.)</p>   |
| 25 | Waxing            | <p>Equipment Used for Wax: Graco Waxing System<br/>Wax &amp; Sealant Supplier: M/s Anabond Essex Limited</p>  |

# Electrodeposition Line

## TEST FACILITIES

Persoz Hardness Tester

Brookfield Viscometer

DFT Meter

Glossmeter

Erichson Cupping tester

Stone Blow Resistance tester – Gravelometer

Salt Spray test Chamber – ASTM B117

CYCLING Salt Spray Testing

    Done in Manual Mode

        2 days in Salt Spray Chamber

        4 days in Humidity Chamber (95% RH, 40°C)

        1 day in outside Atmosphere

    Has passed 10 Cycles equaling 70 days – Test Acceptance Criteria  
    – ASTM B117 Norms

Humidity Chamber

QUV Panel

Xrite Color Spectrophotometer

MacBeth Color booth