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From Bench to Brand and Back:
The Co-Shaping of Materials and Chemists in the Twentieth Century

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Paint as a Material: The Transformation of Paint Chemistry and Technology in America (ca. 1880-1920)

Augustin Cerveaux*

Abstract
This chapter recounts and analyzes the emergence of modern paint chemistry and technology in the United States. Until late in the 19th century, painting was above all a decorative art and craft, and chemists' role in the paint trade was largely circumscribed to the development of new pigments. At the turn of the 20th century, however, the protective dimension of paints rose in prominence and the standing and influence of chemists within the trade and industry rose tremendously. Charles Dudley, a chemist at the Pennsylvania Railroad Company, initiated this movement. A new field quickly coalesced around the American Society for Testing Materials, the Paint Manufacturers Association, and later the American Chemical Society. In the process, the paint coat became firmly established as a material in itself, rather than a mere mixture of heterogeneous ingredients. The erstwhile conflation of "pure" paint with "good" paint became suddenly obsolete.

Keywords: paint chemistry and industry, purity and modernity, Charles B. Dudley (1842-1909), second industrial revolution, American science.

Résumé
Ce chapitre retrace et analyse l'émergence de la chimie et de la technologie moderne des peintures aux États-Unis. La peinture, jusque vers la fin du XIX[e] siècle, consistait en un artisanat dont la vocation était essentiellement décorative, et le rôle des chimistes consistait principalement à découvrir et exploiter de nouveaux pigments. Cependant, au tournant du XX[e] siècle, la dimension protectrice des peintures devient prépondérante, et les chimistes et ingénieurs acquièrent une importante position et influence dans le commerce et l'industrie des peintures. Un chimiste de la compagnie ferroviaire Pennsylvania Railroad, Charles Dudley, a initié ce mouvement, qui s'est ensuite développé au sein de la Société Américaine des Tests de Matériaux, de l'Association des Fabricants de Peinture, et plus tard de la Société Américaine de Chimie. Au cours de cette transformation, le revêtement de peinture devient appréhendé comme un matériau en soi, plutôt que comme une simple mixture d'ingrédients hétérogènes. La tradition artisanale identifiant la « pureté » des peintures avec leur performance est brusquement remise en cause et dépassée.

Mots-clés : chimie et industrie des peintures, pureté et modernité, Charles B. Dudley (1842-1909), seconde révolution industrielle, science américaine.

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THE DOMAIN of paints offers a fascinating research avenue to explore and analyze the co-shaping of chemists and materials. Cars, planes, trains, buildings, bridges, and many household appliances such as ovens, refrigerators and lamps are coated by paints. Each one of them has been formulated by paint chemists, tested and gauged in-doors with a variety of laboratory apparatus, and tested outdoors on exposure panels and in field service. In turn, as I show in this chapter, paints have compelled chemists to leave their benches and venture outside to design and implement outdoor testing methods. What makes a paint durable? Why does a formulation perform well on wood, and terribly on metal? What does it even mean for a paint to "dry"? And above all, how shouldtests and procedures leading to reliable and reproducible experimental data about paints be designed? These were among the most vexing questions that chemists had in mind when they started to erect exposure panel tests throughout America at the turn of the 20th century. By exploring these questions, these chemists contributed to shape the field of materials science and technology in the 20th century.

In this chapter, I recount and analyze the emergence of modern paint chemistry and technology in America, between ca. 1880 and 1920, when chemists and engineers, rather than painters, explored this set of questions. In the process, paint came to be viewed as a material in itself – a coating that could and should be engineered to fit a wide variety of specific purposes. Pre-industrial painting was mostly understood as a decorative art and craft. Yet the chemists and engineers who would shape modern paint technology were above all concerned with their protective properties. Paints' function shifted from aesthetics to protection and durability. New forms of paints disseminated, the more conspicuous being the commercial availability of "ready-mixed" paints, effectively transforming paints into a commodity. Underpinning these changes lay a radical shift in representation, a disruption in the perceived relationship between materials and function. Traditional knowledge about paints drew a clear-cut line between color, brought about by pigments, and durability, resting on the quality of the oil which binds pigments together. "Oil is the life of the paint", a saying among painters went. The new representation held instead that both pigments and the binding medium, interacting together to form a material, are responsible for color and durability.

Section 1 briefly touches on pre-industrial painting in Europe, to give a broader insight into the changes taking place at the turn of the 20th century. I show how painting was historically dedicated to beauty and ornament. Section 2 addresses the introduction of ready-mixed paints in America during the 1880s, and how it affected painters and favored the introduction of chemists into the paint trade. Section 3 focuses on the American chemist Charles Dudley, employee of a railroad company, whose research program shattered traditional knowledge about paints. The ensuing organization of paint chemistry and technology – upheld by two entities in particular, the American Society for Testing Materials and the Paint Manufacturer Association – leant on and expanded Dudley's program, and is the object of section 4. The field organized alongside a nationwide and bitter controversy over paint regulation and labeling enforcement, largely resulting from the dissemination of ready-mixed paints. In the last section I describe how the controversy accelerated the demise of the old, pre-industrial representation of paints.

A Long-Lasting Cultural Tradition of Painting

Unlike other commodities or technologies that emerged entirely out of the industrial revolution – like, say, the railroads or electricity – painting was bounded by a longer tradition. In medieval Europe, guilds of professional painters were established as early as the 12th century. Since the advent of oil painting in the 14th century, linseed oil and lead-base pigments (lead white, lead red and litharge mostly) were the most important materials for painting. Virtually all preparations included lead. Lead white served as a base, and the desired tint was obtained by adding a small quantity of other "colors", as pigments were called until late in the 19th century. Lead oxides were also added to the preparation, to increase the siccative power of the oil (reduce its drying time). As a professional guild regulated by the state, painters were frequently at odd with plasterers and shipbuilders: painters claimed a monopoly over the practice of oil painting, which plasterers often used for themselves in finishing their works. For instance, a dispute during the 1610s in London was settled by excluding the crucial lead whites from the materials plasterers were permitted to use (Englefield, 1923, p. 74-75).

Painters were primarily engaged for decorative works of various kinds – interior objects like cups and cans, as well as carriages and houses. It is telling that, in the mid-17th century, when lead pigments and linseed oil, praised by master painters, were used in shipbuilding to water-proof the hull, no painter affiliated to a guild was permitted to perform these jobs, which were reserved for carpenters and workers on shipyards (Englefield, 1923, p. 134-136; Armitage, 1954, p. 57-60). Yet most shipyards typically hosted painters for finishing works. Their trade was understood as distinct in nature from carpentry, masonry, and plastering. Painting was mostly a decorative art and craft, aligned with its etymological root – from the latin verb *pingere*, which means to impart color.

The identification of painting with color-bringing is reflected in the textual production of painters, chemists, and philosophers who wrote about the trade. There is no entry for "paint" in either Ephraim Chalmers' *Cyclopedia*, nor in Jean D'Alembert and Denis Diderot's *Encyclopédie*, although the entries for "painting" are quite substantial in both. "Paint", as a noun, surfaces scantily in the early 19th century, as a synonym for pigment or "color". Until the mid-19th century, "paint" and "painting" referred to a practice rather than a material thing. Aiming primarily at decoration and ornament, it was above all a cultural practice. This is how D'Alembert and Diderot (1765, p. 246) introduced "painting" in their *Encyclopédie*:

> To impart colors on a flat surface, so as to represent any figure. Also designates the beautification of diverse ornaments in a bedroom, an office, a gallery. […] To paint also refers – though improperly – to sizable works on buildings. One has to *paint* a panel, a cradle, or an iron balustrade to prevent their rusting. But, in that case, to *daub* would be more correct.

It's not that protection was altogether absent from the motives of painters. Rather, "paint" and "painting" were not immediately associated with protection, unlike "varnish". The function assigned to each of the two major classes of materials in the formulation of paints – vegetable oils and mineral pigments – was clear-cut: the pigments bring the color, and the oil the stability and durability of the whole.[1] Failure of paint-coats to retain their color or to stand the deleterious effects of weather was blamed on "adulterated" ingredients: the substitution of cheaper oil for linseed oil, or cheaper minerals like clay for lead white. A good paint was a "pure" paint,

[1] John Smith's *The Art of Painting* (1676), among the oldest painting manuals recorded, gives some indication of how to adjust formulas for outdoor works, exposed to intense weathering. Compared with indoor formulas, he recommends adding stronger solvents and more oil (chap. XVII). The close association of varnish with protection, and painting with ornament is particularly eloquent in *A Treatise of Japaning and Varnishing*, published in London in 1688. In the preface, the authors, John Stalker and George Parker, state that "Painting only is able to keep us in our Youth and perfection. That Magick Art, more powerful than Medæ's charms, not only renews old age, but happily prevents grey hairs and wrinkles. […] Well then, as Painting has made honourable provision for our Bodies, so Japanning has taught us a method, no way inferior to it, for the splendor and preservation of our Furniture and Houses. These Buildings, like our Bodies, continually tending to ruin and dissolution, are still in want of fresh supplies and reparations: on the one hand they are assaulted with unexpected mischances, on the other with the injuries of time and weather; but the Art of Japanning has made them almost impregnable against both: no damp air, no mouldring worm, or corroding time, can possibly deface it."

free of materials coming from other professions, particularly the plasterers – lime, chalk, clay, barytes, gypsum…

Chemists interacted with the paint trade in various ways, the most known being the discovery of new pigments, or new synthetic routes for pigment compounding (Ball, 2003). From the late 18th century on, pushed by a burgeoning paint and varnish industry, chemists prepared general educational textbooks intended for painters and manufacturers. Textbooks usually presented a classification of pigments and associated production processes by color, and a classification of oils, gums and resins (Malepeyre, 1874). Professional chemists probably comprised some manufacturers' staff, to assess the purity of raw materials and more generally to rationalize the relationship between the pigments' production processes and the color obtained, so as to improve the yields and tints. Yet the penetration of chemistry into the paint trade from the late 18th century on was never as extensive as in the textile trade, where chemists' knowledge and practices became essential for the production and innovation of dyestuff (Nieto-Galan & Fox, 1999).

The Reconfiguration of Paint Practices by "Ready-Mix" Brand Materials

- *The Increasing Demand of the Second Industrial Revolution*

In America, the advent of "ready-mixed" paints, also designated as "prepared" paints, was probably the most important contribution of the post-Civil War industrializing trend to the paint trade. Until then, color merchants and druggists sold oils and pigments separately, and the painter mixed them together, on site, to a desired consistency and color according to the type of work to be done and the personal taste of the painter's client. Ready-mixed paints, sold ready for use directly in a can, completely changed this trade regime and condensed the diverse materials and techniques required to prepare the paint into a single product controlled by manufacturers. Ready-mixed paints were bought and sold in retail, and thus opened the way to the commodification of paints and the standardization of their color. Painters, or the railway, building, and carriage-making companies that employed them, became "consumers" of paints, as well as anyone willing to paint a barn, house, or carriage himself.[2]

[2] Paints thus played a key role in the advent of a "consumer" society at the turn of the 20th century. Charles F. McGovern (2006) analyzes the progressive inclusion of consumption within American values during this period.

The steadily increasing demand for paints certainly pushed for this substitution, as ready-mixed paints offered promising opportunities for value-adding and profits, efficiency, standardization, and labor saving in plants and paint shops, and thus curtailed costs. A rapidly industrializing America needed more and more paint to protect and beautify its houses, barns, ships, carriages, buildings, and railroads. In 1838, a 350 ton vessel required about nine short tons of paint and varnish, while a Navy ship upon entering service in World War I had on its flanks more than one hundred times as much (not including maintenance). In between, the annual domestic production of ships of any kind increased, in tonnage, about three hundred times to reach 3.3 million tons in the late 1910s.[3]. One and a half million horse-drawn vehicles were produced in 1900, each requiring between six and thirteen paint coats (Kinney, 2004, p. 34). A similar trend could be highlighted for houses and railroad equipment, the latter demanding paints for rails, freight, and passenger cars. Paint and varnish production grew accordingly, from $27 million in 1869 to 125 in 1909.[4] In 1890, ready-mixed paints accounted for about twenty-two percent of all the production of paint materials and products, in value, and were largely circumscribed to house-painting. By 1919 its share in the paint trade had reached forty-seven percent, and had penetrated the building, ship construction, automobile, and railroad markets.[5] The master painters, as a body, felt threatened by the introduction of ready-mixed paints. The departure from their traditional paint mixing practices represented, after all, a transfer of techniques and skills from the painter to the manufacturer, and more ominously threatened the very existence of the painting profession. Sometimes master painters went so far as to organize collective boycotts of the manufacturers that sold ready-mixed paints.[6]

[3] The figure of 1838 comes from (Green, 1965, p. 35), that of 1916 from (Gardner, s.d., vol. 2) and the increase in ship tonnage from *Statistical Abstracts of the United States*, Washington: U.S. G.P.O., vol. 1 (1878) table 137 and vol. 43 (1920) table 267.

[4] Constant 1909 dollar. Source: U.S. Bureau of the Census, Thirteen Census of the United States (1909), Washington: U.S. G.P.O., 1913, Vol. X: Manufactures, p. 595 table 2.

[5] Figures from U.S. Bureau of the Census, Eleventh Census Report, 1890, vol. I Manufactures, Part III, p. 292 table 2 and Fourteenth Census Report.

[6] For instance in 1885-1886 in Philadelphia: *House Painting and Decorating,* vol. 1, n°4 (Jan. 1886), p. 121.

- *"Ready-Mix" Paint as Deceptively Impure Commodity*

The Harrison Brothers Company of Philadelphia, among the earliest manufacturers in America that ventured into ready-mixed paints, launched a trade journal in 1885 to smooth its relations with master painters. The journal, a monthly entitled *House Painting and Decorating,* featured ads of ready-mixed paints – mostly Harrison brands – and became the official organ of the Pennsylvania Master Painters Association. To ease the switch to prepared paints, Harrison Brothers launched an aggressive marketing campaign persuading painters that their products were as pure as the preparations they could make on their own. They invited any party to send a sample of a suspect preparation for analysis in their labs, and colorfully exposed the cases of adulteration in the journal. For example, in March 1886, a sample sent by a certain "S. & McL". is decried in the following terms: "The result of a careful analysis shows that your coach black contains forty-five per cent of barytes. Can you hope to do a durable job with such trash? Give it up!"[7] Numerous cartoons were drawn and published highlighting the threat of adulteration, and its "subduing" by chemistry (figure 1).

A glance at other trade journals shows that purity was the most important advertising leitmotiv in the trade. In the late 1880s, as painters organized to deter adulteration, they also contracted with independent chemists and confronted the results with manufacturers' claims.[8]

Chemists, then, interacted with the paint trade in various ways, but did not dispute the painters' common knowledge drawing a sharp boundary between respectable and suspect materials. Rather, their expertise in quantitative analysis lent the detection and exposure of adulteration cases more authority. Thus, this new role for chemists in the paint trade espoused a clear division of labor and qualifications: the painter or paint manufacturer expected the chemist to sort out the nature and proportion of the ingredients entering his products, or his peers' or competitors', while the assessment of the overall quality of the paint remained his jurisdiction. In the context of the paint trade, the relationship between painters or paint manufacturers on the one hand, and chemists on the others hand, could then be interpreted as "consultant and testing slaves", as proposed by historian James Donnelly (1994) in his study of the alkali industry.[9]

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[7] *House Painting and Decorating*, vol. 1, n°6 (March 1886), p. 187.

[8] *House Painting and Decorating,* vol. 5, n°6 (March 1890), p. 275-276.

[9] For example, a master painter praised the chemists' analytical skill but dismissed his contribution beyond that: "The analyses of chrome yellow indicated clearly the importance of employing a chemist who has not a little experience in the manufacture of paints or, at least, knows something on the manufacture of

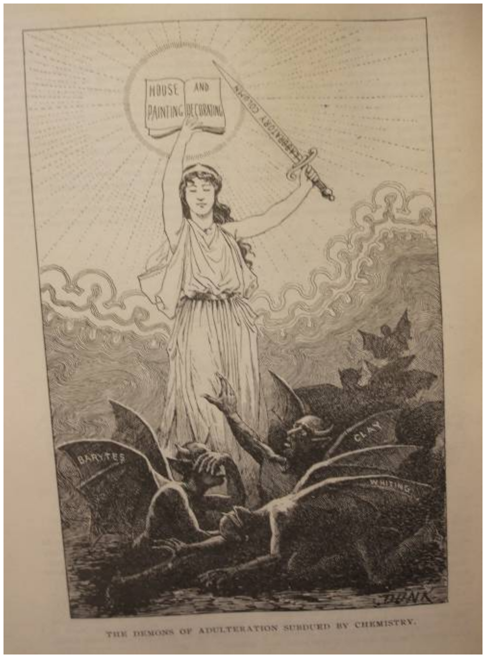

Figure 1 -"The demons of adulteration subdued by chemistry", House Painting and Decorating*, vol. 1, n°6 (March 1886). (Source: Photo taken by the author)*

The comparison with another key material or range of materials of the "second industrial revolution", concretes, and the associated trade and body of occupations and expertise, is particularly helpful to shed light on the historical development of the paint trade. Both concretes and paints underwent tremendous growth in production and consumption in the late 19th century. Unlike the paint trade however, chemists and engineers, not manufacturers or masons, were at the core of the body of expertise setting technical standards over concrete, assessing their overall quality and how it should be laid or applied (Slaton, 2001). Although both materials shared common substances and input, the difference in representation is striking: gypsum, for instance, was considered an essential and valuable ingredient in the concrete trade, whereas in the paint trade it was vilified as an "adulte-

pigments in general. Unless he has such knowledge he is not competent to draw proper deductions from his analysis such as we think should be submitted to master painters." (*House Painting and Decorating*, vol. 5, n°6 (March 1890), p. 276).

rant". In the former case, gypsum is a necessary component of an unavoidable material in modern building technology and civil engineering: concrete. In the later, gypsum is a cheap substitute debasing the purity, and therefore the quality, of a decorative preparation. The idea that gypsum is good for concretes but bad for paints testifies to a long tradition of painting which drew a sharp hierarchy between ingredients. In painting, just a handful of pigments were considered respectable materials; for concrete, anything could go, as long as performance followed.

The next section is devoted to Charles B. Dudley (1842-1909), a chemist at the Pennsylvania Railroad Company, who was the first to consistently and persistently challenge this representation in the paint trade, which posited an inherent hierarchy in painting materials. He was invited in 1890 and later in 1892 by the Pennsylvania Master Painters Association to lecture the painters on the composition and durability of various pigments. His underlying thesis – that adulterants were not necessarily detrimental to paints – would be bitterly resisted and the subject of nationwide legal battles before being fully accepted.[10]

A Functionalized Material: Charles B. Dudley and the Pennsylvania Railroad Co.

During the early 1870s the railroad industry aimed at standardizing its mechanical parts and tests assessing the quality and durability of various procured materials, including iron and steel rails. The major companies thus fostered systematic mechanical investigation and testing facilities. The Pennsylvania Railroad Company, one of the largest American railroad companies, implemented a department of physical and chemical tests in 1875, on the premises of the blacksmith and mechanical shops located at Altoona, in central Pennsylvania. Chemical analyses were sometimes performed on lubricants, steel, and other materials by contracting chemists, and the department would internalize the analyses. Yet the management had no clear idea of the department's organization and outcomes, besides the assumption that in-house physical and chemical testing facilities might

[10] Dudley is a minor figure in the historiography of science and technology, portrayed mostly as one the first leaders of industrial research. His impact on paint chemistry and technology, as well as on the historical development of materials science and technology, has been overlooked. At any rate, he deserves a more prominent place in the historiography. He was in his time a chemist of very high standing, with tremendous influence in both industrial and academic circles. He presided over the American Chemical Society in 1896 and 1897.

benefit the company. Dudley, a Ph.D. in chemistry freshly graduated from the Sheffield Scientific School at Yale, was hired to run the chemical part of the department. With no pre-established specific missions and duties, he was granted, as a managerial experiment, considerable latitude in the choice of his investigations and the organization of the laboratory (Usselman, 2002, p. 195-208; Ely, n.d., p. 51).

Why did some burning oils, used by coach drivers as signals and therefore essential for traffic safety, fail entirely in service? When paint on coaches was found badly damaged after cleaning service, who or what was to blame: the paint, the soap, or the cleaners? These were the kinds of issues Dudley initially tackled, which led him to detect "adulterated" burning oils and soaps and to devise tests preventing the purchase of adulterated goods. Interestingly, these early forays into adulterated goods did not condition his approach to the paint issue a few years later, since he came to reject the very notion of an adulterated paint. Rather, Dudley framed his investigations into paints, from the late 1880s on, on the basis of his findings and achievements on steel rails during the 1880s.

Steel rails, made commercially available after the invention of the Bessemer process in 1856, had replaced most iron rails by the late 1870s, on the basis of a better performance in service. However, there was no reliable physical or chemical test of steel from which to infer its actual performance and durability over the span of years or decades. Steel rails' performance varied importantly from one manufacturer to the next, or even from one batch to the next (Chezeau, 2004). The procurement of steel was thus a source of major conflicts between railroad companies and steel manufacturers. Systematically correlating the observed performance and durability of various samples of rails with the chemical analysis of their constituent steel, Dudley found that the proportion of four elements in the composition of steel – phosphorous, silicon, carbon and manganese – could reliably predict the performance of the rail made thereof. On this basis, he promoted radical changes in procurement practices and specifications which, as one might expect, were met with considerable controversy and triggered heated debates, not least because steel manufacturers were reluctant to be told by steel consumers how to process their steel. Yet eventually Dudley's philosophy of specifications took hold. By the late 1880s, the role of the laboratory was to a large extent defined by the design and enforcement of specifications (Usselman, 2002, p. 204-209; p. 217-223).

Around 1887 Dudley tackled what he called the "paint problem".[11] Despite the vast quantities of paints consumed by the railroad industry, there was no reliable guideline securing the purchase of the best paint formulation for any specific application. The economic incentive to devote a large share of Dudley's laboratory's resources to paints, in a context of unreliable technological knowledge, was thus enormous. There was not even, in contrast to the steel rail problem, a clear and shared understanding of what "paint" referred to. Dudley felt compelled, at the outset of his studies, to state that paint "may be said to be any liquid or semi-liquid substance applied with a brush to protect or give color, gloss, or all three, to surfaces". He added that "in this sense, both whitewash and varnish can be regarded as paints" ("Paints", p. 414). While aligned with the modern definition of coating, this understanding departed radically from the historical conflation of paint with pigment, and reflected the consumer viewpoint of the "problem". Rather than highlighting the process – the mixing of pigments with a liquid binder – the definition emphasized the function of paints. Dudley, as a railroad man, cared more about the durability of the paint-coat than about the proper color of the pigment used, or whether the substance applied was a paint or a varnish.

As a chemist, Dudley felt all the more puzzled since the relationship between composition and performance seemed even foggier than in the steel-rail case. Immersed in a large railroad network covering Eastern and Midwestern parts of the U.S. territory, Dudley had access to firsthand data about the service performance of numerous paints under a variety of climate and exposure conditions. He also appropriated and developed an experimental apparatus and technique at the core of the painters' and manufacturers' practices: the panel test. Painters usually applied their preparations on a wooden board to check the working and drying qualities of any specific preparation. The exposure panel was also a commercial artifact, shown to customers. Dudley had different expectations for the dozens of panels he erected in the vicinity of the laboratory. He had the latitude to devise and conduct experiments aimed at a systematic and general approach to the composition-performance conundrum. Assuming that water was the most significant factor in the degradation of paint-coats, he assessed the

[11] The following presentation of Dudley's researches on paints is based on his series of articles published in *The Railroad and Engineering Journal*, with his assistant F. N. Pease: "Paints", vol. 64, n°9 (Sept. 1890), p. 414-417; "The Working Qualities of Paints", n°10 (Oct. 1890), p. 452-455; "The Drying of Paint", n°12 (Dec. 1890), p. 545-548; "The Covering Power of Pigments", vol. 65, n°2 (Feb. 1891), p. 78-82; "How to Design a Paint", n°4 (Apr. 1891), p. 174-177; "Paint Specification", n°5 (May 1891), p. 162-167.

relative absorption of water by dried coats of various formulations – different proportions of "pure" pigments, adulterants such as barytes, and linseed oil. His conclusion was in direct opposition to the then-prevailing theory of pure paints and oil-induced durability of paints: that pigments, or supposedly detrimental mineral "adulterants", mattered a lot to the durability of the paint coat.[12]

Equally important were his reflections and insights into the physical microstructure of paints. Although there is no evidence that Dudley engaged in microscopic studies of paint films, he identified core issues regarding the relationship between paint properties and physical microstructure – the fineness of pigments' particles and distribution within the oil medium – on which paint technology would concentrate throughout the 20th century. Dudley was probably the first to expound the modern explanation of the opacity of paints, and highlighted the importance of the pigments' particle size and refractive index in this concern ("The Covering Power of Pigments", p. 80-81). His experimental studies and conceptual developments set the stage for the definition of the concepts of hiding power, tinting strength, and the importance of the physical structure of the pigments' particles. As such, he can be regarded as one of the most important figures in the historical development of modern industrial painting.

Reforming the Paint Trade: The American Society for Testing Materials and the Paint Manufacturers Association

Dudley's most important legacy, though, is not his forays into paint technology, but the founding of the American Society for Testing Materials (ASTM). The success of Dudley's approach to the conflicts between railroad companies and steel manufacturers over the durability of rails – bringing together consumers and manufacturers to agree on a set of specifications and tests that steel bars should meet – led to a generalization in the design and enforcement of specifications for other industries and materials.

[12] "We have very little hesitation in saying, and we think all experiments honestly made under proper conditions will prove this point, namely, that it is essential for a good paint that the amount of pigment per square inch or square foot of surface be large. This may look like making the durability of the paint depend on the pigment, whereas the common idea is that the oil is the life of the paint. We are quite free to confess that in our experience we have not been able to confirm the common belief among paint manufacturers and, indeed, among many of the users, that the oil is the life of the paint. The pigment is the life of the paint according to our experience." ("How to Design a Paint", p. 175).

Dudley was the driving force behind the formal institution of ASTM in 1898, and pushed for the creation of a committee specifically dedicated to paints in 1902: the committee on "protective coatings for iron and steel", shortened to committee E. It was chaired by an engineer from the federal government, and equally composed of chemists or engineers from railroad and construction companies, on the one hand, and manufacturers on the other. The committee quickly realized that the kind of specifications regulating the purchase of steel rails – like tensile strength tests and impurity levels – would be grossly inappropriate for paints. Instead of focusing single-handedly on the search for adequate specifications, the committee focused on a few seemingly simple questions or issues that vexed manufacturers and consumers of paints alike, and tried to standardize testing methods throughout its membership to gain robust and reproducible knowledge on these issues. Is a fast-drying paint good or bad for durability? Should metallic surfaces be carefully cleaned and sand-blasted before painting? How should the tests on exposure panels be prepared and conducted to yield reliable and reproducible data about a given paint formulation? These kinds of questions, if at all explored, were previously circumscribed within the occupational sphere of master painters. Chemists' new inroads into the technological realm of painters entailed a radically enlarged scope of investigation: from an auxiliary analytical aide to an overwhelming agent of materials' performance.

Above all, in the spirit of ASTM as envisioned by Dudley, the committee strove to regulate the paint trade so as to ensure a fair competition between manufacturers. The committee's most important sub-committee was dedicated to "field tests", meaning the assessment of paint performances in actual service. The sub-committee established restrictive guidelines over who would conduct the field tests and how the tests would be conducted. Worth mentioning is the fact that independent chemical analysis was mandatory – any manufacturer could not at the same time submit a sample for testing and provide the analysis stating its composition. Besides, the committee kept a sample of each tested formulation for future proofs. The kind of chemical analyses performed by Harrison Brothers as a marketing scheme of self-promotion was precisely what was being resisted. Gustave W. Thompson (1865-1942), chief chemist at the National Lead company and the sub-committee's chair, summed it up this way: "The purpose is not to give any manufacturer any commercial preeminence. It may result, in inspection, in the discovery that certain paints have stood well in their respective treatment".[13] The promotion of economic fairness and techno-

[13] ASTM Proceedings, vol. VI (1906), p. 64.

logical efficiency through science and expertise was certainly a hallmark of the Progressive era. ASTM as a body, and most chemists and engineers trying to reform the paint trade, embodied what historian Samuel P. Hayes (1959) depicted as the "gospel of efficiency". It is not surprising that Thompson later joined the Progressive party (Ingalls, 1930, p. 396), led by Theodore Roosevelt (1858-1919), one of the most influential figures of the Progressive movement.

Among the members of the committee was George B. Heckel (1858-1941), an influential member of the Paint Manufacturers Association, then a recently established national association for ready-mixed paints manufacturers headquartered in Philadelphia. One of the major forces driving the founding of the Paint Manufacturers Association in 1898 was the threat of seemingly imminent government intervention in the regulation of the paint trade. Painters and non-professional consumers protested against "adulterated" paints and several bills circulated to legally enforce, at the state level, paint labeling – the labeling of ingredients, both in composition and proportion. The prepared paints manufacturers felt threatened by such bills, as they were reluctant to disclose what they considered trade secrets, and anticipated the damaging consequences for sales that the listing of "adulterants" on paint labels would entail. Heckel (1931, p. 319-323) monitored the advancement of the bills and for a few years successfully prevented their enactment.[14]

In 1907 Heckel, together with Robert S. Perry, vice-president of Harrison Brothers, instituted a "Scientific Section" formally dependent upon the Paint Manufacturers Association and endowed with laboratory facilities on the premises of Harrison Brothers' laboratory. The Scientific Section was staffed with about a dozen chemists and assistants (cf. table 1), and basically imported the methodology developed by ASTM for paint testing. The section focused initially on wood-painting – that is, tackled the issue of house-painting which was beyond ASTM's scope. Exposure tests on wood panels were performed in Atlantic City, Pittsburgh, and Fargo (North Dakota), monitored by ASTM and local associations of master painters. Atlantic City was a favorite choice for early panel tests due to the harsh climatic conditions it offered, the proximity to Philadelphia, and because early ASTM gatherings took place in Atlantic City. Pittsburgh was selected because of the existing connection with the Carnegie Technical

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[14] The regulation of the economic and industrial "jungle", as it was called by popular muckrakers, was certainly a prominent feature of the Progressive Era. Less known is the legacy of the Progressive Era for paint legislation – that, quite strikingly, either dismissed or altogether ignored the health hazards of lead-paints (Warren, 1999, p. 705-736).

School and the different climate it offered. The choice behind the selection of the Fargo site, detailed in the next section, is more sinuous and yet essential in understanding the rationale behind the panel tests campaign organized by the Paint Manufacturers Association. The campaign basically intended to smash the idea that "pure" paints performed better. Henry A. Gardner (1882-?), the director of the Scientific Section, released the results in bulletin formats in 1909, and published a synthesis in 1911 that concluded unambiguously: "Mixtures of white lead and zinc oxide properly blended with moderate percentages of reinforcing pigments, such as asbestine, barytes, silica and calcium carbonate have proved satisfactory from every standpoint and are superior to mixtures of prime white pigments not reinforced with inert pigments" (Gardner, 1911, p. 190).

Besides exposure panels, Gardner introduced in his 1911 manual a variety of new apparatuses and tests construing the physical and mechanical properties of paint films. He completely overlooked the analytical techniques that aimed to reveal the proportion and stoichiometric formulas of pigments, which until then composed the bulk of the scientific treatises on paints. "The writer's desire", as he put it, "being to treat the subject from the standpoint of the physical properties of painting materials" (Gardner, 1911, p. 70). Following the approach favored by ASTM, the Scientific Section departed from the chemical examination of materials to explore their physical aspects. Chemical formulas were deemed unreliable to predict the performance of paints in "field service". How could paints of similar composition display such wide discrepancies in service performance? The alternative to composition as an explanatory and predictive factor of performance lay in the exploration of paints' microstructure. Concomitant to the physical and mechanical study of paint films, the Scientific Section systematically examined dried and wet paint films with microscopes. Gardner's manual is probably the first to introduce microphotographs of pigments dispersed in binding medium, together with a quantitative measure of their size and morphology. The microscope provided a new method for pigment identification beyond the traditional analytical techniques. It was on this basis that the mystery of "reinforcing-through-adulteration" was subsequently explained: Gardner noticed that the thickness of the coat, and therefore, one may somehow infer, its durability, depended on the coarse materials that composed the pigments. The early photomicrographs and particle size-measurements tended to show that asbestos and silica particles were, on average, coarser than the lead and zinc pigments. Not surprisingly then, Gardner (1911, p. 86-95) elaborated a classification of pigments not according to their elementary composition, but to the size of minute particles.

The Labeling Issue and the Demise of the Old Representation

As mentioned above, Heckel and Perry successfully lobbied states' legislatures to prevent paint labeling enforcement. That is, until they came to grips with the North Dakota state legislature, where powerful state chemist Edwin Ladd (1859-1925) had drafted a paint bill in March 1905 which entered into effect in January 1906. The decision to launch the Scientific Section and the panel tests campaign was reached by Heckel after failing to convince Ladd to abandon his bill: "the passage of the North Dakota paint law sharply emphasized the need of marshaling, systematizing and correlating the technical facts scattered through the industry" (Heckel, 1931, p. 81). However, Heckel succeeded in convincing Ladd to host exposure panel tests in Fargo, on the premises of the North Dakota Agricultural Experiment Station run by Ladd. Several chemists of the Experiment Station later joined the staff of the Scientific Section.

Together with the famous chemist Harvey Wiley (1844-1930), Ladd was instrumental in the enactment of the federal Pure Food and Drug Act in 1906, a landmark victory of the progressive movement under the Roosevelt administration (Young, 1989, p. 181-183). During the bitter legislative and political battle over the Act, Ladd acquired an irreversible distrust of manufacturers, and understood the paint adulteration issue just like food adulteration: a conflict of interest between consumer protection and unscrupulous manufacturers. He had little patience for the arguments from industry representatives like Heckel expounding the value of "adulterants" for paint performance. To him, the paint trade was above all ridden by a pervasive hypocrisy, standing on a general claim of purity that, if confronted with impartial chemical analysis, amounted to a massive lie to consumers. To fight adulteration in the paint trade, he distinguished between what he called "statutory pigments" – lead white and zinc oxide – and "substitutes" – the rest of the mineral matter usually introduced in paint formulation, including the most reviled barytes. Labeling paints that were composed of anything besides statutory pigments and linseed oil was mandatory under the state legislation of North Dakota (Holley & Ladd, 1908). In the few years after, Nevada, Texas, Nebraska, Kansas, and Minnesota passed similar laws.

The Paint Manufacturers Association, and Heckel and Perry in particular, sensed that sea changes were under way, and that their networks of informants and lobbyists would no longer prevent the enactment of legislative requirements that would hurt the industry's interests. Yet the industry's prospects were bright: years of continuous growth seemed to lie ahead, and more and more consumers were shifting to ready-mixed paints despite widespread suspicion over "adulterated" products. Re-assessing its interests in the new context of consumer protection, the Association promoted a new marketing and advertising discourse which amounted to a radical change in the industry's self-portrayal. Rather than parroting the lead manufacturers' discourse of old masters-sanctioned, pure-white-lead products, the Association attempted to turn a major liability – its dependence upon inferior materials like alumino-silicates – into an asset. After all, didn't "science" – in the form of ASTM-sanctioned testing methods – prove that adulterated paints could actually perform better than pure paints? Harrison Brothers was among the first companies to embrace this strategy. In the early 1910s the company edited several brochures intended for their dealers and retailers. "The Truth About Paint", and "Cause & Effect", two brochures that have survived, explain why a diversity of pigments is good for durability and include photographs of the company's laboratory facilities, including the recently acquired microscopes (figure 2).

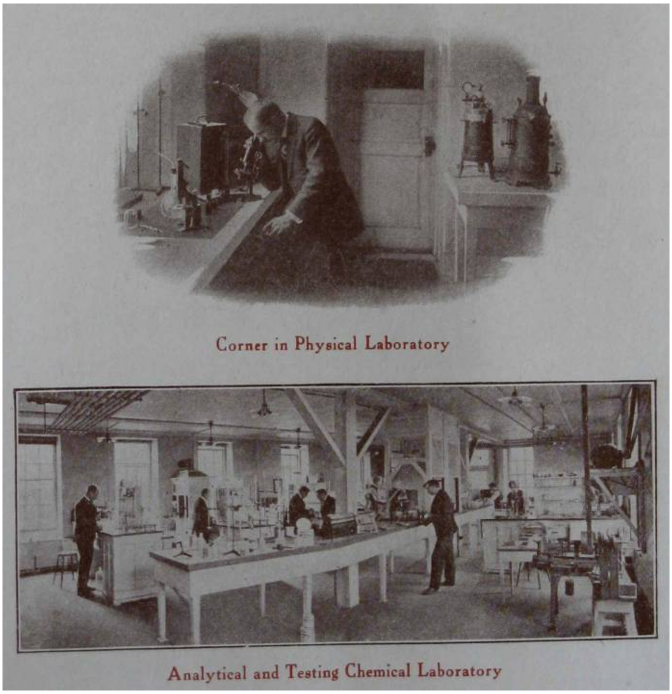

Figure 2 - Extract of the Harrison Brothers advertising pamphlet "Cause & Effect – a Preachment on Paints". (Source: Courtesy of the Hagley Museum and Library)

The modality of exposure tests, under the supervision of "disinterested" parties, enabled Harrison Brothers to portray the claims presented in the pamphlets not as commercial arguments, but as scientific facts.[15] Others manufacturers followed, such as Toch Brothers Co., whose key product, branded R.I.W. – for "Remember, It's Waterproof", was claimed to be scientifically prepared in the laboratory of the company. "Pure paint" advertising did not disappear overnight, of course, but gradually faded away during the 1910s and 1920s.

ASTM and the Paint Manufacturers Association issued circulars recommending the adoption of a new nomenclature for paint materials: formerly despised "adulterants" were christened "reinforcing pigments", "extenders" or "inert fillers". The new terminology thus conveyed a neutral or positive overtone depicting the variety of minerals, besides lead and zinc, that entered paints' composition. Guidelines for branding also departed from the obsession with purity: "*Commercially pure* – The use of this term should be avoided if possible" (Gardner, 1915, p. 64). More importantly, ASTM redefined the meaning of "adulteration" and "adulterant": "a substance substituted partially for another without acknowledgment", putting aside the issue of performance.

In early 1910, Senator Weldon Heyburn (1852-1912) from Idaho introduced a paint-labeling bill in Congress, modeled on Ladd's North Dakota bill. Heyburn had previously and successfully introduced the bill which would become the Pure Food and Drug Act. The paint bill however failed to pass Congress. One of the decisive arguments put forth by witnesses to prevent the bill's enactment was that mandatory labeling would unduly stigmatize valuable materials. Manufacturers' representatives could rely on a body of data demonstrating their value, and also plead their willingness to reform the paint trade to get rid of the "evil practices" of the past.[16] In Sep-

[15] Letter, T. J. Armstrong to John Doe, May 15, 1913, Hagley Museum and Library, Charles Demirjian Collection, Box 1, Harrison Brothers advertisements; "The truth about paint", and "Cause & effect", *Ibid.* A section of the pamphlet read : "We wish we could have space and your indulgence to allow of a description of the many pigments that go into our products and why they are used. That, however, is impossible here. Suffice it to say that the scientific and progressive manufacturer has been forced to the conclusion after long and careful experiment that the all-perfect pigment has yet to be found. No one pigment which we know now can, used alone, produce a paint capable of withstanding the wide variations of climate and extremes of temperature of this country".

[16] Congress, House, Interstate and Foreign Commerce Committee, Hearings on H.R. 21901, Manufacture, Sales, etc., of Adulterated or Mislabeled White Lead and Mixed Paint, 61st Cong., 2d sess., 31 May 1910.

tember of that same year Anderson Polk, chief chemist at a major paint company and a long-time member of ASTM, addressed the Master Car and Locomotive Painters Association in St-Louis. His lecture was entitled "Inert Pigments – Their Use and Abuse", and Polk enjoined the painters and manufacturers to welcome rather than decry inert pigments, and to consider paints as a material that can be designed to fit a specific application:

> A great deal of talk has been made concerning the purity of paint; this is an anomaly. We may talk of pure gold or pure linseed oil, or pure turpentine, but one cannot talk about pure shoes, or pure carpets, or pure furniture; there are some ingredients in paint, such as carbonate of lead, oxide of zinc, that are supposed to be pure when as a matter of fact they cannot be absolutely pure under the methods by which they are manufactured. Paint is a mixture of solids and liquids; ingredients that are put into it are for the purpose of making it accomplish something to be desired. That something is to protect and beautify it. Therefore, it is apparent that it does not matter what goes into the paint so long as the consumer is not deceived, and so long as the paint accomplishes its desired purpose, e.g. some paints are designed for painting buildings, some for barns, some for cars, some for bridges, some for signal blades, some for interior decoration, such as painting walls, floors, woodwork and furniture; therefore it is necessary first of all to design the paint for the particular purpose for which it is to be used. (Polk, 1911, p. 27-28)

Thus, in 1910 the paint labeling controversy brought an issue before the federal courts that reform chemists had confronted for several years. In the process, an inherent ambiguity that propelled the pro-paint labeling movement was settled: for what did Ladd really condemn, the discrepancy between the grandiloquent ads and the actual composition of stuff, or the very presence of – supposedly detrimental – "substitutes" into the composition of paints? ASTM and the Paint Manufacturers Association had marshalled sufficient evidence to prove, including in court, the importance of "adulterants" for paints' material performance. Among his colleagues in the chemical profession, Ladd became isolated in his stance on paint labelling.

Conclusion

Chemists' standing and authority within the paint trade and industry changed dramatically at the turn of the 20th century: from "consultants and testing slaves", per the phrase of historian James Donnelly, to central figures in the promotion of innovation, economic development, and regulation. This generation of chemists rejected what they pejoratively called the "doctrine of purity" in the paint trade (Hugues, 1911). They gathered around ASTM and the Paint Manufacturers Association, and pushed for a full-fledged recognition and integration in academia. The paint and varnish division of the American Chemical Society was established in 1923, and a community of paint chemists equally represented in academia and industry solidified. The relationship between paints' microstructure and physical properties, as raised by Dudley and Gardner, became a major research avenue for this community. For this, chemists relied heavily on colloid chemistry and physics, as testified, for instance, by the research program launched by DuPont in the mid-1920s (Cerveaux, 2013, p. 262-288). While color and decoration absorbed these chemists, protection rose in prominence as a function for painting, and became a major objective of their research programs.

The process of industrialization thus triggered changes that stood at odds with the idea that painting was mostly an ornamental and decorative trade, different in nature from the mechanical arts and crafts. Unlike the painters of earlier times, chemists and engineers in the 20th century treated paint no differently than civil engineers and masons would treat concrete: as a reliable material able to fulfill definite functions – namely, the protection and decoration of a variety of surfaces and materials. During its eighteenth annual meeting in 1915, ASTM redefined paint as "a mixture of pigments with vehicle, intended to be spread in thin coats for decoration or protection, or both" (Gardner, 1915, p. 66). A few decades before, painters or chemists would have found this definition jarring. The distinction between paints and varnishes faded: paint, redefined as a coating, came to encompass both terms. This shift in representation was followed by an organizational shift in which Gardner and Heckel played no small a role: the Paint Manufacturers Association merged with the National Association of Varnish Makers in 1933, to be renamed the National Paint, Varnish, and Lacquer Association.

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Table 1 - Biographical elements of chemists who shaped modern paint chemistry and technology in America (in alphabetical order of name followed by the date of birth)

Éducation	*Career*
Abbott, George Alonzo (1874) 1895: B.S. chemistry, Depauw U. 1896: A.M 1908: Ph.D., MIT	1896-1908: High school teacher 1908-10: Asst prof., North Dakota Col. 1910-: Prof.
Barker, Louis H. (?) ?	1898: Pennsylvania Railroad Co. 1905: ASTM committee E member
Cushman, Allerton S. (1867) 1888: B.S. Worcester, 1889-1890: Freiburg, Heidelberg 1897: A.M. Harvard 1898: Ph.D. Harvard	1892-96: Instructor chem., Saint Louis, Washington 1898: Asst prof. Harvard 1899-00: Asst prof. Bryn Mawr 1901-10: Asst. dir., div. of tests, office of pub. records, USDA 1910-: Director, Inst. of Ind. Research, Washington, D.C.

Dunlop, Frederick Levey (1870) 1892: B.S. Michigan 1895: Sc. D. Harvard 1896: Yale	1896-00: Instr. Industrial chem., Worchester 1900-01: Instr. Inorg. Chem. (Michigan) 1901-07: Instr. anal. chem. Michigan 1907-12: Assoc. chemist, USDA bur. Chem., board of food&drug inspection 1912-16: Consulting chemist, Victor chem works
Dudley, Charles B. (1842) 1875: PhD, Sheffield Scientific School, Yale	1875- : Chemist, Pennsylvania Railroad Co. 1898: ASTM founding member 1902: ASTM president, committee E member and secretary
Gardner, Henry Alfred (1882) 1902: Brown 1903: U. of Penn.	Around 1905: Scientific section, P.M.A., Harrison Bro. Co. 1910: Dir., scientific section, educ, bureau, paint manufacturers assoc. of the US Institute of Paint and Varnish Research, Washington D.C.
Gregg, Norris B. (1856) Washington University, Chemisty	1877-81: Chemist, Southern White Lead Works, Saint Louis 1882-: Chemist, Mount City Paint & Color Co. ?-: President, Mount City Paint & Color Co. ?-: President, P.M.A.
Havens, Franke S. (?) 1896: PhD Chemistry, Yale	?-: Chemist, Harrison Brothers, R.S. Perry assistant, technical matters
Holley, Clifford Dyer (?) 1900: B.S., Maine 1902: M.S. 1904: Ph.D., Michigan	1901-04: Chemist, Maine Experiment Station 1904-07: Prof. ind. chem., North Dakota Agri. Coll. 1908-...: Chief chemist, Acme white Lead & Colors (Detroit)
Holton, E.C. (?) ?: MIT	1898-1930: Chief chemist, Sherwin Williams Co., Cleveland 1902- : ASTM committee E member
Hooker, Albert Huntington (1865) Hon. M.S. Rochester 1920	1889-90: Chemist, Dighton Color Works 1892-93: Opaque Shade Cloth Co. 1894-06: Chief chemist, Heath&Milligan Manuf. Co. 1906-11: Works manager, Hooker Electrochemical Co. (Buffalo, NY) 1911-: Technical director ? - : ASTM committee E member
Job, Robert (1866) 1890: A.B., Harvard	1892-06: Chemist, P. and R.R.R. 1905- : ASTM committee E member 1906-10: Chemist, Booth, Garrett & Blain 1910-: Vice-pres. Milton Hersey Co.
Ladd, Edwin F. Ladd (1859) 1884: B.S., Chemistry, U. of Maine	1884-90: Chief chemist, New York Experiment Station 1890- : Chemist, North Dakota Agricultural college and experiment station 1916: President, Agricultural college and school of chemistry and pharmacy 1921: US Senator, North Dakota
McNaughton, Malcolm (?) ?	?: Dixon Crucible Co., paint and lubricating department superintendent 1902: ASTM member committee E

Nemzek, Leo P. (?) ?: B.S., North Dakota U.	?: North Dakota Experimental Station Around 1910: Chief Chemist, John Lucas & Co., Philly Around 1910: Oil and flax seed analysis, P.M.A. Around 1919: Technical director, Paint dpt., Du Pont Co.
Perry, Robert S. (?) ?: Lehigh University-Chemistry ?: Royal School of Mines, Freiburg, Germany	1898: Vice-president, Harrison Bro. & Co. 1905: Exposure panel tests, P.M.A.; Scientific section, P.M.A.
Polk, Anderson W. (?) ?	1898: Chemist, Lowe Brothers Co. 1902: ASTM committee E member
Sabin, Alvah Horton (1851) 1876: B.S., Bowdoin 1879: M.S.	1876-80: Prof. chimie et physique, Ripon 1882-86: State chemist, Vermont 1897-…: Lecturer, paint and varnish, N.Y. U. 1910-38: Consulting chemist, National Lead
Schaeffer, John A. (1886) 1904: A.B. (U. of Penn.) 1905: A.M. 1908: Ph.D. (chem.)	1908-11: Prof. Carnegie Inst. Of Tech. 1911-20: Research dir., Eagle-Picher Lead Co. 1920-…: Vice-pres., Eagle-Picher Lead Co.
Thompson, Gustave Whyte (1865) - no college education 1927: Hon. PhD, Armour Institute	1902: ASTM committee E member and secretary 1892-19: Chief chemist, National Lead Co. 1919-20: Vice-prs William Harvey Corp. 1920: dir., Titanium Pigment Co.
Toch, Maximilian (1864) 1884-1886: NY U. chemistry (under prof. John W. Draper) + Law School of NY U. LL.B. 1887-1890: Columbia U. (bacteriology & micro-chemistry) 1887 étudie avec Ostwlad et Witt en Allemagne	1887: Toch Brothers Co. 1904: ASTM committe E member 1905-06: Lecturer organic chemistry, Columbia 1909: Municipal lecturer on paint, Col. City NY 1925-35: Prof. chem. artistic painting, National Academy of Design, NYC 1917-19: In charge of camouflage, USA
Walker, Percy Halgrave (1867) 1885-1887: Virginia 1895: M.S., Iowa 1896-1897: Heidelberg & Berlin	...-1904: Prof. assistant multiple colleges 1904-06: Assayer, USDA Bureau of Chemistry 1906-16: Chief contract Lab USDA Around 1913: ASTM committee E secretary 1914-37: Bureau of Standards

Source: biographical information gathered from Heckel, *Paint Industry*, *op. cit.*; Ernest T. Trigg, *Fifty-five colorful years*, The Pequot Press, 1954; James Cattel and Dean R. Brimhall, *American Men of Science: A biographical directory,* 3rd edition, The Science Press, 1921; *ASTM Proceedings,* 1903-1906.