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OFFSHORE PIPELINES

DESIGN, INSTALLATION, AND MAINTENANCE

SECOND EDITION

Offshore Pipelines

Design, Installation, and Maintenance

Second Edition

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AMSTERDAM • BOSTON • HEIDELBERG • LONDON
NEW YORK • OXFORD • PARIS • SAN DIEGO
SAN FRANCISCO • SINGAPORE • SYDNEY • TOKYO
Gulf Professional Publishing is an imprint of Elsevier

GP
P

Gulf Professional Publishing is an imprint of Elsevier
225 Wyman Street, Waltham, MA 02451, USA
The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, UK

Library of Congress Cataloging-in-Publication Data
A catalog record for this book is available from the Library of Congress

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

ISBN: 978-0-12-397949-0

Printed in the United States of America

14 15 16 17 18 10 9 8 7 6 5 4 3 2 1

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Preface

The offshore pipelines in the oil and gas industry have advanced significantly in the last decade. The major changes are the new technologies employed for solving problems in deepwater development. During the many years of teaching oil and gas production engineering courses in academia and in the industry, the authors realized that there is a need for an updated book that reflects the current practice of what the modern offshore pipeline engineers do. Currently available books fail to provide adequate information about how the engineering principles are applied to solving problems that are frequently encountered in the offshore pipeline systems. This fact motivated the authors to write the second edition of the book Offshore Pipelines. In addition to the materials covered in the first edition, the second edition includes more materials in pipeline maintenance.

This book is written primarily for oil and gas pipeline engineers and college students of senior level as well as graduate level. It is not authors' intention to simply duplicate general information that can be found from other books. This book gathers authors' experiences gained through years of teaching courses of oil and gas production engineering in the oil and gas industry and universities. The mission of the book is to provide pipeline engineers handy guidelines to designing, analyzing, and operating offshore pipelines. The original manuscript of this book has been used as course manual for industry trainees and textbook for college students of undergraduate and graduate levels in Petroleum Engineering.

This book was intended to cover the full scope of pipeline systems. Following the sequence of applications, this book presents its contents in 18 chapters presented in 4 parts.

Part I contains 10 chapters covering pipeline design issues. Part II includes 3 chapters presenting principles and rules of pipeline installation. Part III consists of 3 chapters covering pipeline commissioning and operations. Part IV consists of 2 chapters covering condition-based maintenance.

Since the substance of this book is virtually boundless in depth, knowing what to omit was the greatest difficulty with its editing. The authors believe that it requires many books to describe the foundation of knowledge in offshore pipeline systems. To counter any deficiency that might arise from the limitations of space, the book provides a reference list of books and papers at the end of each chapter so that readers should experience little difficulty in pursuing each topic beyond the presented scope. Regarding presentation, this book focuses on presenting and illustrating engineering principles used for designing and optimizing offshore pipeline systems rather than in-depth theories. Derivation of mathematical models is beyond the scope of this book.

This book is based on numerous documents including reports and papers accumulated through years of work in the University of Louisiana at Lafayette, Chevron Corporation, and INTEC Engineering. The authors are grateful to the university and the companies for permissions of publishing the materials. On the basis of the collective experiences of authors, we expect this book to be of value to the pipeline engineers in the oil and gas industry.

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Chapter 1

Introduction

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1.1 OVERVIEW

The first pipeline was built in the United States in 1859 to transport crude oil (Wolbert, 1952). Through the one-and-a-half century of pipeline operating practice, the petroleum industry has proven that pipelines are by far the most economical means of large-scale overland transportation for crude oil, natural gas, and their products, clearly superior to rail and truck transportation over competing routes, given large quantities to be moved on a regular basis. Transporting petroleum fluids with pipelines is a continuous and reliable operation. Pipelines have demonstrated an ability to adapt to a wide variety of environments including remote areas and hostile environments. Because of their superior flexibility to the alternatives, with very minor exceptions, largely due to local peculiarities, most refineries are served by one or more pipelines.

Man's inexorable demand for petroleum products intensified the search for oil in the offshore regions of the world as early as 1897, when the offshore oil exploration and production started from the Summerland, California (Leffler et al., 2003). The first offshore pipeline was born in the Summerland, an idyllic-sounding spot just southeast of Santa Barbara. Since then the offshore pipeline has become the unique means of efficiently transporting offshore fluids, i.e., oil, gas, and water.

Offshore pipelines can be classified as follows (Figure 1.1):

- Flowlines transporting oil and/or gas from satellite subsea wells to subsea manifolds;
- Flowlines transporting oil and/or gas from subsea manifolds to production facility platforms;
- Infield flowlines transporting oil and/or gas between production facility platforms;
- Export pipelines transporting oil and/or gas from production facility platforms to shore;
- Flowlines transporting water or chemicals from production facility platforms, through subsea injection manifolds, to injection wellheads.

Offshore Pipelines. DOI: http://dx.doi.org/10.1016/B978-0-12-397949-0.00001-7

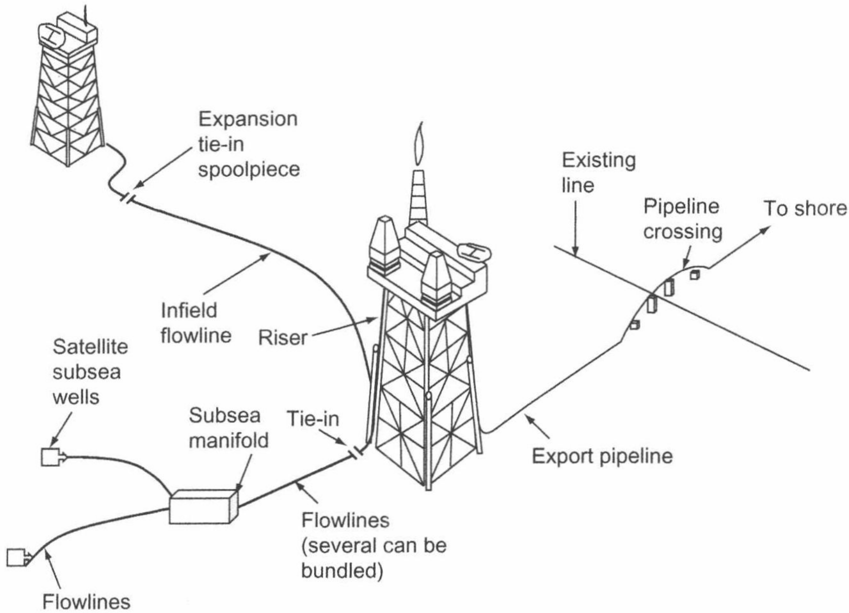

FIGURE 1.1 Uses of offshore pipelines.

Further downstream from the subsea wellhead, as more streams commingle, the diameter of the pipelines increases. Of course, the pipelines are sized to handle the expected pressure and fluid flow. To ensure desired flow rate of product, pipeline size varies significantly from project to project. To contain the pressures, wall thicknesses of the pipelines range from 3/8 in. to 1½ in.

1.2 PIPELINE DESIGN

Design of offshore pipelines is usually carried out in three stages: conceptual engineering, preliminary engineering, and detail engineering. During the conceptual engineering stage, issues of technical feasibility and constraints on the system design and construction are addressed. Potential difficulties are revealed and nonviable options are eliminated. Required information for the forthcoming design and construction are identified. The outcome of the conceptual engineering allows for scheduling of development and a rough estimate of associated cost. The preliminary engineering defines system concept (pipeline size and grade), prepares authority applications, and provides design details sufficient to order pipeline. In the detail engineering phase, the design is completed in sufficient detail to define the technical input for all procurement and construction tendering. The materials covered in this book fit mostly into the preliminary engineering stage.

TABLE 1.1 Sample Pipeline Sizes

Project No.	Project Name	Pipeline Diameter (in.)	Wall Thickness (in.)	*D/t*	Design Criterion
1	Zinc	4	0.438	10	Internal pressure
2	GC 108-AGIP	6	0.562	12	Internal pressure
3	Zinc	8	0.500	17	Internal pressure
4	Amerada Hess	8	0.500	17	Internal pressure
5	Viosca Knoll	8	0.562	15	Internal pressure
6	Vancouver	10	0.410	26	External pressure
7	Marlim	12	0.712	18	External pressure
8	Palawan	20	0.812	25	External pressure
9	Palawan	24	0.375	64[a]	Internal pressure
10	Marlim	26	0.938	28	External pressure
11	Palawan	30	0.500	60[a]	Internal pressure
12	Shtockman	36	1.225	29	Internal pressure[b]
13	Talinpu	56	0.750	72[a]	Internal pressure[b]
14	Marlim	38	1.312	29	External pressure[b]
15	Shtockman	44	1.500	29	Internal pressure[b]
16	Talinpu	56	0.750	75[a]	Internal pressure[b]

[a]*Pipelines with D/t over 30.5 float in water without coating.*
[b]*Buckle arrestors required.*

A complete pipeline design includes pipeline sizing (diameter and wall thickness) and material grade selection based on analyses of stress, hydrodynamic stability, span, thermal insulation, corrosion and stability coating, and riser specification. The following data establish design basis:

- Reservoir performance
- Fluid and water compositions
- Fluid PVT properties
- Sand concentration
- Sand particle distribution
- Geotechnical survey data
- Meteorological and oceanographic data.

Table 1.1 shows sizes of some pipelines. It also gives order of magnitude of typical diameter/wall thickness ratios (D/t). Smaller diameter pipes are often flowlines with high design pressure leading to *D/t* between 15 and 20. For deepwater, transmission lines with *D/t* of 25–30 are more common. Depending upon types, some pipelines are bundled and others are thermal- or concrete-coated steel pipes to reduce heat loss and increase stability.

Although sophisticated engineering tools involving finite element simulations (Bai, 2001) are available to engineers for pipeline design, for procedure transparency, this book describes a simple and practical approach. Details are discussed in Part I of this book.

1.3 PIPELINE INSTALLATION

Once the design is finalized, pipeline is ordered for pipe construction and coating and/or insulation fabrication. Upon shipping to the site, pipeline can be installed. There are several methods for pipeline installation including S-lay, J-lay, reel barge, and tow-in methods. As depicted in Figure 1.2, the S-lay requires a laying barge to have on its deck several welding stations where the crew welds together 40–80 ft of insulated pipe in a dry environment away from wind and rain. As the barge moves forward, the pipe is eased off the stern, curving downward through the water as it leaves until it reaches the touchdown point. After touchdown, as more pipe is played out, it assumes the normal S-shape. To reduce bending stress in the pipe, a stinger is used to support the pipe as it leaves the barge. To avoid buckling of the pipe, a tensioning roller and controlled forward thrust must be used to provide appropriate tensile load to the pipeline. This method is used for pipeline installations in a range of water depths from shallow to deep. The

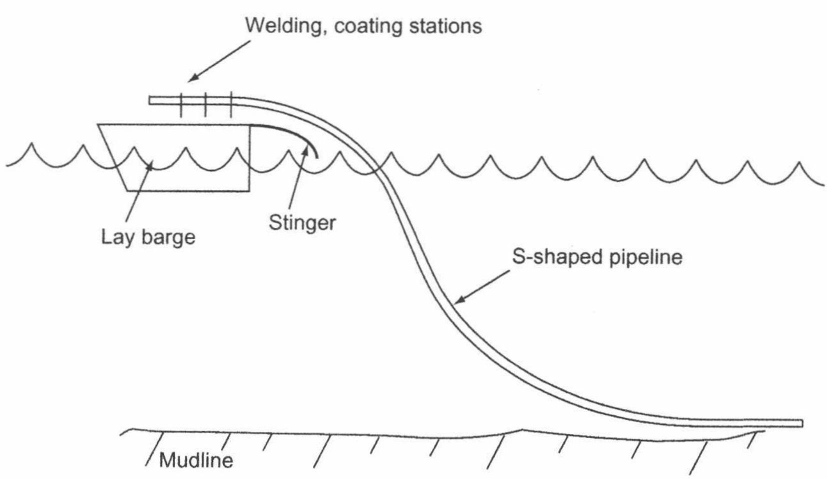

FIGURE 1.2 S-lay barge method for shallow to deep pipelines.