Paint and Coating Testing Manual

15th Edition of the Gardner-Sward Handbook

Joseph V. Koleske
Editor

INTERNATIONAL
Standards Worldwide

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Fifteenth Edition of the Gardner-Sward Handbook

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Preface

For historical purposes, it is important to point out that at a January 1967 meeting of ASTM Committee D01 held in Washington, D.C., the American Society for Testing and Materials (ASTM International) accepted ownership of the *Gardner-Sward Handbook* from the Gardner Laboratory. It was through this laboratory that Dr. Henry A. Gardner published the previous twelve editions of the manual. Acceptance of this ownership gave ASTM an assumed responsibility for revising, editing, and publishing future editions of this well-known, respected manual. The undertaking was assigned to "Committee D01 on Paint and Related Coatings, Materials, and Applications." This committee established a permanent subcommittee, "D01.19 on Gardner-Sward Handbook," whose stated scope is delineated below. The 13th edition was published in 1972 as the *Paint Testing Manual* (STP 500) with Mr. G. G. Sward as editor and contributor. It was updated, expanded, and published in 1995 as the 14th edition, *Paint and Coating Testing Manual* (MNL 17) with Dr. Joseph V. Koleske as editor and contributor. The manual has served the industry well in the past by providing useful information that cannot be readily found elsewhere.

It has been about fifteen years since the 14th edition was published. Interest in the manual has been strong through the years. This new edition of the *Paint and Coating Testing Manual*, the *Fifteenth Edition of the Gardner-Sward Handbook* (MNL 17), has been updated and expanded.

The scope of the new edition is in keeping with the stated scope of Subcommittee D01.19:

> To provide technical, editorial, and general guidance for the preparation of the Fourteenth and subsequent editions of the *Gardner-Sward Handbook*. The handbook is intended for review of both new and experienced paint technologists and the past, present, and foreseeable trends in all kinds of testing within the scope of Committee D01. It supplements, but does not replace, the pertinent parts of the Society's Book of Standards. It describes, briefly and critically all Test Methods believed to have significance in the world of paint technology, whether or not these tests have been adopted officially by the Society.

Once again, in this new edition, ASTM standard test methods, procedures, and other documents are described in minimal detail, with the various volumes of the *ASTM Book of Standards* remaining the primary source of such information. An effort was made to include references in the absence of ASTM documents concerning industrial, national, international, and other society test methods. The new edition contains either new chapters, or the previous topics/chapters in rewritten/revised form. In a few cases, the previous edition was merely updated, attesting to either the quality of the earlier writing, the lack of development in the area, or the apparent waning of interest in the topic. A variety of modern topics have been included. New chapters have been added as, for example, "Measurement of Gonioapparent Colors," "Surfactants," "Powder Coating," and "Coalescing Aids." As in the previous edition, individual authors, experts in their particular fields, were given a great deal of freedom in expressing information about their topics, but all chapters were subjected to peer review by two colleagues. Thus, style and content presentation may widely vary, but efforts were made to have understandable syntax and thus readers should find the information useful and "easy" to read and put to use.

Manuals such at this one are prepared though a great deal of effort by the various authors and through the able assistance and behind-the-scenes concerted efforts of people such as Ms. Kathy Dernoga and Ms. Monica Siperko of ASTM International and Ms. Christine Urso, Ms. Barbara Carbonaro, Ms. Theresa Fucito, Ms. Patricia Mayhew, and Ms. Benita Hammer, of the American Institute of Physics, all of whom ensured that the manual was uniform in style and grammar and that manuscripts were submitted and processed in a timely fashion. The real unsung and unnamed contributors are the reviewers who gave encouragement to the various authors through constructive criticism, editorial information, and recommendations without deleteriously attempting to alter manuscripts from the author's intent. To all of these people, a heart-felt "thank you." Your talents have been utilized, you sacrificed much personal time, and you were patient with the numerous delays encountered on the road to making the manual a success.

Joseph V. Koleske
Editor

Introduction

PAST TO PRESENT

The previous edition of this manual, the 14th, described in detail the changes that took place in the coating industry from the early 1970s to the early- to mid-1990s. Published in 1995, the 14th edition classified powder coating, radiation-cured coatings, and higher-solids coatings as new, with a potentially reasonable growth curve. It noted that at the time, all liquid coatings were at higher solids content (lower volatile organic solvent content) than in the 1960s when Rule 66 came into being. Powder coating and radiation curing were sufficiently new enough that chapters related to testing them were not included in the manual. High-solids development still struggled with the difficulties of decreasing molecular weight for low viscosity purposes and achieving the low molecular weight with functionality on all molecules that quality coatings require. However, the solids level has increased in solvent-based coatings and achievements have been realized in decreasing volatile organic content (VOC).

Since that time, powder coating has exploded. Today the technology is well established, has a significant share of the coatings market, is internationally accepted, and has a strong technical society that aids in future growth. To illustrate the widespread acceptance of powder coatings, one merely needs to look at advertisements. Outdoor metal furniture advertisements, for example, proudly include words that imply quality and durability—that is to say, "powder-coated finishes."

Of course, such furniture certainly is not the only commercial outlet for powder coatings. Applications include lighting fixtures, tubing and aerosol cans, automobile and bicycle wheels, rebars, store fixtures, agriculture and construction materials, and on and on. Initially, colors and color changeovers were considered to be a major obstacle to powder coating development, but today a broad variety of colors is available, including many metallic and special effect finishes with abrasion resistance, brilliance, and overall high quality. Powder coating provides quality, economy in manufacturing space, increased production, energy usage reduction, and other facets important to product development and sales in today's marketplace.

As with powder coating, radiation curing of coatings with either ultraviolet or electron beam radiation is no longer a new process. This technology also has been experiencing strong growth since the last edition of this manual. It is the technology in which, through an *in situ* means, a low viscosity liquid system is converted into a polymeric film or coating directly on a substrate that can be varied in nature—i.e., metal, wood, plastic, composite structures, etc. In effect, the originally liquid system is instantaneously converted into the final high molecular weight, cross-linked coating. Radiation curing of liquid systems is not limited to coatings, and it is growing in the printing ink and adhesive areas. It is considered to be "green" technology, is well established in the marketplace, has garnered a significant portion of the total coatings market, has a strong technical society dedicated to it, and is internationally accepted.

Radiation-curing technology has many facets that will ensure future growth. Harbourne[1] has pointed out that over and above the usual advantages behind ultraviolet radiation curing technology—energy conservation, usage efficiency, and environmental conservation—its driving force is the fact that the UV process has enabled production and development of products that could not have been achieved with earlier existing technologies. Such products include flexible electronics for energy storage and circuit development, polymeric solar cells, printable electronics, medical devices, touch screens, optical films, and on and on. In the area of solar energy, highly efficient organic photovoltaic cells are being developed that are thinner and lighter in weight with significantly decreased production costs. Such cells are used in emergency power generation, lighting, and outdoor power generation. New smart materials with self-healing properties will provide overall cost savings through high value-added finishes on a variety of substrates. Solvent-based, high-solids coating systems continue to be developed. Such coatings have markedly decreased volatile organic content and provide high quality coatings and reduced environmental damage.

FUTURE

As described above, powder and radiation-cured coatings have been experiencing excellent growth over the past decade or so, with each technology growing on its own merits. More recently, a combination of the two technologies—UV–Curable Powder Coatings—has very good growth potential. New opportunities for the combination are due to the same benefits mentioned above—economic, environmental, process, energy savings, and increased productivity.[2] The combination is meeting the less expensive, more rapid, and high quality challenges required by the demanding customers of today. The coatings are being used on medium-density fiberboard, plastics and other heat sensitive substrates, composites, and preassembled parts including completed items. Preassembled items often contain a number of different materials such as electronic components, gaskets, rubber seals, and the like--all of which are heat sensitive in nature. The ability to coat and cure such combinations with systems based on the combined technologies results in less thermal damage to the sensitive materials and thus greater efficiency and productivity along with cost savings.

Nanotechnology is a field of emerging technology that may hold great promise in the future for the coatings, inks, and adhesives industry and certainly for a broad variety of other industries. Nanotechnology has broad implications

[1] Harbourne, A. D. P., "The Evolution of UV Photopolymerization in Global Industrial Manufacturing Markets and the Promising Outlook for the Future of the Technology," *The 31st International Congress on Imaging Science*, Beijing, China, pp. 013–015 (2010).

[2] Schwarb, Ryan and Knoblauch, Michael, "New Opportunities for UV-Curable Powder Coatings, " *Coatings World*, Volume 16, Number 5, pp 43-48 (May 2011).

for new products and there are multi- and interdisciplinary efforts in progress. The technology deals with science on the nano, or one billionth-size, scale. Nanometer "particles" are 0.000000001 meter or 0.001 of a micrometer in size. Within the technology, an assembler or molecular manufacturing technique is used to position molecules through chemical reaction or interaction into new products or existing products with enhanced properties. Although the term "nanotechnology" was initially used to define efforts conducted on a molecular scale, currently the term has taken on a loose connotation for anything that is very small where small means something that is most usually smaller than a micrometer. Many examples of nanometer-designed products exist and a few of these are given below.

Recently a plant was built of produce carbon nanotubes[3]. Such tubes in combination with aluminum result in new lightweight, high strength composite materials that have promise in the energy, electrical, and computer industries. In another area, a multilayered, polymeric nanocomposite has been devised and it is thought to have the potential to make a self-healing paint.[4] In this technology, emulsion polymerization processes are used to develop a polymeric product that is covered with a silica-based layer of nanoparticles. Nanocomposite coatings for fabrics have also been described[5]. These coatings improve gas barrier properties as well as enhance mechanical characteristics.

Another area that is receiving attention is additives for coating formulation. An additive that improves properties of water-based metal coatings has been described[6]. Although the additive is not chemically described, it is said to increase crosslink density and thereby various mechanical properties of cured films. An additive to accelerate the radiation-curing process is a small particle-sized version of nepheline syenite that is prepared by a micronizing process[7]. The micronized, ultra-fine form of this combination mineral—soda feldspar, potash feldspar, and nepheline--is said to enhance optical and physical performance in clear industrial and wood coatings. Properties such as gloss, hardness, and scratch resistance are altered in a desirable manner. Cure rate via double bond conversion was enhanced in the presence of these very small mineral particles.

TESTING

As listed in Table 1, ASTM International has developed several documents that are useful in the area of nanotechnology. Although the documents are not necessarily directly related to coatings and paints, they provide useful background for investigators in this field and, as is apparent, useful guides for laboratory efforts in the areas of terminology, particle handling, effect of nanoparticles on red blood cells, particle mobility through a graduated index, and other areas. In the future, it is expected that this area will further develop within ASTM International.

Joseph V. Koleske
Editor

TABLE 1—ASTM Standard Documents Related to Nanotechnology

ASTM Designation	Document Title
E2456-06	Terminology Relating to Nanotechnology
E2490-09	Standard Guide for Measurement of Particle Size Distribution of Nanomaterials in Suspension by Photon Correlation Spectroscopy (PCS)
E2524-08	Test Method for Analysis of Hemolytic Properties of Nanoparticles
E2525-08	Test Method for Evaluation of the Effect of Nanoparticulate Materials on the Formation of Mouse Granulocyte-Macrophage Colonies
E2526-08	Test Method for Evaluation of Cytotoxicity of Nanoparticulate Materials in Porcine Kidney Cells and Human Hepatocarcinoma Cells
E2530-06	Practice for Calibrating the Z-Magnification of an Atomic Force Microscope at Subnanometer Displacement Levels Using Si(III) Monatomic Steps
E2535-07	Guide for Handling Unbound Engineered Nanoscale Particles in Occupational Settings
E2578-07	Practice for Calculation of Mean Sizes/ Diameter and Standard Deviations of Particle Size Distributions
E2676-09	Practice for Tangible Property Mobility Index (MI)

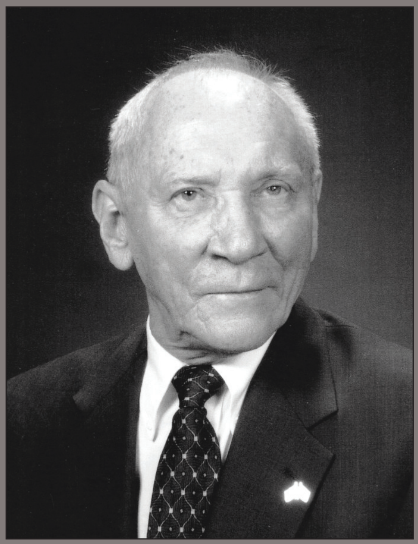
[3] Anon, "Bayer MaterialScience Builds Carbon Nanotubes Plant," *Paint and Coatings Industry*, Volume 25, Number 11, p. 12 (Nov. 2009).

[4] Colver, Patrick J., Colard, Catheline A. L., and Bon, Stefan A. F., "Multilayered Nanocomposite Polymer Colloids Using Emulsion Polymerization Stabilized Solid Particles," *J. American Chemical Society*, Volume 150, No. 50, pp. 16850–16851 (2008).

[5] Eberts, Kenneth, Ou, Runquing, and Shah, Kunal, "Nanocomposite Coatings for High-Performance Fabrics," *Paint and Coatings Industry*, Volume 26, No. 4, pp. 32–36 (April 2010).

[6] Herold, Marc, Burgard, Detlef, Steingrover, Klaus, and Pilotek, Steffen, "A Nanoparticle-based Additive for the Improvement of Water-Based Metal Coatings," *Paint and Coatings Industry*, Volume 16, Number 8, pp. 24–27 (Aug. 2010).

[7] Van Remortel, Scott P. and Ratcliff, Robert E., "Ultrafine Nepheline Syenite as a Durable and Transparent Additive to Accelerate Radiation Cure," *Paint and Coating Industry*, Volume 27, Number 3, pp. 27–34 (Mar. 2011).



Joseph V. Koleske

Dr. Joseph V. Koleske is a retired Corporate Research Fellow from Union Carbide Corporation in South Charleston, West Virginia, where he served for 25 years. After retirement, he was a Senior Consultant for Consolidated Research, Inc., for about ten years in Charleston, West Virginia. In his career, he has worked in the areas of material science; solution properties of polymers, fibers, and polyurethanes; and high-solids, powder, and radiation curable coatings.

He has been a member of ASTM International, the Federation of Societies for Coatings Technology, and the University of Minnesota's CIE and has served on the Editorial Review Board of the Journal of Coatings Technology. He is the editor of the Paint and Coating Testing Manual, Fourteenth Edition of the Gardner-Sward Handbook. He has lectured about radiation-cured coatings during the annual summer coatings short course at North Dakota State University.

Dr. Koleske received his B.S. (ChE) degree from the University of Wisconsin-Madison and M.S. and Ph.D. degrees from the Institute of Paper Chemistry, Lawrence College, Appleton, Wisconsin.

He holds more than 100 patents in the above fields and is the author or coauthor of more than 100 journal articles, book chapters, and books. Authored or coauthored books include Radiation Curing of Coatings, ASTM International, Pennsylvania, 2002, Alkylene Oxides and Their Polymers, Marcel Dekker Inc., New York, 1990, Poly(ethylene oxide), Academic Press, New York, 1976, and Poly(vinyl chloride), Gordon & Breach, New York, 1969.

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