

## CHAPTER 17.3

# PETROLEUM REFINERY COATINGS

by

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## I. INTRODUCTION

Protective coatings are one of the primary means of controlling corrosion in refinery exposures. For this reason, costs for maintenance painting can account for as much as 15-25 percent of the maintenance budget. Adequate interest return is expected for every dollar invested in painting. Production outages should also be reduced and life expectancy of key process equipment extended. Important by-products include improved appearance and better morale and community relations.

Refinery painting, which includes process equipment, storage tanks, piping, etc., presents a broad spectrum of exposures that involves a variety of physical and chemical conditions. Because of this, coating procedures and materials selection change from area to area. Although all areas cannot be covered in this chapter, some of the most common ones will be discussed to aid the refinery engineers in creating an effective maintenance program.

## II. HISTORY OF REFINERY COATING

The evolution of coating technology in the past 20 years has resulted in more efficient materials performance than was previously obtained from oil-base aluminum and other similar coating formulations. With earlier coating materials, painting was an annual occurrence. Today, coating systems that will perform for up to 25 years are not uncommon. A typical high performance system is organic or inorganic zinc-rich primer with suitable topcoats. The total dry film thickness of such high performance systems should be 8-10 mils in atmospheric exposure. These systems can be applied on new construction and are virtually maintenance free for the expected life of the equipment. Economics and investment return can be improved significantly with properly administered maintenance coating programs.

## III. PERSONNEL

Individuals in charge of maintenance coating must work effectively with the entire organization. The coating engineer is called upon to be organizer, manager, corrosion engineer, record keeper, performance analyst, and budget salesman, with a knowledge of materials composition, selection, application methods, and equipment.

Administration of good maintenance programs is paramount to success and overall performance of coatings. However, when management delegates respon-

sibilities for maintenance coating to people already overburdened or unqualified, emphasis on coatings and corrosion protection is reduced. Low priority given to coating work can result in a series of rushed projects, poor specifications, poor vendor selection, improper surface preparation, hasty choice of materials, and, of course, eventual higher costs.

## IV. COATING SCHEDULES

A coating program for the maintenance of refineries should begin with an audit. The audit should include verification of existing and new coating records and an up-to-date appraisal of coating conditions in all areas of the refinery. It is also important to note causes of coating failure. With this data, assessment of coating material requirements, scheduled timing costs, manning, and equipment can be determined for the maintenance coating program. This audit and planning of refinery coating can be handled effectively through inspection departments within the refinery. In day-to-day activity, appraisal of progress in coating application and general conditions of existing coatings can be recorded for reference in program planning.

## V. TECHNOLOGY

Careful consideration must be given to "normal" and "upset" operating conditions before coating materials are selected for a specific refinery painting job. The data should reflect temperatures (high and low), cycling, chemical exposures and mechanical conditions the coating will be subjected to. Also consider whether the equipment is indoors or outdoors and its geographical location. The coating engineer must also know how the equipment will be used in the refining process. For example, tanks are used to store finished volatile products. In order to decrease product loss from vaporization, storage tanks are often painted white to reflect solar heat and decrease vapor pressures.

Coating requirements often encountered in refineries (from a technical and operational point of view) are resistance to chemicals (including crude oils), permeability, tolerance of temperature extremes, abrasion and impact, resistance, flexibility, and weather resistance. Other properties, such as heat emissivity and solar heat reflectance, should be considered where insulating qualities or heat transfer is important. With this background as a guide, desired coating properties can be established.

## A. RESISTANCE (CHEMICALS AND CRUDE OIL)

Petrochemicals produced in refineries deteriorate coating films if proper materials are not selected. Crude oil, for instance, can cause extensive corrosion damage, especially when water separates from oil onto the bottom of storage tanks. High concentrations of hydrogen sulfide in crude oil also result in corrosion damage. For these problems, applications of inorganic zinc-rich primers with epoxy polyamide topcoats, coal tar epoxies and polyesters have performed satisfactorily. These coating systems are effective on exposures that can range from fumes, splash, and spillage to total immersion.

## B. PERMEABILITY

The rate at which water or solvents penetrate dry coating film varies greatly among generic types of coatings, seriously affecting service life of some systems in operations where moisture condenses on equipment during heating and cooling cycles and permeability through the coating increases. Similarly, the permeability rate increases in humid weather. Some coatings used to control these conditions are aliphatic urethanes and inorganic zinc-rich primers with epoxy polyamide or vinyl topcoats at a dry film thickness of 6-8 mils.

## C. TEMPERATURE

High and low temperature resistance is often required in refinery coating. Temperature may be ambient or steel skin temperatures of process equipment. In atmospheric temperatures the range can be from  $-40^{\circ}\text{C}$  ( $-40^{\circ}\text{F}$ ) in northern climates to  $54^{\circ}\text{C}$  ( $130^{\circ}\text{F}$ ) in southern climates. The process temperatures will range from  $-40^{\circ}\text{C}/\text{F}$  to a high of  $648^{\circ}\text{C}$  ( $1200^{\circ}\text{F}$ ). Temperatures as low as  $-40^{\circ}\text{C}$  will be found in refrigeration systems and on boiler breaching as high as ( $648^{\circ}\text{C}$ ) in the typical limits of the refinery. Coating materials selected for this broad temperature range include epoxy, modified epoxy, phenolics, modified phenolics, acrylics, silicone acrylics, urethanes, inorganic zincs, silicones, and heat inducing, glass-filled inorganics.

To obtain accurate steel surface temperatures, the skin temperature of equipment surfaces should be measured, since it can be higher or lower than operating temperatures. Significant energy savings can result if the proper coatings are selected.

## D. ABRASION AND IMPACT

In a refinery coated surfaces can be damaged by airborne abrasives such as sand, coke dusts, and/or products containing particulate matter. In daily maintenance operations and during refinery turnaround, coated equipment is bumped together when new piping or vessels are installed. During maintenance repair, heavy wrenches and tools are often dropped on coated surfaces. Another source of damage is steel cables and slings that are used to hoist

coated parts into place. Because of these conditions, coatings must have properties that will resist abrasion and impact. The coating selected should be a fast-cure that will form a hard film within several hours. For these applications, self-cure, ethyl silicate based, inorganic zinc-rich primers and other similar fast cure primers are used. In some areas, where pH ranges are between 6.0-9.0, the primer is not topcoated. Where top-coating is necessary, epoxies, vinyls, acrylics, urethanes and other fast-dry coatings are used to coat equipment after installation.

## E. FLEXIBILITY

Wind, temperature or process pressures can cause materials to flex. For example, in large floating roof storage tanks, roof sections can flex as much as 10 inches under high wind velocity. In process operation, the heating and cooling of thin shell vessels produces flexing as well as contraction and expansion. Materials that will meet flex requirements are, generically, epoxies (flexible), vinyls, urethanes, neoprene, and other similar materials. Each parameter should be investigated before a coating system is selected.

## F. WEATHERABILITY

Weather resistance of coating materials varies widely. Close to the Equator, coatings must withstand intense solar radiation. Close to the Arctic Circle, coatings must withstand intense cold. In hot, humid and cold climates, vinyls, epoxies, acrylics, alkyds, urethanes, chlorinated rubber, and similar generic types are good candidate materials.

## G. HEAT EMISSIVITY

As the need to conserve energy increases, emissivity becomes important. Coating materials can be used to decrease or increase heat transfer to save energy. Consider compression areas where gases are passed through piping to storage under pressure. In this case, compression requirements can be decreased if process equipment temperatures are decreased using solar-reflective materials. In other applications, heat can be absorbed to assist in raising the temperature of a tank's contents for pumping, such as with some crude oils. Where reflectance of solar energy is required to conserve volatile finished products, white coatings can be used advantageously. Heat/light reflection of black is near 0, aluminum and medium gray 40-50, and white above 80.

## H. COMPOSITION

To select coating materials that will provide the performance expected, the material's generic composition must be known. The binder, pigments, fillers, emulsifiers, and other additives contribute to film properties and subsequently to film performance.

When referring to materials on coating specifications,

the exact name of the generic materials coating formulation should be given. It is not good practice to specify by broad generic names alone, such as "epoxy", because of the considerable difference among epoxy coatings. The performance of epoxy polyamide and epoxy amine can vary widely. There are areas where they should or should not be used. For example, when the application of an uncured coating is subject to condensation or high relative humidity, an epoxy amine may not cure properly. The amine catalyst can be leached out of the coating by moisture and thus not be available to react with epoxy resins. Epoxy polyamide should be used in such cases because cure will continue even though moisture is present, although cure may be at a slower rate. Other materials, such as self-cure inorganic zincs and moisture-cured urethanes, can be used under moist conditions.

Paint and coating materials are manufactured by a batch process. Components in a formulation can vary. To assure consistent quality and composition, coating materials should be "fingerprinted", using infrared methods described in ASTM Reference "Paint Testing Manual". These methods require little time but are very effective in monitoring quality of materials. Other methods, such as pyrolytic gas chromatography and mass spectroscopy are useful in identifying components of dry films or liquid samples. In critical projects requiring large quantities of coating materials, samples from each production lot should be tested. Lots should be scanned by infrared to establish and ensure consistent material composition.

For coating applications in refineries, the generic materials most frequently used are alkyds, acrylic latex, coal tar epoxy, epoxy, epoxy phenolic, chlorosulfonated polyethylene, inorganic zinc-rich primers, mastics, organic zinc-rich primers, polyester, silicones, silicone acrylics, urethanes, vinyls, and vinyl latex.

## I. REGULATIONS

Federal, state and local regulations control abrasive and solvent materials used to clean or coat equipment surfaces. The regulations that apply include those written by the National Fire Prevention Agency (NFPA), Occupational Safety Health Administration (OSHA), Environmental Protection Agency (EPA), Department of Defense Fuel Containers List (DOD), California Air Resources Board (CARB), Texas Air Control Board (TACB) Regulation 1, Philadelphia Regulation V, and similar local controls.

In coating internal storage tanks for military fuels, the coating material should be approved and included on the DOD list. If zinc or other extraneous liner material is found in jet fuels, the product will not be purchased by the government or by some domestic customers.

Other regulations are directed to controlling solvent, dust and emissions of other materials into the environment where they are hazardous. The limits and federal regulations can be obtained from the Federal Register. State and local regulations can be obtained from respective government offices. These documents reference regulation

details. They will not be reviewed here because of their complexity.

## VI. SPECIFICATIONS

To assure satisfactory coating performance, clear, accurate specifications for coating application should be written. A coating manual prepared by the combined efforts of research engineering and inspection departments would make the job of writing specifications easier. The manual will include information on surface preparation, coating materials, areas to be painted, exposures, and special applications. In Appendix A is a typical form used by refinery management to initiate bids on work and provide a definitive coating specification. Other similar forms are used for coating stationary and on-stream process equipment. Whatever system is used, all specifications should clearly establish the following items as they relate to scope and objectives:

- a) Type and grade of surface preparation, abrasives, and anchor pattern.
- b) Generic type of primer and finish coats.
- c) Wet and dry film thicknesses of primer and finish coats.
- d) Number of primer and finish coats.
- e) Equipment to be used for applying materials (airless gun, spray gun parts such as nozzle, hoses, etc.).
- f) Safety precautions to be observed.
- g) Weather limitations such as high relative humidity, rain, cold temperatures, etc.
- h) Inspection, type of tests to be performed, by whom, and results to be expected; instruments required.
- i) The manufacturer's coating instructions, noted and referenced.
- j) Spot repair procedures.

When specifications are complete, they are used to obtain contractor bids on the coating application. During negotiations of the contract, any changes or additions to the specifications should be agreed upon. From this point until the job is completed, the specifications should be closely followed to achieve optimum coating performance.

## VII. LABORATORY TESTING

An effective program for materials research and new product evaluation should be maintained to update technology and coating performance in refinery maintenance. Research projects provide guidance in selecting materials and improving coating service performance. The data provides a basis for projecting economic costs and service life expectancy, and ultimately, for making decisions on coating system investment. At the same time, materials that are not adaptable to refinery conditions are screened, eliminating early and costly maintenance coating repairs and replacement.

Laboratory screening tests should employ a series of viable tests using simulated refinery conditions and ASTM procedures. This approach can project what might be ex-

pected in service environments. Test parameters for physical and chemical exposure must be accurately established before testing can proceed. These parameters should include skin temperatures of equipment, surface irregularities, chemical concentrations, adjacent process effluent, contamination drift, weather conditions, thermal shock or cyclic conditions and other pertinent history available from engineering and operations. With this background, screening tests can proceed. Tests most often used are

- a) Abrasion — ASTM C-190
- b) Cathodic Disbonding — ASTM G8-69T
- c) Drying Time — ASTM D-1640
- d) Exterior Exposure (Coastal & Inland) — ASTM D-1014
- e) Flexibility — ASTM D-6222
- f) Synthetic Seawater Spray (4%) — ASTM B-117
- g) Fresh Aerated Water Immersion — ASTM D-879
- h) Synthetic Seawater Immersion Aerated — ASTM D-870
- i) Solvent Resistance — ASTM D-2792
- j) Temperature Resistance — ASTM D-2488
- k) Weatherometer — ASTM D-822
- l) Heat Emissivity — ASTM E-307-68T
- m) Permeation — ASTM D-1653

To substantiate laboratory data, as much in-service data as possible should be obtained. Documented evidence, such as case histories of materials in similar refinery conditions, should be considered. To reduce the risk of making errors in the application of paint to test panels in the laboratory, arrangements should be made with the manufacturer to provide first-coated test panels. Usually, the coating manufacturer will supply coated panels and/or wet samples. Other manufacturers should be excluded from test information. After the first series of screen tests, some in-house panels should be coated to establish material workability, ease of clean up, drying times, hiding power, and other data. If some of the tests are suspect, panels can be prepared for retesting.

Of current interest are rapid laboratory instrument test methods and procedures using the scanning electron microscope (SEM), pyrolytic gas chromatography (PGC), infrared spectrophotometry (IR), emission spectroscopy (ES), and ultraviolet spectroscopy (UV). Methods and procedures for these tests are available from ASTM Reference "Paint Testing Manual", STP-500, Thirteenth Edition, and other sources. These procedures can be used to determine coating film generic composition, mechanisms of film deterioration, coating composition comparison with similar products, and to control quality by infrared "fingerprinting" coating materials.

In laboratory tests of maintenance coating systems, scribing is used to determine how effectively a coating will protect metal after it has been abraded, chipped and exposed. A scribe  $\frac{1}{16}$  inch wide is cut in an "X" shape across the coated test panel to a depth sufficient to expose the metal substrate. Edges of the coating along the scribe should not be damaged when the scribe is cut, or poor test

agreement will result. To accomplish this a panel scribe equipped with a metal saw is used. With this equipment scribes are uniformly and easily cut to the desired depth (Figure 1).

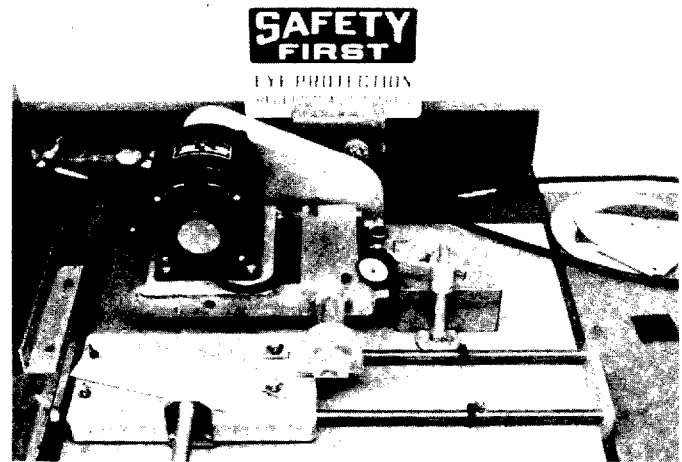


FIGURE 1

Panel Scribe

Courtesy Gulf Oil

## VIII. FIELD TESTING

Once initial screen tests are complete, field evaluation will substantiate laboratory results. This phase will generate in-service data to assist management when making investment decisions on coating systems. Personnel making the field tests also have an opportunity to evaluate film forming, handling, and drying characteristics. Field test applications on exterior and interior tank surfaces yield beneficial data that can be effectively used to determine expected performance of a coating system.

To evaluate coating materials for internal use on process vessels, test racks are used. Racks are designed to hold about 10 to 12 (size 3" x 5" x  $\frac{1}{8}$ ") coated panels and two mild steel corrosion coupons. Metal frames and support rods used to construct racks are made of Monel or 316 stainless steel. When racks are assembled, support rods are insulated from the frame with Teflon tubing; each panel is separated from the other by one-half inch Teflon spacers. Metal corrosion coupons are accurately tarred to measure corrosion loss in the vessel. From field test data suitable materials and necessity for coating can be established (Figure 2).

At the refinery, test records are usually developed by the Inspection Department. At regular intervals a report of test items is compiled. This background and data is then filed for future reference.

## IX. SURFACE PREPARATION

In all refinery coating applications, proper grade of surface preparation is vital in obtaining satisfactory coating performance.

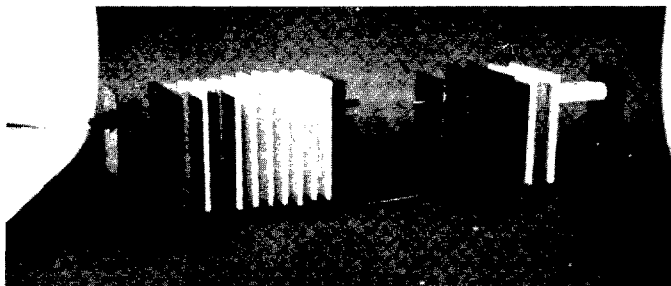


FIGURE 2

Typical Test Rack Assembly For Internal Vessel Testing

Steel Structures Painting Council Surface Preparation Specifications and Photographic Standards (SSPC-Vis 1) are used to establish conditions and degree of coating deterioration. With these procedures, we can identify specific surface preparation requirements. Other conditions that should be observed for surface preparation are

#### *General Cleaning*

All surfaces must be free of condensation or moisture prior to surface preparation or coating.

#### *Steel*

Where millscale is present, shop blasting and pickling and blasting are effective and practical. When required, on-site blasting is preferred to hand cleaning. On-site pickling is unsatisfactory due to problems with handling acid solutions and safety. In field blasting, the first coat of paint should be applied the same day that steel is blasted to prevent rust from forming on the blasted surfaces (free of chromates or other toxicants).

#### *Dry Blast Cleaning*

Abrasives used in blasting should be selected from materials of mesh size to produce the anchor pattern required for the coating to be applied. Abrasives may be sand, steel shot, grit and others that will not contaminate the etched surfaces.

#### *Coordination*

Operations of sandblasting and painting should be coordinated to avoid embedding sand or other debris in tacky or wet paint films. Lack of coordination can cause coating problems, particularly when internally coating tanks where dust from blasting can accumulate on surfaces to be coated.

#### *Hand Cleaning*

When hand or mechanical cleaning (SSPC-SP 2) is used to remove weathered millscale and other contamination, the proper primer should be selected. The primer should have good wetting and slow drying properties and should be followed by compatible top-coats.

#### *Galvanizing*

New galvanized surfaces should be cleaned by oil dissolving solvents, detergents, brush blasting or chemicals before coating to avert disbonding and

poor intercoat adhesion. Galvanized surfaces should be permitted to weather for several months to improve paintability. Where neither approach is possible, special primers can obtain proper bonding of the top-coat. Vinyls, epoxies, latex base coatings and wash primers are widely used on galvanized surfaces.

#### *Copper*

Copper and its alloys are not coated since they form their own protective oxide film. However, should coating be necessary, copper should be allowed to weather until dark oxides appear or roughening of the surface develops. The primer used should be conventional alkyd or oleoresinous materials. Where coating is not possible and discoloration of copper is objectionable, the use of lead coated copper should be considered.

#### *Aluminum*

Aluminum can be cleaned and etched by using a solution of water containing about 1%/wt. caustic or by brush blasting (SSPC-SP 7). Effective proprietary solutions are also available for preparing aluminum to receive coatings. Surfaces should be coated with zinc chromate-base primer or other lead-free materials. If lead is present, it will promote pitting of an aluminum surface.

#### *Wood*

Before painting, wood surfaces should be tested with a moisture meter to be certain the wood is dry. Where new wood is finish coated with water dispersed latex systems, the test should also be made, since primers are usually oil base. Previously painted wood can often be painted, even though some moisture is present, if water soluble latex coatings are used and priming is not required.

#### *Masonry*

New plaster, concrete, and brick should be allowed to cure before coatings containing solvent are applied. When new water soluble coatings are used, complete cure is not essential. It is advisable to acid etch concrete with a muriatic acid solution 10 to 20% by



FIGURE 3

Typical Refinery Tank Farm