DAWN V. ROGALA

Industrial Literature as a Resource in Modern Materials Conservation: Zinc Oxide House Paint as a Case Study

ABSTRACT

This paper is an introduction to the benefits of incorporating period industrial literature into conservation research. Conservators of post-WWI art regularly work with objects containing industrial materials of unknown composition and behavior. Period publications offer unique insight into material properties and formulations that may be at odds with preservation goals. Industrial literature is an accessible and informative resource, and should not be overlooked by the modern materials conservator. This paper reviews the available mid-century literature related to zinc oxide-containing house paint, as a case study in the assessment of industrial literature and its value to conservation efforts.

The research and related bibliography are the result of a Conservation of Museum Collections postgraduate fellowship at the Smithsonian Institution, Washington, DC. A literature search initiated in the early stages of the fellowship revealed only a small number of relevant articles in the existing conservation literature. An expanded search identified a wealth of period industrial literature. Patterns within the literature became apparent, and an informed examination of the assembled articles revealed unique and useful information. This resource was instrumental to the final outcome of the project. This paper reflects the focus of its associated fellowship research: mid-century, American, oil-based zinc oxide house paint.

Note: This paper was also presented at the May 2011 international symposium "From Can to Canvas: Early uses of house paints by Picasso and his contemporaries in the first half of the 20th century," a joint effort of the Centre Interrégional de Conservation et Restauration du Patrimoine (Marseille), The Art Institute of Chicago, and the Musée Picasso (Antibes).

INTRODUCTION

Conservators of twentieth-century art regularly work with objects containing industrial materials, and the design of a conservation treatment plan can be complicated by period additives and formulations that work against the long-term stability of an artwork. Although the growing need for conservation of twentieth-century artwork has recently led to a number of important collaborative research ventures, conservators looking for reference material on particular paints may find a limited number of scholarly publications on their topic. Viewed with a critical eye, period industrial literature can be a valuable resource for the conservator.

The motivation for this project stemmed from a research effort focused on a group of Abstract Expressionist oil paintings in the collection of the Hirshhorn Museum and Sculpture Garden, Smithsonian Institution. Analysis of these works revealed a relationship between zinc oxide ground layers and certain types of upper layer paint failure. A literature search initiated during the early stages of the project produced few articles related to zinc oxide in the existing conservation literature, but documentary and anecdotal evidence of the Abstract Expressionists' use of house paints supported the idea of expanding the original literature search to include contemporaneous industrial publications. This expanded literature review identified a wealth of industrial publications from the same period as the research group paintings. The inclusion of selected earlier and later publications placed the mid-twentieth century articles within a larger context of technological advances and commercial influences, and patterns within the literature became apparent. Examination of the assembled articles revealed unique and useful information that was instrumental to the final outcome of the research project (Rogala et al. 2010; Maines et al. 2011).

Whether faced with an analytical similarity between paints formulated for industrial markets and commercially-prepared artists' paints, or acknowledging an artist's use of industrial materials as an integral part of their artwork, the conservator can only benefit from a well-informed review of the publications emanating from within the commercial industry. This paper presents an overview of the available literature related to zinc oxide-containing house paint from the first half of the twentieth century, as a case study in the examination and assessment of industrial literature in the service of modern materials conservation. The commentary on literature from this period has been organized into 25-year periods, followed by a discussion of parallel trends and industrial and conservation research, and a brief review of modern industrial research topics. The role played by period literature in the associated Smithsonian research project is noted throughout the paper. The extended bibliography includes an overview of zinc oxide in the conservation literature, as well as a chronological list of industrial zinc oxide paint literature of relevance to those interested in the properties of zinc oxide-based paints.

Methodological Note on the Classification of Literature

The term "industrial literature" is used in this paper as an inclusive category for material published by all non-conservation industries. The industrial resources discussed in this paper range from paint manufacturing texts and papers to technical manuals for the professional and the amateur, as well as peer-reviewed scientific literature. The information contained in these period publications is a valuable addition to the research available in traditional conservation texts.

ZINC OXIDE IN INDUSTRIAL LITERATURE BEFORE 1925

The industrial literature produced before 1925 reflects the commercial coatings industry's struggle to fashion an opaque and durable alternative to lead (carbonate hydroxide) white paint. Prior to the 1920s introduction of titanium dioxide white as a bulking agent, early lead white substitution efforts were focused on zinc oxide coatings. Much of the early literature, such as G. Petit's 1907 treatise *The Manufacture and Comparative Merits of White Lead and Zinc White Paints*, reflects a marketplace wary of the new material. In the chapter entitled "Zinc White Paint and Zinc White Coatings—Their Merits and Defects," Petit raised early doubts about zinc oxide's suitability as a durable paint. A public backlash by displaced lead white raw materials producers is to be expected, and is evident in the back matter advertisements for lead white materials and technical manuals. Yet even at this early stage in the pigment's introduction there are concerns about zinc oxide's stability, including Petit's own admonition that "Zinc white covers poorly. It dries poorly. It stands the weather badly" (Petit 1907, 84).

Within a few years a shift in industry attitude towards zinc oxide is apparent in the literature, which now portrays the switch to zinc white as inevitable. Practical manuals such as P. Fleury's 1912 *The Preparation and Uses of White Zinc Paints* address the commercial painter directly, suggesting that the pigment's reputation as a temperamental material is easily combated with training in the appropriate handling techniques. Yet concerns remain about zinc oxide's stability. Both Petit and Fleury acknowledge the brittle nature of a zinc oxide paint film, as do H. A. Nelson and G. W. Rundle in a 1923 article for the American Society for Testing Materials. Paintings conservators will be especially interested to note that the high incidence of cracking in zinc oxide paint films led to E. Täuber's 1909 (86) warning against using zinc white as a ground layer: "Sehr gefährlich erweisen sich als Untergrund auch Zinkweiß . . ." Interestingly, in the research on Abstract Expressionist paintings associated with this literature review, all of the research group paintings exhibiting severe paint layer failure were found to have zinc oxide ground layers.

ZINC OXIDE IN INDUSTRIAL LITERATURE BETWEEN 1926-1950

The most useful articles from this period appear mostly in industry journals and symposium post prints. Articles from this period focus mostly on market demand and product adaptation, which may not initially seem applicable to conservation, but in fact provide uniquely informative material that is available only in the industrial literature.

Competitive Bias

As zinc oxide paint was adopted by the consumer market, the commercial debate shifted to determining the best raw material for successful paint formulations. The audience for these articles was the paint manufacturer, and accordingly, much of the information regarding raw materials was conveyed through papers presented at industrial symposia. Of the nearly fifty articles gathered from this period, the authors of approximately a quarter of the studies note their affiliation with a university or scholarly research center, while a far larger number of authors acknowledge their role as employees of paint and raw pigment manufacturers. Sponsored symposia articles are suspect, especially when the authors present the superior qualities of their product with little explanation of analytical methods and limited bibliographies (some examples are Kekwick 1938, Calbeck 1941, Davidson 1949). The 1949 Zinc Oxide Symposium, sponsored by the Victorian Section (Australian Branch) of the Oil & Colour Chemists' Association and reproduced in a special issue of *Paint Notes: A Journal of Paint Technology* (1949), contains several examples of so-called "comprehensive" literature surveys whose bibliographies are limited to authors with similar agenda. For example, K. R. Bussell's survey of literature promoting the use of acicular zinc, which begins with the statement: "the literature on zinc oxide is, of course, very extensive" (1949, 217) contains a bibliography of articles exclusively by industry representatives. Such publications should not be ignored, however. Symposia post prints also include papers by impartial authors who offer comprehensive citations and unbiased discussions of paint film behavior. The writings of F. L. Browne (1936 and 1941), D.W. Robertson (1935 and 1936), J. R. Rischbieth (1949) and F. C. Schmutz (1935) stand out because of their inclusive references and accessible language. Despite an irregular citation style, bibliographies from these articles are invaluable in building comprehensive period literature lists. Period post prints also contain pertinent information about period additives (such as surplus post-WWII rubber plasticizers) or industrial formulations based on engineered failure properties, a topic of particular relevance to the conservator.

Weathering Tests and Engineered Paint Film Behavior

Unique information about engineered paint film behavior can be found in weathering test articles from this period, which contain several examples of "common knowledge," defined for the purposes of this article as the repeated mention—in various publications and by varied authors—of assumed information. For example, Rischbieth's article from the Australian symposium (1949) focuses on zinc oxide paint performance in Australia, but also notes a global industrial preference for acicular zinc pigment, purposefully used because the brittle acicular zinc oxide paint films will preferentially micro-fissure during failure. Such widespread chalking caused the upper layers of zinc oxide house paint to slough off in the rain, creating the appearance of a perpetually clean paint surface. Weathering test literature from this period debate the best formulation for achieving this so-called "renewal" of the paint film surface, which was preferred over more sporadic crack patterns that were difficult to level and prepare for repainting. This engineered difference between industrial paint and artist's paints of the same period is useful information for the modern paintings conservator. In relation to the associated conservation research, paints engineered for such failure characteristics would provide an ineffective support layer for the heavy paint application of Abstract Expressionist compositions.

Industrial paint formulations also reflect regional climate differences. As Robertson stated in his 1935 article for the *Official Digest of the Federation of Paint & Varnish Production Clubs*: "fifty percent of the day, a house in a latitude such as that of England has no direct sunlight" (Robertson 1935, 252). As weathering test performance determined the viability of paint in different environments, paint formulations would be changed to respond to regional climate differences. For conservation concerns, this means that different formulations (and behaviors) could exist in the same brand of zinc oxide paint used by contemporaneous artists from different regions. On a larger scale, formulations using zinc oxide as the primary pigment may remain in the house paints used by artists in mild European climates well beyond the mid-1950s replacement of zinc oxide (by titanium dioxide) in industrial paint formulations for the wide-ranging climate of the American market. As Robertson noted (1935, 252): "In France, Germany, and Panama we have high zinc content paints. In England we have paint that will last from five to six years, but it would not last two years in the United States."

It is worth remembering that early house paints were not formulated for long-term stability. Frequent statements in the weathering literature confirm that while zinc oxide was still considered a poor film-former, the industry requirements for durability differed significantly from those of the modern paintings conservator. As proclaimed by S. Werthan in a widely-distributed 1947 promotional publication from The New Jersey Zinc Company entitled *Post-War Exterior House Paints* (reproduced the same year in the *Paint, Oil, & Chemical Review*): "a white house paint possesses real merit if it maintains a clean-bright surface free of significant film failure for a period of three years" (Werthan 1947, 38). This sentiment is repeated in later literature, including a comparative exposure tests article by R. W. Bailey and A. Pass for a 1953 issue of the *Journal of the Oil & Colour Chemists' Association* (171): "Zinc fails by checking and cracking with flaking and erosion which seems fairly severe. . . . Paints containing zinc pigments have, however, a natural useful life of at least three and a half years." (As early as 1935 (241) Robertson observed: "No [exterior] paint containing zinc oxide in any form . . . has failed to show cracking after one year.") An engineered three-year life expectancy for zinc oxide paint is important information for conservators faced with the prevalence of house paint use by artists in the first half of the twentieth century.

Two-Coat Paint Systems

A number of articles appeared in the 1930s and 40s regarding the challenges posed by the use of zinc oxide in a composite paint system; conservators working with objects that may contain industrial paints should not overlook the literature on house paint primers. Articles by Browne (1941), Robertson and Jacobsen (1936) and Schmutz (1935) echo Täuber's earlier warnings against the use of zinc oxide as a priming layer. As emphasized by Robertson and Jacobsen (1936, 403): "There is a direct relationship, in terms of performance, between relative hardness of undercoat and top coat, and that certain combinations are incompatible." In his article for the *Paint, Oil, and Chemical Review*, Schmutz notes (1935, 356): "In the aim of developing a better primer it is possible that too little thought has been given as to how this primer might work under the different finishing paints. . . . In some cases there is a marked increase in checking and cracking of the finishing coats and in others an actual decrease in adherence of the whole system vitiating all of the desirable properties shown by the primer alone." Industrial articles regarding the behavior of two-coat paint systems are particularly useful when applied to the conservation of paintings and painted objects. The associated Abstract Expressionist study group paintings exhibited the same behavior foretold thirty years earlier: cracking of the upper compositional paint layers indicating widespread failure and delamination of an underlying zinc oxide ground layer. That study concluded that Abstract Expressionist works produced during the early twentieth-century era of popular house paint usage should be carefully observed during instances of mechanical stress or changes in the environment, when the stress response behaviors of the zinc oxide ground and adjacent compositional paint layers may be incompatible. As stated by Browne in 1941 (901): "Complete elimination of zinc oxide from primers is recommended by one school of thought on the subject and is opposed by another. . . . Conclusions about the use of zinc oxide in primers must be subordinated to the more fundamental problem of compatibility between primer and finish paint."

FORESHADOWING CONSERVATION RESEARCH IN THE INDUSTRIAL LITERATURE

Despite the disparity between early twentieth-century analytical techniques and today's scientific methodology, the period literature contains forward-thinking articles on topics that have recently gained attention in conservation research. For example, period articles regarding the impact of zinc oxide on the mechanical properties of paint film foreshadow the conservation community's examination of the relationship between environment and paint film mechanics that began in the 1980s and 90s in the United States (Mecklenburg et al. 1991 and 1992), Canada (Michalski 1991, Moar and Murray 2007), the United Kingdom (Young et al. 2004; Hagan et al. 2007) and Europe (et al. 2006); later industrial research on zinc ion migration in anti-corrosive coatings (van Eijnsbergen 1978) may parallel recent conservation science analysis of ion migration between paint films (Mecklenburg 2010).

Period zinc oxide literature also addresses the role played by critical pigment volume concentration (CPVC) in film failure characteristics, a topic explored in the 1960s by conservation scientists such as Robert Feller (1964). Period CPVC topics include blistering and peeling (Hess 1965), as well as articles by Browne (1955 and 1957), Funke (1967) and the team of Eissler and Princen (1966, 1968, 1970, 1972) on the effects of zinc oxide on the water sensitivity of oil paints, also the focus of recent conservation research in the United Kingdom and Europe (Mills et al. 2008; Tempest et al. 2010). Period authors may cover more than one topic of interest, such as Browne, who writes about zinc oxide's role both in two-coat paint systems (1941) and water sensitivity (1955 and 1957, in an unexpected resource entitled *Forest Products Journal*).

A striking example of industrial literature presaging modern conservation inquiry appears in the coatings industry's early interest in the formation of zinc soaps, a topic of recent conservation research worldwide (van der Weerd et al. 2003; Singer and Liddie 2005, Noble and Boon 2007; Shimadzu et al. 2008). Zinc soaps are mentioned as early as Petit's 1907 manuscript, with articles focused solely on the subject of soap formation appearing in the early 1940s. In a 1941 issue of *Industrial and Engineering Chemistry*, Jacobsen and Gardner hypothesized a lamellar structure for saponified zinc oxide oil films. The authors' discussion of zinc oxide's unique behavior in relation to oleic acid was instrumental in interpreting the unusual oleic:azelaic fatty acid ratios found in gas chromatography analysis of the Abstract Expressionist study group paint samples (Rogala et al. 2010; Maines et al. 2011).

Zinc Oxide in Acrylic Paint

A discussion of acrylic paint media lies outside the scope of this article, but it is worth noting that industrial literature regarding attempts to formulate stable zinc oxide latex paints begins in the early 1970s (Hoffmann and Saracz 1969 and 1972; Madson 1971 and 1974; Johnson et al. 1991; Diebold et al. 2003). Early industrial literature on latex formulation may also foreshadow current conservation research on acrylic paints. Conservators researching this topic may find useful bibliographies within these early texts.

ZINC OXIDE IN RECENT INDUSTRIAL LITERATURE

Returning zinc oxide topics found in the post-1975 industrial literature include the role of CPVC (Bierwagen 1992; Perera 1995), and the role of particle shape in mechanical behavior (Feliu et al. 1993; Hare and Kurnas 2000). The bulk of modern zinc oxide research, however, has shifted to the technological sector as the properties of zinc oxide are explored for use in electronic circuitry (Klinshirn 2007). Like Jacobsen and Gardner, recent articles by the teams of Xu et al. (2004) and Vasudevan and Barman (2006 and 2007) hypothesize a plate-like structure within a zinc oxide paint film, which would weaken the film by sporadic disruptive bond formation. Earlier zinc oxide film failure site comparisons by Funke (1967) and Eissler and Princen (1972) support the idea of plate formation on a macro scale within the paint film layer. In combination with an understanding of fatty acids distribution within the zinc oxide matrix (Keune 2005; Boon 2006), this recent industrial research played an important role in interpreting the zinc oxide intra-layer cleavage pattern observed in the associated Abstract Expressionist study group paintings.

CONCLUSION

The articles presented in this literature review focus on the mid-twentieth century development and production of oil-based zinc oxide house paint. The sequence of the industrial literature is familiar: introduction of a new material, competition for market share, consumer feedback and product adaptation, and new research spurred on by potential new markets. But an examination of even this narrow range of articles illustrates the useful information that can be obtained through a review of the period literature. Industrial articles produced at the same time as an artist's use of a material provide unique information about formulation and behavior, which is especially important if the purposeful manufacture of the material is at odds with the long-term preservation goals of the conservator. When read carefully, industrial literature is an accessible and valuable resource for the modern materials conservator.

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AUTHOR

Dawn Rogala
Postgraduate Research Fellow, Museum Conservation Institute, Smithsonian Institution
Doctoral student, Preservation Studies Program, University of Delaware
E-mail: RogalaD@si.edu

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