ABSTRACT

Through an active research program, ExxonMobil has identified safe and cost effective design practices for pipelines in seismic and arctic areas, where strain-based design criteria are needed. As part of this work, we have developed analytical methods and models to quantify the strain demand on the pipeline due to seismic and permafrost hazards. In addition, we have developed analytical models to better understand pipe buckling and wrinkling failure modes, and have conducted tests to quantify the capacity of the pipe and its welds to safely accommodate the strains generated by the seismic and permafrost hazards. This paper will describe some of ExxonMobil's work in this area, present results from case studies considered to date which highlight some of the key challenges in designing pipelines to operate safely in a strain-based design environment, and discuss design approaches that can be used to overcome these challenges and produce safe and cost effective pipeline designs. The paper will also discuss some of the limitations found in existing Industry Standards for addressing seismic and permafrost hazards and explain how limit state design approaches can be used to develop rational design criteria for such pipelines.

KEY WORDS: Pipeline; seismic; arctic; strain based design.

INTRODUCTION

ExxonMobil Corporation's current and future interests include the need to design, install and operate oil and gas pipelines in seismic and arctic areas, where significant ground movements could occur during the service life of these pipelines. Industry Codes and Standards provide very general guidelines on how to produce safe designs for pipelines in areas where large ground movements and hence plastic strains are expected, but rarely provide explicit design criteria or performance standards on how to achieve this important objective. Quite often, operators considering installation of pipelines in such areas find it necessary to supplement the guidelines found in existing Codes and Standards with project specific design criteria. These criteria must be carefully selected to be consistent with the spirit and intent of existing Standards and provide more direct guidance to designers on how to achieve the desired objectives.

This paper provides an overview of various ExxonMobil research and development activities that are either completed or are ongoing, which aim to enhance our ability to produce safe and cost effective pipeline designs in seismic and arctic areas, where the pipelines must be designed to accommodate some plastic strain. This work covers both onshore and offshore pipelines, and addresses both buried and unburied pipelines.

Although the focus of the current paper is on strains caused by seismic and arctic hazards, it must be stated that there many other situations or hazards that can also produce plastic strains in pipelines. Examples include installation of pipelines by reeling, pulling of risers through J-tubes, unintentional strains caused by lateral or upheaval buckling due to thermal or pressure loads, and unintentional yielding caused by accidental overloads from various sources. Although these situations will not be addressed directly by this paper, the fundamental principles discussed in the paper can also be applied to assess the integrity of pipelines subjected to any loadings that produce plastic strains in the pipe.

Design Objectives for Seismic Areas

The main objective of seismic pipeline design is to make the pipeline and pipeline facilities resistant to the effects of potential earthquakes that may occur during the operating lifetime of these facilities, and prevent failures that can adversely impact health, safety and the environment. A second, but also very important objective, is to minimize capital loss and disruptions to operations.

Buried and above-ground pipelines can be affected by permanent ground deformation (PGD) and transient ground deformation (TGD).