Chapter 3
Paint Material Specifications, Procurement, and Testing

3-1. Introduction

This chapter is intended to provide the engineer with an understanding of how coating systems are specified, procured, and tested prior to being applied on a large scale to USACE structures. Generally, coating materials can be specified by product name and manufacturer; Federal, military, and other coating formulations; product name or “approved equal”; qualified products list (QPL); and performance. All have inherent merits and limitations; exposure to each will give the engineer a basis for preparing coating specifications. Procurement of USACE coating materials for in-house application is conducted either through the Rock Island Consolidated Paint Acquisition Contract or by using the Government Services Administration (GSA), under regular procurement or the Multiple Award Schedule. Procurement by contractor is the most common method because most USACE work is contract painting. This chapter provides the engineer with an understanding of each of these methods of procurement. Coatings testing—including sampling procedures, material identification, and coating performance tests—is critical in establishing if the supplied coatings meet the formulation requirement and if they will provide corrosion protection to the structure. This chapter will provide the engineer with an understanding of the various tests that can be performed and what the test data mean in terms of coating performance.

3-2. Types of Coating Material Specifications

Coatings specifications can be produced by product name/manufacturer, standard specifications/formulation, product name or approved equal, QPL, and specification by performance. Each type of specification will be discussed.

a. Specification by product name/manufacturer. The product name of a reputable manufacturer is one way to specify a coating material. Although private industry specifies coating material by product name/manufacturer the USACE currently does not. Specifying a coating material by product name is suitable (and advantageous) when a specific coating material has proven successful. If the material is suited for the service environment, it can be expected to continue to perform well. The manufacturer usually will provide technical advice for the application of the material to ensure that it is applied in the best possible manner. A drawback to specifying by product name/manufacturer is that it eliminates competition, and the USACE may pay a premium price for the product. Refer to 48 CFR 1-10.002 and ER 1110-2-1200 concerning restrictions on specifying proprietary products.

b. Specification by standard specifications/formulation.

(1) Standard specifications are issued by nationally recognized authorities (Federal, military, American Society for Testing and Materials [ASTM], Steel Structures Painting Council [SSPC], etc.) and can be used in selecting paints for civil works activities. Some specifications are formulation based; others are based on product performance. Coating materials specified by formula require the manufacturer to follow a “recipe” during the manufacturing of a coating for a customer. In specification by formula, a coating manufacturer competitively bids on supplying the customer with the product(s) formulated as directed in the specification. No additional expertise is required, and the manufacturer has no responsibility but to supply the product(s) as dictated by the formula specification. For example, SSPC has developed many formula specification materials that have been used since 1955. These formulas were developed because many outstanding coatings that were being studied did not meet available specifications or had specifications for limited distribution. Therefore, the SSPC paint specifications were issued to make it possible for anyone to specify these materials by formulation. SSPC formula-specification paints are widely referenced and accepted throughout the industry. With the exception of those containing lead (to be withdrawn in 1993/1994), SSPC formula coating materials are readily available from several major U.S. manufacturers. Each SSPC Painting System Specification combines all of the requirements necessary for a complete paint job in a single formula. These specifications include all of the components for surface preparation, paint application, paint thickness measurements, primer, midcoat, topcoat, safety, and inspection. There are two methods of using the SSPC Painting System Specifications: specifying the use of an SSPC Painting System Specification by number—recommended for most situations—or using painting system guides to prepare modified systems for special situations. The USACE uses a similar system to specify special formulation vinyl paints commonly used on inland hydraulic structures.

(2) There are limitations to formula specifications. The specified composition may represent a compromise because it may have been developed through laboratory testing only; actual field exposure testing may never have been done. Also, state-of-the-art technology usually is not maintained. For example, the last revision to the SSPC systems was made in 1991. Since then, zinc-filled moisture-cured urethanes and other innovative coatings types have been developed but are not included in the listing.

(3) Much confusion can result from the use of standard specifications for paints and ingredients if the project specification writer does not keep thoroughly up to date and well informed. When a standard specification covers several types or grades of material, the project specification writer may have failed to designate the type and grade of material to be used; thus the contractor, who will be guided by cost considerations rather than applicability, will make the selection. Users of Federal and other standard specifications should consider the comments (Paragraph 9.0, "Notes," in the SSPC Painting System Specification) at the end of such specifications. These comments frequently provide valuable information about intended uses of various classes and grades. Standard specifications can lead to minimum quality manufacturing and materials. A formula coating must be manufactured with tight quality control and tested by the purchaser. When these steps are followed, formula specifications can be a good method of specifying coatings.

c. Specification by product name or "approved equal." Specification by product name may not be desirable because it eliminates competition. The product name or approved equal specification is intended for competitive bidding and often requires the manufacturer to perform tests to prove that the listed materials are equal in performance. Although this type of specification encourages competition, it seldom, if ever, is workable for paint products. "Similar and/or equal" cannot be satisfactorily proven within the short time usually available for compliance testing of the products. "Equal" means equal performance on the contemplated surfaces and under the completed exposure conditions. This type of comparison can be determined only by practical, long-range exposure testing of the product in question alongside the standard of comparison. The "or equal" clause sometimes is avoided by writing a highly restrictive specification around the preferred proprietary product without naming it. This procedure is seen as a ruse by other manufactures and is more likely to create animosity than if the preferred product is simply specified by name.

d. Specification by QPL. Coatings specification classified by a QPL combines the advantages of coating materials/systems that have been evaluated and approved for use in a given service environment and competitive bidding. A QPL is developed by an owner (i.e., USACE) and implemented by inviting manufacturers to participate in a coatings evaluation program funded by the USACE; or the manufacturer may be encouraged to fund the testing for placement on the QPL. Minimum performance levels are established, and a determination is made about whether or not the manufacturer's product/system is qualified for use. The use of a specification that includes the establishment of a QPL is workable, but it involves considerable time and effort. Under this system, a paint product would be tested for suitability on practical surfaces for a significant period of time. Those products accepted would be placed on the QPL with the stipulation that the manufacturer furnish exactly the same material as was originally accepted. Failure to do so would result in removal from the list.

e. Specification by performance. A performance specification does not designate the material by formula, but it specifies the required performance of a material. Because all coating jobs are different—with different application and service variables—only comparative testing of coatings under actual field operating conditions will provide an accurate determination about which materials best meet the requirements (e.g., test patches). When performance specifications are based on laboratory test results, they are limited to a few, short-term tests that may not accurately depict the field performance. But the cost and time involved in applying field test patches may dictate the use of laboratory testing. The alleged principal merit of a performance-type specification is that it takes advantage of the manufacturer's knowledge and experience. However, there is no real advantage unless the manufacturer actually is highly experienced in formulating paint for the particular contemplated use and if this experience is actually put to work for the benefit of the consumer. A major difficulty with a performance-type specification is that the acceptance tests, which purport to show that a paint is satisfactory for a practical use, must be finished within a short period of time and may not be dependable in predicting actual performance. For example, passing a 500-hour salt spray test may be a requirement—even though the contemplated exposure does not involve exposure to salt—or passing a flexibility test after 7 days final drying time, whereas a more meaningful test would involve determination of flexibility after years of exposure. These short-term acceptance tests encourage the manufacturer to formulate the product merely to pass the tests rather than to provide long-range, practical performance.

3-3. Coating Material Procurement

Coating materials can be procured by the contractor, the Rock Island Consolidated Paint Acquisition Contract, or the GSA. The advantages and limitations of each source of supply will be discussed.

a. Procurement by contractor. Most painting by the USACE is done by contract, and it is the contractor's responsibility to procure paint that meets the specification. Neither the Rock Island Contract nor GSA normally is made available to the contractor. These sources of supply are for USACE procurement and are used mostly for in-house applications. The USACE may use these sources of procurement to supply the paint to a contractor, but this is seldom done because the USACE would be responsible for storage, short or excess supply, timely delivery, and hazardous waste.

b. Procurement by Rock Island Consolidated Paint Acquisition Contract. Coating materials can be procured by USACE personnel through the Rock Island District (CENCR). Engineer Regulation ER 700-1-1 identifies CENCR as the Mission Supply Support Activity for special formulation paints outlined in Guide Specification CWGS-09940. Annually, CENCR issues an invitation for bid on a two-part contract. The first part is a fixed quantity contract. Known quantities of various types of paint are clearly outlined, and an agreement to purchase those quantities is included. The second portion of the contract is known as the open-end schedule. This open-end schedule formerly included more paint than the fixed quantity portion; however, in recent years the quantity has been reduced to an amount less than that of the fixed quantity. The open-end schedule is only an agreement by the successful bidder to furnish the materials specified in quantities up to the amounts given by the contract. The Government is not required to purchase any of the quantity on the open-end schedule. To determine the types and amount of paint to be included in the fixed quantity portion of the contract, field offices are surveyed and asked to order the amount of paint they will need for the coming year. Quantities of each type of paint ordered are totaled, assembled into an invitation for bids, and offered to paint manufacturers. The open-end portion is provided for those field offices who were, for one reason or another, unable to determine their needs and for those who underestimated the quantities they would require. On occasion, the total quantity of one or more of the items on the open-end schedule will be purchased. When this occurs, the obligation of the supplier to furnish paint at the contract price ends. However, the supplier usually will continue to furnish the paint at the contract price rather than compete with other paint manufacturers. When the supplies are exhausted or contracts are terminated, procurement of special formulation paints is still the responsibility of the CENCR. Only the special formulation paints, such as all the vinyls and the epoxy zinc primer, are procured through this contract. Prior to 1993, the contract also furnished a number of special formulation phenolic paints. The procurement of these paints was discontinued because of low usage and the fact that one of the phenolics contained lead. The contract cannot furnish Federal or military specification paints or proprietary products. Districts must procure these paints through GSA or other standard procurement practices.

c. GSA—Federal Supply Schedules. The GSA provides a simplified procedure for obtaining commonly used materials purchased at volume prices through their Federal Supply Schedule (FSS). For many years, the FSS has provided both large and small quantities of paints that meet Government paint specifications. Under this schedule, GSA purchases, stores, and distributes paints, as well as other commodities, for authorized users. The FSS was used by Corps activities mostly for supplying paint for in-house labor. Although it could have been used to provide contractors access to paint, difficulties including storage for early deliveries, claims for late deliveries, and disposal costs for excess materials diminished its use. In recent years, the GSA has expanded the FSS with a “Multiple Award Schedule” (MAS) for some high volume paints.

d. GSA—MAS.

(1) General. The MAS differs from the FSS in that the paints are not purchased according to Government specifications, and GSA does not purchase, store, or distribute the paints. Under the MAS, GSA issues contracts with suppliers for comparable coating materials. GSA accepts the bids and places the names of the multiple suppliers on a list for each generic category of paint. Government agencies may purchase paint directly from the manufacturers at the GSA-negotiated price. At this time, the MAS includes both interior and exterior architectural primers and finish coats. Three levels of gloss are available for each type of finish coat.

(2) Using the MAS. In response to Congressional insistence, the Secretary of Defense is urging the use of commercial materials rather than Government-specification materials. If it is in the Government's interest, contracting officers may authorize contractors to use products from the MAS in performing Government cost-reimbursement contracts and other types of negotiated contracts. Procurement procedures were eased in 1991 so that the limit above which the nonuse of the lowest price item must be justified was raised to $2,500 or 10 percent of the small purchase threshold (48 CFR 1-13.106). This allows the selection of products from the MAS for many projects without justification for not ordering the lowest cost item. For orders above the $2,500 limit, justifications can be based on delivery time, special requirements, comparability with existing systems, or special features of the product that are required for effective program performance.

3-4. Paint Testing

Testing of protective coatings (paints) generally falls into three categories: testing of the raw materials, testing of the finished product (material characterization), and performance testing using accelerated weathering and other simulation-type methods of evaluation. The purpose of paint testing is twofold: to help ensure that the minimum requirements for ingredients and material characterization (e.g., generic type, volume solids, percent zinc in dry paint) are met by the coating manufacturer on a batch basis, and to help ensure that the formulated product will provide satisfactory performance in the environment. The USACE does a fair amount of performance testing, both accelerated (laboratory) testing and field testing. To conduct a credible evaluation and generate meaningful data, comparison of the new product is made with that of a product with a known performance. The products being compared truly must be compared on an equal basis, including equal attention to meeting the recommended surface preparation, application requirements for both the new and the control product, and selecting identical exposure locations in the field. The results of the performance testing are determined in real-time. In some instances this has resulted in products being changed or discontinued and companies going out of business before the test was concluded.

a. Sampling methods and techniques. To a greater degree than many other engineering materials, paints must be sampled and tested to ensure reasonable compliance with the specifications. Plant inspection can ensure that the approved raw materials are entering into the manufacture of the finished products and the correct proportions are being used in the batching. Even a small paint plant carries hundreds of raw materials in stock and makes dozens of finished items by batch. Therefore, specification requirements are greater than for many other construction materials. Sampling and testing are vital to ensure receipt of specified materials. Acceptance of paint manufacturer certificates of compliance and manufacturer's performance test reports is not an advisable practice for paint products. Certificates of compliance from the raw material suppliers typically provide sufficient evidence of the quality of the raw materials. However, this usually is not the concern. Formulating of the raw materials into a finished product and any performance testing conducted by the manufacturer may be suspect. Coating materials may be improperly formulated or may be formulated using less expensive raw materials than those specified. Performance testing conducted by the manufacturer may be biased. For example, the immersion resistance of a coating material may be stated as “excellent” but the test's unstated duration was only 30 days.

(1) Sampling of ingredient materials. In general, examination of only the finished product cannot determine positively that the specified ingredients for particular epoxy coal tar and vinyl paint formulations [shown in detail in the Special Paint Formulations Section of CWGS-09940 were actually used. Immediately on being awarded the contract, the paint manufacturer should be required to submit samples of all raw materials proposed to be incorporated into the finished products. In addition to samples of the raw materials, the manufacturer should submit a list indicating the trade name and/or code number by which the producer identifies the raw material. These identification provisions often can save considerable analytical work because manufacturers of raw materials frequently indicate in their literature which standard specifications their products comply with. The raw materials should be tested in the laboratory to the extent considered necessary, and a copy of the notice of approval and the raw materials list should be furnished to the plant inspector. Laboratory test results must be submitted in a timely manner so the manufacturer may proceed with making the finished product.

(2) Plant inspection. Actual plant inspection may be advisable in the procurement of large quantities of paint, particularly of the special formulation vinyl-type paints. If adequately carried out, this phase of inspection permits laboratory testing to be minimized. The degree of inspection provided may vary, depending on past experiences with the manufacturer, the nature of the finished products, quantities involved, and other factors. Also, plant inspection is of no value when the paint is specified purely on a performance basis and there are no detailed formulation requirements. A suggested sequence of operations for the inspection of large-quantity items of a paint procurement contract follows.

(a) Sampling of finished product. Samples of finished products should be laboratory tested for color, fineness of grind, consistency, pigment content, volume solids, and similar, easily conducted tests described in subsequent sections of this chapter. If there is doubt about the quality of plant inspection or any question about the accuracy of control and the thoroughness of the manufacturing operations, the samples should be given as complete a chemical and physical analysis as is practicable. If there is concern that the factory sample is truly representative of the product delivered to the field site, a field sample may be obtained and tested.

(b) Container marking. Filled containers should be suitably marked by the plant inspector to ensure that approved materials are shipped. If the finished product is held in storage tanks pending approval by the laboratory, the inspector should seal the storage containers or take other measures to ensure that the material as packaged is identical to that which was sampled and approved.

(c) Batch sampling procedures. Paints are made in batches; thus, a sample from each batch must be taken if sampling is to be representative of a total quantity. Duplicate samples of each batch should be taken if it is deemed necessary to retain an unopened reserve sample in the event of disputes. It appears elementary that the paint being sampled be thoroughly mixed, yet this is frequently a source of error. Failure to identify samples properly with respect to applicable specification, gallons represented, batch number, and manufacturing date is common; and failure to properly seal the can against spillage during shipment also is frequent.

b. Testing procedures. The large variety of tests for finished paint products generally fall into two categories: material characterization tests and performance tests. Most of these are standard tests described in ASTM Volume 06.01, "Paint—Tests for Formulated Products and Applied Coatings." Federal Test Method Standard (FTMS) 141C, "Paint, Varnish, Lacquer, and Related Materials; Methods for Sampling and Testing" describes additional coating tests. Some of the more common of these material characterization and performance tests are discussed here.

(1) Coating material characterization tests. A series of material characterization tests can be conducted to "fingerprint" finished coatings. The results of the tests can be kept on file and used, if necessary, for comparison with samples from future production batches. This practice provides a method to verify that the material being supplied is similar in formulation to the material that was qualified for use. The results also can be used for comparison with certifications supplied with each batch. If application or performance problems are encountered with subsequent batches, they can be analyzed and the results compared with the original, qualified batch to detect any deviations in composition.

(2) Infrared spectroscopic analysis. Infrared spectroscopic analysis is a common analytical tool in the coatings industry. A conventional infrared spectrometer consists of a source of infrared radiation, a dispersing element to selectively monitor any frequency of radiation, and a detector. The output is termed an infrared spectrum and serves as a "fingerprint" of the resinous vehicle. Typically, an infrared spectrum of the cured coating is obtained. With multicomponent coatings, the components typically are mixed in the proper portions and cured prior to analysis. Scrapings can be taken of the cured sample, and a spectrum can be run using the potassium bromide pellet technique. This involves grinding the scrapings in a mortar and pestle with potassium bromide and fusing the mixture into pellets under high pressure. Spectra of individual components also can be obtained, but a different technique may be required to account for the liquid nature of these samples. Usually, this is a cast film technique in which a small amount of each liquid sample is cast or drawn down as a thin film on a potassium bromide plate and dried to remove solvent. To the trained analyst, an infrared spectrum provides useful information about the composition of the sample. Alkyds, for example, give dramatically different spectra than urethanes or epoxies. Infrared spectroscopy generally cannot detect minor (<5 percent) differences in formulation. Most additives (flow and wetting agents and others) used in coatings are below this level and do not complicate the spectrum to the point of making a generic identification difficult. A possible exception is the use of certain plasticizers, which sometimes are present in sufficient amounts to complicate the spectrum. An analyst familiar with paint formulation can recognize this complication for what it is, and no difficulties arise. But in some instances additional analytical techniques, such as size exclusion or gel permeation chromatography, can be used to separate and isolate the additives and allow unambiguous identification of the vehicle.

(3) Volume solids. Testing for solids by volume, or volume solids, is performed by Method ASTM D2697. Whereas the weight solids test determines the percentage by weight of nonvolatile matter in a coating, the volume solids test determines the percentage by volume of nonvolatile materials. This test is somewhat more tedious than the weight solids test and involves the coating and weighing of metal coupons both in air and when suspended in water. Though somewhat more difficult to obtain, the volume solids test generally is more representative of how a paint will perform in terms of coverage. Coatings containing a volume solids content lower than specified will result in additional material cost because of an increase in the amount of coating material required to cover a given area.

(4) Nonvolatile content (weight solids). This test usually is conducted according to ASTM D2369 and is a determination of the percentage by weight of solids in the coating. The technique is simple and straightforward; it involves weighing small samples of wet paint both before and after heating in an oven maintained at 110 °C (230 °F). Weight solids can affect coating cost and performance, and they directly affect the application properties. Sagging, orange peel, and insufficient dry coating thickness may result if the weight solids is insufficient. Also, the weight solids is directly related to the VOC of the coating. The VOC level is determined by multiplying the weight volatile by the density (weight per gallon) of the coating.

(5) Density/weight per gallon. Commonly referred to as weight-gallon, this test usually is performed according to ASTM D1475. The weight of wet paint needed to just fill a special weight gallon cup is determined; and the density of the paint in pounds per gallon can be determined from this amount of paint. The density of a coating material also is related to the VOC of the coating.

(6) Viscosity. There are many ways to measure the

viscosity of a coating. Eflux cups, such as the Ford and Zahn, measure how long it takes for a certain amount of coating to pass through an orifice of a specified dimension. These cups are common in both the field and the laboratory. The Krebs-Stormer and Brookfield Viscometers consist of a motor turning a paddle or spindle, and they measure the resistance imparted by the paint. These instruments are common in the laboratory. Viscosity and volume solids are interrelated and impact the performance and ease of application, thinning, and flow-out of the coating material. For example, if a coating material is too viscous (high viscosity), orange peel, gun spattering, and a general lack of ability for the coating to knit together when applied will occur. Solvent entrapment also may occur. Conversely, if a coating is too thin (low viscosity), runs, sags, drips, and other application-related defects may occur.

(7) Drying time. As with viscosity measurements, there are a number of ways to determine the drying time of a coating. ASTM D1640 outlines eight methods for determining drying time: set-to-touch, dust free, tack free, dry-to-touch, dry hard, dry through (handle), dry-to-recoat, and print free. Of the eight methods, dry-to-touch and dry hard are the two most commonly referenced in specifications. This information is useful in determining whether the coating is formulated to dry or cure as stated by the manufacturer. Coatings that exceed the dry time either do not contain sufficient driers or do not chemically react properly after being catalyzed.

c. Coating system performance tests. Coating system performance tests must be carefully selected and must be based on the service environment or intended use. For example, a corrosion resistance test performed on a coating system intended for use in an office building would be both wasteful and unenlightening. This is an obvious example of mis-selecting a performance test. The selection of which laboratory test or test series will accurately depict field conditions is not always clear-cut. For example, a USACE dam frequently is subjected to the synergistic effects of immersion, abrasion, impact, and other conditions. The effect of a dislodged tree impacting and sliding along a dam gate is difficult to duplicate in the laboratory. Although it is important to select performance tests that are representative of field conditions, laboratory testing rarely, if ever, duplicates actual field conditions, and relative comparisons must be made against the performance of known control systems to obtain meaningful data. A listing of common performance tests and a brief description of each follows.

(1) Adhesion. Perhaps the most fundamental requirement of a coating is that it adhere to the substrate and to previous coats. As important and fundamental as this performance property is, the method used to assess it frequently relies on the common penknife. Although cutting, gouging, and chipping may give valuable adhesion information, the knife test is somewhat subjective. However, there are two other convenient, widely used methods that provide somewhat more quantitative data: tape adhesion testing and tensile adhesion testing. Although each test evaluates the adhesion characteristics of coatings, data have shown that results from tape adhesion testing may vary dramatically from results obtained by tensile adhesion testing, perhaps because the tape test evaluates shear adhesion strength rather than tensile adhesion.

(a) Tape adhesion. The tape adhesion test method is described in ASTM D3359, Method A (X-cut tape test) or Method B (crosscut tape test). The procedure for creating the crosscut involves making a series of closely spaced parallel knife cuts through the coating and making a second series perpendicular to the first; a special pressure-sensitive adhesive tape is applied to the grid pattern. The tape is rapidly removed, and the crosscut or grid area is inspected for coating removal. A standard included with the method rates the adhesion from a maximum rating of 5 to a minimum rating of 0. Tape adhesion is used to evaluate a coating’s ability to adhere to underlying coats and to the substrate. Tape adhesion frequently is used to qualify the existing coating for topcoatability (the ability of underlying coats to withstand the stresses of topcoating). However, adhesion testing is not an indicator of product performance. From a corrosion protection viewpoint, a coating with an adhesion value of 2 or 3 probably will protect as well as a coating with an adhesion value of 4 or 5.

(b) Tensile adhesion. Tensile adhesion can be measured with instruments described in ASTM D4541. Briefly, pull-stubs are bonded to the coating surface with adhesive and allowed to cure thoroughly, sometimes overnight. The instrument then measures the force required (in pounds per square inch) to disbond the coating by placing increasing tensile force on the pull-stub. Tensile adhesion also will reveal the weakest link in the coating system whether between two coats, within a coat, or between the substrate and first coat. In some situations, the coating adhesion exceeds the strength of the adhesive used to adhere the pull-stub. As with tape adhesion, tensile adhesion is not a true indicator of performance or corrosion protection. A coating system with a value of 350 psi probably will protect as long as a system with a value of 700 psi. In fact, a range of results spreading 100 to 200 psi may be found on the same substrate/coating system, and research has shown that results among tensile adhesion test instruments can vary even more. Therefore, tensile adhesion testing should be performed using one type of tester, several test stubs should be pulled, and a range of test results should be provided.

(c) Interpreting adhesion results. ASTM standards are useful in describing test equipment and procedures. However, ASTM rarely provides information about the meaning of the test results. Most individuals would consider a tape adhesion rating of 5 to be good and 0 to be bad; however, there is little agreement on the intermediate results (ratings of 4, 3, 2, or 1). Furthermore, there usually is less agreement on the results for tensile adhesion testing because of the lack of reproducibility and differences in values obtained from different adhesion testing instruments. But adhesion testing has a relative value for acquiring comparative adhesion test data despite the limitations.

(2) Hardness. Several methods for evaluating hardness exist and are thoroughly described in the Gardner-Sward Paint Testing Manual. Pencil hardness is probably the most widely referenced method in most manufacturer's product data sheets. The true meaning of the hardness result is not always evident. The tests can be used to determine which coatings are harder or softer than other coatings, but the required degree of hardness or softness is not always obvious. Indeed, for some applications such as flexible elastomeric coatings, hardness may actually be considered detrimental.

(a) Pencil hardness is described in ASTM D3363 and the National Coil Coatings Association Bulletin II-12. The hardness of a lead pencil required to rupture a coating is recorded and termed the pencil hardness. Because the technician uses hand pressure on the pencil, the result of the test is somewhat subjective and can vary from technician to technician.

(b) For thicker coatings and plastics, Barcol Hardness (ASTM D2583) and Shore Durometer Hardness (ASTM D2240) can be used. The durometer is a hand-held device with a sharp needle on one face that is firmly pressed against the coating. The degree of penetration of the needle is reflected by the pointer on the instrument scale. The Barcol impresser operates on a similar principle. The tests can be conducted rapidly and easily, and both tests provide numerical results.

(3) Flexibility. Test methods for measuring flexibility include ASTM D522 and Federal Test Method 6221. These methods involve the bending of a coated substrate over a mandrel and determining the amount of bending that can take place before the coating cracks. With ASTM D522, a conical mandrel can be used as well as cylindrical mandrels, and a calculation of the coating material's percent elongation can be determined. The inherent flexibility of a coating is related to its ability to protect edges, weld seams, and steel imperfections; and it is related to the impact resistance of a coating. For example, after a coating with limited flexibility is cured, it may crack and disbond over any uneven surfaces or on impact. To a lesser degree, a coating's flexibility will aid in withstanding the stresses of steel expansion and contraction during freeze/thaw or other temperature fluctuations.

(4) Impact resistance. In addition to flexing, certain applications require that a coating be resistant to impact damage. Impact resistance and flexibility are related coating properties. “Deformation (impact)” is commonly used and involves dropping a known weight from various heights until the coating fractures or disbonds. The result is reported in inch per pound, and thus has the advantage of a numerical rating, which can easily be compared from one coating to another. An example of this application is the coating on USACE dam gates, which frequently are subjected to impact damage from floating debris.

(5) Abrasion resistance. If a coating is expected to be exposed to continued sources of abrasion damage, a measure of its abrasion resistance is desirable. A convenient and rapid method of measuring abrasion resistance is the Taber Abrasion method, described in ASTM D4060. Although ASTM reports that this method exhibits poor interlaboratory reproducibility, it is one of the most widely known and specified methods. A coated test plate is mounted on a turntable that rotates under a pair of weighted abrading wheels, and the weight of coating loss per thousand revolutions is measured. Although it may be difficult to select an actual abrasion resistance rating, the test is useful for comparing the abrasion resistance of one coating with that of another. Unfortunately, poor correlation has been found between this test and an environment in which floating debris gives more impact and cutting damage than abrasion damage.

(6) Accelerated weathering. The performance tests discussed here all have one thing in common: they are typically used to measure the initial properties of a coating. However, the real-world environment is considerably different from the laboratory environment. Although a perfect simulation of the real world may never be achieved, several tests that attempt to provide information about coating performance over the long term have been developed. This is known as accelerated weathering testing. A coating's ability to withstand the outdoor environment is called its weather resistance, and a variety of devices have been developed to measure it. The elements most commonly associated with outdoor weathering are light, heat, moisture, and oxygen. Therefore, although different in their actual method of operation, the various accelerated weathering instruments all rely on some combination of these elements in varying levels of intensity to degrade coatings. Moisture may be introduced by spray,

condensation, or immersion; the damaging UV component of sunlight may be introduced by either arcs or fluorescent tubes. Regardless of the apparatus used, this test, as is true of so many other accelerated tests, primarily is useful in generating comparative results; and efforts to relate the number of hours of artificial weathering to a period of natural weathering are difficult at best, and probably impossible. Common tests for weathering are: ASTM G23, ASTM G26, and ASTM G53. Although the duration of testing cannot be directly correlated to natural weathering, it is common to see test results based on an exposure period of 1,000 hours. The properties measured usually consist of loss of gloss, chalking, crazing, blistering, or other visual defects. Physical properties (adhesion, hardness, flexibility, etc.) also can be measured both before and after accelerated weathering.

(7) Corrosion resistance. Another common requirement of protective coatings and linings is that they have good corrosion resistance. The ability of a coating to provide barrier protection between the steel substrate and the environment is an inherent corrosion protection factor. Coatings systems subjected to immersion, splash, salt water, chemical solutions, and other corrosion-causing elements should be evaluated for their relative resistance. The coating systems being evaluated may be intentionally damaged (scribed) to simulate abrasion or impact damage and the coating's ability to resist undercutting corrosion examined. As simple as this requirement sounds, the ability to accurately measure corrosion resistance in the laboratory is a subject of controversy.

(a) Salt fog. The most commonly performed corrosion resistance test is the salt spray or salt fog test described in ASTM B117. Coated panels are placed in a closed cabinet and exposed to a warm mist of atomized, neutral 5 percent sodium chloride solution. The duration of the test varies considerably, depending on the intended use of the coating. Aerosol paints designed for consumer use (e.g., lawn furniture) may last only a few days in a salt fog cabinet before severe blistering and corrosion occur. Conversely, inorganic zinc-rich primers designed for use on structural steel can last thousands of hours before rusting is evident. Salt spray test data should be regarded as comparative test data only; it usually is impossible to extrapolate from salt spray results to obtain an expected service life under field conditions. There is some controversy about whether salt spray testing even remotely resembles the conditions seen in actual service, and some studies show that certain coatings that perform poorly in salt spray perform well in the field, and vice versa.

(b) Prohesion. The Mebon Prohesion Cabinet, widely used in Europe, is an accelerated corrosion device that some studies indicate provides more reliable results than salt spray. The device is not recognized by ASTM at this time (1995). The mist atomized into the cabinet is not the 5 percent sodium chloride solution used in ASTM B117, but a dilute solution of ammonium sulfate and sodium chloride termed “Harrison Solution.” The solution is atomized at room temperature rather than the elevated temperature of the salt spray cabinet; it is purged with dry air to produce a cyclic condition of wetting and drying. The results of this testing should be used as comparative data only.

(c) Humidity. Coatings can be exposed to moisture without being exposed to salt. Methods are described by ASTM D2247 and D4585. These methods expose coated panels to either warm, 100 percent relative humidity or warm condensation. The most common failure mechanism is blistering. A common test duration is 1000 hours, which provides comparative test data but does not allow an extrapolation to length of field service.

(8) Chemical resistance. A common use of coating materials is protection from chemicals, either in a generalized industrial environment or, with linings, in specific reaction or storage vessels. In the former instance, the selection of an appropriate and meaningful test can be difficult because attempts to simulate an industrial environment may be infinitely variable. However, testing that closely duplicates the actual field service conditions frequently can be performed.

(a) If, for instance, that the intended use of a coating is to line a carbon steel vessel to be used for the storage of dilute sulfuric acid, coated test coupons can be immersed in the same acid at the same concentration. The test coupons can be tested at either ambient temperature or at an elevated temperature (if representative of field conditions) to achieve accelerated results. A convenient way of evaluating coatings is described by ASTM D1308. Coatings may be tested for simple spot resistance by applying the chemical or substance to a coated panel and covering it with a watch glass, or by immersing coated panels in beakers containing test solutions. Elevated temperatures also may be used.

(b) A more aggressive and versatile method of evaluating chemical resistance involves the use of a one-sided testing apparatus described by both NACE TM-01-74 and ASTM C868. The test cells consist of a glass cylinder with connections for condensers, heaters, and thermometers. The coated test specimens are mounted in a way to constitute the ends of the cylinder, and are sealed to the cylinders through the use of gasketing and bolt/nut fixtures. The cell is filled approximately one half to two thirds full with the desired test solution, and a heater is used to achieve the desired temperature. A water-cooled condenser prevents evaporation of the solution. A wide variety of chemicals can be tested at various temperatures, plus the design of the apparatus permits simultaneous testing of the coating in both the immersion phase (lower one half to two thirds) and the vapor phase (upper one half to one third). The cells can be disassembled, and the coating can be evaluated periodically for blistering, corrosion, cracking, discoloration, or other visual defects in both the liquid and the vapor phases.

(9) Field testing. An important criterion for including a particular coating in a specification is the availability of historical field data in similar or identical facilities or environments. In addition to historical data, if time permits, test panels prepared with the candidate coating systems can be prepared and installed at the site. This may involve placing coated panels on test racks exposed to the general atmospheric environment or actually mounting panels in an immersion or splash zone. If such testing is undertaken, enough coated test panels should be used so they can be removed at specific time intervals to ascertain the rate of coating system degradation. An even better method than placement of coated test panels is to apply test patches of candidate coating materials to the actual structure. Careful (and thorough) documentation should be maintained during the application of test patches (surface preparation, application conditions, etc.) because this information will prove invaluable during full-scale application. Field testing utilizing coated test panels or field test patches is the optimum “litmus” for determining the suitability of a coating system for a given service environment. Much of the manufacturer's published data are based on accelerated weathering testing, which does not accurately predict the performance of the coating system.

d. Interpretation and accuracy of test results. The most common problem that arises in paint testing and the interpretation of results concerns deficiencies small enough to raise a question about whether the material should be rejected or accepted. This problem is bound to arise in formulation-type specifications, regardless of whether the specified percentages of ingredient materials are on an absolute, zero-range basis or a minimum-maximum range is provided. Some persons believe that, if the specification provides a range of percentages for the various ingredients in a paint, the manufacturer is somehow obligated to more than meet the barest (least costly) requirements. Logically, however, this viewpoint is not supported; a paint that contains the required minimum percentages of the more expensive ingredients and does not go above the permissible maximum for the less expensive ingredients meets the specification just as completely as a paint in which the manufacturer has been more liberal.

(1) Variance thresholds. The first question in deciding whether a minor deviation from the specification warrants rejection of a batch of paint is the accuracy of the test result. Even when conducted in the most competent and experienced laboratories, a prescribed and analytical test method is capable of only a limited degree of precision. Another unavoidable source of possible error may be the characteristics of an individual laboratory. A typical example of a peculiarity may be that the laboratory consistently obtains low results in analyzing an alkyd paint vehicle for phthalic anhydride content. A deviation revealed by testing that is smaller than the bias error of a laboratory obviously should not be used as the basis for rejecting a batch of paint. In addition, rejecting a paint because of an apparent deviation—when the result is within the inherent limits of the test method—raises a serious question. Some specifications attempt to bypass the question of rejection because of small deviations (which are within the limits of experimental error) by stating that, on analysis, the paint shall show the specified amount of an ingredients. This raises the interesting question for the manufacturer about how to adjust the indicated ingredient proportions so they test within the specification limits—assuming the manufacturer recognizes the subtleties of the wording in the specification.

(2) Clarification of variances. If a paint is still deficient after a justifiable allowance is made for the degree of precision inherent in a prescribed test method, a decision must be made about whether the deficiency is serious enough to warrant rejection. This decision may vary in specific situations, and no attempt will be made here to suggest guidelines. Among the factors that may influence a decision are: the magnitude of the deficiency, the estimated effect of the deficiency, if there is more than one deficiency, if deficiencies are balanced by positive features in which the manufacturer has more than met the specification, fairness to other potential suppliers, etc. Nothing significant to the paint's performance should be sacrificed; however, stiff, unyielding adherence to the specification ultimately may not serve the best interests of the Government. Four alternatives related to the interpretation of test results include:

- The test result complies with the specification's stated test data, and the paint may be recommended for use.

- The test result deviates from the specification's stated test data but is within laboratory experimental error; and the paint may be recommended for use.

- The test result deviates from the specification's stated test data and is outside of experimental error; however, the deviation is believed to be unrelated to the performance characteristics of the coating material. Therefore, the material may be recommended for use.

- The test result deviates from the specification's stated test data and is outside of experimental error; and the deviation is believed to affect the performance life of a coating. Therefore, the coating may not be recommended for use.

(3) Testing laboratories are not permitted to approve or disapprove a paint; they can only recommend acceptance or rejection to the contracting officer. In some instances, the laboratory will check with the field office about the specific use of a paint before making a recommendation on a paint that fails specific tests.