

# Subsea Transportation of Cryogenic Fluids

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The authors report on the recent successful establishment of ITP-designed sub-sea insulated refrigerated LPG pipelines on the Camisea Project in Peru. The article describes the progress of a Joint Industry Project to qualify the design for LNG applications, and the potential benefits for jetty to shore LNG transfer.

Subsea transportation of cryogenic fluids (LNG and LPG) for both loading and offloading terminals can have a significant impact on cost, environmental and visual impacts, local approval, and security. Taken together, the net result is that the overall project approval cycle can also be improved, and thereby improve project viability and economics.

The technology for subsea transportation of cryogenic fluids is maturing rapidly, in large part due to a joint industry project (JIP) to qualify an LNG pipeline design and through the successful installation and operation of subsea propane and butane pipelines on the Camisea Project in Peru.

## Camisea Propane and Butane Subsea Pipelines

Figure 1 shows the loading berth for propane and butane from the Camisea fractionation plant located near Pisco, Peru. What is noticeably absent in the picture is the presence of a trestle and pipeline connecting the berth to the fractionation plant located 4 km away (1 km onshore and 3 km offshore). The conventional trestle that was originally proposed generated local objections based on high visibility and concern that it would interfere with fishing boat routes. The trestle was also higher cost and more exposed to natural risks (such as tsunamis).

The berth is connected to the Pisco fractionation plant via two sub-sea, 20 inch pipelines which transport propane and butane at temperatures as cold as -45 °C. Each carbon steel pipeline is insulated and encased in a 24 inch, carbon steel outer pipe. In addition to the propane and butane pipelines, naphtha and diesel are also transported subsea in separate, uninsulated pipelines.

The subsea cryogenic propane and butane flowlines and risers are among industry's first, in that they employ the unique, thermally efficient "pipe-in-pipe" configuration using the highly thermally efficient Izoflex microporous insulation system (a patented insulation system for pipeline applications owned by ITP). It provides a high thermal performance (0.35 W/m<sup>2</sup> K "as installed"), while using only 20 mm of insulation, which results in a compact overall pipe-in-pipe design. It would have required more than three times the thickness of polyurethane foam

insulation to achieve a similar thermal performance. Consequently, with the traditional insulation systems, the outer pipe diameter would be significantly larger.

In addition to the thermal performance, the Izoflex insulation system offers other benefits.

(a) It can be used over a wide temperature range (-200 to 900 °C). This characteristic greatly simplifies the design and the fabrication process since it is possible to weld directly over the insulation without damaging it. All field joints of the pipe-in-pipe are simple butt welds. Bulkheads were used only at either end of the pipeline.

(b) It has high compression carrying characteristics. No centralizers are needed between the two pipelines.

Using the local labor workforce, individual 20 inch pipe sections were insulated and inserted into the 24 inch outer pipe at a temporary fabrication facility set up on-site in Peru (see Figure 2).

There are significant construction and installation benefits, and accompanying reduced cost and risk, associated with minimizing field joints. This led to a decision to complete as much fabrication as possible onshore. With concurrence from the fractionation plant EPC contractor, space was set aside at Pisco so that the entire 3 km offshore pipelines were built



Figure 1 Camisea berth with subsea pipelines connecting to the onshore plant



Figure 2 Onsite fabrication of pipe-in-pipe sections

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Figure 3 Flat pack containing pipelines and buoyancy modules during installation



Figure 4 Cross section of ITP LNG pipe



Figure 5 Full scale test section installed at SBM's facility in Nice, France

2004 when the first load of butane was shipped. Field measurements of the pipe-in-pipe loading system in operation indicate that the designed thermal performance was met or exceeded. While the system is designed to continuously circulate products through the cryogenic lines to keep the pipelines cold, the excellent thermal performance of the system results in such a low boil-off rate that the pipelines can be shut-in between shipments for greater than a week, while still maintaining operating temperatures without recirculation.

The successful fabrication, installation and operation of the Camisea cryogenic pipelines demonstrate many of the design, fabrication and installation processes for ITP's subsea LNG pipeline system design.

### Joint Industry Project to Qualify LNG Subsea Pipe Design

Through a JIP with four major oil & gas companies, ITP InTerPipe has received DNV's "Statement of Feasibility" and ABS' "Approval in Principle" for its proprietary subsea LNG pipeline design. This is the first subsea pipeline designed for LNG transportation that has received both of these certifications.

The primary JIP objectives were to receive DNV and ABS certifications, to demonstrate to potential clients with LNG projects that the technology was sufficiently mature to conclude that there were no technological "show stoppers", and that subsea LNG pipeline technology can be considered as a technically viable alternative to potentially long distance jetties that are currently being designed. To achieve the primary objective of agency certification, the JIP designed, fabricated, and tested a large-scale section of 24 inch ID, triple wall pipe-in-pipe. However, a double wall pipe design is technically feasible depending upon the specific application of the pipe and

completely onshore. These were placed on a temporary railroad track and later pulled offshore as a unit. The so-called "flat pack" contained the two 20 inch x 24 inch pipe-in-pipes, a 24 inch naphtha line, a 10 inch diesel line, a power / instrument cable (umbilical), as well as buoyancy modules (see Figure 3). The towing process was performed by Land & Marine (based in UK). Four days after the trench was completed, the pipeline had been towed to the base of the platform.

The installation of the pipelines and risers was completed in August 2004. The pipeline became operational in September

director for the Camisea Project. He has more than 30 years varied experience in the oil and gas industry and prior to his career at Paragon, he worked at Marathon Oil Co. for nearly 25 years, most recently as the Deepwater Development manager. He earned a bachelor's degree in Chemical Engineering from the University of Dayton, a master's degree in Chemical Engineering from the University of Florida, and an MBA from Texas A&M in Kingsville, Texas.

Raul Gaurisse is Facilities Project Manager on the Camisea Project for Pluspetrol Peru Corp., S.A. He has more than 18 years of experience as a project engineer and project manager for the construction, commissioning, and start-up of natural gas processing and treatment plants, gas compression plants, and refinery units. He earned a bachelor's degree in Industrial engineering from the University of Buenos Aires.

Dr Vicki Niesen is President of ITP InTerPipe, Inc. a subsidiary of ITP SA. She has 15

years experience in thermal, hydraulic, and flow assurance modelling for subsea pipeline systems. She earned a BS in chemistry from New Mexico Tech and a MS and Ph.D. in chemical engineering from Colorado School of Mines. ...

Michael Offredi is currently the TOTAL Forvie project manager with ITP InTerPipe and has been involved with the engineering, fabrication and laying of deepwater and cryogenic highly insulated pipelines for seven years. He was Project Manager for the

Camisea LPG pipelines. He was in charge of the development of the LNG Subsea Cryogenic Pipe and responsible for four JIPs, two on deepwater flowlines and two on the LNG Subsea Cryogenic Pipeline led by Gaz de France and more recently by ChevronTexaco. He is a graduate of the Ecole Spéciale des Travaux Publics (ESTP) of Paris, civil engineering school.

M B (Skip) Mick is Vice President, Deepwater / Special Projects for Paragon Engineering Services. He was Paragon's project

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the individual operator's risk assessment.

The specific tasks in the JIP included:

- Demonstrating the complete fabrication process using 36% Ni steel inner pipe, including full-scale bulkheads
- Demonstrating the welding procedures required for 36% Ni steel
- Pressure testing the test section at a typical design pressure for LNG service
- Fully instrumenting the test section, and thermally cycling it at liquid nitrogen temperatures, to measure the mechanical stresses induced at cryogenic temperatures
- In boil-off tests with liquid nitrogen, measuring the thermal performance of the "as built" test section
- Validating finite element modeling techniques by developing an FEA model of the test section, and comparing results against actual physical stress and temperature measurements obtained during thermal cycling
- Providing cost and schedule estimates

Figure 4 provides a cross sectional view of the triple-walled test section fabricated for the JIP. The inner pipe is made of 36% Ni steel, which has a coefficient of thermal expansion ten times less than stainless steel. This allows the pipeline to be built without the traditional expansion loops or bellows used for stainless steel pipelines, and greatly simplifies the design of a subsea cryogenic pipeline.

The Izoflex insulation located in the inner annulus provides an overall, "as built", thermal performance of 0.13 W/m<sup>2</sup> K, which is a factor of 10 better than typical subsea pipe-in-pipe lines. It also minimizes the overall system diameter. The inner pipe is located within intermediate and outer carbon steel pipes, which are both designed to sustain hydrostatic head. They are made of carbon steel because the temperatures of both remain near ambient seabed temperature.

The completed test section (shown in Figure 5) was 18 meters long including a 5-D bend that was included to test a section of riser. SBM was subcontracted to perform the thermal cycling and boil-off measurements using liquid nitrogen. The test section was installed at SBM's test facilities in Nice, France.

## Conclusions

The combination of the successful installation and operation of the Camisea propane and butane pipelines, and the ABS and DNV certifications of the ITP proprietary

LNG subsea pipeline design, demonstrates that subsea pipeline transportation of cryogenic fluids has matured to the point of allowing implementation of subsea LNG pipelines without technological "show stoppers".

Subsea transportation can have significant benefits for a project. The cost can be substantially lower as compared to a long

distance jetty (which sometimes also requires long distance dredging). As shown with the Camisea project, the subsea pipeline can often play an important part in gaining environmental and local approval. When identifying risks and concerns involved with the implementation of the LNG pipeline technology, the potential user should also evaluate the

risks associated with the "traditional" jetty technology. In the current world environment, a subsea, buried pipeline is likely to be shown to have lower risks.

Lastly, while the design and qualification work have focused on subsea application of the LNG pipeline, a simplified pipe-in-pipe design can be easily implemented onshore as well. ■

# GAIL (India) Limited



## Invitation for Expression of Interest (EOI) (under International Competitive Bidding Process) for Supply and Delivery of LNG (Liquefied Natural Gas)

NIT No. ND/Sourcing/LNG - ICB/2004

- I. GAIL (India) Ltd, one of the leading Public Sector Companies in India, is the dominant player in Natural Gas Transmission and Distribution with more than 92% market share and dominant presence in all aspects of Natural Gas value chain in the country. GAIL has created superior value for all its stakeholders throughout its existence since the past 20 years. Platt's Global Survey 2002-03 has ranked GAIL as number 1 company among global gas utilities in terms of Returns on Invested Capital. GAIL has been rated as among the top 10 companies in terms of profits and revenues in India. GAIL is in a strong financial position with a gross turnover of USD 4.6 Billion and Net Profit of USD 416 Million. For more information about GAIL, please log on to [www.gailonline.com](http://www.gailonline.com).
  - II. As a Dominant Natural Gas Player, GAIL owns and operates more than 5600 Km of High Pressure Natural Gas Pipelines serving more than 400 major gas customers. These pipeline networks carry both domestic gas as well as re-gasified LNG being imported at Dahej Terminal operated by Petronet LNG Ltd. GAIL is a partner in Petronet LNG with 60% marketing rights of the re-gasified LNG. GAIL's JV companies, Indraprastha Gas Ltd, Mahanagar Gas Ltd and Bhagyanagar Gas are responsible for CNG and City Gas distribution in cities of Delhi, Mumbai and in the state of Andhra Pradesh. In addition, GAIL is in the process of setting up city gas distribution networks in 21 major cities across the country. GAIL has recently ventured into overseas CNG/City Gas Distribution Projects in Egypt and has taken equity participation in the projects.
  - III. Further, GAIL has expanded along the Natural Gas Value Chain and owns and operates the largest Petrochemical plant in North India with an installed capacity of 310,000 TPA of Polyethylene (HDPE & LLDPE) based on Natural Gas. GAIL also owns and operates 7 Gas processing facilities with installed capacity of 1.3 MMTPA of LPG and other liquid hydrocarbons like Propane, Pentane and SBP. GAIL is a pioneer in the LPG transmission segment and has created the world's longest LPG pipeline (1269 Km) connecting West India (producing) to North India (high consumption centre).
  - IV. In order to secure upstream supply sources, GAIL has entered the Exploration and Production Segment with equity participation in 12 blocks, 11 in India and 1 in Myanmar. In view of the synergy between the Natural Gas and Power sector, GAIL has participated in a gas based 156 MW power plant, Gujarat State Energy Generation Ltd. (GSEG).
  - V. While demand for Natural Gas in India is increasing, the Country is facing supply constraints due to limited domestic resources and geo-political barriers in sourcing Natural Gas through transnational pipelines. Due to this the Indian Gas Market is facing a significant demand - supply gap which is expected to widen in the years to come. Indian Markets on account of the ongoing reforms in the Energy Sector offers a substantial opportunity for LNG supply. GAIL, as the market leader in NG business, foresees an important role in serving the customer needs and development of NG markets. To serve the development of the NG industry, GAIL seeks to source additional LNG from multiple sources across the globe. Supplies of LNG to GAIL therefore, offers attractive opportunities to potential suppliers to consistent high sales volumes, and long term business opportunities.
  - VI. Based on GAIL's internal assessment of potential market demand, GAIL would like to import LNG at the existing and proposed LNG Re-gasification West Coast terminals at Dabhol (Dahej), Kochi and East Coast terminal at Ennore. The LNG requirement would range from 0.7 MMTPA to 15 MMTPA with a built up to start from 2005-06 and to reach a plateau by 2008-09. The LNG can be supplied from single or multiple liquefaction facilities either on Ex-ship or FOB basis. Ex-ship delivery would be preferred in the initial stages of the supply.
- GAIL would also like to work along with interested party / parties for development of upstream facilities and downstream Re-gasification facilities.**
- VII. GAIL therefore, invites **Expression of Interest (EOI)** from prospective suppliers of Liquefied Natural Gas for Long Term (20-25 years) & Short Term (5-10 years) bases, supply and delivery of LNG at multiple sites on competitive terms. GAIL is looking for 20-25 Year Ex-ship / FOB supply contract based on international commercial terms like take or pay/ supply or pay obligations with LNG club rules and upward / downward flexibility, pricing formula (fixed + variable components), price indexation (JCC/Brent/Dubai) etc.
  - VIII. **Information required as part of EOI**  
The prospective suppliers are required to submit the following information along with the EOI:-
    1. **Company Background**  
Legal status, including Board of Directors, capital and shareholding structure and key personnel.
    2. **Upstream Sources**
      - a. Likely source(s) from which LNG is proposed to be supplied
      - b. Location
      - c. Sufficient or Proven Reserves
      - d. Expected Quantum
      - e. Duration of gas supplies from such source(s) with documentary evidence thereof.
      - f. Documentary evidence in respect of right of exploitation of Gas reserves
    3. **Details of Liquefaction plant(s) from which LNG is proposed to be supplied**
      - a) Greenfield or Brownfield project
      - b) Location of the liquefaction plant
      - c) Details of liquefaction technology
      - d) Expected date of commissioning of proposed project
      - e) Details of experience in developing, financing, constructing and operating liquefaction facility.
      - f) Capacity to supply additional quantity of LNG, if required by GAIL.
      - g) Any other relevant information in this regard.
    4. **Loading port**
      - a. Location of the loading port
      - b. Existing (brownfield) or proposed (greenfield)
      - c. The maximum ship size the loading port can handle
      - d. Documentary evidence of shipping contract, if any, for LNG supply.
      - e. Additional handling capacity that can be created
      - f. Status in respect of statutory clearances/ contracts/ financing and the ship size
    5. **Status of Statutory Clearances**  
List of various clearances/permits required for Export of LNG and the status thereof.
    6. **Capacity**
      - a. Current contracted/committed capacity,
      - b. List of existing buyers
      - c. Total surplus capacity available, if any, with documentary evidence thereof.
      - d. Draft Term Sheet.
      - e. Preferred agreement period for supply of LNG.
    7. **Financial Capability**  
Details of Financial capability with documentary evidence thereof such as audited balance sheet and profit/loss account for the past 3 years.
    - IX. All pertinent information that may affect the performance of the responsibilities such as ongoing litigation, financial distress or any other must be disclosed.
    - X. Prospective suppliers shall be required to qualify against the Qualifying Requirements of GAIL, to be specified in the bidding document (Request for Qualification) and mere submission of EOI and/or submission of additional information does not automatically entitle any party to claim for qualification and/or participation in the bidding process.
    - XI. GAIL reserves the right not to issue the bid document and/or accept or reject any or all the offers at any stage of the process and/or to modify or annul the process without assigning any reason whatsoever. GAIL reserves the right to seek additional information from the prospective suppliers who respond to this invitation for EOI.

Prospective suppliers may submit their EOI (on their letter heads) along with all the required information as given above latest by **15th March 2005** at the following address:

**GM-Sourcing**  
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