Chapter II

COATING CHARACTERISTICS AND TYPES OF COATINGS

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2.0. COATING CHARACTERISTICS

Protective coatings are unique method of corrosion control. They are used to give long term protection under a broad range of corrosive conditions, extending from atmospheric exposures to full immersion in strongly corrosive solution. Protective solution provides little or no structural strength, yet they provide other material so that the strength and the integrity of a structure can be maintained.

The function of protective coatings is to prevent highly corrosive industrial fumes, liquids, solids, or gases from contacting the reactive underlying substrate of the structure. This physical separation of two highly reactive materials, the atmosphere and the substrate, is extremely important.

That coatings are, in general, a relatively thin film separating the two reactive materials indicates the vital importance of the coating and the concept of a corrosion free structure. The coating must be, according to this concept a completely continuous film in order to fulfill its function. Any imperfection becomes a focal point for corrosion and the breakdown of the structure.

2.1. COATING PROPERTIES

Corrosion resistant coatings must be characterized by many essential properties. These may very, depending upon the specific use of the coating, but there are several basic characteristics required by all coating materials.

2.1.1 Water Resistance

Resistance to water is perhaps the most important coating characteristic since all coatings will come in contact with moisture. Water is the universal solvent. Both iron and steel oxidize under even normal basic water conditions. There is no one coating that can be effective under all water conditions. The different types of water encountered only multiply these mechanical problems. Swamp water, which may be pure enough to drink, is ordinarily acidic and will corrode both steel and concrete. Sulfide water, which is prevalent in many areas, reacts readily with metals. High conductivity water or seawater leads to rapid formation of anode-cathode areas on steel, which results in severe pitting. Pure water from the snowfields will dissolve calcium out of the concrete at a rapid rate, leaving the aggregate exposed. Water with high oxygen content will also create anode cathode type corrosion areas. The problem is thus a very complex one since no single type of material will provide a universal answer.

For a high-performance corrosion-resistant coating shall have excellent water-resistant means that it must not only withstand continuous immersion in water or seawater, but it must do so without blistering, cracking, softening, swelling or loss of adhesion. It must also withstand repeated cycles of wet and dry conditions, since such coatings are normally exposed to an atmosphere of condensing dew in the evening and night hours and sun drying during daylight.

2.1.2 Chemical Resistance

Chemical resistance is the ability of the coating, and particularly the resins from which it is formulated, to resist breakdown by the action of chemicals to which it is exposed.

Chemical resistance depends on the both the coating formulation and on the resins from which the coating is produced. Generally, a coating which is considered chemical-resistant and which would be used for corrosion resistance in a chemical atmosphere should be resistant to salts, acids, and alkalis of a rather wide pH range. It should also be resistant to organic materials such as diesel oil, gasoline, lube oil, and similar materials, since these are compounds found in almost all industrial operations.

Alkali resistance is, of course, extremely important in a primer. Since one of the chemical reactions in the corrosion process is the development of strong alkali at the cathode, any primer which is not highly resistant to alkali will tend to fail in the cathode area, resulting in undercutting of the coating and spreading of corrosion underneath the coating.

2.1.3 Proper Adhesion

A corrosion-resistant coating must also be highly adherent. Since the property of adhesion is essential in preventing the effects of water on the life of the coating and in preventing the problems caused by a temperature gradient across the coating, adhesion is probably the key requirement in a corrosion-resistant coating. Irrespective of most of its other properties, the coating with very strong adhesion to the surface will retain its integrity much longer than one with less adhesion but other strong characteristics.

2.1.4 Abrasion Resistance

Coatings, which are applied to ships, helicopter decks, barges, offshore platforms, and other similar areas, are excellent examples of why many corrosion-resistant coatings also require abrasion resistance. In these areas, coatings are subject to the movement of heavy equipment, foot traffic, possible wheel traffic and damage by tools and equipment. In order to withstand this type of service and remain effective as a corrosion-resistant film, a coating must be tough, extremely adhesive, hard and resistant to shock.

The most effective abrasion-resistant organic coatings are the polyurethane coatings. These have exceptional resistance to impact, scouring and abrasion. Inorganic zinc coatings, however, because of their good adhesion to the steel surface and because of their silicate and zinc composition, have proven outstanding when applied on the decks of barges and ships.

2.1.5 Ability Of Expand And Contract

Each coating material has a different coefficient of expansion. Any coating, which is to withstand corrosive conditions, must also have the property of expanding and contracting.

Epoxies or alkyds may after some considerable aging, become brittle and cease to expand and contract. This can lead to cracking and spalling from the surface because of the temperature cycling.

A proper corrosion resistant coating must withstand temperature changes without loss of adhesion and without checking or cracking. Inorganic zinc coatings have proven to have exceptional resistance to such changes in temperature.

2.1.6 Weather Resistance

A weather-resistant protective coating must withstand the sun's rays, rain, snow, dew, freezing, and thawing, expansion and contraction of the substrate, chemical fumes, dusts, as well as continuing wet and dry cycling-usually on the daily basis. Weather resistance combines into one property almost all of the properties required of a coating for more specific uses. To be weather-resistant, a coating must resist the above conditions without excessive checking, chalking, flaking, blistering, loss of adhesion or substantial colour or appearance change.

2.1.7 Resistance To Bacteria And Fungus

There are two ways in which bacteria and fungus can affect a coating. First, where they settle on any dirt that has accumulated on the surface of a coating, they tend to live and thrive. They attack on the coating and form colonies. These fungus colonies are living on one or more of the coating ingredients and can eventually lead to premature coating breakdown.

Underground conditions can also lead to coating breakdown due to bacteria attack.

2.1.8 Pleasing Appearance

Although a coating is primarily used to prevent corrosion and protect the basic structure, it should also be pleasing to the eye and maintain its colour.

2.1.9 Easy Application

Application is one of the most important coating characteristics, especially when dealing with structures with many corners, edges, recesses, and similar areas. If a coating is somewhat difficult to apply, these are the areas which suffer and which breakdown first in the corrosive atmosphere.

2.1.10. Resistance To Extreme Temperature

While all coatings are subjected to temperature and come temperature cycling, these conditions are generally moderate. Temperature, however, can be key factor in coating used for stacks, pipes, the exterior of process vessels, and for other similar uses. Where coating is used for excessively cold temperatures the three general characteristics to be considered are adhesion, shrinkage, and brittleness.

2.1.11. Radiation Resistance

Atomic energy and atomic power coatings have been used extensively for protection against the radioactive contamination of various substrates including steel, concrete, stainless steels etc. in order to be effectively used on such installation, coatings must be able to withstand varying amounts of radiation.

2.1.12. Friction Resistance

Some coatings are subject to friction, particularly when they are used as faying surface where two sections of metal are riveted or bolted together to form a friction joint. Inorganic coatings have proven to be very satisfactory under such conditions, while most organic coatings are unsatisfactory.

2.2. TYPES OF EXPOSURES

There are three essential types of exposures which corrosion-resistant coatings are subjected to: Atmospheric exposure, Immersion and Underground exposure.

2.2.1 Atmospheric

The obvious major difference between atmospheric exposure, immersion and underground use is that of weather resistance. Coatings which are immersed or which are designed for underground use are not usually exposed to weathering conditions. A coating under atmospheric exposure must withstand a multitude of conditions, which includes the radiation, heating, and cooling, maximum exposure to oxidation, chemicals, and alternate wetting and drying. Atmospheric coatings are usually relatively thin films, which makes the retention of the above properties and the general aging of the coating extremely important. The condition of exposure for an atmospheric coatings are extremely broad ranging coatings which are used very hot, dry atmosphere and those used under tropical conditions to those which are used essentially in cool cold climates.

Because of their use in such a very broad range of conditions, atmospheric coatings require careful development and formulation, as well as application, in order to obtain the corrosion resistance needed.

2.2.2 Immersion

Immersion coatings, as compared with atmospheric coatings, are primarily to water solutions ranging from vary pure water to ones containing high concentration of various chemicals. The primary coating requirements for immersion are adherence and resistance to moisture vapor transfer, ionic penetration, chemicals, and varying temperatures. Whenever a coating is to be used under immersion conditions, the conditions should be precisely determined prior to the selection of any coating.

2.2.3 Underground

The coating requirement for underground conditions are quite similar to those for immersion; adhesion, moisture vapor transfer, resistance to ionic passage, Pipes or structures underground are subject to varying backfill conditions, varying soil movement, and expansion and concentration due to more or less moisture in the soil. Soil forces can be strong enough to actually pull the coating from the surface of the metal, which then cracks it and allows other external forces to react on the metal itself. Thickness is important since rock points and damage during backfill are quite common. Thickness also helps contribute to moisture impermeability as well as to the impermeability of various soil chemicals.

In general, many coatings applied to pipe and under ground structure are thicker than atmospheric coatings. Many pipes have an extruded plastic coating, which may very from 50 to 250 mils in thickness.

Pipe wraps of various types using hot-melt coatings are commonly used to build a reinforced laminated coating over pipe surfaces. Thin coatings are generally less satisfactory and less durable.

When to build or bury a structure for long service life, one that will be relatively stable and free of excessive maintenance, a selection of the coating type best suited for the task to be performed must be made to also meet the design requirements of operation and maintenance.

2.3. TYPES OF COATINGS:

No one expected to be a chemist; however, some basic knowledge of the different types of coating materials and their chemical and physical properties as explained earlier can be advantageous.

Generic coating types take their name from the resin in their formulation. Thus a coating may be referred to as a vinyl or an epoxy, although it may be highly modified, or in some cases, it may be combination of two or more different resins, one of which will usually be predominant. For example, vinyl resins are often modified with alkyd or acrylic resins, or coal tar pitch may be used in conjunction with epoxy resins. Such modifications produce the thousands of combinations today. The most common generic types of coatings are:

1. Acrylics
2. Alkyds
3. Bituminous
4. Chlorinated rubbers
5. Epoxy amine
6. Epoxy coal tar
7. Epoxy ester
8. Epoxy Phenolic
9. Epoxy polyamide
10. Inorganic and organic zincs

11. Silicones

12. Urethanes

13. Vinyls

The more significant features of the different generic types of coating materials are as follows:

1. Acrylics

Acrylics have excellent colour and gloss retention for outdoor applications and are often combined with other resins because of these properties. They are ideal for use in areas of mild chemical fumes but are not recommended for tank linings. They are somewhat inferior to vinyls or chlorinated rubbers in chemical resistance. They cure by solvent evaporation. They are often used as a topcoat over other chemical resistance coatings are applied, because of their color and gloss retention.

2. Alkyds

Alkyds are usually natural oils that have been chemically modified to improve the rate of cure, chemical resistance and hardness. They are general-purpose coatings designed for applications to a wide range of substrates. They are easily applied and can be used as primers or topcoats. They provide good colour retention and gloss but exhibit poor chemical resistance. Since they are subject to saponification, which is chemical interaction of fat with an alkali that forms a soap, they are not suitable for applications to alkaline surfaces. They cure by air oxidation.

3. Bituminous

Bituminous coatings are low-cost, heavy-bodied materials applied either hot or as a cut back with solvent. They provide good moisture barriers, have good-to-fair resistance to chemical fumes and spillage and exhibit good acid resistance and poor solvent resistance. They form very heavy films but have no corrosion inhibiting qualities. When they are damaged, undercutting can be serious problem. They are available in black only. Materials such as clay, slate, mica, asbestos and other powders are sometimes added to increase film thickness and toughness. They cure by solvent evaporation.

4. Chlorinated Rubber

Chlorinated Rubber coatings are similar to vinyls in that they form fairly rough, thin films that have good abrasion resistance. They have excellent weathering properties and provide excellent resistance to most mineral acids and alkalis, salt and fresh water, and fungus growth. They are frequently modified with alkyd resins to lower their cost and improve their application characteristics. Curing is by solvent evaporation.

5. Epoxy Amine

Epoxy amine coatings are catalysed or hardened by an amine curing agent. These materials form a hard, abrasion resistant coating with good-to-excellent alkali, acid, and solvent resistance. They must be applied to a thoroughly cleaned surface and are moisture-sensitive during application. They have a tendency to fade and chalk in direct sunlight and to embrittle on ageing.

6. Epoxy Polyamide

Epoxy Polyamide coatings are not as resistant to acids, alkalis, or solvents as the amines. Polyamides have greater flexibility and provide water and salt solution resistance. They have a tendency to fade and chalk indirect sunlight and do not embrittle as much as the amine epoxies do on ageing.

7. Epoxy Coal Tar

Amine or polyamide epoxy resins are often modified with coal tar pitch to produce relatively high film build-up for good chemical and moisture resistance. Resistance to hydrogen sulphide and acids in general is dramatically improved over a straight epoxy. They have a tendency to embrittle on ageing, and delimitation between coats or beneath touch-up patches is common unless special pre-cautions or taken during applications. They are normally black in colour.

8. Epoxy Phenolic

Epoxy Phenolic coatings combine a portion of Phenolic resin with epoxy resin. They are usually employed as tank linings but have used extensively in nuclear plants, as interior coatings for vessels. They have good resistance to the effects of radiation.

9. Epoxy Ester

Epoxy ester coatings are a combination of an epoxy resin and a drying oil. These coatings cure by a combination of solvent evaporation and oxidation. They do not require the use of catalyst or hardener. Chemical resistance is better than alkyds but still rather poor. However, they can be applied by relatively inexperienced painter on surface having only marginal surface preparation. They do not lift most old, sound paints. Their whether resistance is fairly good, but they will chalk and yellow after extended exposure to sun. They do no saponify over alkaline surfaces to the same degree as an alkyd.

10. Inorganic And Organic Zincs

Metallic Zinc is used as the pigmentation with the variety of vehicle for inorganic and organic zinc coatings. They may be one- two- or three-package materials, post cured, moisture cured, solvent based or water based. The end product in all cases is metallic zinc suspended in extremely hard, tough silicate matrix. Acid or alkali resistance is poor but solvent, moisture and salt resistance is excellent. Their weather resistances is extremely well and are often used as a single cost system for structural steel or tanks. Abrasive blasting is required, and the dry film thickness of the applied film thickness of the applied film is critical.

11. Silicones:

Silicone coatings are semi-inorganic polymers which, when formulated into coatings, have outstanding heat resistance and excellent water repellency. Properties depend on the amount of silicone resin and the type of modifying agents used (i.e. alkyd, acrylics, etc). In high heat applications, such as stakes, they are used to temperatures as high as 1200^0 F.

12. Urethanes:

Sometimes called polyurethanes or isocyanets, these coatings are a fairly new development but may be obtained in a wide range of formulations. Normally, two-package, catalysed materials, the aliphatic urethanes are hard, tough and abrasion resistant, with excellent weathering properties and gloss retention. They exhibit excellent solvent resistance, only slightly inferior to that of an epoxy, and withstand mild acids and alkalis. Their adhesion properties are excellent; however, they are usually applied over an epoxy primer. Urethanes can be applied at lower than most other chemically cured coatings. During applications, urethanes are moisture sensitive, but after they have cured, they exhibit outstanding resistance to high humidity.

13. Vinyls

Vinyls are thermostatic materials and cure solely by solvent evaporation. As such, they can be applied at much lower temperatures than any catalysed coating. Acid and alkali resistance is excellent, but solvent resistance is poor. Because they are soluble in their own solvents, repairs are easily made. Water and weather resistance is outstanding characteristics. A clean, preferable abrasive blasted surface is required for proper adhesion. They usually employ special primers.

2.3.1 COMPONENTS OF COATINGS:

All paints or coatings consist of two major components: the vehicle and the pigment. The vehicle consists of the basic resin portion of the coating, which is usually dissolved, in a solvent. This component of the coating is called the "binder" it binds the pigment together and is the basic film-forming portion of the coating. The pigment portion of the coating contains not only those pigments that impart colour to the coating, but may also include extenders and reinforcing agents such as silica flour, flake glass, mica etc., inerts, thixotropizing agents, ultraviolet screening pigments, corrosion inhibitors, and other activities necessary to yield specific properties to the coatings or lining. When the coating is applied to a surface, the volatile portion of the coating evaporates, leaving only the non-volatile binder and pigments to form the protective film. This is normally referred to as the "solids" of "non-volatile" portion of the coating.

2.3.2. COATING SYSTEMS

General coating systems is,-

a) Application of primer
b) Application of Intermediate coat
c) Application of Top coat or Finish coat.

a) **Primers:**

The primer is universal for all anticorrosive coating and is considered one of the most important components of the coating system. The primary purpose of a primer are listed as follows:

1. Adhesion (strong bond to substrate)

2. Cohesion (high order of internal strength)
3. Inertness (strong resistance to corrosion and chemicals)
4. Intercoat bond (high bond to intermediate coat)
5. Distention (appropriate flexibility)

The primer is the base on which the rest of the coating system is applied. As a base, it must have strong adhesion to the substrate surface. Primers are actually the key to the adhesion of the total coating system. The primer must also provide a proper and compatible base for the topcoats. Primers, then, have dual requirements; adhesion to the substrate and provision of a surface will allow proper adhesion of the topcoats.

Primers are often applied and allowed to stand for many days or months prior to the application coats. Therefore, they must also have sufficient resistance to the atmosphere to protect the steel substrate from any corrosion during the period between the time of primer is applied and the time that the topcoats are applied. If it allows corrosion to take place during this period, it is not performing the whole purpose for which it was designed. A primer generally must have the ability to retard the spread of corrosion discontinuities such as pinholes, holidays, or breaks in the film.

b) Intermediate Or Body Coats

Intermediate or body coats are usually used in coating systems, which are designed for specific purposes. The primary purposes of intermediate coat are to provide:

1. Thickness for total coating
2. Strong chemical resistance
3. Resistance to moisture vapor transfer
4. Increased coating electrical resistance
5. Strong adhesion
6. Strong bond to primer and topcoat

The formation of the intermediate coats is important, primarily as it increased thickness. Physical thickness improves many other essential properties of a coating, such as increased chemical resistance, increased abrasion, and impact resistance. The body coat or intermediate coat must also provide strong adhesion to the primer, as well as a good base for the topcoats. Another important role of the intermediate coat is in providing a superior barrier with respect to aggressive chemicals in the environment or when immersed. The intermediate coats are usually deficient with respect to appearance properties so that they are generally not used as finish coats. They may also be used to add physical resistance. Most intermediate coats are used with the impervious type coating system.

c) Topcoats Or Finish Coats:

Topcoats also perform several important functions in that they provide,-

1. A resistant seal for the coating system.,
2. Form the initial barrier to the environment,
3. Resistance to chemicals, water, and weather,
4. A tough and wear resistant surface,
5. A pleasing appearance.

In the primer, intermediate coat, and topcoat system, the topcoat provides a resinous seal over the intermediate coats and the primer. The first topcoat may actually penetrate into the intermediate coat, thus, providing the coating system with an impervious top surface. The topcoat is the first line of defense against aggressive chemicals, water, or the environment. It is the initial barrier in the coating system. It also provides the coating system with the characteristics of appearance through its colour, texture and gloss.

2.3.3. THINNERS AND SOLVENTS

Often referred interchangeably, the terms "thinners" and "solvents" for all practical purposes mean the same thing to most of the painters. There is distinction, however, and it can be of extreme importance. Most thinner can be used as solvents, but not all solvents can be used as thinners. Coating manufactures will specify particular thinners to be used with their materials, some of which are blends of different solvents. The manufacturer's recommended thinner must always be used in the quantities recommended to thin coatings. Many painting contractors will buy inexpensive solvents that are particularly adapted for cleaning equipment. If a solvent is not recommended by the coating components manufacturers is used to thin the paint, it can cause separation of components, coagulation, too fast or too slow drying, changes in flow characteristics, lifting of previous coats, and a host of other undesirable conditions. Cleaning solvents must always be kept segregated from the coating materials and thinners.

The different types of thinners in common use and the type of coating materials for which they are typically used are:

I) Mineral spirits - Oils or Alkydes,

II) Aromatics (benzene, xylol, toluol) - Coal tar epoxies, Alkydes, chlorinated rubbers,

III) Ketones(MEK, MIBK) - Vinyls, epoxies, urethanes,

IV) Alcohols (isopropyl) - Phenolics, inorganic zincs,

V) Water - Acrylics, some inorganic zincs

The solvents or thinners used with most coatings produce vapours that are heavier than air, as a result, will collect in tank bottoms of confined locations unless means are employed to disperse them. The exception, of course, is water used as a thinner in some inorganic zinc and acrylic coatings. The Ketones have the lowest flash point; however, a connection of any organic solvent in the right proportions with the air can create an explosive combination.

2.3.4. CURING OF COATINGS:

All should be familiar with the types of curing mechanism of the coating & the correct curing. The applied coatings must be properly cured before it is top coated and before it is placed into service. Premature failure will occur if the coating is top coated before the primer or intermediate have sufficiently cured. The uncured coating, if top coated, may blister because of entrapped solvents. This may result in lifting of coating film. Many coatings, such as coal tar, epoxies, have maximum recoat times. Also, if the coating cures beyond the required period for top coating, the topcoat will not bound properly. It is especially critical in the applications of tank lining that the coating be sufficiently cured before being put into service. A differentiation must be made between "drying" and "curing. A coating may be dry to the touch and still may not be cured. Following is the list of curing methods, together with the generic types of coatings using each method.

i) Air oxidation - Alkydes, Epoxy, Ester,
ii) Solvent Evaporation - Vinyls, Chlorinated Rubbers, Bituminous, Acrylics,
iii) Chemical reactions - Epoxies, Polyurethanes, Vinyl-Esters, Inorganic Zincs,
iv) Heat Cure - Silicones, Phenolics

The following is the description of each of the curing methods,-

i) Air Oxydation

Coatings that cure by oxidation, or air drying, depends upon oxygen to penetrate the film after the solvents has evaporated. There is limit to the film thickness, which can be achieved with this type of coating. Alkyds are examples of coating that cure by this method. If they are applied too thick, the solvent will evaporate from the surface, the oxygen will cure the top layer of the coating film, and it will be difficult for the solvent to evaporate from the lower layers of the coating. At the same time, oxygen will have difficulty penetrating the rest of coating film, and the coating will not cure properly.

ii) Solvent Evaporation

Almost all coatings, unless they are 100 percent solids, will undergo solvent evaporation prior to curing. The solvent completely evaporates as the coating film cures, leaving the film of the resin and pigments on the surface.

iii) Chemical Reactions

Coating that cure by the addition of a catalyst or hardener, or coatings that are chemically cured, are usually packaged in two or more containers, each container holding a carefully pre-measured amount of material. These proportions are very critical and, for this reason only complete units of any coating should be used. Do not attempt to proportion the different components of a multi component coating. Unless a chemically cured coating is mixed in the proper proportions and unless all the components are used, it is highly unlikely that the coatings will cure properly. Once these components are mixed together, the coating has a pot life, which refers to the length of time the coating material can be used. Material should not be used after its pot life has expired.

iv) Heat Cure

These coatings require heat curing to obtain maximum stability and durability.

In this chapter, studied the coating characteristics, type of exposures, types of coatings materials that are most commonly used.

Type of substrate, surface preparation, selection of coatings, application of coatings, coating failures, repair methods of coatings, etc have been studied in the next chapter.