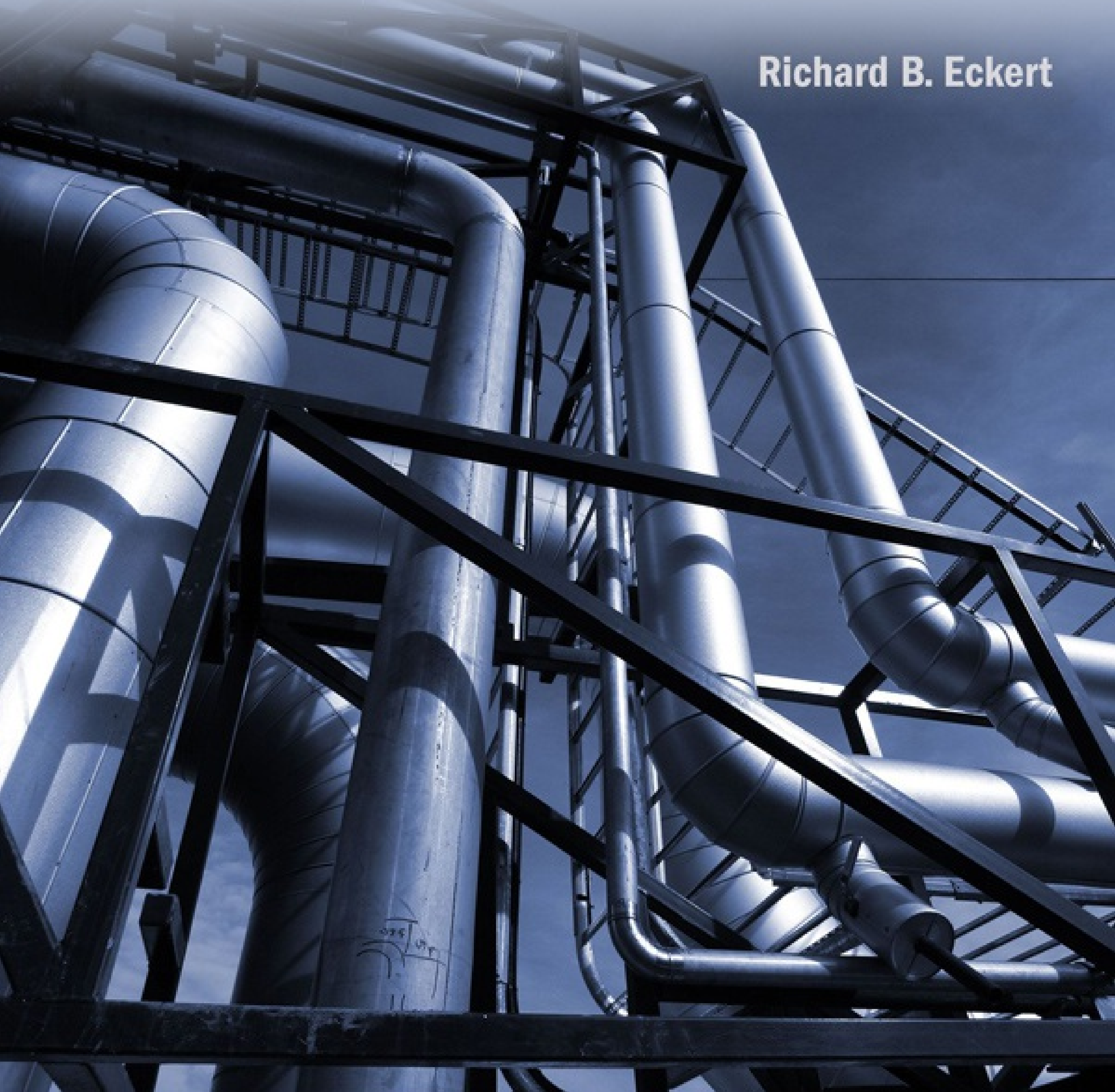
FIELD GUIDE TO Internal Corrosion Mitigation *and* Monitoring for Pipelines

Richard B. Eckert



Field Guide to Internal Corrosion Mitigation and Monitoring for Pipelines

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NACE International
The Worldwide Corrosion Authority
15835 Park Ten Place
Houston, TX 77084
nace.org

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Foreword

The human body is miraculously designed. Organs, bones, muscles, cells, ribosomes, and amino acids, to name but a few, work flawlessly in perfect unison as we blithely go about our daily business. The life processes of metabolism, growth, motion, respiration, responsiveness, and cellular reproduction are the music of a continuous symphony that largely goes unheard, unless one of the instruments becomes out of tune.

The first indicator of dissonance in our bodies is usually the onset of a symptom, something unusual and probably unpleasant that alerts us to a problem. Sometimes we choose to address the symptom ourselves by resting, eating hot chicken soup, or finding a remedy in our medicine cabinet. Other times we might wait for the symptom to disappear on its own, never knowing the cause and hoping that it doesn't return. We could visit a physician who, after a quick examination, might promptly prescribe a plethora of pills to address every conceivable cause. In some cases the treatment leaves us feeling worse than when we began. The issue is this: Without understanding the actual cause of the symptom, there is no assurance that the real problem has been addressed. The body is complex and getting to the actual cause of a problem is sometimes difficult. A number of tests and analyses may be needed to determine the cause and then find the proper cure.

The same holds true in determining the "cure" for pipeline corrosion. Without clearly determining the primary causes of internal corrosion, efforts to mitigate or prevent the symptoms may be ineffective or even detrimental. In this book, the reader will find that significant attention is placed on determining the cause of corrosion before seeking the cure. Based on my experience, this approach is absolutely essential if the plague of corrosion is to be remedied, or at least subdued for a time.

In my first book, "Field Guide to Investigating Internal Corrosion of Pipelines," the reader was led through the process of corrosion failure investigation by assuming the role of a corrosion "detective." In this Mitigation and Monitoring book, the reader takes on a slightly different role, which I will explain.

In my career as a corrosion and materials engineer in the oil and gas industry, I've had the privilege of working alongside and learning from many industry experts. In my first real job fresh out of college, I was thrust into a totally unfamiliar role as an inspector of various pipeline commodities, such as large ball valves, pressure vessels, gas processing equipment, etc. While there was much to learn about the fabrication, engineering and quality control of these commodities, my mentor explained the essence of the job as having four main roles. He said, "To be an inspector, you need to be a politician, a detective, a good-will ambassador, and a *(expletive omitted*[1] *= not a nice guy)*." The point was that sometimes an inspector needed to be the bearer of bad news or make decisions that were not viewed warmly by the vendors. In assuming the various roles of an inspector as described by my mentor, I essentially became the "owner" of whatever valve or vessel I was inspecting. It was my equipment, and I needed to do whatever was needed to ensure it was built properly to all codes and design specifications, and tested to ensure it was safe and functional. My experience has been that successful corrosion engineers take on a similar role; they take ownership of managing corrosion in the pipelines or assets to which they have been entrusted. As "owners" they seek to understand how those assets were designed, how they function, the potential internal corrosion threats, and how to manage those threats. Thus, in this book, I invite the reader to assume the highly respected, yet seldom appreciated, role of a corrosion engineer.

Corrosion engineers assume many roles in their jobs. Besides being technically proficient in corrosion science, corrosion engineers often interface with engineering, operations, design, integrity management, inspection, procurement, planning, risk management, and other functions within their organization. To be effective in these interfaces, the skills of a politician, good will ambassador, detective and sometimes even *(not a nice guy)* are often needed. Corrosion engineers need to have some working knowledge of materials selection, production chemistry, non-destructive inspection, oil and gas operations, fluid mechanics, process safety, construction methods, regulatory codes and design standards, economics and budgeting, computer modelling of corrosion rates, microbiology, and so on. There are always new things to learn in a corrosion engineering career and that is what makes it so interesting.

To be fair, the corrosion-engineering role can also be rather thankless. Think about this: When no corrosion is occurring, the need for a corrosion engineer may be questioned, and when corrosion is occurring, the corrosion engineer was clearly asleep at the wheel. Alas, the poor corrosion engineer cannot win. But, take heart: Entropy and human nature are on our side. Metals will continue to corrode until the end of time, and human beings will continue to make mistakes resulting in more corrosion. The makings of the universe have provided job security, so give thanks. Philosophy aside, the conclusion here is that the corrosion engineer must also have a good (or at least some) sense of humor to succeed in their role.

This book is intended to help oil and gas pipeline operators, corrosion professionals, integrity experts and risk management practitioners assess, control, and manage the effects of internal corrosion on pipeline systems, thus improving the safety, reliability and integrity of their operations. While the focus of this book is on pipelines, the content is broadly applicable to upstream equipment, processing facilities, mid-stream pipelines, liquid and gas storage assets, and delivery/distribution assets.

Another intention of this book is to not only provide technical information about internal corrosion control, but also to provide suggestions and potential strategies for applying this information. The fundamental process of managing internal corrosion consists of threat assessment, mitigation selection and implementation, and monitoring the effectiveness of mitigation. This book is divided into these three main sections to help emphasize the point that corrosion management is a process, not a one-time event (more on this in the Introduction).

Although pipelines are one of the safest means of transporting oil and gas commodities, internal corrosion still causes roughly 10% of all pipeline leaks and ruptures today in North America. The potential for an internal corrosion threat depends on the type of commodity and the way in which the pipeline was built, operated, and maintained. Typically it is not the oil or gas itself that is corrosive, but water and solid contaminants that enter the system. Pipelines run through urban areas with high population densities and environmentally sensitive areas. Depending on the fluid transported, a pipeline leak or failure can have serious consequences to human health, safety, environment, and infrastructure sustainability.

Clearly, internal corrosion is an integrity threat that must be effectively managed. This corrosion engineering business is important work. My hope is that this book will provide the reader with some help in whatever role they may have in managing internal corrosion.

Corrosion engineers—thanks for your contribution to making the industry safer and sustainable, and providing energy to meet the needs of the modern world. You have an important job. Now, read on!

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1. While this is intended to be a family-oriented corrosion book, the reader may insert their word of choice here.

Introduction

In this chapter, we start with exploring how to begin the processes of internal corrosion control and the major steps involved. Regardless of one's background in corrosion or level of knowledge or experience, this organized approach will help the reader visualize where all of the pieces of the corrosion management puzzle fit together. At the end of this chapter, the reader will know the main questions to ask when going about the process of diagnosing and controlling corrosion. The corrosion management process is a continuing cycle, which ensures that corrosion is controlled long term. We will also establish a common understanding of some technical terms such as "risk" and present some suggestions to help the reader get the most from this field guide.

Where to Begin

So, you have found yourself either by design (or by default) in the role of a corrosion engineer. You now have some responsibility for managing internal corrosion in a pipeline, a facility, or even an entire network of pipelines. How do you begin to figure out what to do first, the questions to ask, or the information to gather? Which monitoring methods should be used and what will the monitoring data mean?

Perhaps you have inherited a new installation, or maybe a pipeline network that is 50 years old or more. Maybe the chemical supplier faithfully runs the internal corrosion control program, or the dusty remains of the old corrosion program are buried in stacks of documents left by your predecessor. Regardless of the circumstances, a path or roadmap is needed to help get to the end goal of managing internal corrosion in any particular asset.

Although there are probably thousands of questions one could ask in the process of attempting to understand internal corrosion, really only four questions are essential to begin. These four questions will guide the reader in identifying the information needed to take the next step.
The four essential questions are:

- Is there the potential for an internal corrosion "problem" in the asset?
- Can the cause of the corrosion problem be defined?
- How can the corrosion be prevented or mitigated?
- Is the mitigation response effective?

These seem like simple questions, right? I propose that if one could fully and confidently answer each question, perhaps this book is not needed after all. However, even if you think you can answer the four questions now, I encourage you to read on –you may find that you are less sure of your initial answers than you thought. Let's look at each question in detail.

Is there the Potential for an Internal Corrosion "Problem"?

To answer this question, first one needs to be able to define "the asset" and all the design, operating, and fluid composition characteristics that could present a corrosion threat to the integrity and continued safe operation of the equipment. One needs to know where the asset begins and ends, and everything connected to it along the way. Surprisingly, this may be the most difficult question to answer completely, as many times the potential for internal corrosion is mistakenly tied to assumptions about how the pipeline operates, the fluid being transported or the historical absence of corrosion. Understanding with confidence whether a corrosion threat exists is solidly based upon the quantity and quality of information available. The point is that one cannot understand or assess a corrosion threat without adequate information. What information? Part One of this book, Threat Assessment: Finding and Evaluating Internal Corrosion, explains the type of information needed and the methods to apply to collect this information.

Making assumptions about internal corrosion causes and contributing factors is a common error that can result in shortcomings in corrosion control programs. Collecting historical operating information, taking and analyzing samples, walking down piping circuits, gathering inspection data, and so forth, takes time and costs money. In some cases, there may be a lack of operating data or the available design information is out of date. Please, be assured, the investment in data collection is worthwhile. Inadequate and inaccurate information used in the corrosion threat assessment provides little confidence that the mitigation measures chosen will actually be effective. Bad data equal bad decisions.

Once the extent of the asset is clearly defined, assessed and the right information and data are in hand, the next step is determining the corrosion threat mechanisms that are present and the rate and type of degradation that could be expected. This will help determine whether the corrosion mechanisms are likely to become a "problem" (i.e., an integrity threat) to the asset, and how soon the problem will become serious enough to require a response. One could, for example, have a very low rate of general corrosion in a pipeline with a significant corrosion allowance (i.e., additional wall thickness to account for corrosion damage), which may not be a concern needing an immediate response. On the other hand, a pipeline with extensive previous internal or external wall loss may have little remaining life as even a low corrosion rate could soon make the pipeline unfit for service and at risk of failure.

Every engineered structure on the planet is continually undergoing some form of material degradation due to the thermodynamics associated with refining ores into metals. We add energy to make steel, and eventually that steel returns to a lower energy state as iron oxide. As a corrosion engineer, your job is to manage that degradation rate to an acceptable level. The rate of corrosion degradation typically does not become a "problem" until the asset becomes unfit for performing its intended function for the length of time required.

A corrosion problem is typically thought of as a leak or rupture, and this is certainly the case sometimes. However, more commonly, corrosion results in premature replacement of equipment, unplanned repairs, costly mitigation and monitoring efforts, loss of functionality, regulatory non-compliance, negative publicity, and so on.

So what constitutes a corrosion problem? That is something that must be defined by each company and each asset owner, taking into account many factors that create and drive operational and business risk. For now, let's define a corrosion problem as an event related to internal corrosion that has an undesired outcome. As one can see, the essential questions are not quite as simple as they may at first appear. Now, on to the second question . . .

Can the Cause of the Corrosion Problem be Defined?

In answering the first question, we collected data about the asset to define the corrosion threats that were present, their damage rates, and then we determined the parameters that constituted a corrosion "problem" for the asset. Fortunately, this process also helps significantly in defining the <u>cause</u> of the corrosion problem.

The corrosion threat is not the actual cause of the problem. The cause of the corrosion problem is the set of conditions and events that allow the corrosion threat to be manifested to a point where the outcome is not acceptable. Let's think about that for a minute.

Suppose that our main corrosion threat is under deposit corrosion (UDC) and we find that UDC has resulted in wall loss that threatens the integrity of the pipeline. Solid deposits can form crevices, retain moisture in contact with the pipe, promote concentration cells, provide a favorable environment for biofilms, prevent effective inhibition, and so on. How did the deposits get in the pipeline in the first place? Perhaps a producer did not maintain their separators, and solids carried through into the pipeline due to their poor maintenance practices. Of course, we don't come to find this out until long after UDC was discovered. So what was the real cause of our corrosion problem? Working backwards from the discovery UDC:

UDC discovered

Solids absorbed moisture, allowing corrosion to occur

Pipeline operator lacked maintenance pigging program to help remove solids

Solids accumulated in pipeline

Solid particles entered line from producer

Pipeline operator failed to enforce producer quality standards

Producer failed to maintain separation equipment, allowing solids to enter pipeline.

Looking at this list of events, we see that even though the source of the solids was from a producer, there were steps along the way (underlined above) that the operator could have taken to prevent the UDC threat from escalating. If the operator was aware of the potential UDC threat, they could have instituted a maintenance pigging program, monitored pig returns for solids, and implemented more strict enforcement of product quality standards at the producer tap.

This question is important, as without understanding the real cause of the corrosion problem, determining effective mitigation, preventative and monitoring measures will be difficult, if not impossible. Details about failure analysis of corroded components and root cause analysis are discussed in Chapter 11.

How can the Corrosion be Prevented or Mitigated?

Once the threat mechanisms and contributing causes are understood, the next task is to determine how to control the corrosion damage. Controlling (managing) corrosion is taking action to reduce the corrosion damage to a level that allows continued safe operation for the planned life of the asset. Ideally, this planning happens in the design stage of the asset, when it is possible to select the proper materials of construction and add engineering features such as pig traps and chemical injection points. In the design of oil and gas assets, it is common to have corrosion engineers provide input on the potential corrosion mechanisms, rates of corrosion and means of prevention or mitigation. Chapter 14 provides more details about designing to reduce corrosion. Once an asset reaches the operations stage, it becomes more difficult to make significant engineering changes to improve corrosion control.

Often, people in industry speak of reducing "corrosion risk," which sometimes confuses the actual meaning of the term "risk." The generally accepted and somewhat oversimplified definition is that risk is the combination of likelihood and consequence. (The terms likelihood and probability are used interchangeably).

***Risk* = <u>Likelihood</u> of a threat AND resulting <u>consequences</u>**

For example, the likelihood of a meteor falling on your house is infinitesimally small, while the consequences of your house being destroyed if a meteor did hit are certainly high. Even though the consequences are high, the likelihood is so low that the resulting risk is low. Most people don't lie awake at night worrying about a meteor coming through the roof. If the likelihood were higher because a major shower of large meteors was heading for the earth, then the risk would also increase. If you had built your house from "meteor-proof" material, this would reduce the risk by reducing the damage (consequences) of a meteor hit.

The concept of threat likelihood and consequences can also be visualized using a so-called "bow tie" diagram, as shown in Figure I-1. In the bow tie diagram, the key event (corrosion leak or failure) is shown in the center, with likelihood on the left side and consequence on the right side. Looking at the left side of the diagram, we see that preventative measures (mitigation) are intended to prevent the corrosion threats from reaching the point of failure by reducing the likelihood of those threats. Once the key event occurs, consequence mitigation measures (on the right side of the diagram) can be employed to reduce the resultant effects of the failure. For example, a spill response team can be in place to immediately respond to an event, deploying containment measures to reduce the area impacted by the spill, reducing the consequences.