Corrosion—When You See the Signs, Which Way Do You Go?

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Decision-making for drivers is dictated in part by their experience, in part by their familiarity with their destination, and in part by the expected/unexpected traffic patterns that remain a variable constant. Signposts generally aid the decision process to inform or warn of future actions that direct or focus drivers to arrive safely at an intended destination, in good time, without injury to themselves, other people, or the surrounding infrastructure. Close parallels apply to corrosion, where material degradation processes need to be better defined and appreciated by communities at large.

“Corrosion” signposts do not exist, but there is a need to recognize signs of corrosion because, once appreciated, these can often deflect more serious repercussions. Awareness of the signs of corrosion is persuasive in that it directs attention to corrective actions that may otherwise be missed, sometimes at enormous cost to people, property, and the environment.

By using the concept of corrosion signposts, the uninitiated will become better able to recognize corrosion and take action to reduce or eliminate their problems. To this end, it is increasingly
necessary to develop knowledge transfer systems to disseminate relevant and practical information to those who need it. A better appreciation (recognition) of a corrosion process is a start because the issue can frequently be avoided or controlled to minimize continued material failures. Short cuts (as with driving) may be less reliable and ultimately less cost effective. The old adage that “seeing is believing” provides plenty of scope and opportunity to improve awareness; others encourage the sharing of “good” failures via the media or advocating that “failure brings improvement”.

**Corrosion Awareness and Control**

It is the author’s experience that awareness is only half of the issue. Positive corrective actions are required to resolve or avoid a corrosion problem, otherwise further failures will continue according to another maxim, “Why does history repeat itself?” A distinction should be made between failures resulting from a total loss of design function and those where the intended design function is partially or temporarily lost. Typically, corrective action is taken only when the intended design function is fully compromised and a total loss is encountered. The differences warrant further appreciation because the former are usually sudden, often catastrophic, and more frequently attract media attention when the circumstances so dictate (Figure 1). Such failures include fracture, seizure, bursts, collapse, explosion, fire, and vapor clouds, and often relate to power equipment (gas turbines, boilers, etc.), pipelines, and the infrastructure (buildings, bridges, etc.).

Situations associated with a temporary or partial loss of design function are less likely to attract media interest. Indications of damage include cracks, distortion, swelling, discoloration, leaks, fumes (odors), stains, and noises. Two advanced examples (Figure 2) show the extensive deterioration resulting from unchecked corrosion where the temporary loss of design function can be ranked more as total loss of design function with a high risk of collapse from further corrosion.

The major causes of corrosion are attributed to design deficiencies and faulty or incorrect use of materials, compounded by fabrication errors, poor assembly, inadequate inspection and maintenance, and instrument faults. Failures (partial or complete) are influenced by human errors, which are attributed to a lack of knowledge and experience that translates to a lack of appreciation of the basic fundamentals, which are overlooked, absent, misused, or abused.

The differences between total and partial (temporary) loss of design function warrant further consideration. Examples are many and often unacceptable (e.g., a

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**FIGURE 1**

The results of a boiler explosion. 
Gas turbine blades with corroded lacing.

Shown are pieces of equipment with total loss of design function where replacement is required. Additional issues are related to site personnel, buildings, and the environment.
temporary fix to provide a short-term solution that may later result in more serious consequences). Two similar approaches to “control” corrosion involved a fractured electrical lamp standard and a cracked process line. Temporary fixes, respectively—to ensure productivity (profits) at all costs!—involved wire ties to secure the broken plate, and a stainless steel sheet clamped over the cracked process line that was still operating (Figure 3).

Different design options that play a role in reliability warrant attention because each approach influences material choice and performance expectations. Options include the “Avoid-Failure Approach,” an overdesign option to limit undesirable upsets with fail-safe devices and easy controls; the “Keep-It-Working Approach,” an easy maintenance option with corrosion monitoring and effective inspection to ensure component replacement before failure; and the “Let-It-Fail-Then-Replace Approach,” a design option requiring hands-on expertise with available spares at short notice for minimal down time.

Regardless of the particular option, the implications of taking no positive action to address or control corrosion are many and include financial, technical, social, safety, and (sometimes) political ramifications.

Knowledge Transfer

As already noted, there are no corrosion signposts; the path forward requires knowledge transfer (or management rationales) to improve communication of reliable data and experience (knowledge) to those who require it. In today’s world, the challenges for the corrosion community are considerable and include aging structures, inadequate standards, declining numbers of professionals in user organizations, lost expertise through early retirement, and the adequacy of education and training.

Books, technical papers, courses, databases, and knowledge management systems may not necessarily be the ideal media for knowledge transfer for the novice engineer; one-on-one mentoring with experts using Web portals, for example, are considered more persuasive. Good communication minimizes misunderstandings and contributes to improved reliability for the designed equipment or product over its anticipated service lifetime.

Effective corrosion control continues to be a management problem, as was echoed in the reported findings of an earlier study within a corrosion-aware sector of industry (i.e., chemical processing). The findings, shown in Figure 4,
revealed that management was always informed about the agreed causes of failure in their plant; however, site personnel and designers were less informed (about 75% and 55%, respectively). Contractors who installed and repaired the plant were the least informed (10%).

Corrosion Costs and Savings

Decision-makers in industry and in local or national government dealing with corrosion issues should be better aware of the significant potential savings available by using existing knowledge and expertise from the corrosion control community—in recent years especially because of government-sponsored surveys. With estimated potential cost savings of about 25 to 40%—reported from the several corrosion surveys conducted since 1971—and with growth in international membership of corrosion associations and institutes worldwide (NACE International membership alone exceeds 30,200), it is time to promote more awareness and to further alert (lobby) government agencies about the enormous benefits to be gained from corrosion control.

Parallels can be drawn between police and crime, where the onus focuses on monitoring and control rather than attempting the impossible task of eliminating crime. Human disease presents a further useful paradigm for corrosion, with developed economies expending 7 to 14% of their GNP on the health of their human assets, which equates closely with corrosion expenditures. With health expenditure close to the top of political agendas in all developed countries, it is time that corrosion and protection achieve commensurate recognition and resources to deliver the full potential benefits to the national economies.

Education

Corrosion education is lacking and is a prime area for action from professional societies—first, to provide training and accreditation for members, and second, to address the fact that corrosion is not widely taught to undergraduate engineers in universities and colleges. As a current example, one major U.S. engineering school offers corrosion as an elective, in alternate years, based on a syllabus written six years ago. This academic offering is intended to “identify, formulate and solve engineering problems in materials selection and design.”

In a world where assets and resources are severely challenged—for example, the aging infrastructure in the United States where over 150 bridges per state are classified as structurally deficient or fracture critical—corrosion education is of great concern. A report published by the U.S. National Academies notes curricula limitations and ineffective education to address national costs/losses. Recommendations are made to both government and the corrosion community to prioritize areas where science can integrate with and improve the much-needed engineering aspects of corrosion control.

Scope for Reducing Corrosion Expenditures

Given the wealth of knowledge and improvements in communication over...
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Signposts generally aid the decision-making process by informing or warning us so we arrive safely at an intended destination without injury to ourselves, other people, or the surrounding infrastructure. Close parallels apply to corrosion, where material degradation processes need to be better defined and appreciated by communities at large.

In the past 30 years, it is important to recognize that a vast amount of corrosion persists because of misunderstandings, poor communication, and the delusion that all is properly installed and operated in the intended manner. Draftsmen’s delusions can account for unexpected events that were unforeseen in the overall designs.18

Significant and increasing use of risk-based methodologies for managing corrosion problems—life cycle costing, reliability/availability/maintainability modeling, and risk-based inspection—have not depleted the opportunity and need for further potential corrosion savings.14

The media responds to calamitous events and needs to be alerted regarding those events that involve corrosion. Estimates associated with the ravages of Hurricane Sandy—the tropical storm that impacted the New York/New Jersey coastline in October 2012—are estimated to be about $42 billion for New York and $30 billion for New Jersey.19 Costs to address transit, power, and sewage treatment—all involve corrosion—exceed $10 billion alone.

It has been noted that corrosion control expenditures have enabled developed economies to sustain high levels of economic activity through the availability and reliability of their infrastructures and wealth-creating physical assets.14 Given an improved focus of attention, all can benefit from hearing about the “good” failures, but that requires action to ensure that the curve has a rising learning slope.

The general direction in the field of corrosion and its control is forward. Our understanding of corrosion continues to benefit from focused fundamental and applied research, from advances (improvements) in monitoring and reliable data acquisition techniques, and from improved knowledge management and people-to-people communication. Opportunities to improve awareness and therefore reliability should be taken, notably interacting with the media that can reach far wider audiences. Missed opportunities to alert a wider audience lead to further unexpected and undesirable consequences (Figure 5).

Corrosion signposts may not be a figment of our imagination; there is optimism for the future. Global positioning devices may extend to corrosion apps that will benefit corrosion awareness and help minimize the perils of poor direction, inappropriate short cuts, and misunderstandings that lead to enormous financial, health, and safety repercussions for people, property, and the environment.

References