

## **Critical Thermal, Corrosion and Material Issues Related to Flowline Pipe-in-Pipe (PIP) Systems**

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### **ABSTRACT**

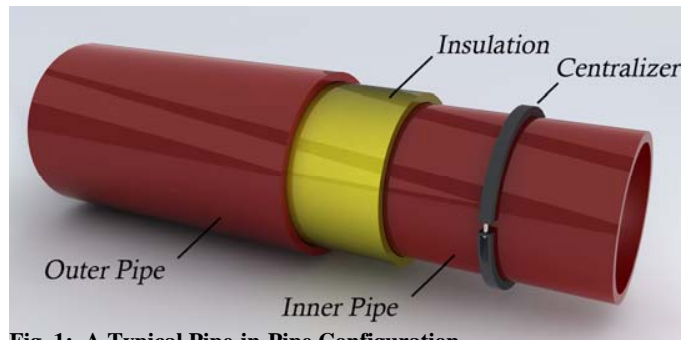
The common method of achieving enhanced thermal insulation performance of flowlines (U values of 1.0 W/m<sup>2</sup>K, or less) requires a 'Pipe-In-Pipe' (PIP) insulation system, in which the inner pipe carrying the fluid is encased within a larger outer pipe separated by an annulus insulation material. However, with all PIP systems it is important to ensure that the structural integrity is maintained for both installation and operational loads for each of the PIP components (thermal insulation, linepipe, centralisers, waterstop seals, and loadshares). The temperature of the internal contents of a PIP system can have a significant effect on the long term degradation and performance of materials. It is not uncommon for recent designs of pipelines to be considered for temperatures up to 350°F (177°C). Also it is important to ensure integrity for the entire life of the project, and that undesirable degradation of the thermal and structural performance does not occur. The effects of temperature on the PIP components are discussed within this paper. Various insulation materials are considered and these consist of mineral wools, polyurethane foam, granular or microporous materials, ceramics and Aerogels. Annulus related corrosion integrity issues including monitoring, inspection and on-going degradation and aging management are addressed. Performance of insulation in terms of thermal, heat transfer and effects of corrosion under wetting conditions and cathodic protection at the field joints will also be considered. The new technology presented in this paper is; a discussion into the critical aspects of testing PIP components for high temperature applications (centralizers, waterstops, loadshares, thermal insulation), a critical evaluation of different thermal insulation materials, mechanisms of MICC 'Microbially Influenced Crevice Corrosion' and the hidden annular 'Corrosion under Insulation' for pipelines, and inspection methods. Hence, this paper discusses key issues associated with PIP systems in terms of the structural integrity, corrosion and material integrity with regards to the PIP components. Lessons learned from recent J P Kenny / IONIK PIP projects, and key technology gaps and recommendations for the future are identified and discussed.

**KEY WORDS:** Thermal, Corrosion, Material, Integrity, Flowlines; Pipe-in-Pipe (PIP); Centralizers: Cathodic Protection.

### **INTRODUCTION**

Pipe-in-pipe is increasingly being used for the transportation of hydrocarbons. Pipe-in-pipe (PIP) flowline systems are frequently used in the

GoM for subsea tie-backs where there is a requirement for high thermal performance. A PIP system consists of the inner pipe carrying the fluid encased within a larger diameter outer pipe. The outer pipe seals the annulus between the two pipes and the annulus can be filled with a wide range of thermal insulating materials that do not have to withstand the hydrostatic pressure. A PIP flowline has the advantage over traditional wet insulated pipelines of allowing a lower 'Overall Heat Transfer Coefficient' (OHTC) or 'U' value for the system. It is a common method of achieving low U values of 1.0 W/m<sup>2</sup>K or less, and has been used on a number of Projects in both the North Sea and in the GoM. Fig. 1 shows a typical PIP system configuration.



**Fig. 1: A Typical Pipe-in-Pipe Configuration**

For longer subsea tie-backs, a lower OHTC allows the production temperatures of the internal contents to remain above the wax allowable temperature (WAT). This facilitates longer 'cool-down' times during a 'shut-down', to prevent hydrate conditions. A shut-down time of at least eight to ten hours is considered to be the minimum requirement, which can be a large challenge for long tie-back distances.

Today, it is not uncommon for PIP designs to be considered in water depths up to 3,050 meters (10,000ft) and flowline temperatures up to 177°C (350°F) (J P Kenny, 2006).

This paper is part of massive analysis works related to extra high pressure and high temperature PIP sponsored by a major operator (J P Kenny, 2007). The study targets the Gulf of Mexico (GoM), where subsea production wells are drilled at a water depth (WD) down to 10,000 feet, with a flowing product temperature up to 177 °C (350°F), and a system shut-in pressure of 64.8MPa (65ksi). These temperatures