Introduction

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Since the beginning of the twentieth century, liquid petroleum products and natural gas have been transported by extensive underground networks of steel and iron pipes.[1,2] The American Gas Association reports that, in 2013, over 2.4 million miles of buried steel mainline pipe was used for the transport of natural gas within the United States.[3] Trunk lines for natural gas products add to this total. There are, in addition, 170 000 miles of pipeline for transport of crude oil and refined products.[4] The soil environment contains oxygen and is sufficiently conductive to allow passage of electrical current; therefore, buried steel structures are subject to corrosion. By the late 1920s, the number of leaks had begun to increase alarmingly and, by the early 1930s, all major pipeline owners were providing some measure of corrosion mitigation to their pipelines, including application of coatings and cathodic protection.[1]

Severe corrosion can lead to perforation of the pipe. As described in this book, other phenomena, such as hydrogen embrittlement, stress corrosion cracking, and microbiological influences, may lead to loss of pipeline integrity. The potential consequences include loss of product, service interruption, property damage including fire, contamination of water supplies, and loss of life. The consequences of pipe failures are increasing, due in part to encroachment of housing developments onto pipe right-of-ways. While prevention of the social and economic costs of pipeline failure is a sufficient goal in itself, corrosion mitigation is also driven by the recognition that the pipeline represents a valuable asset that should be protected.[2] Optimal allocation of resources requires proper design of pipeline systems, effective identification of locations where corrosion mitigation strategies are insufficient, and design of remediation strategies that can return an under-protected pipe to the protected condition.

This volume contains contributions from experts in the fields of corrosion and corrosion mitigation as applied to pipelines. The object of this work is to provide a basic understanding of the problems and to explore the state of the art in corrosion prevention. The contributions range from descriptions of field applications to discussion of mathematical and physical fundamentals. The book contains two parts, the first dedicated to understanding and managing corrosion processes, and the second to methods for detecting corrosion.

In Chapter 1, Richard Norsworthy (Polyguard Products Inc., USA) provides a basic explanation of electrochemistry as it applies to the corrosion process. He discusses factors that influence corrosion both inside pipes and on the exterior surfaces, including concentration and temperature cells, environmental cracking, and microbiological influences.

In Chapter 2, Bernard Tribollet (LISE, France) and Michel Meyer (GDF-Suez, France) discuss corrosion of underground pipes induced by high-voltage electric power lines or by AC-powered railways systems. They provide a fundamental perspective on the manner in which the induced alternating potential causes corrosion, the role of cathodic protection, and the changes in local environment associated with the induced electrochemical reactions.

In Chapter 3, Phil Hopkins (Penspen Group, UK) covers the assessment of corrosion in onshore (underground) pipelines, providing a state-of-the-art review, with both recommendations and insights into the various assessment methods available today.

In Chapter 4, Chao Liu, Alok Shankar, Mark E. Orazem (University of Florida, USA), and Douglas P. Riemer (Hutchinson Technology, Inc., USA) provide a historical perspective and a mathematical framework for the development of models for cathodic protection, including calculation of both on- and off-potentials at arbitrarily located surfaces. Application of the model is presented for interpretation of ECDA results in terms of the condition of the buried pipe, simulating the detrimental influences of competing rectifier settings for crossing pipes protected by independent CP systems, and simulating the influence of coatings and coating holidays (or defects) on the CP of above-ground tank bottoms.

Vedula S. Sastri (Sai Ram Consultant, Canada) provided two chapters to this volume. In Chapter 5, he reviews sources of corrosion in underground pipelines carrying oil and gases such as hydrogen sulfide and carbon dioxide. He discusses and compares corrosion monitoring techniques such as linear polarization resistance (LPR), electrochemical impedance spectroscopy (EIS), electrochemical noise (EN) techniques and the use of sensor probes. In Chapter 6, he reviews the use of corrosion inhibitors in the oil and gas industry, including production factors affecting corrosion inhibition, criteria for selecting corrosion inhibitors, mechanisms of corrosion inhibition, and types of corrosion inhibitor.

In Chapter 7, Tom Bubenik (Det Norske Veritas (U.S.A.), Inc.) discusses electromagnetic in-line inspection tools as they relate to pipeline integrity. He emphasizes magnetic flux leakage (MFL), the most commonly used inspection technology for pipelines, which has been successfully employed for nearly 50 years, to detect, identify, and size metal loss due to corrosion.

In Chapter 8, Angel R. Kowalski (Det Norske Veritas (U.S.A.) Inc., USA) provides a description of pipe-to-soil potential close interval surveys (CIS or CIPS), used to evaluate the effectiveness of the cathodic protection system of a buried or submerged pipeline. CIS principles are presented together with data collection quality assurance. Examples of CIS results are provided to illustrate the advantages of the tool.

In Chapter 9, David Eyre (Penspen Limited, UK) presents the Pearson survey, the oldest above-ground survey technique for finding coating holidays on buried pipelines. This chapter describes the technique, the equipment, and recent developments. It discusses the advantages and disadvantages of the Pearson survey over similar above-ground survey techniques.

In Chapter 10, Stephan Brockhaus, Markus Ginten, Stefan Klein, Michael Teckert, Olaf Stawicki, Dorothee Oevermann, Sabrina Meyer (ROSEN Technology and Research Center GmbH, Germany) and Derek Storey (ROSEN Technology AG, Switzerland) describe in-line inspection (ILI) for detecting and qualifying flaws which would survive hydrostatic testing as well as flaws close to pipeline's failure. Successive ILI measurements conducted over a period of years can reveal the growth rate of active flaws. Because an ILI tool is driven by the propellant of the pipeline, there is no need to stop pipeline operations to inspect the line. This chapter describes a variety of techniques which comprise non-destructive evaluation (NDE).

In Chapter 11, C. Sean Brossia (Det Norske Veritas (U.S.A.) Inc.) provides his perspective on methods used for external corrosion monitoring of pipelines. He concludes that a combination of methods should be considered that provide complimentary information on the present state of the pipeline as well as trending information.

I would like to express my gratitude for the contributors to this volume. Each chapter, written independently, provides a unique and important perspective on corrosion, sensing, and corrosion mitigation associated with pipelines. I express our appreciation as well for the editorial staff of Woodhead Publishing, who had the vision, tenacity, and editorial talent to shepherd this work to completion.

References

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