Camisea Offshore Loading System – Design and Construction of Subsea LPG Pipelines

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Abstract
This paper discusses the recently completed design and construction Camisea Offshore Loading System which is part of a larger project that extracts natural gas from the San Martin and Cashiriari gas fields in the Camisea region of central Peru.

The gas is exported from a marine terminal facility which is located on the Pacific coast near Pisco and is designed to deliver gas products to marine tankers for exporting with a pipeline loading rate of 30,000 barrels per hour (4,770 m^3 per hour). The loading lines connect the Pisco Facility to a marine berthing facility approximately 3 kilometres offshore in 15 metres of water.

The loading system consists of the following elements:

- Two off 20" low temperature, insulated LPG pipe in pipe systems (24" carrier) with riser;
- One uninsulated 24" Naphtha line with riser;
- One uninsulated 10" Diesel line with riser;
- One J-tube for power/control umbilical.

Subsea LPG pipelines were made feasible through the application of ITP's advanced pipe in pipe insulation technology IZOFLEX.

The paper describes the design and construction challenges, including:

Design criteria
Material selection
Design challenges
Pipe in pipe configuration
Field joint configuration
Tie-in methods
Installation methods
Inspection requirements
System reliability
Typical project costs and schedule

The use of insulated, subsea LPG pipelines in place of a loading jetty has resulted in a significant CAPEX reduction.

Camisea Location of the fractionation plant

To send out the gas coming from the Andes, the consortium chose to export the heavy parts as LPG resulting in the need of building a plant and an export terminal. The Peruvian coast is a desert on flat land facing the Pacific Ocean. It is open to oceanic swell and tsunamis resulting from far earthquakes. Several locations were studied south of Lima with very few naturally protected areas. The Paracas peninsula in front of Pisco acts as a breakwater and therefore this area was chosen.

Environmental Issues

This peninsula is part of highly protected Natural Reserves and Pisco has an active fishing industry, requesting world class environmental friendly solutions. The projects had to face the local authorities and the worldwide non governmental organisation lobbying to the financing banks. This led the consortium to choose the innovative design subsea pipeline proposed by ITP which reduces the visual and local traffic impact with significant costs savings. For more safety/security, the pipe was buried, the dredging was performed with an ecological clamshell.

Design Criteria

Following a review of relevant offshore pipeline design codes encompassing ASME/ANSI, BS Standards and DNV design codes, DNV OS-F101 was chosen as the preferred code for the low temperature, insulated pipelines. Although ASME 31.5 is applicable in terms of the temperatures encountered in this project, it is essentially a process piping code and hence more appropriate for refinery type application. As such its' prescriptions on allowable stresses are low; and are considered prohibitive with respect to the stresses that will be seen by the pipeline during its' design life.

DNV OS-F101 was chosen for use as it represents the current state-of-the-art in offshore pipeline design and can be used for systems encountering this project's temperature range without restriction on allowable stress and strain on the proviso that selected materials are tolerant of all applicable temperature-induced issues.

It should be noted however, that as DNV OS F-101 is essentially a subsea pipelines code, ASME 31.5, ASME 31.4 and ASME 31.8 were referenced for the onshore sections of the LPG system (i.e. for road crossings, etc.).

Design Challenges

Pipe in Pipe Configuration
Each LPG pipe in pipe bundle consisted of 4km of a 508OD by 12.7WT API X65 inner pipe with a 609mm by 20.4Wt API X70 outer pipe with 20Thk Izoflex insulation layer.

Material Selection
Special low temperature carbon steel with adequate toughness at –60Deg C was sourced for the liner pipe, the end bulkheads and the field joint half shells.

Insulation Requirement
The insulation requirement for the complete 4km LPG system was a U-value of 0.35 W/m²/K. This is required to limit the boil-off to a minimum. This was achieved though the use of Izoflex which is a microporous insulation system, patented by ITP. It comes in the form of panels which are wrapped around the inner pipe and inserted in the outer pipe.

Field Joints
Two type of field joints were designed. Type one included half shells and was used for joining prefabricated pipe-strings and end bulkheads. Type two butted the inner and outer pipes without use of half shells. The type 2 field joint was used for the making up the prefabricated pipe strings on site.

Special low temperature service weld procedures were developed with TWI.

End Bulkheads
The parallel 4km long pipelines have continuous annulus sealed at the end with bulkheads. These pieces offer stress distribution between the two pipes so that the loads remain low and decrease the need for large spool pieces.

Tie-in Spools and Risers
Tie-in spools were used to connect the pipeline to the risers. The same system of pipe in pipe insulation was used for the tie-in spools and risers. Flanged connections were used on the tie-in spools. Special shrouds were designed to prevent ice forming round the flanges and to prevent heat loss.

Tsunami and Seismic Conditions
The design needed to withstand a 60-year tsunami wave of 4.5m period, 20min period and 5.0 m/s on-bottom velocity. This excludes any transpacific events or tsunamis triggered by landslides.

The development is situated in one of the most seismically active areas in the world. The pipelines and associated appurtenances within the scope of work are designed for a 200-year return earthquake whose acceleration is 0.6g.

On Bottom Stability
The pipelines are installed in a trenched and backfilled to a 1m depth of cover. Extensive soil liquefaction analysis was performed to ensure the backfill material would not liquefy under tsunami loading and be removed from the trench. A high pipe SG was specified to prevent the pipe floating if the soil liquefied.

Contraction
The operational contraction of the pipe in pipe system at the tie-in to the risers was less than 600mm.

The contraction at the tie-in to the onshore plant was less than 150mm

Fatigue Analysis
The fatigue analysis was based on the DNV RP-C203 code. This proved that the fatigue usage for each of the pipelines was acceptable based on the specified design life of 35-years and the assumed fatigue-loading regime.

Fabrication

Single joints
The pipe-in-pipes were prefabricated on site with local contractor. This included the insulation and the insertion of 12m long units. 20 pipe-in-pipes were fabricated per day.

Flat-Pack
As land was available the client offered the possibility to fabricate the offshore lines on a 3km rail track and pull it at once offshore. The 5,000 t flat-pack gathered the two 20"/24" pipe-in-pipes, the bared 24" Naphtha and 10" Diesel lines and an umbilical for power and information.

Field-Joint Configuration
The pipe-in-pipe field jointing operations consisted in welding the inner pipe, X-ray the weld, insulating the remaining bare part, sliding the outer pipe and then welding the outer pipe above the insulation with no specific protection.

Installation Methods

Onshore Section
The onshore section connecting the plant to the landfall was assembled in the trench and buried to a depth of 1.5m

Flat-pack Pulling
In order to avoid disturbance to the construction of the fractionation plant and the local roads, the railroad was built with a large bending radius outside the site and a tunnel was dug under the coastal road. The flat-pack on the rail track was first pulled easily with two side booms up to the beach.

Offshore pulling
A 1.5m deep trench was pre-dredged using a low sediment disturbance clamshell dredging technique.

All of the pipelines were installed in a single flat pack using an on-bottom mode using a linear winch mounted on an anchored pull barge.

Land & Marine was in charge of the offshore pipe pulling and the installation of the tie-in spools on the berthing dock.

Tie-in Methods
The pipe in pipe tie-in spools were installed by divers.

The flange bolts were tightened using hydraulic tensioning equipment.

Inspection and Monitoring Requirements
Provision was made for inspection pigging of the inner pipeline.

A pressure gauge controls permanently the integrity of the system through the annulus pressure between the two concentric pipes.

The tie-in spool and risers have been inspected for ice formation and leaks at the flanges.

System Reliability
The design life of the system is 35 years.

The system design is based on using materials and fabrication methods with a proven track record of subsea reliability.

A full system design HAZOP and safety assessment was carried out.

Insulation Performance
In service measurements of the Camisea system have confirmed the insulation is delivering the required insulation.

Microporous insulation use on pipelines has been pioneered by ITP since 1997 with the HP/HT Shell ETAP project, the extensive track record today of its applications correlated with site measurements demonstrates its reliability.

Project Costs and Schedule

From the first meeting with the client to the first cargo shipment the elapsed time was 21 months. When compared to conventional pipes on a trestle, the subsea pipe option overall project cost reduction is estimated as 30 to 50%.

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Figure 1.0 Camisea Location

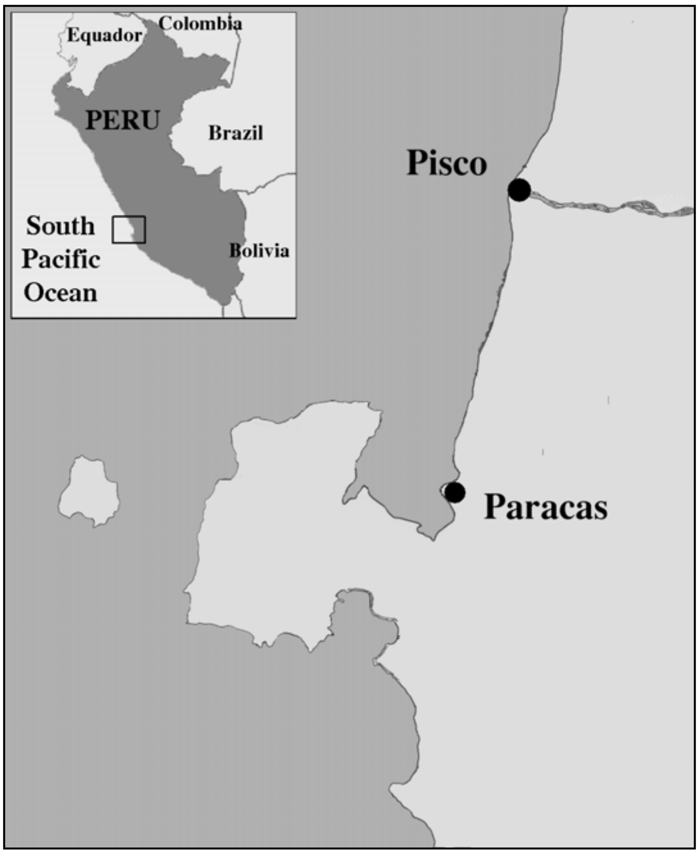

Figure 2.0 Pipeline Route Layout