any people quote, “Hubble, bubble, toil and trouble” as the witches’ famous line in Shakespeare’s play, *Macbeth* (Act 4, Scene 1, vv. 10-11). So the general populace might assume the quote is correct. But it is not. The real quote is “Double, double, toil and trouble.” The incorrect quote is assumed bona fide because of its repeated use.

This article discusses similar assumptions made about many coating specifications and the trouble the assumptions cause. In the discussion, the toil is in the tests. Aside from the use of successful track records, it is common for coating specifications to be based on test criteria deemed important by specification authorities. But are the tests relevant to the intended service environment? Has the meaning of the test data been misinterpreted? Have the tests been ascribed a level of accuracy and dependency that the test method simply cannot deliver? These vital

**Editor’s Note:** This article was first presented at PACE 2010, held February 7–10 in Phoenix, AZ, where it won the SSPC President’s Lecture Award.
When it comes to coating failures, the problem often starts with the test data in the spec.

Toil and Trouble

Take issues surrounding the use of adhesion measurements. Some coating manufacturers crave large adhesion values to gain a favorable coating specification position. Obtaining and promoting those large values may even be an element of a coating company’s strategy to buttress coating superiority claims and have high adhesion values adopted as de facto standard with specification authorities. Other coating manufacturer strategies with specifiers include the deliberate blend of irrelevant test data with relevant data to make it harder for a competitor’s coating to obtain “or equal status.” And there is no definition of “equal” status.1,2

Discrete values of coating adhesion sometimes receive inordinate significance.3 Specifications that mandate adhesion values of, say, 850 psi minimum, imply the values have great meaning. A clue that an understanding of the significance of coating testing is absent in a coating specification is when a litany of non-relevant test requirements is culled from a product data sheet and physical criteria such as weight per gallon, mix ratio, and volume solids are prescriptive in the specification.

The basic physical parameters of coatings have no value with respect to coating system performance. Ironically, specifications exclude many good coating candidates that should have been chosen judiciously and would have offered superior performance compared to approved products chosen poorly. Perhaps a novice specification writer “researched coating materials” by scouring the Internet rather than conducting a proper literature search. In so doing, specifications may be written around a particular product with no emphasis on coating system performance.

Few would argue that test data in a specification should have reasonable relevance to the intended service conditions for a given system. An example is testing for anticorrosive properties of coatings in aggressive chemical immersion. Laboratory tests on new low VOC coatings or potentially higher heat- and chemical-resistant coatings should always be conducted alongside the same test on a control coating with known performance in the actual exposure environment. Theoretically, taking accelerated laboratory tests to the point of coating failure is far more meaningful for attempted correlation with real-life coating performance in the field.

Increasingly, engineers want faster tests and data. But faster tests mean the results are less likely to correlate with real-life performance. One research tool, however, Electrochemical Impedance Spectroscopy (EIS), used with autoclave tests, has been employed to evaluate potential high temperature resistant tank linings in 5–8 days and has proven to be a good indicator of real life performance.4

Comparing test data obtained at different times, by different operators, or in different laboratories must be done carefully. Many standard coating test methods were originally designed for comparative testing in a single test series, not for generating an absolute test value. Other methods have options that can significantly affect results. Some ASTM test methods contain precision and bias statements based on round robin studies. Unfortunately, the statements are often ignored when comparing data; equally unfortunately, many test methods have not been studied to properly ascertain their reproducibility and repeatability. Unless you understand the fine details of a test method, you cannot compare data generated at different times and places.5

Consequently, unless the details of the test methods used for coatings are understood, the data is often assumed to have a much higher accuracy than the method deserves. During new coating product development, the test method is good enough if it can differentiate between experimental formulations that are obviously unsuited to a certain set of service conditions and formulations that will perform well. With coatings that perform reasonably well, the ability of most methods to finely distinguish different levels of performance is often dubious because of the inherent variability in many test methods (and operators).

ASTM B117 Salt Fog Testing: Potable Water Tank Specifications

Pogo’s Observation—We have met the enemy—and it is us. Awaiting an audience with a respected
Industry consensus holds that the mechanisms of corrosion and degradation in the ASTM B117 test do not correlate with real world, atmospheric coating deterioration. Instead, results from ASTM D5894 testing (Standard Practice for Cyclic Salt fog/UV Exposure of Painted Metal) accord far better with in-service coating performance.7-9

Something was awry. Quite apart from atmospheric exposures, how could the mechanisms of corrosion in a salt fog testing environment be relevant to those in a potable water immersion environment? Where’s the salt?

Soon, the specification writer sat down with the coating manufacturer’s representative and discussed the matter in earnest. The specifier appreciated and recognized the representative’s technical reasoning. A typical failure in the ASTM B117 test would be scribe undercutting. A typical failure in potable water immersion would be blistering. How different.

The higher resistance of potable water would equate to low conductivity and a low corrosion current, and little in terms of corrosion.

Osmotic, or electroendosmotic, phenomena, would be more prevalent with coatings immersed in fresh water compared to salt water: hence, the greater propensity for blistering in potable water service and fallacious reasoning deployed in an attempt to meaningfully correlate ASTM B117 with potable water immersion (Fig. 1).

By the interview’s end, the specifier appreciated the coating manufacturer’s point that attempting to meaningfully correlate ASTM B117 laboratory results with the anticipated service life of a coating in potable water immersion stretched credulity. The requirement for the ASTM B117 test was withdrawn from the specification. More emphasis was placed on the water resistance of the coating system.

How, one may ask, could things go wrong if the ASTM B117 test criteria had been adopted? The specifier would have inadvertently prevented the facility owner from using the most cost-effective coating system for the potable water immersion project. The coating system that the visiting coating manufacturer offered—with the longest track record of proven success and best life cycle costs—was about to be sacrificed on the altar of thousands of irrelevant, arbitrary hours in a salt fog chamber.

For tank exteriors, many specified coating systems consist of two or three coats of high-performance materials. The test criteria used to approve a system may be based on data for individual coats, not the actual system itself. We found specifications where ASTM B117 requirements are cited for over 1,000 hours for the polyurethane finish alone when it was part of a multi-coat system such as a zinc, an epoxy, and a
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polyurethane, but the specifier did not cite an ASTM B117 requirement for the three coat system.

For corrosion resistance, ASTM B117 was the norm for years but the coating industry has largely subordinated it because of its poor correlation with real world coating performance. Nevertheless, the 1,000-hour pass/fail criterion of ASTM B117 might occasionally be deemed to have merit such as in a splash zone on an offshore platform, where the criterion has more relevance than it would to structural steel on, say, a silo in Kansas.

Test methods that introduce a cyclic environment (wet/dry or hot/cold or both) afford enhanced relevance for most applications. Cyclic tests such as ASTM G85, ISO 20340, ASTM D5894, and NACE TM0304 are routinely employed but the story remains the same: it is still important to obtain better correlation of the test and the intended exposure environment. Despite unprecedented technological progress, we still find ourselves in the realm of corrosion testing that differentiates coating systems by the degree of rust creep at the scribe of a test panel. And the subjectivity involved in panel preparation, the removal of loose paint from the scribe, and subsequent corrosion ratings stems from the variability in the operator doing the work. As a result, the adhesion data generated in terms of scribe creep values is best used comparatively rather than to generate an absolute "number." Although round robin studies of the same systems in different laboratories, or in different test regimes, may give fairly consistent performance rankings, the absolute scribe creep values may vary widely.

**Atlas Cell Testing and the Canadian Oil Patch**

*A cold dose of Canadian oil patch reality is a good thing.*

When an internal coating or lining fails prematurely in the Canadian oil patch, a facility owner can lose revenues of hundreds of thousands of dollars per day while the facility is out of service. For cost reasons alone, proper selection of the high performance coating and the coating supplier cannot be overemphasized.

To judiciously select coating systems in the oil patch, third-party independent testing is needed to evaluate the effects of chemical and physical stresses on candidate coating systems. Several laboratory test methods are typically used to determine whether or not coatings meet pre-qualification criteria for tanks and vessels.

- Autoclave testing (NACE TMO185-02)
- Electrochemical impedance spectroscopy (EIS) (ISO 16773)
- Cathodic disbondment (ASTM G8, G95 or CAN/CSA Z245.20/21-02)
- Standard Atlas Cell test (NACE TM0174-02)
- Pressurized Atlas Cell test (modified field NACE TM0174-02)
- Chemical cycle tests at elevated temperatures
- Adhesion (parallel scribe method)
- Impact test (modified ASTM G14 or CAN/CSA Z245.20/21-02)

Of interest here is Atlas Cell testing, its use to try to correlate real world service, and the specifier's recognition and interpretation of the testing to qualify or disqualify coatings for tanks and vessels in the oil patch.

For several decades, coatings and linings subject to the cold wall effect have been studied using Atlas Cell and pressurized Atlas Cell tests. Such tests have been used to compare the performance of internal linings for high temperature, high pressure, and chemically aggressive oil patch applications (where external temperatures are at ambient) to rank and pre-screen linings for particular service environments. For determining suitable pipeline coatings, the predictive capability and usefulness of Atlas Cell tests have been well established.

Many people contend that Atlas Cell tests are invaluable for ranking and pre-screening linings for tanks and vessels. Testing initiated by facility owners has shown that some high-performance epoxies with the longest, most successful track records in oil patch service actually fare miserably in standard Atlas Cell tests compared to many other coatings. As a result, specifiers may reject the epoxies out of hand.

So what's the problem? First, based on
the Atlas Cell test, a lining ostensibly most fit for purpose is mistakenly deemed inferior and, therefore, unsuitable for real life service compared to another lining that performs well in the test. Second, and most importantly, the facility owner’s desire for optimum life cycle costs can be thwarted by over-reliance or over-interpretation of an Atlas Cell Test. Third, from a technical perspective, tanks exposed to the chilling temperatures of Canadian winters might erroneously be thought to be subject to a much stronger cold wall effect than is actually present.

Against this backdrop, and to test cold wall hypotheses, a custom built Atlas Cell was used (Fig. 2). The “multi-port” Atlas Cell was designed to evaluate eight coatings simultaneously, and temperatures on the hot and cold sides were far better controlled than with the standard test model. The procedure revealed a pronounced difference between chilling with air and chilling with water (or glycol) in the Atlas Cell test. When an Atlas Cell test is run with a given temperature gradient between the hot and cold side, the actual temperature gradient will be considerably higher when the chilling is done with water compared to air. This factor is never taken into account when reporting Atlas Cell test results.

Certain tightly cross linked epoxy novolac coating systems perform poorly and blister relatively quickly when the Atlas Cell is chilled by water—i.e., how the standard test is normally run (Fig. 3). Although many specification authorities like the Atlas test, the difficulty is in correlating the test results with real world coating performance in hot process fluids. In real life, the tanks in the freezing winters in the Canadian oil patch are chilled by air. Guess what? The coatings on the inside perform for decades when the tank externals are chilled by air (Fig. 4).

Paradoxically, the better the coating performed in real life, the worse the coating performed in the Atlas Cell test. Why? The difference between the heat capacity and thermal conductivity of air and water accounted for the discrepancy between Atlas Cell test results and field observations for the coating. Air has a low heat capacity and a low thermal conductivity, whereas water has a high heat capacity and good thermal conductivity. Therefore, when it contacts steel, chilled water can draw out a significant amount of heat, exerting a strong chilling effect and producing a substantial cold wall effect.

In marked contrast, air has little capability to produce a cold wall effect in the real life freezing conditions in the Canadian oil patch. The actual temperature gradient in the tank walls is significantly lower than that produced in the Atlas Cell chilled with water; given the same difference between inside and outside temperature. It has been shown that if the temperature gradient is controlled rather than the temperature of the hot and cold media, on the hot and cold sides of the Atlas Cell respectively, laboratory results match field results very well.

Coatings with high chemical resistance appear to be associated with low permeability and low tolerance to a cold wall effect.
Ironically, specification authorities may continue to screen out such proven "field performers," preferring instead Atlas Cell test’s "good-performers." Meanwhile, facility owners can lose out, while poorer performance coatings squeak through to the job site.

Adhesion Testing
Eng's Principle—The easier it is to do, the harder it is to change.
Lo and behold, do we want, or need, high adhesion values to be stipulated in coating specifications? Should arbitrary adhesion numbers serve as pass-fail criteria? Does the magnitude of adhesion numbers correlate in real life with how long coating systems actually last?

These questions, though by no means all encompassing, underscore a need to assess the implications of adhesion where intermolecular forces such as Lewis acid/base interactions (including hydrogen bonding) and Van der Waals forces operate.14

Adhesion Tests—Structural Steel
Let’s take a hypothetical but typical situation. Measuring adhesion of Coating Systems A and B for structural steel is a relatively straightforward process for the coating manufacturer when ASTM D4541 is used. The results are given to a coating specifier. At first glance, the temptation for our specifier is to say that if Coating System A gave a 2,500 psi adhesion value, it is markedly better than the 1,800 psi value measured for Coating system B. Not so fast. If the method of measurement has an accuracy (Coefficient of variation) of ±20%, then the result for System A is actually between 2,000 and 3,000 psi, and the result for System B is between 1,440 and 2,160 psi. Because the ranges overlap, you cannot state conclusively that one is better than the other. The significance of the differences in results depends on the number of data points and the accuracy of the measuring sys-
Beware the one data point comparison! So there is little, if any, significance in the difference between 1,500 and 2,500 psi adhesion numbers. Simply put, based on these adhesion numbers, no meaningful argument exists for the specifier to differentiate between either coating system. But the specifier is in the dark; no one told him about coefficients of variation. He screens out Coating B, and Coating A becomes the standard of quality. Difficulties do not end there. Porous thin films, for example, where the glue penetrates more extensively, might give superior adhesion values.

The consensus from an SSPC survey of coating manufacturers revealed that "tenacious adhesion" was cited most often as a primary factor to ensure successful bridge overcoating projects. And how was "tenacious adhesion" thought to be most likely assured? In essence, by obtaining high numerical adhesion values for the coating system.

No one would dispute the importance of good adhesion as a criterion for the success of a coating project, but what defines the breadth or narrowness of "good"? For example, good adhesion may have far more to do with an ability to withstand the rigors of hygrothermal stress from inclement weather conditions and the rigors of internal coating stresses than what is inferred by a large adhesion value. Counter-intuitively, when it comes to overcoating lead-based alkyd paints, the chemistry behind single-component coatings with low adhesion values (approximately 200–300 psi) can provide far better coating test results and longevity than coating systems based on two-component technology with very high adhesion values.

Accelerated laboratory tests routinely include ASTM D4541 pull-off adhesion tests. Although pneumatic testers have precision superior to that of mechanical ones, the accuracy and relevance of the adhesion data may be questionable and over-interpreted, and may lead to erroneous conclusions.

No significance whatsoever can be attached to a test failure value reported without an accompanying description of the failure mode. For example, a coating system that fails cohesively at 750 psi is arguably less prone to catastrophic field failure than another coating system that has intercoat or substrate adhesion failure at 1,000 psi. Once again, a higher adhesion value is not indicative of a better coating system.

Different opinions also abound on the comparative merit of adhesion measurements where cutting around the adhesion dolly before the pull is advocated (as in the ASTM procedure) versus cutting around the dolly (as in the ISO procedure). Testing authorities who advocate the ISO test method contend that the ASTM procedure does not strictly measure adhesion but also measures the tensile properties of the coating. Granted, this is the case. However, what coating system is subjected to a force that essentially "sucks" it off the substrate? Conversely, testing authorities who favor ASTM counter that cutting the coating may cause a micro-crack flaw around the cut edge, where cracks propagate into the coating, thereby making the adhesion test area vulnerable to a differ-
It is important to evaluate both dry and wet adhesion (adhesion after immersion in water). Recoat times touted as 30 days, 60 days, indefinite, and so on, are often based on dry adhesion data, which then finds its way to specification authorities. The rest is history. If the wet adhesion values had been obtained, the conservative and true recoat times would have been much shorter and premature failures avoided.

What are some of the dire consequences of coating selection choices based on poor adhesion data? One particular case is noteworthy. A bridge coating contractor was told by a coating manufacturer that the recoat time for the field-applied epoxy was several months. All would be fine. The contractor was to simply wash and clean the aged epoxy and spray apply the polyurethane finish. The adhesion data apparently supported this procedure. Months later, in bitterly cold weather, the temperature plummeted rapidly, and the polyurethane finish coat could be heard coming off the bridge structure as the coat delaminated from the epoxy.

Proactively, several coating manufacturers now age coated panels used for recoatability (intercoat adhesion) studies both in the laboratory and in different real world conditions, such as those found in California, Florida, and Texas. In one test regimen, after application of a polyurethane refreshment finish coat to samples from laboratory and field sets of aged panels, the new coating system was exposed to high humidity for 2–3 weeks, and the resultant wet adhesion was measured. When compared to dry adhesion data from the remaining set of panels, the wet adhesion test yielded far shorter recoat times than those from dry adhesion tests. But the manufacturer’s data sheets often give the longer and riskier recoat times based on dry adhesion times.

Thus, an all-too-familiar problem can be avoided, namely, a polyurethane applied per a dry adhesion recoat test that looked fine on a mid-coat of epoxy for six months but that later delaminated in a patchwork quilt pattern.

Interestingly, wet adhesion tests of aged and water-washed epoxy coatings with the same epoxy reveal a dependence on where the epoxy was aged. In one in-house study, the wet adhesion measured on panels aged in California after six months was excellent. However, the wet adhesion on panels prepared in Texas and Florida was virtually zero, which suggested contaminants might have been a major factor for de-adhesion. The same coated panels aged in the laboratory, however, gave excellent wet adhesion values.

Ultimately, wet adhesion results are deemed best to establish recoat times for aged coatings, more meaningful adhesion values for coating systems, and a more appropriate foundation for good specifications. Reliance on dry adhesion testing may prove to be problematic, and we might suffer the consequences (Fig. 5).

Adhesion—Tanks and Vessels in the Oil Patch

Unlike coated structural steel, coated tank and vessel steel invariably receive adhesion testing by an altogether differ-
ent method. In the Canadian oil patch, the aggressive chemical, temperature, and pressure environments are simulated in an autoclave in which coated steel panels are placed for a 96-hour test. Part of the test regimen consists of rating the adhesion of the coatings before and after the test using the parallel scribe method. Two cuts, \( \frac{3}{8} \) inch apart, are cut through the coating on steel panels down to the base metal with an abrasive disc on a Dremel tool, whereupon coating adhesion between the scribe marks is evaluated by prying with a utility knife (Fig. 3). In an autoclave test, the adhesion is evaluated within an hour after the panels are removed from the autoclave so that wet adhesion is measured. Adhesion ratings are shown in Fig. 6.

Another test to evaluate wet adhesion is CAN/CSA Z245.20-98 (Section 12.14). Coated test panels are immersed in tap water at a specified temperature and duration. The panels are subsequently removed, and the adhesion of the coating is assessed by cutting a rectangle into the coating, followed by prying it with a utility knife to determine if the coating within the rectangle can be lifted from the metal surface.

The CSA test conditions are 75 C for 24 hrs and 28 days. However, many other test temperatures and exposure times are commonly used.

The rating schedule used in the CSA standard is as follows. Ratings of 1 to 3 are specified as a pass in coating prequalification, Table 2, under the CSA specified test conditions. Adhesion ratings are shown below.

1. Coating cannot be removed cleanly.
2. Less than 50% of the coating can be removed.
3. More than 50% of the coating can be removed, but the coating demonstrates a definite resistance to levering.
4. The coating can be easily removed in strips or large chips.
5. The coating comes off as a single piece.

Unfortunately, adhesion test methods incorporating a knife to pry the coating are highly subjective (knife adhesion is best
used comparatively in the same laboratory by the same operator as discussed earlier). The generic type, flexibility, hardness of the coating (e.g., high-build polyurethane or epoxy linings), and the tensile strengths render a knife adhesion test lacking in objectivity. A complicating variable is the degree of force used by the individual carrying out the test to pry the coating. On the downside, adhesion tests such as these help to decide which coatings are specified and used in the oil patch and which are not. On the upside, specifiers invariably demand coatings with Ratings A, B, and C for pre- and post-autoclave testing. And while a more objective adhesion test has yet to be developed, there have been few instances where specified coatings have failed because of inadequate coating adhesion stipulations. This is a far cry from the world of structural steel coatings.

**Toward a Better Way**

**Herodotus’s Law**—circumstances rule men; men do not rule circumstances.

The bottom line is that the coating industry has a vast repository of test data, but putting it all together in some meaningful way has proven elusive. Test data and observations provide an anecdotal view of how coatings will work in specific situations. But we need a predictive power based on actual performance testing, a move beyond general assessments to correlations between tests and real-world performance correlations.

In the authors’ view, the protective coatings industry has put in place two fundamental barriers that largely prevent meaningful testing of products and systems. These barriers are the use of testing protocols that are not relevant and the establishment of arbitrary acceptance values resulting from the testing.

**Fundamental Barrier 1**

The use of test protocols that lack relevance has many sources, including well-meaning but misguided specifiers and apparently smart coating folks who find ways to manipulate specifications to freeze out the competition. Repeatedly, specification writers include test protocols that are not relevant to real world conditions to which the coatings will be subjected. Three brief examples serve to illustrate the point.

- First, 6,000 hours of ASTM B117 salt spray was required for the exteriors of wind towers slated for erection in the desert region of West Texas. How much of a salt spray environment is there in West Texas?
- Second, a coating system had to pass the requirements of ISO 20340 for an application in industrial China subject to acid rain conditions. ISO 20340 is a test protocol designed for the harsh environment of North Sea off-shore structures. Far better, and arguably more relevant, would be the selection of the ASTM D5894 cyclic prohesion test.
- Third, a Taber Abrasion test was specified for an abrasive slurry conveyed in a pipe. The Taber test is not used for liquid environments.

**Fundamental Barrier 2**

The second barrier is the establishment of arbitrary acceptance values resulting from testing. What is the true significance of testing to ISO 12944 C-5 corrosion test for 1440 hours and requiring 1 mm maximum of scribe creep? Likewise, what is the true significance of a 725 psi pass value for pull-off adhesion required in ISO 12944 (Fig. 7)? Or what is the true significance of establishing a scribe creep value of 3 mm in ISO 20340 (Fig. 8)? Does that mean 3.1 mm is automatically, intrinsically bad? In standards and specifications alike, it is common to set an essentially arbitrary test duration and result requirement. Indeed, there may be some value in testing a product against a standard product at some arbitrary duration to see how they compare. Nevertheless, standards such as ISO 12944 and ISO 20340 as well.
as customer-specific specifications are not really about comparisons; they are about absolute pass or fail criteria for coating systems. Arbitrary values so gleaned arguably have no real world basis. Rather, using these arbitrary values gives a distorted view of the real-world performance of a coating system.

What are we to do? How do specifiers handle testing relevancy and arbitrary test result requirements? Lamentably, there is no easy answer, although the industry would like a better way. Presently, the sequence is that hypothesis leads to perceived reality, which in turn leads to method establishment and thus to problems of relevance and arbitrariness. Time, ingenuity, and energy spent in laboratory work are necessary to throw meaningful light on the issue.

Thinking Outside the Proverbial Box
Problem solving has many guises. A fairly simple idea would prove invaluable to provide meaningful tests for facility owners: work initially with a few of them to really understand their needs, delve into their processes, fully comprehend the type of environment to which the coating/system will be exposed, and develop a clear understanding of performance expectations for the coating system. Here are some details.

1. Establish with the owner what constitutes a failure to a system for a given application. What degree of coating system deterioration would trigger a substantial investment to correct the deteriorating conditions (such as removing the old coating and recoating the structure). Properly understanding this element of deterioration is pivotal because there is no one definition of failure.

2. Develop test protocols and test the coating system to the point of failure established above.

3. After studying and understanding the application history, develop some correlation between the real world and laboratory testing as to how long a particular coating or coating system will last.

4. Knowing the capability of the coating system from its track record and a broad spectrum of tests already in the coating’s library, so-to-speak, you will take a powerful step forward to meet the owner’s real requirements. From this combined data, meaningful real world specifications can be established.

So, for example, in the past, where a specification would have required a maximum of 3 mm scribe creep resistance after 5,000 hours of ASTM B117 salt spray, a new specification might state a minimum of 5,000 hours of salt spray exposure without scribe creep exceeding 3 mm. Hence, a coating system that displays a scribe creep of 3 mm after 4,000 hours would fail; if the coating system displayed a scribe creep of 3 mm after 7,500 hours, it would pass. Systems would then be categorized not by the degree of scribe creep, but by the hours necessary to reach that degree of scribe creep. On the positive side, this approach would allow the customer to choose the
coating or coating system that provides value based on real performance-related testing.

Of course, this view has a couple of downsides. The first is the many variables, known and unknown, that may make it difficult (but not impossible) to give accurate predictions over the full range of possibilities. One way to deal with the variability is the approach weather forecasters take: they assign the likelihood of a precipitation event. For coatings, we could assign probabilities that the system will provide the necessary performance over a duration for a given test, or series of tests.

Conceptually, it appears reasonable to provide a customer a "performance probability" based on both laboratory testing and real world results that would help them choose an appropriate system for their application.

The second downside to categorizing coatings by time to failure is that the testing takes more time than testing to duration. But we need to start somewhere, and testing to failure yields far more useful data.

Another idea with merit has worked well in lining applications for field tanks in the Canadian oil patch. Accelerated laboratory tests were carried out on prospective linings applied to test panels made from virgin steel and field-retrieved steel (from the tank itself). First, the coatings on the differently prepared panels were "benchmark" tested in the laboratory before being placed in the tank. Second, the coated steel panels were immersed in the process fluids of the tank. Third, after a prescribed time in this real-world environment, the panels were withdrawn and the coatings re-evaluated side by side with those not subjected to field exposure. In this way, the particular tests carried out had a more meaningful correlation with real world service environments.

"Hubble, bubble, tests and trouble" suggests a brighter side for the future of coating testing with an improved correlation with real life coating performance. Yet the future, as we all know was not so good for Macbeth as the famous, and correctly quoted witches’ incantation prophesied, "Double, double, toil and trouble."

So let’s finish where we began with the witches of Macbeth and one more omen: “By the pricking of my thumbs something wicked this way comes.” With all our good science let us not ignore our own portents of possible disaster in the world of protective coatings.

**Conclusions**

Caveat emptor: Buyer, or in this case, “Specifier” beware.

• Avoid over-reliance on big adhesion numbers, or hours of duration in salt fog tests. The “values” have little to commend themselves.

• The field performance in the Canadian oil patch shows that the longest lasting, chemical resistant epoxy novolac tank linings gave some of the poorest results in an Atlas Cell Test when unrealistically high temperature gradients were used in the testing regimen. The result reflects chilling with water versus chilling with air in the test.

• The genesis of a new paradigm has been offered to improve the correlation between laboratory testing and real-life coating performance.

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- **ONE-COAT SYSTEM** – RUST GRIP® was designed as a one-coat system - serves as both a primer and topcoat. Applies directly over firmly bonded paint or rust without loss of performance.

- **LIMITED SURFACE PREPARATION** – RUST GRIP® was designed with special resins and additives to be applied directly over existing firmly bonded paint or rust without any loss of performance. A white metal blast (SSPC SP-5) or a near white metal blast (SSPC SP-10) is not required. RUST GRIP® will greatly reduce the overall cost of a project.

- **ENCAPSULATION** – RUST GRIP® is patented (patent # 5,695,812) as an encapsulant of bio-hazardous materials including lead based paints, rust, and asbestos. RUST GRIP® can be applied directly over lead based paint without removal or exotic containment.

- **REDUCE COSTS - SAVE MONEY** – RUST GRIP® replaces the traditional three coat system at a fraction of the time and cost.

- **HIGH SURFACE TENSILE STRENGTH AND DURABILITY** – RUST GRIP® will achieve a surface tensile strength of 6,780 psi and has a life expectancy of 15 years.

- **PASSED 8,800 HOURS WITH NO FAILURES IN CONTINUING SALT SPRAY TESTING**

- **APPROVED AS A QUALIFIED PRODUCT FOR USE IN THE STATES OF LOUISIANA, MISSISSIPPI, AND FLORIDA**

For More Information,
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