# Protective Coatings Research: A Look Ahead

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Coatings research has provided a technical basis for changes in coating materials brought about by

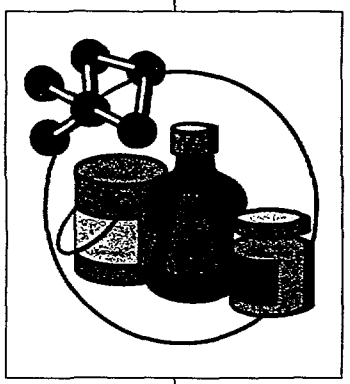
- the development and availability of new raw materials,
- users' expectations for more durable and easier to apply coatings,
- issuance of new government regulations involving volatile organic compounds (VOC) and toxic material content limits, and
- marketing concerns.

Further, research results have provided useful information for making improved decisions in related areas, including lead-based paint removal, overcoating systems for lead-containing paint films, worker and environmental protection, and disposal of lead-containing paint debris.

As summarized in two recent articles[1,2], however, several key performance issues related to mechanisms of coating failure or protection remain unresolved. For users of protective coatings, the practical questions that encompass the fundamental issues are "How long will a particular coating system last in a particular environment and how can the prediction be assured." Asked another way, "What kinds of data, test methods, measurements, and other procedures are needed to predict service life, and how can this information be obtained?"

Another rapidly growing area of importance to the coatings industry relates to advances in computers and electronic networking, which provide a powerful new framework for managing and distributing knowledge.[3]

This article discusses some specific research issues associated with these general topics and is focused on corrosion control coatings for steel. To help understand these new issues, let's first review past methods for determining durability.



**A Brief History of the Traditional Approach to Estimating Durability**

Before the advent of VOC and hazardous materials regulations, protective coating formulations tended to remain relatively constant over many years. Thus, well-established performance histories were often available to use in empirically estimating the durability of a coating. Evaluations of new coatings were often done by comparing the field performance of a traditional material with performance of the new ones. Performance assessments were mostly qualitative; moreover, the quality and quantity of data generated were limited and usually not permanently recorded.

However, due to recent rapid changes in coating chemistries and technologies and to the improved performance of coatings, durability estimates based on service histories are no longer very practicable. This is because of the unacceptably long time it takes to accumulate adequate field performance data. In addition, laboratory testing, which could provide information in a much shorter period of time than field exposures, is often viewed as being unreliable by coating users. Thus, because of the pressing need for quantitative estimates of durability or service life of new coating systems, another approach for developing methods to predict service life has been investigated.[4]

**Service Life Prediction Methodology: A New Approach**

Martin, et al. have convincingly argued that the service life prediction (SLP) problem must be attacked systematically.[4] That is, instead of trying to solve the SLP problem through the application of one or more "universal" exposure tests, the following requirements must be met.

- Experiments must be designed to answer specific questions.
- Data must be quantitatively collected and recorded, and be comparable from experiment to experiment.
- Laboratory exposures must include the range of expected service conditions.
- All important service variables must be included in experimental designs.

Martin and his co-authors propose a methodology that satisfies these requirements and has the ability to integrate knowledge gained from empirical testing, fundamental studies, and outdoor exposures.

Through this approach, the coatings knowledge base will continuously grow and will provide data necessary for modeling degradation responses, identifying strengths or weaknesses of systems, and refining formulations for specific uses. With systematically maintained databases, the amount of repetitive testing should be minimized, and communication among all people involved in producing and using coatings (raw material suppliers, coating manufacturers, coating system designers, applicators, and facility owners) should be improved.

Based on current knowledge, general SLP questions can be grouped into several classes. These include environmental conditions, nature of the surface being coated, application parameters, and material properties. In addition, the systematic approach described above demands improved data quality characteristics and data management procedures. Specific important research topics in each of these classes are suggested below. It is expected that answers will be obtained from both fundamental and carefully designed laboratory studies.

**Characterization of the Environment**

The exposure environment is directly linked to coating degradation. Hence, characterization of key environmental factors is

essential in predicting performance. However, because we may not know specifically what environmental conditions or combinations of conditions cause the greatest coating deterioration, research is needed to do the following:

- identify the key environmental conditions or combinations of conditions primarily responsible for coating deterioration, e.g., times or incidences of extreme temperature and wetness;
- investigate the relationships between these conditions and coating performance;
- develop additional procedures, as needed, to quantitatively monitor the key environmental conditions; and
- develop database architectures and procedures that will provide a framework for electronic environmental databases.

**Nature of the Surface Being Coated**

The nature of the surfaces being coated ranges from previously painted surfaces to new materials. Many studies have shown that the characteristics of an uncoated surface greatly affect the surface life of a new coating. Further, recent studies involving overcoating of lead-containing paints have illustrated the importance of interactions between the properties of the existing film and the new coating material.[5] Some specific research issues include

- identification of properties of substrates most important in determining coating service life (e.g., level of inorganic contaminant, surface roughness);
- improved procedures for characterizing these key substrate properties;
- for bare surfaces, identification of relationships among substrate cleanliness, coating properties, environmental exposure conditions, and service life;
- for coated surfaces, identification of relationships among existing coating properties (adhesion, mechanical, thermal aging, and others as needed) and key properties of an overcoating system, environmental exposure conditions, and service life;
- development of additional standardized procedures for preparing test panels to simulate previously coated or contaminated surfaces; and
- development of additional field procedures for quantitative assessment of important surface properties, e.g., millscale.

**Application Parameters**

The problem of predicting service life is complicated by the fact that a coatings manufacturer supplies one material (i.e., coating in a can) while a different material (i.e., a coating film) protects a substrate. Thus, film properties of the same coating are likely to be different because of differences in application procedures, environmental conditions during application and cure, and film thicknesses. Such differences affect service life. There is also empirical evidence that some newer coatings are more sensitive to changes in application and cure parameters than the traditional oil-based coatings. Thus, the needs for research associated with application and film formation have increased. These needs include

- improved or more efficient coating application techniques,
- improved quantitative characterization of film application defects,
- improved field procedures to determine extent of cure, and
- improved procedures for quantitative measurement of wet film thickness.

**Material Properties**

Fundamental studies are being conducted to investigate relationships between performance and many properties of coating films, including mechanical; ultraviolet light degradation; diffusion of water, ions, and oxygen; and wet and dry adhesion.[4] This type of information helps researchers reduce the number of variables in experiments to develop service life prediction test procedures.

Other areas in which additional material property research is needed include

- identification of key properties of unaged films (e.g., film defects) and development of quantitative procedures to assess these properties in the field;
- additional methods for quantitative characterization of macroscopic deterioration, e.g., corrosion, blistering, and loss of adhesion;
- identification of relationships between changes in microscopic or chemical properties, and formation and growth of macroscopic defects (because microscopic changes often occur much sooner than macroscopic defects).

**Data Management and Integrated Knowledge**

The quantity of data being collected and the overall coatings knowledge base are growing rapidly. It is important to consistently increase the base of knowledge that is easily accessible and useable by coatings researchers (e.g., to provide the ability to discover relationships and interactions among experimental variables and to confirm hypotheses). It is also important to facilitate linkages among data sets. Work therefore is needed to support database management and integration of information. Some important topics in this area are the following:

- identification of appropriate material and performance properties to include in databases;
- development of suitable database architectures and formats so that data from any research or testing program can be easily related to results from another;
- development or revision of standardization procedures to facilitate use of databases;
- development of tools to support integration of all types of electronic data, information, and knowledge, including that stored at different sites; and
- development of knowledge-based systems that use databases as a foundation for making informed coating decisions.

**Summary**

Coatings research has helped manufacturers provide new and

improved products to meet the changing needs of users. However, there are still some unanswered questions on the selection and use of coatings, ranging from "What level of coating adhesion is needed?" to "How clean does a surface need to be?" The answer to these and similar questions is, "It depends." Because of the continuing introduction of many new materials, there is a great need for laboratory-based procedures for predicting the service life of a coating system as used in a particular situation. A systematic methodology is needed that takes into account all the important variables affecting coating performance and that effectively uses existing knowledge. A key benefit of such a methodology is its dynamic character. That is, existing data and knowledge can be used effectively, and new information can be added effectively to the overall coatings knowledge base.

The outlook is bright for making continuing significant contributions to the coatings knowledge base and for improving methods to predict coating service life for a particular end use. This is in part due to the increasing understanding of coating performance and to significant advances in microscopic, mechanical, chemical, and other characterization equipment, as well as in techniques for modeling performance. Advances in computers and electronic information exchange are also making possible integration of data and knowledge from diverse sites. For researchers, as well as coating suppliers and users, it is an exciting time.

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