ROSIGNANO LNG TERMINAL: INNOVATIVE SOLUTIONS TO SAFETY AND ENVIRONMENTAL CHALLENGES

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ABSTRACT

The Rosignano LNG-Ethylene Import Terminal is being jointly developed by BP and Edison on an existing industrial site on the north-west coast of Italy belonging to Solvay Chimica Italia. The terminal will be ideally situated for access to the large and expanding Italian gas market. However its location close to an area of natural beauty allocated for tourist development has provided the project with significant technical and environmental challenges. This paper will explain the innovative solutions adopted by the project to meet these challenges.

Rosignano is already the site of a terminal that imports approximately 200,000 tonnes per annum of ethylene to an adjoining polyethylene plant. The new LNG terminal will take advantage of the existing jetty, extending it by around 400 metres and building a dedicated LNG berth. Simultaneous unloading of LNG and ethylene will be possible.

The existing ethylene storage and regasification plant is located on the coast, about one kilometre from the jetty root. Part of the scope of the LNG project is to replace these facilities with new ones, built alongside the LNG terminal in a chemical works two kilometres further inland. The existing ethylene terminal will then be demolished, freeing up the beach area for tourist development.

The proposed route of the ethylene and LNG unloading lines covers a distance of approximately 5 kilometres, of which approximately 2 kilometres is on the jetty and 3.0 kilometres onshore. The Project is planning to take advantage of advances in cryogenic pipeline technology and bury the entire onshore section of the unloading lines, which crosses a public road, a railway and a small river. This will not only reduce the risk of pipelines being damaged by external impacts but also minimize the visual impact of the new facility.

The environmental performance of the project will be further improved by using waste heat from the existing chemical facilities to meet a large proportion of the duty of the LNG vaporizers. This thermal integration means the terminal will not need to extract additional seawater or significantly increase emissions from the chemical site.

Further energy savings will be realized by using cold extracted from the LNG to liquefy boil-off gas from the ethylene tank rather than the mechanical refrigeration package utilized by the existing plant.

It is hoped that the project will receive authorization to construct the terminal in the first half of 2006, with first gas passing through the new facilities in 2010.
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1 INTRODUCTION

In 1917, the Belgian company Solvay founded an integrated chemical works close to the town of Rosignano on the North-west coast of Italy. Since then, the town of Solvay-Rosignano has grown up the around site; initially as a base for employees and their families, but more recently as a diverse community, integrated with the wider local economy.

Almost 90 years later, in 2002, the Italian energy company, Edison signed an agreement with Solvay to develop an LNG import terminal at Rosignano. BP, which had a presence on the site through a jointly owned high density polyethylene plant, joined the project the following year. Not surprisingly, the attitudes of industry and the public to risk and environmental impact at the beginning of the twenty-first century are very different to those faced by Solvay at the beginning of the previous one. This paper describes the safety and environmental challenges faced by the Project and the part that technology has played in meeting them.

2 HISTORY OF THE ROSIGNANO LNG TERMINAL PROJECT

2.1 Location

Solvay-Rosignano lies on the north-west coast of Italy approximately halfway between the ports of Livorno and Piombino. It is located within the Province of Livorno, which is part of the Region of Tuscany (see Figure 1). Although historically an industrial area, it increasingly relies on the service sector, particularly tourism, for its prosperity. The location is ideally situated for access to the large and expanding Italian gas market.

Figure 1: Map of Region of Tuscany Showing Terminal Location
At the heart of the town is the Solvay Industrial Site, one of the largest industrial complexes in Tuscany and a key part of the local economy. The site employs around 1,500 people and produces a variety of bulk chemicals and polyolefins including soda ash, chlorine, hydrogen peroxide and high density polyethylene (HDPE). During the 1960s and 1970s, it also contained a small thermal cracker that produced ethylene feedstock for the polymerization plant. However, in 1979 the cracker was shutdown and ethylene has since been imported by ship via an ethylene import terminal constructed close to the town of Vada, approximately two kilometres to the south-west of the main site.

The site for the new import terminal was selected for its good access to deep water and its proximity to Solvay's existing marine facilities. However, this outpost of the Solvay complex was constructed in a largely non-industrial area, close to two small villages and within a few hundred metres of a popular tourist beach, a nature reserve and an important archaeological site. Furthermore, the decision to use a single-containment tank for storing liquid ethylene, whilst completely in keeping with contemporary design practices, has subsequently placed considerable constraints on further development in the surrounding area.

2.2 Project Scope

The Rosignano LNG Terminal Project will replace the existing ethylene terminal with an integrated LNG and ethylene import facility. This entails:

- extending the existing jetty and constructing a berth for LNG carriers;
- removing the existing onshore ethylene facilities and constructing new ones for both LNG and ethylene;
- constructing a connection to the Italian gas network for the export of vaporized LNG.

The project was originally conceived as a relatively small-scale development, based around the construction of a single LNG tank and a new ethylene tank on farmland adjacent to the existing terminal. It was hoped that using partially-buried, full-containment storage tanks would produce a design compatible with the local and regional governments’ desire to develop the coastline between Rosignano and Vada for low-impact tourism. However, by 2004 it was clear that, despite receiving environmental approval, the construction of new industrial infrastructure was not acceptable so close to the town of Vada. The Project therefore investigated a number of alternative locations, before settling on an option that located the new onshore facilities within the main Solvay Industrial Site.

The relocation created an opportunity for the Project to increase the capacity of the terminal to $8 \times 10^9 \text{Sm}^3$ of natural gas and 200,000 tonnes of ethylene per year. Furthermore, the new location created opportunities for closer integration between the terminal and the Solvay Industrial Site. However, it also posed new challenges; not least because the distance between the jetty head and the storage tanks is now more than 5 kilometres and the route of the unloading lines crosses a public highway, a railway and a river.

In September 2005, after a further twelve months development, the Project submitted a, Preliminary Project Description, an Environmental Impact Assessment and a Preliminary Safety Report for the revised scheme to the Italian authorities. The new project, which is based upon the construction of all onshore facilities within the Solvay Industrial Site, contains the following elements:

- A dedicated berth for LNG carriers accessed by means of a 400 m extension to the existing 1.8 km long jetty trestle;
- 5.2 km long LNG unloading, recirculation and vapour return lines running between the jetty head and the storage tanks;
- 2 full-containment LNG storage tanks with a net capacity of 160,000 m³ each;
• An LNG sendout system, using Open Rack Vaporizers, with a capacity of approximately $1 \times 10^6$ Sm³/h of natural gas at a pressure of 75 barg;

• A 4.5 km long, 32-inch diameter gas export line connecting the terminal to the Italian Gas Distribution Grid at Castellina Marittima;

• Retention of the existing berth for ethylene carriers;

• 4.8 km long ethylene unloading and recirculation lines running between the ethylene berth and storage tank;

• A full containment ethylene storage tank with a net capacity of 20,000 m³;

• An ethylene sendout system, using Open Rack Vaporizers, with a capacity of 30 tonnes/h of ethylene at a pressure of 45 barg;

• Demolition and removal of the existing onshore ethylene plant and pipelines and remediation of previously occupied sites so that they are available for the development of tourist facilities.

It is hoped that the project will receive authorization to construct the terminal in the first half of 2006, with first gas passing through the new facilities in 2010.

3 UNLOADING LINES

3.1 Background

As previously stated, the driver for locating the onshore part of the new terminal within the Solvay Industrial Site is to ensure that the new facilities do not constrain the local authorities’ plans to develop the area close to the shoreline for tourism. Specifically, the terminal must comply with the land-use criteria set out in the Structural Plan for the municipality of Rosignano Marittimo and with the risk criteria set out in national legislation. These same criteria apply to the pipelines that transfer LNG and ethylene from the jetty to the storage tanks and - given that the lines follow an approximately 5 km long route that crosses roads, a railway and a river as well as passing close to housing - the design of the pipelines for the Rosignano terminal poses some unique challenges.

3.2 System Description

The unloading line system will comprise the following five pipelines running along a single right-of-way.

**LNG Transfer Lines**

The LNG transfer lines will run for a distance of 5.2 km, of which 0.4 km is on the jetty extension, 1.8 km is on the existing jetty and 3.0 km is onshore. The system is designed for an unloading rate of 12,000 m³/h and will contain the following components:

• 2 x 36-inch inside diameter LNG unloading/recirculation lines;

• 1 x 18-inch inside diameter vapour return line

**Ethylene Transfer Lines**

It is planned to retain the 1.8 km section of the ethylene transfer lines that runs along the existing jetty. A new 3.0 km onshore section will run from a tie-in point at the jetty landfall to the ethylene storage tank. The system is designed for an unloading rate of 100 tonnes/h and will contain the following components:
• 1 x 12-inch inside diameter liquid ethylene unloading line;
• 1 x 4-inch inside diameter liquid ethylene recirculation line

The section of the existing ethylene transfer lines that runs from the jetty landfall to the existing ethylene storage tank will be decommissioned once the new lines are operational and proved to be reliable.

3.3 Routing

The offshore section of the unloading lines will run along the south side of the jetty. On the newly built jetty extension, the lines can be easily accommodated on a specially designed piperack but, on the original section, the LNG lines will have run alongside or above the existing ethylene lines. Furthermore, because the project is committed to minimize disturbance to the seabed, it will not be possible to build supports for additional expansion loops alongside the existing jetty.

The jetty meets the coast between the southern end of a popular tourist beach and a small harbor used by Solvay for product export. The connection between the new and existing ethylene lines will be made immediately after the lines reach the shore.

From the end of the jetty, the route follows an existing right-of-way along the edge of the harbor and then through a wooded area close to a small village. From this point, the pipelines follow the access road to the existing ethylene storage plant, crossing a number of minor roads and tracks before turning east and crossing a busy public highway (Strada Provinciale No. 39, also known as the Via Aurelia). Immediately after crossing the main road, the route passes beneath the Rome-Genoa railway before heading north across the river Fine and entering the Solvay Industrial Site.

With the exception of the main road, the railway and the river, the right-of-way is entirely within land owned by Solvay. Most of the route passes through farmland, although the section immediately to the south of the Solvay Industrial Site must go around a disused landfill. None of the onshore areas through which the right-of-way passes is classified for industrial use and the Project has therefore had to develop a design that allows the lines to pass through areas designated for agriculture, tourism or domestic occupancy.

3.4 Technology Selection

The challenge facing the Project is to ensure that the unloading line system meets the following objectives:

• presents a risk that is compatible with the urban plan;
• maintains acceptable unloading flow rates;
• does not require the use of expansion loops on the existing jetty;
• minimizes visual impact;
• does not unduly affect project economics

Given the length and characteristics of the route described above, the Project has decided that the optimum solution is to bury the entire onshore section of both the LNG and ethylene unloading lines.
Conventionally, LNG transfer lines are constructed from austenitic stainless pipe insulated with polyurethane (PUR) or polyisocyanurate (PIR) foam. However, this type of pipeline is not suitable for direct burial because of the poor mechanical strength of the insulation and the need for expansion loops to accommodate the contraction as the lines cool from the ambient temperature at which they are installed to their operating temperature. Consequently, the Project has explored technically innovative, non-conventional solutions.

Like others in the LNG industry, BP has been working to develop cryogenic piping systems that are suitable for subsea service. Collaboration with technology suppliers and contractors, participation in joint industry projects and in-house development has produced a range of concepts each with its own benefits and challenges. It is clear, that with only slight modification, many of these concepts could also be applied to onshore burial.

In April 2005, the Project engaged a pipeline engineering contractor, JP Kenny, to carry out a detailed review of the available technologies and assess their applicability to the Rosignano Project. After carefully considering criteria such as safety, availability, constructability and operability, the review identified two potentially suitable technologies both of which are based on a pipe-in-pipe configuration.

The first system has been developed by a joint industry project led by ITP of Louveciennes, France and including BP. It eliminates the need for expansion loops by using an inner pipe made from a 36% nickel – iron alloy (such as Invar) that has a very low coefficient of linear thermal expansion (1.4 x 10^-6/°C compared to 1.5 x 10^-5/°C for a typical austenitic stainless steel). The inner pipe is wrapped in a blanket of microporous insulating material and housed in an outer pipe that provides mechanical protection. It is expected that the outer wall would be constructed from stainless steel to provide additional containment in the extremely unlikely event of a leak from the inner pipe.

The second technology under consideration is the Vacuum Insulated Pipeline (VIP) system produced by Chart Industries Inc. It uses conventional austenitic stainless steel for the inner pipe, but overcomes the contraction issue with in-line internal bellows. Cryogenic temperatures are maintained by a vacuum jacket, the outer wall of which also provides mechanical protection for the inner pipe. The VIP system has a good track record of service in aboveground LNG pipelines and BP has been working with Chart to investigate the implications of burial. Once again, it is expected that the outer wall would be constructed from stainless steel to provide additional containment in the extremely unlikely event of a leak from the inner pipe.

The Project is now undertaking more detailed geotechnical and topographical surveys along the proposed right-of-way to further define the material and mechanical designs for the two potential systems. It also continues to progress constructability and operability issues as well as working on the development of suitable codes, welding and testing philosophies.

It should also be noted that the technology review identified a number of other systems that could be potentially applicable to the Project, but were not yet felt to be sufficiently well developed for full evaluation. The Project will continue to monitor the progress of these technologies.

4 THERMAL INTEGRATION WITH EXISTING CHEMICAL PLANTS

4.1 Introduction

The Solvay Industrial Site, inside which the new terminal is to be built, is a typical bulk chemical manufacturing complex containing a variety of production plants supplied by a network of utilities and supported by centralized services. As such, there are many opportunities for reducing capital and operating costs by integrating the new terminal with existing facilities (e.g. electrical supply, fire-fighting systems and emergency services). However, there is also a significant opportunity to reduce the environmental impact of both the new and existing facilities by using waste heat from the existing processes to supply part of the energy required to vaporize LNG and ethylene.
The principal production plant on the Solvay Industrial Site is a unit producing around $1 \times 10^6$ tonnes/year of soda ash (sodium carbonate). This plant is provided with cooling water by the following systems:

**Seawater System**

A system of pumps, filters and distribution pipework supplies the Solvay Industrial Site with seawater at a flow rate varying from 6,000 m³/h in the winter (when the sea temperature can be as low as 12 °C) to 15,000 m³/h in the summer (when the sea temperature can reach 29 °C). As well as supplying the soda ash plant, seawater is also fed to a 400 MW Combined Heat and Power (CHP) plant and, from September 2006, it will be supplied to a second 400 MW CHP plant that is currently under construction. Heated seawater is returned from the soda ash plant to the ocean via an open channel known as the *Fosso Bianco*.

**Fresh Water Cooling System**

The seawater cooling system is supplemented by a closed-circuit fresh water cooling system based around two large natural-convection cooling towers. The heat dissipated by this system normally varies between 70 and 110 MW depending on production rates and ambient conditions. The flowrate of water through the cooling tower varies between about 5,000 and 10,000 m³/h and the system requires up to 340 m³/h of make-up water to replace losses due to evaporation and purging.

The Project intends to utilize the waste heat absorbed by these two systems to supply part of the energy required to vaporize LNG and ethylene.

**4.2 Process Description**

The Project has worked with Sofregaz – a specialist natural gas engineering contractor - to develop a design for an integrated network that meets the heating/cooling requirements of the LNG-ethylene terminal, the soda ash plant and the two CHP plants. The scheme has been designed to ensure that operation of the new terminal does not require the capacity of the existing seawater system to be increased.

*Figure 2: Block Flow Diagram of Typical Thermal Integration Scheme*
A tie-in point downstream of the pumping station and upstream of the existing users will divert the entire flow of the seawater system through the terminal’s vaporizers where a duty of approximately 140 MW will cause its temperature to drop by 8 °C. Chilled seawater will then be pumped back into the network upstream of the existing users. Approximately one-third of the seawater leaving the terminal will go to the soda ash plant, where cold energy from the vaporization process will be recovered by heat exchange with the fresh water from the cooling towers. Part of the remaining two-thirds of the chilled seawater will be sent to the two CHP plants with the balance being discharged directly into the Fosso Bianco.

4.3 Benefits of Integration

A thermally integrated cooling water network incorporating both new and existing facilities allows the terminal to be operated without requiring an increasing the capacity of the seawater system. It also offers significant advantages over the current situation, namely:

- A reduction in the temperature difference between the seawater intake and outfall streams;
- Considerable recovery of the cold energy from the vaporization process leading to a reduction in the thermal load on the fresh water cooling system. This will result in a decrease in evaporation from the site’s cooling towers and consequently reduce the need for fresh water make-up in an area where resources are under severe pressure;
- An increase in production from the Solvay soda ash plant, which is currently constrained by a lack of available cooling during the summer when sea temperatures are higher. More accurate control of the cooling water inlet temperature should also increase the plant’s efficiency;

5 INTEGRATION BETWEEN THE LNG AND ETHYLENE FACILITIES

5.1 Background

The existing ethylene import terminal uses a refrigeration unit and a high pressure compressor to deal with boil-off gas generated in its unloading lines and storage tank. However, the new combined LNG-ethylene terminal will avoid the need for such equipment by using cold energy from the LNG facilities to condense ethylene boil-off gas.

5.2 Process Description

As a first approach, it is assumed that high-pressure LNG will be sent directly to vertical shell and tubes condensers located on the roof of the ethylene storage tank. This will allow condensed ethylene to drain directly back into the tank thereby avoiding the need for additional rotating equipment.

It is also planned to install additional LNG-ethylene heat exchangers in the recirculation loop of the ethylene unloading lines to sub-cool the ethylene returning to the storage tank during the periods when no unloading is taking place. This will avoid generating excessive boil-off gas when warm ethylene comes back from the jetty to the tank, particularly at the start of the unloading process.
6  CONCLUSION

Rising demand and a desire to diversify supply sources has led to a proliferation of proposals for new LNG import terminals, often with at least the tacit encouragement of national governments. However, national and regional energy strategies need to be balanced against local concerns, particularly along the highly developed coastlines of Europe and North America that have been the focus of much of the recent increase in activity.

The Rosignano LNG-Ethylene Terminal Project provides an example of how technology can allow developers to respond to local concerns without jeopardizing project viability. Such innovation and flexibility by no means guarantees a smooth passage through the approval process, but is likely to become increasingly necessary as the awareness of the public and the sophistication of opponents develop in parallel to growing energy demand.