# OTC 20301

# Risk Assessment and Technology Qualification Process for Offshore LNG Pipelines

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This paper was prepared for presentation at the 2009 Offshore Technology Conference held in Houston, Texas, USA, 4–7 May 2009.



## Abstract

The Liquefied Natural Gas (LNG) market is growing significantly and there is considerable demand for LNG plants and terminals. The challenge for these facilities is even greater in view of public opposition, mostly in the US, to the construction of these facilities onshore because of safety, security and environmental concerns. For these reasons, the oil and gas industry is looking offshore to locate LNG facilities. As part of this development, the safe transport of large quantities of LNG from the LNG offshore terminals, Single Point Moorings or offloading platforms to the storage tanks ashore for gas distribution has become a relevant technical issue, and cryogenic subsea pipelines became a crucial emerging technology. Since neither prior in-service experience nor comparable design review history exist for emerging technologies, the acceptability of such novel concepts for classification requires thorough analysis.

An improved process to assist the classification of offshore LNG pipelines has been successfully applied by the authors for the review of several subsea cryogenic pipeline designs. A combination of engineering analyses and risk assessments was employed, creating an effective process to review the proposed design against established safety guidelines. The qualitative risk analyses performed were very effective in identifying risk issues and discussing how they could be prevented and/or mitigated. The analysis of proposed subsea cryogenic pipeline designs concluded that they are technically feasible from both safety and functional perspectives and the so-called Approval In Principle was granted to proposed designs.

## Introduction

New concepts are continually emerging as the offshore industry expand its traditional activities and challenge their existing boundaries in order to keep up with society's needs. These novel concepts do not have any prior in-service experience, neither any classification rules, statutory regulations nor industry codes or standards directly applicable to them. Therefore novel concepts require a different approach to classification, including the use of new tools and techniques in order to determine if the concept provides acceptable levels of safety in line with current offshore and marine industry practice.

The development of designs for LNG offshore terminals, LNG single point moorings and LNG offshore offloading platforms is relatively recent. As part of this development, subsea cryogenic pipelines for the safe transfer of large quantities of LNG for import/export terminals became a crucial emerging technology.

Typical subsea cryogenic pipeline designs consist of two coaxial pipes, or Pipe-in-Pipe (PiP) concept. Some designs add a secondary containment (third pipe) to create the so called Pipe-in-Pipe-in-Pipe (PiPiP) concept. The inner pipe transports the cryogenic fluid, the annular space provides the necessary insulation properties and the outer pipe(s) offers protection from the external environment (pressure, corrosion, impacts).

The primary function of a cryogenic subsea pipeline is to transport LNG safely and reliably during its service life. A successful design needs to fulfill the following functional requirements:

- Contain LNG under all foreseen conditions
- Thermodynamic performance to prevent/minimize LNG vaporization and maintain outer pipe temperatures within acceptable ranges
- Accommodate the anticipated contraction/expansion of the pipeline
- Means to relief a potential pipe pressure increase due to LNG vaporization
- System to quickly detect any LNG leakage, isolate, and drain/purge the pipeline
- Proper arrangements to allow for installation, maintenance, inspection and repairs