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Offshore pipeline construction cost in the U.S. Gulf of Mexico

Mark J. Kaiser

Center for Energy Studies, Louisiana State University, Baton Rouge, LA 70803, United States

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ABSTRACT

The oil and gas pipeline network in the U.S. Gulf of Mexico is the largest offshore pipeline network in the world, but construction cost statistics are not a frequent topic of investigation. Using data sources from the Federal Energy Regulatory Commission, industry publications and press releases, pipeline construction cost in the U.S. Gulf of Mexico from 1980 to 2014 are examined. The average inflation-adjusted cost to install FERC pipelines from 1995 to 2014 was \$3.3 million/mi (\$2.1 million/km), and industry publication pipeline cost average \$3.1 million/mi (\$1.9 million/km). Data sources vary in their scope and quality and need to be interpreted with an understanding of their limitations. A description of each data source and its limitations are provided.

1. Introduction

Pipelines have been called the arteries of the oil and gas industry, and although less spectacular and less visible than platforms and floating production systems, play an important role in the safe and economic development of offshore hydrocarbon resources. Nearly all offshore production in the U.S. Gulf of Mexico (GoM) is transported to shore via pipelines, and at the end of 2014, about 44,000 miles (70,800 km) of pipeline have been installed in federal waters (Fig. 1).

The U.S. offshore industry is one of the most transparent markets in the world, but companies are notoriously reluctant to share cost data and generally do not provide detailed cost on project developments. Little cost information is publicly reported. The Oil and Gas Journal (OGJ) publishes a summary of Federal Energy Regulatory Commission (FERC) pipelines, but these represent gas export systems exclusively and the majority of these pipelines are onshore. Industry and trade publications describe offshore project cost on a sporadic basis across various sources, and require time and patience to collect and track down, but also provide useful data. The purpose of this paper is to review and evaluate public sources of offshore pipeline construction cost in the U.S. GoM to inform the industry and expand the knowledge base in the area.

The first offshore wells were drilled in the GoM in 1947, and by 1978, the first pipeline was installed in over 1000 ft (300 m) water depth. Today, GoM pipelines transport oil and gas in water depths up to 9500 ft (2900 m). From 2000–2009, one-third of all pipeline miles in the region were installed, with almost half of all mileage (43%) coming from deepwater (> 1000 ft or 300 m).

The outline of the paper is as follows. The paper begins with a review of stages and components of pipeline construction, system architecture, and contract strategies. A description of cost categories and the primary components that comprise each category provide context for the cost statistics reported. Data sources and processing methods are discussed and evaluated separately and compared. The paper concludes with the limitations of the analysis. In Appendix A, the installation process on the *Castoro Sei* is shown step-by-step, and in Appendix B, two FERC pipeline examples illustrate cost estimation procedures.

2. Offshore pipeline construction

2.1. Stages

Pipeline projects normally consist of the following operations:

1. Gather and analyze data for flowline route;
2. Design, engineer, and procure pipelines;
3. Mobilize/demobilize the pipelay vessel and auxiliary equipment to the job site;
4. Lay pipe between subsea well(s) and platform, and between platform or pipeline endpoint(s);
5. Install risers on platforms or subsea assembly tie-ins to pipelines;
6. Install all umbilicals, jumpers, flying leads, and other subsea equipment;
7. Inspect, test, and commission.

In the GoM, the seafloor topography ranges from the flat and featureless shallow waters to the complex conditions on the continental slope and deepwater. Pipeline routes are selected to avoid areas of possible landsliding and faulting, mud seeps, undulations, and rocky

E-mail address: mkaiser@lsu.edu.

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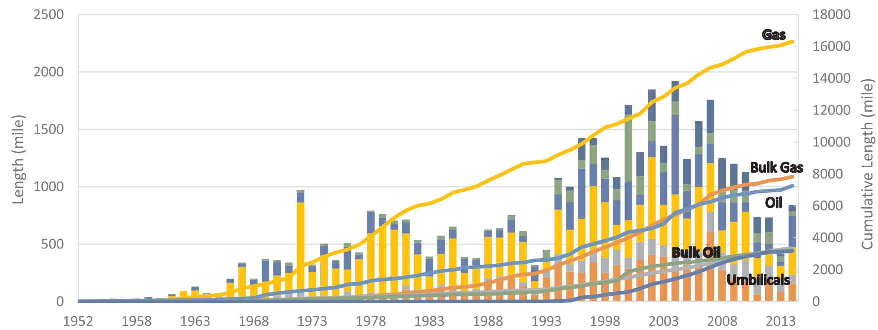

Fig. 1. Length of installed pipeline in the Gulf of Mexico by product group, 1952–2014. Source: BOEM.

outcrops. Routes may be selected to avoid difficult terrain, but the added length needs to be compared with the cost to rectify the spans [1]. A survey of the proposed route and contingency routes are performed collecting bathymetry data and core samples to determine soil characteristics [2,3]. The soil information is used to predict potential span and perform stability checks. Oil and gas companies typically perform or oversee the route selection process and are involved to varying extent with the engineering, procurement, and construction process. Installation and commissioning are performed by third-party marine contractors.

2.2. Components

A pipeline is in principle a very simple structure, normally made of a piece of steel with a hole in it with the sole purpose to deliver fluid from one point to another. Most steel pipelines are 40 ft (12 m) long segments referred to as joints that are joined by welding. The joint has to be straight and the hole has to be round and the diameter and thickness of the pipe have to be able to withstand all the forces acting upon it during installation and over its design life. Offshore pipelines have diameters that range from 3 to 54 in. (7.6–137 cm) with wall thickness that run from 0.25 to 1.5 in (6–38 mm). The steel for the lines is usually high-yield strength 50,000 to 70,000 psi (350–500 MPa) selected for its strength, ductility, toughness, and weldability.

In the 1950s, the diameters and operating pressures of offshore oil and gas pipelines were modest, and many lines were fabricated from seamless pipe, but as operators explored deeper and more remote waters and service requirements became more severe, diameters and wall thicknesses needed to increase which necessitated changes in welding techniques and steel composition.

Pipeline design is governed by throughput, installation and site requirements [4]. After selection of pipeline diameter based on throughput requirements, selection of wall thickness and coating follow. Wall thickness is determined by operating pressure, external hydrostatic pressure and the need for sufficient pipeline weight for stability [5,6].

Two types of pipeline systems are utilized in offshore development, those associated with transporting processed oil and gas from a processing facility to shore and referred to as export systems (or sales quality pipelines), and those pipelines associated with delivering raw fluids from a remote subsea wellhead or platform to a host facility, referred to as infield flowlines (or gathering systems).

A pipeline system is described by the flowlines, risers, and export lines associated with field development. Risers are the fluid transfer system linking the seabed and the deck and are associated with drilling, production and import/export pipelines. Risers are different than the pipelines and flowlines that reside on the seabed since they are subject to a range of changing forces over long periods of time. Ocean currents, water pressure, vessel motion, and wave actions are the primary forces that risers encounter over their lifetime, and therefore, must be designed to minimize fatigue damage. Risers attached to fixed platforms are also considerably different than risers attached to floating structures.

Pipelines may be rigid steel, flexible line, or pipe-in-pipe[1] systems manufactured using two pipes separated by insulation. All types are used in the GoM and elsewhere throughout the world but rigid steel and flexible lines are by far the most common in terms of miles laid. Rigid pipe is the simplest and least expensive and often considered the most reliable for long-term service. Flexible pipe is used for small diameter, short distance flowlines, as jumpers from wellheads and well manifolds to rigid flowlines, and as static and dynamic risers. Pipe-in-pipe systems are relatively expensive because of the need for a second pipe and complexity of fabrication.

2.3. Installation methods

Every installation project is evaluated individually. The J-lay and S-lay methods are named for the shape each pipe assumes during construction (Fig. 2). In J-lay mode, the pipe departs the vessel with a large departure angle leading the pipe to a single curvature, or J-shape. S-lay mode uses a smaller departure angle and the pipe has a double curvature, or S-shape. Lay rates are vessel and project specific and depend upon the weather and other factors, but for a given pipe diameter and thickness and assuming all other factors constant, reeled pipelines can be installed faster than S-lay line which is typically faster than J-lay.

There is an obvious trade-off between vessel specification, dayrates, and performance [7]. High spec vessels cost more to construct, charge higher dayrates, and perform services faster than low spec vessels. Some construction activity require a specific mode of installation (e.g., J-lay at deepwater floater), while others may allow a combination of methods, and there is a wide variety of vessels available for installation (Fig. 3). S-lay dominates pipelay work in the deepwater GoM, with over three-quarters of all pipelines measured by length in over 3000 ft (910 m) water depth through 2006 installed in this manner [8]. See Appendix A for the process operations of S-lay on the high-spec *Castoro Sei*.

2.4. Architecture

Subsea architecture and field development strategy determine the amount and type of pipeline required. There are many variations of system configurations and complexity which depends on the nature and areal extent of the reservoir and hydrocarbon fluids, development strategy, the time of development and available capacity on pipeline

[1] Pipe-in-pipe systems are used to maintain the temperature of the fluids to prevent formation of hydrates, reduce wax deposition, or to reduce the pressure drop by reducing the viscosity of heavy crudes. In a pipe-in-pipe scheme, the transported fluid is carried by an internal line, which lies within a larger pipe supported by spacers. The annulus may be partially evacuated and filled with another gas.