Meeting the Challenge of Radical Change: Coatings R&D as We Enter the 21st Century

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In early 1980's, the late Dr. Marco Wismer, one of the coatings industry's more visionary members, enunciated "Six Strategic Goals for the Coatings Industry" which have never been far from our collective thoughts in the years since:[1]

WISMER'S SIX STRATEGIC GOALS

1. ***Corrosion Protection***
2. ***Elimination of Solvents***
3. ***Conservation of Energy***
4. ***Reduction of Toxic Wastes***
5. ***Cost Reduction***
6. ***Improved Durability***

Although stated over fifteen years ago, these six goals are more valid than ever in 2001, and it is clear that the various global coatings marketplaces, both industrial and consumer, are seeking (in some cases, *struggling*) to provide positive, proactive, and economically viable realizations for each of these goals. The extent to which any given market segment is succeeding varies, of course, but these goals seem to be clear to almost everyone, almost everywhere. The challenges are many, and the solutions demand, in many cases, new—even radical—responses from the coatings industry. Of course the coatings industry cannot "go it alone," and we must engage the cooperative support of both our suppliers and our customers if we are to benefit from the full spectrum of creative insight regarding potential new approaches to these goals. In this paper, I would like to offer my views regarding "where we are," as a global industry, "where we might be able to go," and "how we might be able to get there."

ENVIRONMENTAL CHALLENGES

Today, in the first year of the first decade of the first century of the Third Millennium, I am reminded of a statement made by my colleague, Dr. J. D. Remijnse, on the occasion of his presentation to the *Third International Paint Congress* in Sao Paulo, Brazil, on 6 September, 1993: "Faced with a great groundswell of public opinion and the first tangible effects of years of environmental neglect, governments around the world are tightening up environmental legislation at a rate that sometimes takes our breath away." Environmental issues are no longer "topical"—they are here to stay, and they affect, to one degree or another, every aspect of the global coatings community. Traditionally, "environmental" concerns have meant "lower VOC's," but today the phrase connotes a wide variety of issues, from elimination of the use of hexavalent chromium to identification and elimination of endocrine disrupters. Some of these issues are of greater concern in certain parts of the globe, and others in different parts—but all will need to be addressed eventually.

One of the major challenges facing the North American coatings industry, for instance, arises from a variety of local and national environmental concerns which are active in Canada, the United States and Mexico, but particularly in the U.S., on which these comments are

 CCC 1022-1360/00/$ 17.50+.50/0

principally based. Issues of major concern at the Federal level include Hazardous Air Pollutants (HAPS) and its subset of heavy metals, which are also the subject of separate State and Local legislation, as well. The HAPS list is comprised of ~188 materials (subject to change) targeted by the USEPA for substantial reduction, per the Clean Air Act Amendments (CAAA). This list includes many common coatings solvents (Volatile HAPS ["VHAPS"]), but also includes heavy metals, toluene diisocyanate (TDI), coke oven emissions, etc. VHAPS are volatile organic compounds (VOC's)—but not all VOC's are HAP's. Examples of the latter would include ethyl-3-ethoxyproprionate, propylene glycol ether acetate, dibasic ester, and several others. Under current U.S. laws, the EPA is required to develop a variety of MACT ("maximum available control technology") Standards and Proposed Rules by various deadlines for various industries, such as wood, coil coatings, general metals, *et al.* Although some of the Final Rules are pending, the program could be objectively characterized as being "on-track," but not without incident.

. . . The heavy metal issue, however—whether as addressed by HAPS legislation or other federal, state or local legislation—may be even more difficult to resolve. While it is not possible to be comprehensive in this paper, the metals which are subject to the most intense scrutiny in both North America and Europe are lead, cadmium, mercury and hexavalent chromium. At the moment, the most active legislation in the United States is taking place in the State of Minnesota, where paints and coatings containing these metals were banned as of 1 July, 1998. Of particular interest, not just in North America, but globally, has been the use of hexavalent chromium ion, particularly in the form of zinc and strontium chromate corrosion-inhibitive pigments in coil and spray industrial primers. Currently, hexavalent chromium is ubiquitous in two areas of industrial coating: pretreatments and primers. Because "chrome VI" ion possesses unique corrosion-inhibiting properties on a variety of metallic substrates, it is not at all clear where—or even if—its usage can be eliminated or substantially reduced in the North American marketplace. Both the pretreatment suppliers and the coatings community have been hard at work on "chrome-free" systems for the better part of twenty years, but only with mixed results. One of the serendipitous properties of chromate inhibitive pigments is that they tend to work over multiple substrates, but this has not proven true with either the so-called "white pigments" which are being proposed to replace hexavalent chromium pigments in chrome-free primers, or with the non-chromate chemistries which are being explored in "chrome-free" pretreatments. There has certainly been a certain amount of success in the aluminum arena—both chrome-free pretreatments and primers are commercially available from multiple sources, and are being used on a daily basis. Their quality seems to be acceptable, although they tend to be less user friendly than the chromate-containing products which they replaced.

Once we enter the steel arena, however, the scenery changes. In the coil coatings industry, a substantial user of both chrome-containing primers and pretreatments, there does not appear to be any commercial use of either chrome-free pretreatments or chrome-free primers over cold-rolled steel (CRS) in North America at the present time. This statement is basically true, with a few exceptions, with regard to hot dipped galvanized steel (HDG), although there is considerable research activity being conducted in this area by the pretreatment suppliers, and—perhaps to a lesser degree—by the primer suppliers. Since a certain level of success has been reported in Europe, particularly in Italy and Austria, it is to be hoped that the North American activity will prove successful, as well, but this is by no means assured. The North American, South American, Australian and European marketplaces frequently have different expectations of similar products, and it would not be surprising, therefore, if a "solution" for one marketplace were not automatically considered to be an acceptable solution for another. The current outlook for chrome-free pretreatments and primers for zinc/aluminum coated steel is not particularly positive, however. Certain combinations of chrome-containing pretreatments with chrome-free primers, and chrome-free pretreatments with chrome-containing primers give rise to cautious optimism, but the current state of performance for chrome-free primers over chrome-free pretreatments leaves much to be desired. (A pithy American phrase, "the wheels come off," is fairly descriptive of the current state-of-the-art.) Where will this lead? At the moment, no one can know. The state of Minnesota is granting both permanent and temporary exemptions, on a case-by-case basis, for the use of hexavelant chromium in both pretreatments and primers intended for steel surfaces. For at least the next few years, other rule-making governmental bodies are likely to do the same. At some point, however, U.S. industrial applications may be required to run "best available" technology, whatever that means. If such a requirement were applied uniformly throughout North America, this may be an acceptable solution, but if it were not—if "chrome-free" production were forced to compete with chrome-containing production—the suppliers of the chrome-free products may face insurmountable obstacles to successful competition in the North America marketplace. It would take true mastery of a crystal ball to predict where the "chrome-free" movement will end-up, and I suspect that, ten years from now, this will still not be a completely settled issue. Different parts of the globe will respond in different ways and at different rates, and will consider different scenarios to represent "the solution." Based upon everything generally known at present, it is likely that the EU countries will arrive at a "chrome-free" solution first, followed by North American, Australia, Japan and, finally, the "rest of the world." Part of the difficulty in making a confident transition to chrome-free status revolves around the fact that the anticipated performance of new systems is being assessed through the use of traditional accelerated "performance prediction" methodologies. Well-founded controversy, however, rages around the meaning and value of many such testing regimes.

ACCELERATED PERFORMANCE PREDICTION

George Orwell, in his famed 1949 novel, ***Nineteen Eighty-four,*** maintained that if one repeats a statement often enough, it will come to be believed *even if it is obviously and patently untrue.* The world saw many living examples of Orwell's premise when the iron-curtain countries of the world were at their zenith, and our own industry has succumbed, to a degree, to the Orwellian curse. Consider, for example, the following examples of conventional industry wisdom:

- Salt spray testing predicts "real world" corrosion performance
- Accelerated U-V devices predict "real world" durability
- "Falling Sand" tests predict "real world" coating erosion rates
- Etc., etc., etc.,—*ad nauseam*

George Orwell was no dummy....

Even though the preponderance of evidence would suggest that none of the above are true statements, they are nonetheless believed by many coatings manufacturers and users, and no greater evidence of this exists than the presence of these tests in a wide variety of product specifications. This is partly understandable, insofar there are no other tests universally regarded as being more predictive of corrosion activity, exterior durability, abrasion resistance, etc.—but it does place the entire research community at the mercy of testing methodologies which (at best) are unreliable and (at worst) may be downright misleading. Attempts to predict the "real world," using accelerated methodologies are fundamentally flawed, although such tests—when used as part of a much larger research protocol, in conjunction with other accelerated tests, actual exterior exposure panels, and interpreted in the light of sound chemical and performance models—may produce helpful "pieces of the puzzle." Reliance on only one or two accelerated tests, such as salt spray, will serve no purpose other than to inhibit progress toward viable long-term solutions to the economic, performance and environmental goals which are being pursued by the global coatings community.

The area in which accelerated methods have traditionally been most used and abused has been in weathering prediction. In 1977, the Cleveland Society for Coatings Technology organized a symposium entitled "Accelerated Weathering: Myth vs. Reality." (In fact, one of my colleagues at Akzo Nobel, J. A. Chess, was a co-author of a paper presented at that meeting.[2]) The title of that symposium certainly spoke volumes about the state-of-the-art with regard to accelerated weathering two decades ago, but I doubt that some of the papers presented at that meeting so long ago would be seriously out of place at this meeting today. We've certainly generated a lot of data in the twenty-four years since that meeting, but do we know any more about accelerated weathering now than we did then? Perhaps. . . . . but we have only moved forward incrementally; no "silver bullets" have been discovered during the past quarter century, nor has anyone postulated a "unified weathering theory" pulling together all known information on the chemical and physical mechanisms by which diverse materials degrade, and how such degradation processes may be accelerated and correlated with "real world" results. Still, progress has been made in certain areas, and we must be prepared to use the products of this progress to optimum advantage. Based upon the results of correlation studies with outdoor weathering prepared by all of the companies that eventually comprised the North American Coil Coatings Business Unit of Akzo Nobel, my colleagues and I feel that—although no accelerated test is an infallible predictor of "real world" conditions—there are six statements that we believe to be not only true, but deeply important to the future health of our industry:

What We Believe About Durability Prediction[3]

- ***The best predictor of durability is real-time exposure in the location where the coating will be installed.***
- ***The second-best predictor is real-time exposure in Florida at 45° facing south (for roofs) and 90° facing south (for sidewalls).***
- ***The (distant) third-best predictor is one of several available accelerated weathering devices; mounting evidence suggests that UV-A, Fresnel-type, and Xenon Arc are the most reliable.***
- ***Accelerated weathering data is only valuable when it is placed into a proper context by skilled coatings scientists, who use it as one of several tools at their disposal to predict long-term weathering effects.***
- ***No accelerated weathering device, when used in a "stand alone" fashion, can predict real world weathering with any level of accuracy.***
- ***Even the "real world" is a kind of myth—ever changing climatic, atmospheric, environmental, chemical, thermal and other considerations render the "real world" a dynamic exposure site.***

This is our creed, based upon over thirty years' worth of serious attempts to correlate accelerated weathering tests with the "real world"—whatever that is. It applies specifically to coatings for metal building product components, which are applied by the coil coating process and thermally set or cured, although my guess is that our creed can probably be applied to all exterior coatings, regardless of chemical type or application method. Our work has benefited from the scientific inquiries and different practical approaches of several companies, since Akzo Nobel's current worldwide Coil Coatings organization is the product of a series of mergers, beginning in the late 1970's, which eventually involved the Wyandotte Paint Co., Pontiac Paint, Hanna Chemical Coatings Corp., Celanese, Reliance Universal, Akzo Coatings, Midland Dexter, Svensk Färgindustri, Nobel Industrial Coatings, and Courtaulds. Each organization brought its own theoretical and experimental approach to the table, and each brought the results of its empirical testing, as well. Our current work is able to draw upon information generated by tens of thousands of exterior exposure panels exposed in over two dozen "UV," "aggressive chemical," and "corrosion" sites worldwide. It is upon these panels that we have based our current beliefs.

Not only is durability difficult to predict—it is difficult to define. "Durability" is often in the eyes of the beholder. There are parts of the world where rapid gloss loss of exterior coatings is valued because the coating has reached its "final" color very early in its life cycle and its appearance can be expected to remain relatively unchanged with time. In other areas of the world, however, rapid, precipitous gloss loss might cause the local denizens to clutch their chests because they prize the appearance of a glossy building and their concept of durability transcends mere color stability. Clearly, *appearance* depends upon far more than just color, and here's where the complications begin—"durability" is a concept which involves freedom from some combination of color change, gloss change, chalking, cracking, crazing, blistering, peeling, etc., etc., etc., but that "special combination" may differ from observer to observer, or market to market. Since no two observers can be reasonably counted upon to agree on the exact weighting of these various factors, they must all be tested for, and it is desirable that they all be "predictable."

Over the years, in pursuit of this "predictability," the coatings industry worked with just about every predictive methodology—and every piece of predictive equipment—which has come along. Witness the evaluation of accelerated testing methods from 1906 to the present:

- ***1906—North Dakota Agricultural Experiment Station***
  This was the first test site for comparison of coatings in this country. Over time, this exterior test method moved to Florida and became ASTM G-7. Today, 5, 45, and 90-degree testing are common, along with black box, direct, and heated methods of testing.
- ***1918—Fade-Ometer***
  First used for textiles, this was a dry test method and is no longer used for coatings. The carbon arc used did not achieve sufficiently short wavelengths for correlation with exterior exposure.
- ***1927—Weather-Ometer***
  Water spray was added to the Fade-Ometer for improved results. However, the light distribution was still very poor.
- ***1933—Sunshine Carbon ARC Lamp***
  This is the "Weather-Ometer" or "Atlas Weather-Ometer," as it has commonly been known for at least the past quarter century. The spectral light distribution from this equipment delivers considerably more energy than was obtainable before, but provides a poor simulation of natural sunlight in the UV region. Filters are, consequently, used to help improve the correlation. Two different types of filters are currently in use—the 2.5mm Corex 7058 and the newer 3mm Pyrex 7740 type. All types of carbon arc accelerated weathering are now covered by ASTM G-23.
- ***1960—Xenon Arc Lamp***
  With filters, the "Xenon Arc" spectral light distribution places it in the position of being one of the best light sources for accelerated weathering. This method, covered by ASTM G-26, can reasonably approximate sunlight in both the UV and visible light range. The equipment, however, is both expensive to purchase and expensive to operate.
- ***1960—Equatorial Mounts with Mirrors***
  Fresnel-type testing (commonly referred to as "EMMA" or "EMMAQUA") is a method of employing natural sunlight as the source of light but concentrating it with mirrors. With the addition of airflow for cooling and water spray for moisture, quite reasonable

correlation to natural weathering has been reported. The most important factor for correlation has been to record only UV light exposure as MJ/M^2, rather than as total light exposure, reported in Langleys. ASTM G-90 covers this test method; both "night time" and "day time" wetting methods are used, with "night time" giving results which are significantly closer to Florida exposure, in our opinion.

1965—Dew Cycle Weather-Ometer

The development of coatings with greatly improved durability made normal carbon arc exposure methods too time-consuming. The "Dew Cycle" method, covered by ASTM 3361, is based on the assumption that, when both moisture and radiant energy are present at the same time, the most rapid film degradation takes place. To maintain humidity during the dark period, cold water is sprayed on the back of the test panels. Also, to speed-up results, the filters are removed to increase the intensity of the light.

- ***1970—Fluorescent UV Condensation***

  This relatively inexpensive method of accelerated weathering uses fluorescent UV lights in a humidity condensation apparatus. It had, however, the same "excess UV light" drawback as an unfiltered Atlas Weather-Ometer. In 1987, a new bulb, QUV-A 340, was introduced which gives a good match to the short wave bands of UV in sunlight.
- ***1985—Predicting Coating Durability with Analytical Methods***

  Several papers have appeared, since 1985, which examine short-term exterior exposure panels with a variety of analytical methods used to follow chemical changes in the coating. The goal has been to predict the service life of the coating without using harsh or misleading acceleration factors. To date, the methods have worked best with basecoat/clearcoat systems. It is not yet certain how effective this approach will be with low gloss pigmented systems, but this work looks very promising.

The truth is that there is no "silver bullet"—no single, infallible predictor of outdoor durability, but there are some weathering devices which, when placed into the proper context and interpreted by expert coatings specialists, greatly increase the confidence level with which outdoor durability can be predicted. One such device is the QUV-A Weathering Tester, originally engineered and marketed by Q-Panel Lab Products, a leading company which has traditionally been on the cutting edge of accelerated testing methodology, whether radiation-related (UV-A and UV-B), cyclic corrosion, or condensing humidity. Q-Panel engineered both of the fluorescent-UV/condensation testers which the coatings industry commonly refers to as "QUV-A" and "QUV-B." Here is what Q-Panel has to say about these two devices:

> *UV-A's are especially useful for tests comparing generically different types of polymers. Because UV-A lamps have no UV output below the normal solar cutoff of 295 nm, they usually do not degrade materials as fast as UV-B lamps. However, they usually give better correlation with actual outdoor weathering.*[4]

At the time that QUV-A was introduced, "QUV" testing was being done by nearly everyone, but wasn't designated as "UV-B" testing. A lot of people felt that it ***was*** the silver bullet, and—for certain systems, under certain conditions—perhaps it was. Nonetheless, the opinion that the ubiquitous QUV-B tester was not perfect and might be improved upon was not an opinion unique to its creators; in the late 1980's, it was being echoed throughout the industry. After comparing the weathering of automotive clearcoats in three different accelerated weathering instruments (carbon arc, xenon arc, and UV-B), Dr. David R. Bauer, Ford Motor Company's internationally-reknowed coatings scientist, and his colleagues found that ". . . .since the degradation chemistry that occurs in these tests is unnatural," none of these devices were acceptable for the coatings that Ford was testing. Dr. Bauer concluded, "although acceleration factors can be calculated (based on amide II signal loss rates) they cannot be used reliably to predict service life."[5] This was reinforced, nearly a decade later, at the Spring, 1996, European Coil Coating Meeting, by Dr. G. C. Simmons of Becker Industrial Coatings: "It is now established fact that they [ASTM B117 salt spray and QUV-B] do not correlate well to natural exposures, and in some specific cases can lead to totally wrong conclusions being made."[6]

Nothing has occurred, in the fourteen years since Dr. Bauer's comments, to change my own thinking with regard to dissatisfaction with broad use of the weathering devices utilizing UV-B bulbs. In fact, it was reinforced by Ford's Dr. John L. Gerlock at a major scientific gathering in 1997 when he indicated that an FS40 bulb (UV-B) might be "good for studying the aging of the Taurus in low earth orbit," but not on the earth's surface.[7] Nor have such observations been limited to the automotive and coatings industries. In an important study by 3M Company, in which an attempt was made to develop an accelerated weathering test for films using two types each of carbon arc and UV-B bulbs, the researchers concluded that the results indicated "poor predictive ability using any of the laboratory devices."[8] They further noted that Spearman ranking of the results from the UV-B samples ranged from "perfect correlation (1.0) to an almost complete reversal (-0.8) with essentially random scatter in between."[9] 3M's conclusion was that "commonly used cycles in carbon arc and fluorescent UV-condensation [UV-B] test equipment exhibited generally unacceptable correlation levels for these materials."[10] A major study by Dr. Carl J. Sullivan of ARCO Chemical Company (UV-A, UV-B, carbon arc and xenon arc) seconded this opinion: "These four accelerated test procedures yield contradicting conclusions on the weatherability of these four resin systems."[11] Dr. Sullivan notes that "the Florida exposure data clearly corroborate conclusions drawn from A-340, Xenon, and EMMAQUA studies and contradict B-313 results."[12]

While it is true that UV-B testing certainly accelerates the aging and degradation processes, it may—depending upon the coatings system—be accelerating the wrong chemistry, thereby vitiating any value that the information might provide, and, consequently, discrediting the test. Our own work has repeatedly shown that UV-B testing is so riddled with anomalies that—even when its predictions are in the right church—they are only rarely (and possibly coincidentally) in the right pew. It was this general lack of correlation with real chemical reactions and authentic exterior weathering results that led to the development of the UV-A lamp testing devices, which correlate more closely with sunlight. This was a very important advancement because many of the most durable coatings in the "real world" are unnaturally damaged by the more destructive short wavelength of UV radiation below 295nm that is emitted by UV-B—radiation which **does not occur** in natural sunlight.

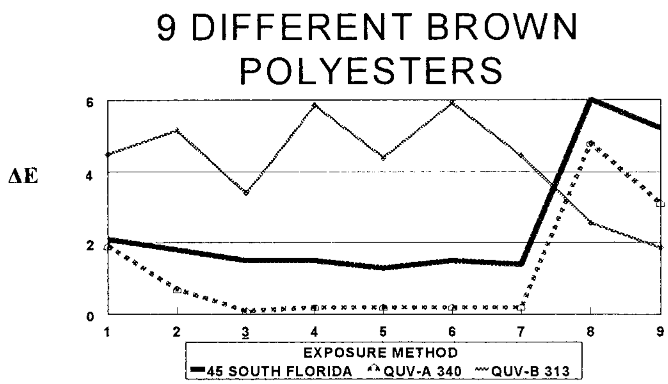
Even the American Society for Testing Materials (ASTM), which usually maintains a discreet silence on the appropriateness of its testing methods, allowed the inclusion of the following comments under the "non-mandatory information" section of Standard Method G53, "Standard Practice for Operating Light and Water Exposure Apparatus (Fluorescent UV-Condensation Type) for Exposure of Nonmetallic Materials," which is followed by laboratories around the world for running UV-A and UV-B accelerated testing:

> *All UV-B lamps emit UV below the normal sunlight cut-on.* [sic] *This short wavelength UV can produce rapid polymer degradation and* ***often causes degradation mechanisms that do not occur when materials are exposed to sunlight. This may lead to anomalous results***. . . . *For certain applications, the longer wavelength spectrum emitted by UV-A lamps is useful. Because UV-A lamps typically have little or no UV output below 300 nm, they usually do not degrade materials as rapidly as UV-B lamps, but* ***they may allow enhanced correlation with actual outdoor weathering***.[13] (Emphasis the author's.)

In the course of the work which my colleagues and I have done at Akzo Nobel, we certainly haven't found the mythical "silver bullet" but, in UV-A testing, we have definitely found an accelerated device which has enabled us to make surprisingly accurate predictions of the "real world" behavior of experimental polymer systems, and—especially—of modifications to existing polymers. We have not, however, found UV-A accelerated exposure to be especially valuable for the prediction of the service performance of pigments, but we are not disappointed or disillusioned by this fact either. Although little generalization can be made about the huge group of different chemistries, both inorganic and organic, that make up the group of coatings components which are collectively referred to as "pigments," it seems clear that their performance can be so dramatically affected by chemical environments which are present at various places on the surface of the earth that it cannot be predicted with a high level of confidence by testing devices which lack these specific chemical atmospheres. (Xenon arc testing, which adds infrared and visible light components absent from UV-A testing, may prove helpful in evaluating the service life of pigments, albeit at a significantly higher operating cost—and still without benefit of the localized chemical environments at work in the "real world".) It would be nice to compare "brown coatings X, Y, and Z" from different sources based on different polymeric systems in a simple weathering device, but obtaining meaningful, valid data from such attempts is more wishful thinking than sound science.

Perhaps the most attractive aspect of UV-A testing, at least in our own program, has been the consistent absence of ***truly damaging, seriously misleading*** data. This was the most treacherous aspect of our past work with such devices as the dew cycle carbon arc tester and the UV-B tester. While not ideal, we can all live with systems that look bad in an accelerated test but good in "real life." The worst that can happen is that we fail to sell a good product. If we were to believe anomalous testing results, however, that predicted ***good*** weatherability and went to the market with what turned out to be a ***bad*** product, this could spell disaster. ***This does happen, however***. We found many examples of coatings that looked good in an accelerated test, but poor under actual exterior service life conditions. This, of course, is the worst possible scenario. We have seen cases where dark brown plastisol films, based on poly(vinyl)chloride (PVC), have compared favorably in UV-B exposure to similarly pigmented dark brown fluoropolymer films, based on poly(vinylidene)fluoride (usually abbreviated "PVDF" or "PVF_2"). Plastisol coatings have a very definite specialized niche in the building product marketplace, which they serve admirably, but no one expects them to perform over time at the level of a fluoropolymer—nor do they. In another dramatic case involving new, experimental polymers, we ran multiple accelerated tests that we were able to correlate with Florida. As can be seen from the data, if we had taken samples No. 8 and 9 to the marketplace based upon UV-B results, we would have been making a grave mistake. ***(See Figure)***

These disappointing results occurred because the new polymers were partially based on a relatively new, low-use cycloaliphatic monomer which does not absorb UV radiation in the 280-295nm range, where UV-B does its greatest damage. For this reason, these polymers looked wonderful in the UV-B test, even though they did not look acceptable under actual service conditions, where other factors—most likely the twin gremlins, "heat" and "humidity"—were apparently at work. The manufacturer of this monomer later included this *caveat* in its product literature: "The use of QUV-B 313 is not suggested as a screening tool because the low-wavelength portion of the exposure spectrum can lead to anomalous results."[14]



SAMPLES

The fact that even the UV-A failed to predict the full extent of the poor field performance of these polymers, based on new, unusual chemistry, leads us to another important aspect of "what we believe":

Accelerated Weathering Devices Only Have Proven Value—

- ***When testing materials which are very similar to other materials for which correlation factors with real-time outdoor exposure at a variety of test sites have already been established;***
- ***When they are used in conjunction with other "real-time, real conditions" test data;***
- ***When the data which they yield are analyzed by an experts and compared against real-time, long-term exterior exposure data.***

We cannot stress this point too much or too often because a distressing new trend is emerging in the market place: Tools and data intended strictly for use in the scientific community, in the hands of skilled and experienced coatings scientists, are being moved into the marketplace, where they are being misused as marketing tools. This is clearly exemplified by cases where sales or marketing representatives are attempting to sell coatings, based on new chemistry, solely on the basis of their performance in an accelerated weathering device. The device of choice is often UV-B, probably because of its ubiquitous nature and "known destructiveness." Since almost any coating looks good in *some* accelerated test, there are those who arm themselves with such testing data, then imprudently and improperly enter the marketplace crying "Eureka" from the housetops. Potential customers then attempt to require competitive products—based upon completely different chemistry—to match the same set of test results, and the "accelerated testing wars" have begun. This is a dangerous development in the marketplace because it places the emphasis not on actual field performance but on accelerated testing data, which—in this context—is only so much *hocus-pocus*. Which brings us to the final major aspect of "what we believe":

Running unknowns, such as competitive products, in an accelerated testing device for the purpose of predicting actual field performance is extremely risky business and becomes "pseudo-science" in the hands of anyone other than expert coatings scientists.

ccelerated testing data has its place—but that place is in the laboratory, in the hands of skilled coatings scientists, and in the company of related data from other complementary testing regimes, which place the data in a proper context.

THE "BOTTOM LINE" ON DURABILITY PREDICTION

Science: There are no "silver bullets"—it takes time, expense, experience, expertise and a lot of hard work to develop a new coating.

BOTTOM LINE: You get what you pay for.

Pseudo-Science: Anyone can compare coating "A" to coating "B" in some type of an accelerated testing regime, with meaningful results.

BOTTOM LINE: Flip a coin; it's faster, cheaper, and generally just as accurate.

Wishing Thinking: Somewhere "out there" is a weathering device that will predict the durability of all systems under all conditions.

BOTTOM LINE: There is no free lunch.

Now it is time to focus our attention on other archaic testing regimes, such as the "B 117 Salt Spray" test and the so-called "falling sand" test, among others. The results of such tests are questionable, at best—and dangerously misleading, at worst. Almost anything would be an improvement, and, as an industry, we owe ourselves such improvements. I am aware of no industry colleagues who do not feel that these testing protocols should be replaced by ones that are more reliable and—if, ten years from now, we are not looking back upon such tests through bemused eyes, wondering how we ever could have relied upon them for meaningful results—then shame on us.

WHAT COATINGS PRODUCTS WILL BE NEEDED IN THE FUTURE?

Growth in the coatings industry has been pretty well synonymous with "change" in the coatings industry, and—because we are so used to such a dynamic environment—it never occurs to most of us that this is not true in all industries. In 1948, however, when the author first drank cow's milk, it looked and tasted essentially the same as it does in 2000. The handling and processing of cow's milk may have changed over this 53-year time span, but such changes are transparent to the end-user, who only knows that the milk basically looks and tastes the same. Many of the products of the coatings industry today, however, are most decidedly ***not*** the same as they were twenty years ago, much less forty or fifty years ago. Today's coatings bear little resemblance in toughness, flexibility, durability and user-friendliness to their predecessors—the final products which result from the advanced technology being incorporated into our coatings and application equipment would have been unimaginable to all but the most visionary of our industry forefathers.

Even five years ago, who could have possibly guessed that the theme of the National Coil Coating Association's (NCCA) Annual Meeting in 1999 would be, **"Challenges, Changes and Choices on the Road Less Traveled: Coil Coating in the Automotive Market,"** or that five of the past six European Coil Coating Association (ECCA) Congresses would feature a paper on "coil automotive"? In the mid-1960's, the thought that we would one day be routinely coil coating refrigerator wrappers and microwave ovens ("critical surfaces"), louvered HVAC panels ("cut edges"), metal roofs in the shape of Spanish tiles ("too much 'work' on the metal"), and "self-lubricating" steel sheet which can undergo deep drawing without the need for press oil would have been met with skepticism, at best—and more likely with either disbelief or derision. The obstacles to realizing such products, using the coil coating process, were simply too great. Yet the obstacles were overcome, and limits were transcended, and—viewed from the year 2000, a mere thirty years later, when all of these wild-eyed concepts have become proven, commercial realities—our doubts of the past inspire disbelief that we could have had so little faith in ourselves and in our industry. These are just examples taken from one specialized segment of the coatings industry.[15] Many other examples of "limits transcended" and "obstacles overcome" have been documented in virtually all industrial and consumer segments of the global coatings community.

Replacement of Traditional Roofing Materials

Residential roofing is "established," insofar as the coatings technology is available. It is commonly used in Scandinavia, we see it on the occasional house in North America, and there are certified installers scattered around who are not afraid of it. This is a far cry from its potential penetration, however. The "best guess" information available suggests that only ~3% of the 17-18 billion square feet of residential roofing installed annually in the United States is made from painted metal.[16] This is big business, and it requires a carefully orchestrated plan of attack—a plan of attack which, happily, seems to be underway in North America, in the form of the ***Metal Roofing Alliance,*** and in Europe, where a similar concept is being organized by the ECCA. But will this be enough? Probably not. We are certainly going to need coatings which serve the needs of energy conserving programs, such as the joint USEPA/DOE "Energy Star" initiative, and the Cool Roof Rating Council. We're likely to need coatings which look even more like (and perhaps *feel* more like) cedar shakes and asphalt roofing than is currently the case. If we are smart, we will create a new roofing option that cannot be mimicked through the use of alternative materials, although creating a "new look" can be a scary business. Imagine, if you will, the look on the faces of consumers when they were first offered tar shingles to replace their slate roofs. Nonetheless, try we must, because this is one of the few ways in which we can positively affect the value chain of the coatings industry.

Solvent-Free Coatings

The opportunity for utilizing new application techniques to add value and to create both new looks for existing products, as well as to create actual new products, abound at the moment. Methods of applying powder coatings at undreamt-of speeds (>1000ft./min. have been reported) have emerged in the past few years, courtesy of the "Powder Cloud" concept from MSC/SMS, and the "Electromagnetic Brush" (EMB) concept from DSM. If the curing chemistry of the powder coatings themselves can catch up, we may be looking at powder coatings in a whole new way—as coatings which are not only environmentally friendly, but which can be applied at high speed, while producing thick, textured, functional and novelty finishes, as well. A glance at the current powder literature, which discusses new potential applications[17] and new approaches to curing mechanisms (such as U-V[18]) on an on-going basis, suggests that the future of powder is very bright, indeed. Likewise, "solid block" and "hot melt" coatings concepts hold great potential as "leap frog" technologies which may go nowhere, or which may catalyze a paradigm shift which will forever change the face of the coatings industry. Such technology holds the promise of new and novel patterns and designs, at both thin and thick films, in very small or very large runs with minimal clean-up and fast turnaround, on coating lines that produce very low emissions, require no coater room, have a very low energy demand and represent only a modest capital investment. Such lines were a dream in 1985, but became a reality in 1994, with construction of the first "solid block" line at BHP's Port Kembla facility in Australia. It's up to us to determine how (or even *if*) to utilize these new coatings and application technologies. If we want them to work for us, however, we can't just "wait and see"—there are many obstacles to the successful use of these technologies, and if we want them to work for us, we must ***make*** them work for us.

Radiation-curable Coatings

We hear more and more about "radiation curable coatings." Yet, when they are mentioned, most of the people in any given room look to the others, to see if they are interested. A survey of R&D managers of one-hundred thirty-two (132) U.S. manufacturers of paint and powder coatings indicated that 16.3% percent of the respondents are funding "radiation cure" projects of one stripe or another, although they are only investing an average of 3.9% of their total R&D budget in doing so.[19] U.V. curable coatings have found homes in the beverage can business, on high-end paper products and on certain types of wood products, such as household and office furniture, but they tend to have more novelty than reality for producers and users of coated metal products. (It is significant, however, that—in his 1999 presentation to the ECCA's June, 1999, General Meeting—DSM's Paul H. G. Binda described the application of a U.V.-curable powder coating, using electromagnetic brush technology.[20]) Even more removed from our thinking process tends to be electron beam (E/B) curing, but why? It's true that the coatings produced, using either U.V. or E/B curing methods, tend to be brittle, and are probably hampered by high internal stresses that work against adhesion. On the other hand, such coatings are generally very hard, extremely abrasion-resistant, and can withstand significant chemical attack. With the right work, we might see a variety of value-added products emerge from this technology, perhaps as a result of a two-stage cure, akin to what is often done in the plastics area—"step one" would cause the coating to harden sufficiently (yet remain sufficiently ductile) to be easily handled and formed (if necessary or desirable) then, in step two, high energy radiation (perhaps even visible light[21]) would be applied to give the fabricated object its final, "diamond-like" cure.

Automotive Challenges and Opportunities

"End of the line coating." "Mill-applied coating." I'm not sure that these are phrases which anyone, other than steel mills, find immediately comforting—and many of them probably have concerns of one type or another, as well. This is not a new idea, at least conceptually—Stein Heurtey, in France, claims development of this concept as early as 1984, and Kawasaki Steel's Chiba facility coupled electrogalvanizing and coil coating for certain automotive applications in 1988.[22] While this has not become widespread practice in the years since, it is probably significant that Danieli Wean announced last summer, on the Web, that they had received an order from A.G. Ban-Color S.A. for a new hot dip galvanizing line with an in-line painting section, to be commissioned in the second half of 2001 in Jerez de los Caballeros, Spain. Regardless of the relative lack of current, specific activity in this area, it is my impression that virtually all steel mills, as a result of actual or implied encouragement from segments of the automotive industry, are incorporating the concept of "mill-applied coatings" into their thinking process, as they contemplate the future—and many are including space and other key elements in their schematics for new metal coating lines. It is doubtful that anyone knows for sure what the future holds, with respect to this new approach, but it is equally doubtful that anyone can afford to risk being left "in the dust." Of course, there are a great many suppositions in this scenario. . . .

. . .Including the emergence of a significant need for precoated metal in the automotive industry, a supposition which is by no means a "given." There is, I am convinced, no element of a "done deal" about the future of what is increasingly referred to as "coil automotive." To bring the promises of the year 2000 to fruition in the year 2005 and beyond will require strategy, commitment, financial investment and good, old-fashioned hard work by the coil coaters, steel and aluminum suppliers, and coatings suppliers. We already have concrete examples of weldable, coil-coated primer being used as the base for electrodeposition coating, and rumors abound regarding the "automotive coil" plans of the various OEM's. In Europe, plans for the future go as far as to include a "fully coil coated" concept employing a combination of coatings and films. These are very encouraging signs—signs that were not in general evidence even five years ago, and still tend to be surrounded with an aura of secrecy and mystery. A few experimental cars were quietly built in the 1980's from coil-primed metal, and—thousands of miles and over a decade later—I took off my suit coat to climb over and under one of them, checking for corrosion and signs of other problems. It looked great—at least as good as a similar vehicle built using traditional materials, and possibly better. It ***can*** be done. Imagine the face of our industry in the year 2015, if automobiles are routinely coil coated, rather than electrocoated and spray-coated. Imagine the cost savings to the automotive industry if hem flanges are formed from coil coated steel, and no longer require wax and sealers. Imagine the labor savings if sanding and repair issues were to be reduced or eliminated. Times are changing, and opportunities of great magnitude are being created—but they bring with them equally great challenges, and the global coatings community must be prepared to meet these challenges with creative, economical, and environmentally, sound solutions.

HOW CAN THE R&D COMMUNITY RESPOND TO THE CHALLENGES AND OPPORTUNITIES OF THE FUTURE?

The past few years have seen the market introduction, in various parts of the globe, of an impressive variety of new high-performance coatings products, including self-cleaning coatings, I.R.-reflective roofing coatings, wrinkle finishes, 500μm textured plastisols, high-heat resistant coatings, and a host of others, in addition to those emerging technologies (powder, hot melts, solid block, chrome-free primers and weldable automotive primers) which I have already discussed. These have been the result of successful R&D programs conceived, appropriately funded and executed many years (usually 3-10) in advance of commercialization. But what about the products which will be needed to keep our industry both dynamic and viable five, ten and fifteen years from now? We need to be working on them today, but what is the state of those R&D programs? R&D programs cost money, and money is in short supply. It is no secret that less R&D (and, as a result of industry consolidation, less *diverse* R&D) is being funded today, compared to a decade ago, and that what *is* being funded has a much shorter-term focus. At the same time, the potential to investigate new chemistry, and place it in the service of the global coatings industry, has never been greater than it is today. The mind fairly reels at the availability of new chemistries and chemical concepts which are on the horizon: What, for instance, could our industry do with ceramic-like coatings ("ceramers") made using emerging sol-gel concepts? In the May 1, 2000, issue of *Chemical Engineering News*, published by the American Chemical Society, occurs the following, startling statement: ". . .according to government R&D planners, nanotechnology is nothing short of the next Industrial Revolution."[23] I agree. In my opinion, nanotechnology, which is the control of matter at the atomic and/or molecular level, has the potential to exert a profound influence on the physical and performance properties of products, such as coatings, which are engineered using these principals—properties such as hardness, flexibility, permeability, adhesion, corrosion-resistance and other parameters of critical interest to our industry. What if we were able to produce improved "self cleaning" coatings that worked equally well under all conditions, or better yet—coatings that don't actually get dirty to begin with? The ramifications of such a concept transcend mere aesthetics, and work being performed in a variety of laboratories, including the U.S. Naval Research Laboratory[24], suggests that, with appropriate R&D, this can happen.

Coatings that look like stainless steel. . . coatings for metal that emerge from high-speed applicators with patterns and designs permanently fixed in the coating, without the need for inks . . . self-healing coatings which would minimize—or perhaps actually prevent damage from handling abuse. . . solventless coatings. . . self-stratifying coatings[25] which would require only a single application to produce both primer and topcoat—and possibly even pretreatment, as well. . . coatings based on hyperbranched/dendritic polymers with advanced—possibly even *new*—properties. . . coatings that could be cured using high-energy, *visible light*. . . . What if we were able to apply the principles of combinatorial chemistry, currently being utilized with dazzling virtuosity by the pharmaceutical industry, to facilitate the rapid development of new coatings with undreamt-of properties? . . . . The list goes on and on, and these are not pipedreams—they are all possible. The real question is whether or not we are willing, as an industry, to provide the quality and quantity of research to take full advantage of these opportunities. Will we invest in new R&D approaches for the future, or will we attempt to "make do" with products and processes based upon incremental improvements (when available) to the same old technology?

Personally, I see no choice, and I am deeply concerned that, as an industry, we seem to be pondering this question as if there *is* a choice. At the end of the day, the answer is—the answer *must* be—that we are willing to tackle the future in the same way that we built our past: By setting our sights high, and by supporting each other in an industry-wide pursuit of new opportunities. It's our choice—let's make it a thoughtful, well-reasoned, *strategically sound* one.

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