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Mechanical Design of Subsea and Buried LNG Pipelines

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Abstract

Design of subsea and buried LNG pipelines presents challenges such as low operating temperatures (-160 °C), multiple pipe walls, and differential expansion of materials. ITP has developed an LNG pipeline design that has been certified by DNV as “Fit for Service” for LNG subsea transport. JP Kenny has developed and applied a comprehensive FE model to ITP’s triple-walled (PIPIP) LNG pipeline design to successfully demonstrate the robustness of the pipe design. The FE model is used to determine the displacements and stresses in each of the three pipe walls under all the operating conditions and to provide input data for detailed analyses of the bulkheads, risers, riser supports, and tie-ins to external piping. The basis of the model is presented along with a description of the PIPIP. Typical results of the modeling are presented, which demonstrate how the design of the PIPIP limits the stresses, displacements, and end loads. The use of the model results for design of ancillary and connecting systems is also reviewed.

Design Considerations for LNG Loading/Offloading Pipelines

LNG loading/offloading pipelines present several design challenges:

- Low temperatures (-160 °C)
- Relatively long distances
- High thermal performance requirements
- Low risk tolerance

The material selected for LNG pipelines has traditionally been stainless steel 304L. Although suitable for the low temperature, 304L has the disadvantage of a high Coefficient of Thermal Expansion ($CTE = 13.6 \times 10^{-6} K^{-1}$ between ambient and -160 °C). For the stresses in a 304L LNG pipeline to be acceptable, the pipeline must be allowed to contract with temperature. Consequently, either expansion loops or bellows are required.

Heat ingress to the pipeline must be limited for operating cost and operational (Boil-Off Gas) reasons. As such, very low overall heat transfer coefficients (U-values less than $0.15 W/m^2 \cdot K$) are required. Low U-values have traditionally been obtained by using either Vacuum Insulated Pipe (VIP) or very thick conventional insulation.

All of the product from an LNG export facility must flow through the LNG pipeline. As LNG facilities involve high capital costs, there is a very low risk tolerance for LNG pipelines. If a subsea design is to be preferred over the conventional trestle design, the subsea design must be robust and able to withstand impacts that might occur in near shore regions with ship traffic.

To apply an LNG pipeline subsea, the thermal performance must be maintained; the design must be robust and reliable; and bellows and expansion loops must be eliminated. ITP has developed a design that satisfies these criteria using a triple-wall design with different materials for the pipes, and with bulkheads only at each end of the pipeline. The triple-walled design and bulkheads complicate the determination of the stresses, displacements, and end loads. JP Kenny has developed a pipeline analysis model that allows the design to be rigorously evaluated.

ITP LNG Pipeline

ITP began development of its cryogenic pipe design in 1996 and performed the first full-scale tests in 2001 with LNG. In 2003, ITP was joined by four major oil companies in a joint industry project with the objective of qualifying ITP’s LNG pipe