First LPG Storage Cavern in India

Loran Karwacki, PM & Neeraj Sanghi, CEO
South Asia LPG Private Ltd.

Introduction

South Asia LPG Company Private Ltd (SA LPG), a joint venture between Hindustan Petroleum Corporation Limited (HPCL) and Total Gas and Power India (100% subsidiary of Total) is currently building a 60,000 T (120,000 m3) underground LPG storage cavern facility at Visakhapatnam for receipt, storage and transfer of (mainly) imported LPG.

Visakhapatnam is located in the India's south eastern state of Andhra Pradesh. HPCL has a refinery of 7.5 million TPA at Visakhapatnam. Until 1996, considerable LPG was being imported at Visakhapatnam for meeting LPG needs of Andhra Pradesh and adjoining states. These imports used to take place in the inner harbour, where draft were limited to accommodate a maximum of 8000 tonne parcel. Vessel entries were also limited only to weekends. In the early 1990's Visakhapatnam Port Trust (VPT) reviewed the feasibility of a LPG terminal in the outer harbor. Construction of the 'outer harbour' LPG berth was completed in 2004. In 1996, there was a fire due to an LPG accident at the Visakhapatnam Refinery which highlighted the need for safer LPG handling and lead to the advancing of development of an underground storage cavern adjacent to the outer harbor berth. A cavern was identified to be the safest and most economical method of storing large quantities of LPG. From 1996 until 2004, only small volumes were handled at inner harbour. However, since commissioning of the outer harbour facilities in 2004, imports have picked up. A Gas Authority of India Limited (GAIL) pipeline from Visakhapatnam to Secunderabad, which was implemented in 2002, will augment the utilization of these LPG evacuation facilities already available from Visakhapatnam and further promote LPG market penetration.

Verwijderd: South Asia LPG Company Private Ltd (SA LGP),

Verwijderd: joint venture between Hindustan Petroleum Corporation Limited

Verwijderd: Total Gas and Power India is currently building

Verwijderd: medium-size

Verwijderd: LPG

Verwijderd: 120,000 m^3

Verwijderd: , India.

Géostock, of France, has participated in the preliminary studies for establishing feasibility of the Project, executed the Basic Engineering Design and currently provides detailed engineering design revision and underground construction management support to SALPG during the construction of cavern and necessary facilities.

Larsen & Toubro, a leading Indian construction company has undertaken the execution of the Project on an EPC basis. Project construction is now scheduled to be completed in 2007.

Cavern and Terminal Design Characteristics

Verwijderd: ¶

This facility is designed (including certain modifications to the existing unloading arms) to receive the largest size LPG vessels (40000 T) as well as smaller pressurized vessels throughout the week. Receipt in large parcel will benefit users with savings in the freight rate. Also, the project includes facilities for re-export of LPG to other ports in India or to neighboring countries. The cavern shipping benefit over the cavern and terminal tariff provides an opportunity to supply Andhra Pradesh and adjoining states at an economical price.

Front End Engineering

Safety Engineering

Working from the original feasibility studies and risk analysis performed for the VPT by Engineers India Limited (EIL), SALPG commenced basic engineering design (BED) with Géostock.

Execution of impact area studies using safety exposure limits and credible event parameters of Total confirmed the acceptability of the site for the risks associated with the LPG facility. Detailed engineering later reduced the anticipated fire zone, hazardous area classification and restricted areas using 3 dimensional gas dispersion modeling. Taking advantage of the site 3 m barrier walls, perimeter water curtains were avoided with only one area of gas dispersion barrier curtain being required.

At the HPCL refinery and other LPG facilities in Vizag, LPG is currently being stored in aboveground spheres. There can be no BLEVE risk with underground storage because of the natural insulation of the cover. Safety hazards on account of sabotage, storms, earthquakes and explosions caused by leaks are minimized by emergency isolation of the storage with very small volume inventory retention in aboveground exposed piping.

The natural containment of the cavern rock is enhanced by a hydraulic containment principle. A water curtain above the cavern hydraulically seals the cavern. All the seepage water which enters the cavern and comes in contact with the LPG is evacuated and cleaned before being released. Water flooding of the process shaft connections provides another safety system that will also isolate the LPG safely below the ground in any emergency event.

Verwijderd: .

Geological Suitability

After an extensive geological investigation carried out at the site in two phases, the site's geological conditions were considered ideal for the construction of a mined rock cavern. The actual geological conditions have turned out to be as good as predicted (type 1 in the cavern). The storage is made of an unlined cavern at a depth down to 180m below sea level. The debris of the excavation (muck of gneiss and fines) is being stockpiled for future use by the Visakhapatnam Port Trust for jetties or breakwaters thus minimizing the future impact of these projects from quarrying.

Process Equipment

Terminal additions are also required to facilitate the larger refrigerated LPG shipment parcels include new LPG loading arms, chilling and booster pumps, a seawater heat exchanger and pump house. Cavern and incoming inventory mixing equipment such as a mixing skid and a vapour ejector are required to avoid temperature shock from the cold product entering the cavern. The existing unloading arms will be used as backup or for loading of smaller vessels from the cavern for re-export. The use of seawater heating was

driven by the desire to avoid ignition sources onsite as well as not using the LPG inventory in bonded storage.

Controlled implementation of technical innovation has been attempted on this LPG storage facility as this is the first underground storage cavern in India. However, modern Distributed Control (DCS) and Emergency Shutdown (ESD) and Fire and Gas (F&G) System specified to high Safety Integrity Levels will help ensure the safety of the facility and minimize any potential impact upon the neighboring area or anything passing in the harbor. This project has inspired other underground storage projects to begin feasibility evaluations based on the efficiency, safety and economy of this storage technique. The contractor has mobilized practically all new underground construction equipment for the mechanized cavern excavation.

Concluding the BED and confirming the project feasibility, SALPG began the process to implement the project.

Verwijderd: This facility will be supplied by LPG carrier vessels and will fuel the local market as well as the HPCL refinery located at 5 km from the port, the network of LPG bottling plants and a newly completed LPG pipeline to supply neighboring markets. The cavern capacity and terminal modifications have been designed to accept the large refrigerated and smaller pressurized vessels and will also allow for delivery of LPG to provision neighboring ports via smaller pressurized vessels. Beyond changes to the jetty loading and unloading arms, the Visakhapatnam outer harbor will easily facilitate large draft vessels. ¶

Verwijderd: Géostock, of France, has participated in the preliminary studies, executed the Basic Engineering Design and currently provides detailed design revision and construction management support for the storage cavern construction for SALPG. The storage is made of an unlined cavern at a depth down to 180m below sea level. The storage is currently under construction with anticipated underground completion in mid 2006.

Project and Construction Management

After an original call to tender with international contractors failed to attract any competitive offers, a method of obtaining competitive bids using the established Indian capacities was devised. The project scope was split into 2 contracts; underground and above ground, and re-tendered again also including prominent Indian Contractors. An EPC contract was awarded to Larson and Toubro (L&T) for the underground construction capitalizing on Géostock expertise to handle the geomechanical and hydrogeological aspects of the rock mechanics and the actual site geology. L&T was also the successful bidder for the above ground EPCC contract.

Final negotiation allowed for both L&T and SALPG to create a wrap contract to deal with the interfaces between the 2 contracts and capitalize on the benefits of having effectively one contractor for both scopes. Both L&T and SALPG have benefited by needing only one project, design and construction management team to control and monitor each contract.

Insitu Stress

As anticipated by Géostock, as early as possible within the underground project development, a series of insitu stress measurements were taken to quantify the actual insitu stresses in the rock at cavern level. These measurements were foreseen in the contract documents. Indeed, due to uncertainty related to the in-situ stress, the execution of the in situ test was accelerated earlier in the contract execution through the mechanism of a Contract Change Order. The verified results were significantly above the original Géostock design assumptions and a modification therefore became necessary to adjust to the new information. This resulted in the necessity to modify the cavern design.

The design modifications recommended by Géostock respond to the higher than anticipated horizontal stress in the rock mass, and the associated risk of loss of containment through horizontal faults that may open as a result. The design modifications consisted of the following:

1. Extension of the water curtain coverage by 5 meters, and the addition of 3 extra bore holes (to suit the revised layout) to ensure that any horizontal cracks will be adequately filled with water at all stages of construction and operation.

2. Revision of the cavern cross section from a tall and narrow shape, that would have been appropriate for proportionately higher vertical stresses, to a more rounded shape that will better resist the horizontal stress and the resulting tendency to open horizontal faults.

3. Change from a « U » shaped cavern layout to two parallel galleries with connecting tunnels. This change removes the end of the « U » which would otherwise have been subjected to the strongest horizontal stresses.

Additionally the design modifications incorporate the approvable design modifications proposed by the contractor earlier (refer to Figure 1 below for the contractor proposed changes). These changes were basically connection size changes to optimize construction logistic support or reduce volumes in linearly paid Water Curtain Gallery (WCG) excavation. As well, the contractor proposed to align the Upper Shaft Connection (USC) and the Access Ramp (AR) connections and offset the Operating Shaft (OS) to provide for earlier handover to the Above Ground Contractor.

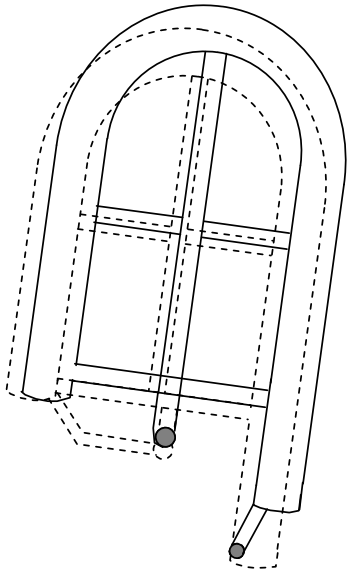


Figure 1: Contractor Proposed Changes

The modified design proposed parallel galleries (optimally aligned to the principal horizontal stress) in keeping with the following requirements:

- LPG mixing (lower connection required)

- Construction methodology (Contractor's proposals)
- Shaft positions (actual location)
- Headgear installations (existing)
- Boundaries of plot (lease).

The final Géostock recommended layout & section is shown in bold lines in Figure 2 below, while previous shape & design (with previous Contractor optimizations incorporated) is shown in dotted lines.

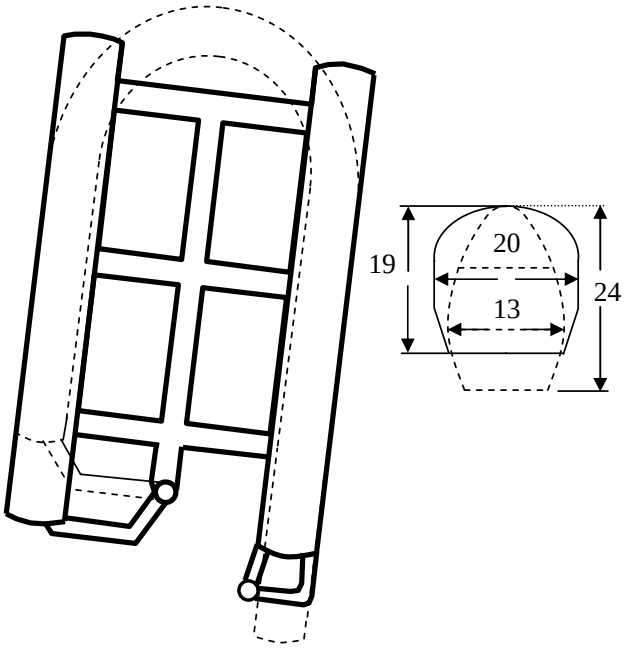
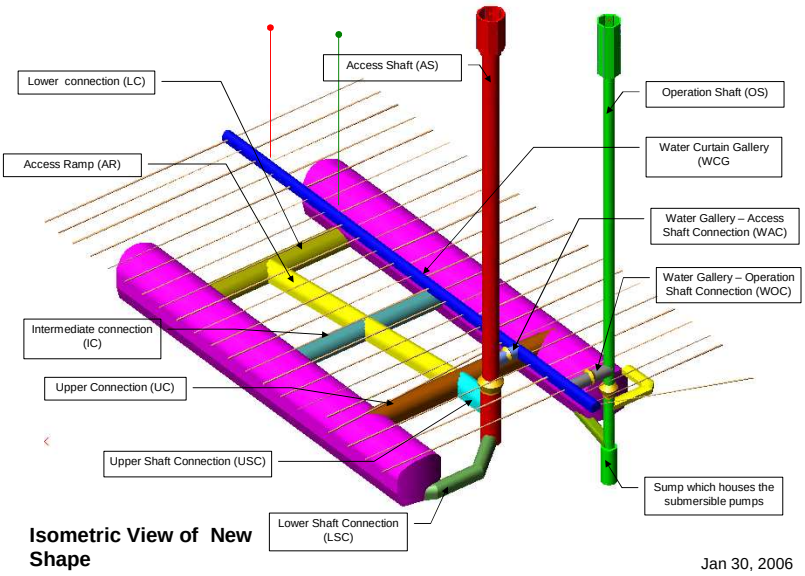


Figure 2: Revised shape from Géostock accepting some changes proposed by the Contractor

As with any significant change or event in a contract like this, the contractor has requested compensation for extra time and extra cost anticipated. These claims may be substantiated for the following:

1. Re-work of planning that has already been done based on the previous design
2. Extra cost to excavate the new cavern related to the proportionately higher volume of top heading works (the top heading work is more difficult to excavate)
3. Extra time associated with any new quantities.

These design modifications are within the 'scope of changes' that had been foreseen in the contract. The underground contract being a unit rate based, bill of quantities form, also included the ability to modify any section by 25% without impacting the unit rate.



Isometric Sketch of cavern

Additional HSE efforts

Due to early performance of the contractor with respect to Health and Safety, SALPG identified the need for additional Construction HSE management. The originally anticipated 1 person reporting to SALPG executives has been augmented to a 5 plus member team lead by an expatriated internationally experienced Construction Safety Officer. This has benefited the project in raising local standards to international levels expected by the project promoters. Audits in the early phase identified a multitude of non-conformances. Auditing with the same independent team in 2005 has struggled to identify non-conformances from international levels. Improvement areas are still identified, but, programs are immediately implemented to address issues as they are identified by the Contractor or SALPG.

A specific high risk has been identified for the muck haul road for disposal of the cavern rock due to the existence of an auspicious temple along the route that is visited by pilgrims approaching by a ferry crossing. Surveys of the road and passenger traffic resulted in a plan to add traffic and crossing marshals in the critical areas using public relations to motivate pedestrians to avoid walking in the road way. Sidewalk barrication, speed breaker installations and signage were also implemented to reinforce the desire behavior necessary to avoid any conflict with the muck hauling to the disposal site.

The Quantitative Risk Analysis (QRA) techniques used in the evaluation of the project, followed by job specific safety analysis of activities has allowed the project to avoid any

serious injury accident during the construction. A construction permitting system has been fully adopted to ensure HSE mitigation in planning for all phases. These measures culminated in September of 2005 with celebrating reaching a first 1 million construction man hours without lost time accident.

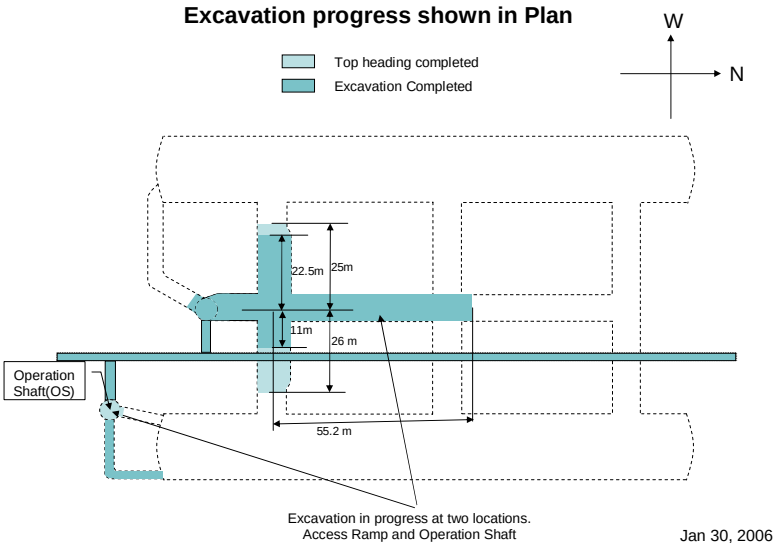
To ensure the detailed design being finalized under the EPC scope complies with all the parent companies and international standards, the Total "Project Technical Review" (PTR) process has been fully followed. Independent design and safety experts have convened at various stages to evaluate the design and project. The detailed design PTR was recently completed and review findings are now being incorporated into the final designs in time to avoid construction changes.

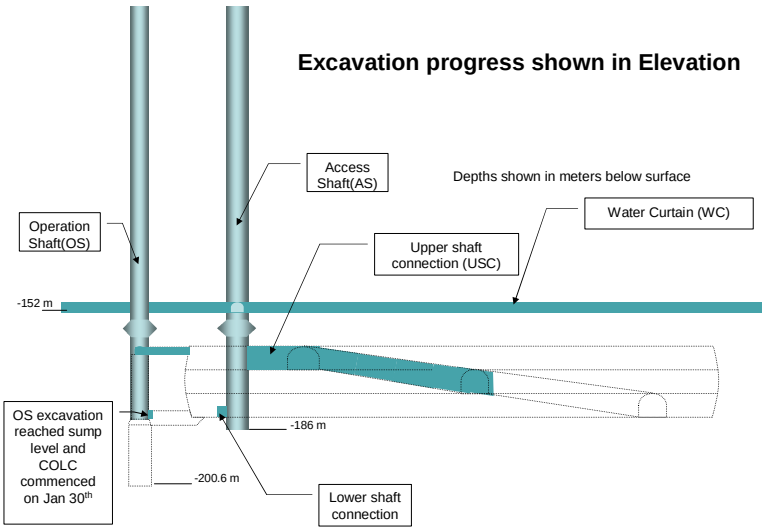
Current Status

As of the end of January, the water curtain has been completed and is being operated to test the connectivity and permeability of the rock mass and jointing system. Some anticipated underground manometer and far field piezometers are still being implemented to augment the ongoing hydrogeological monitoring to avoid rock mass desaturation during construction.

The operating shaft is nearing completion elevation level (has reached the cavern invert elevation).

The Access Shaft has reach final depth and is now being used for the cavern excavation. With transformation from shaft construction to cavern excavation, the mechanized equipment has been lowered down the shaft and mechanized excavation tunneling has commenced in January of 2006.

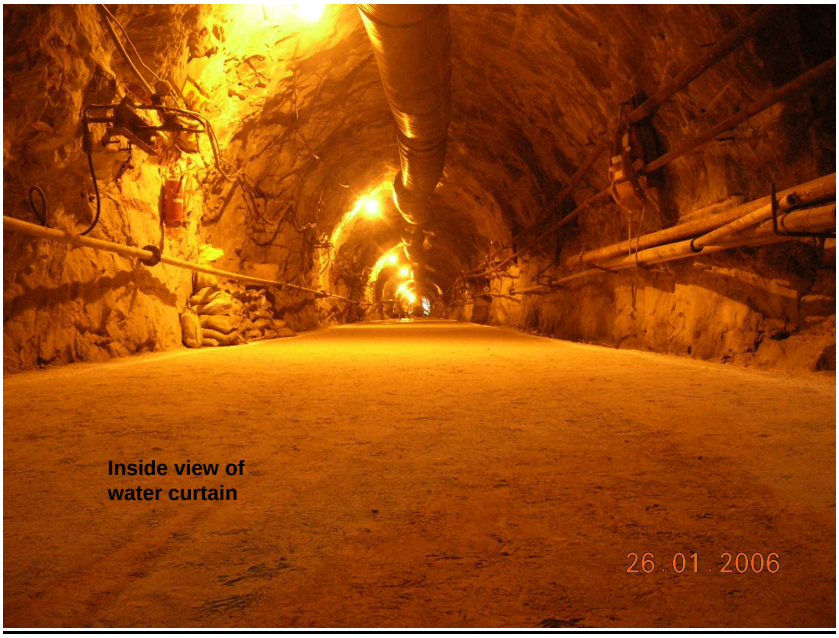




The contractor has experienced various setbacks mostly due to learning on this their first cavern project. Shaft access has proven to be a challenge as has the local availability of personnel experienced in modern mining techniques. The site is located in close proximity to this beach fronted tourist city, but, attracting and keeping expertise has been one of the largest challenges of the project due to the high demand internally within India in other more modern centers, as well as externally from the neighboring Arabian Gulf states.

The cavern underground construction will now be completed in early 2007 for handover of the shafts to the above ground team. The above ground team has completed a large portion of the civil construction and has recently commenced mechanical installations.


View from the Access Shaft
towards the Access Ramp
26.01.2006


Inside view of
water curtain
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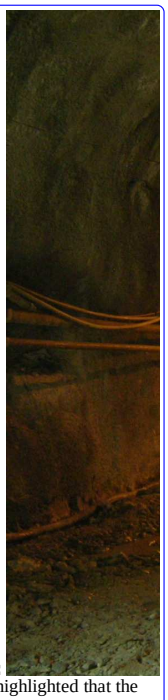
Advantages of Cavern Storage of LPG

In a more general view, this underground storage enables stockage or reception of larger volumes and thus to be supplied by larger LPG carriers. This increases the efficiency of transportation of the liquefied gas and thus reduces the environmental cost of the LPG.
Another advantage is the minimization of aboveground installations in this underground storage which will have a reduced visual as well as area usage impact over the traditional LPG spheres.

All these positive aspects are coming in addition to the intrinsic advantages of LPG as a source of energy considered as a clean fuel. With no emission particles from combustion, LPG replaces polluting fuels such as wood, coal or biomass in the local market. Hence, the project contributes to sustainable development of the region by contributing to reduction in environmental pollution and avoiding deforestation.



Verwijderd: It can also be highlighted that the minimization of aboveground installations using underground storage will have a reduced visual impact over the traditional LPG spheres. ¶

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Met opmaak: Uitvullen

Verwijderd: emission

Verwijderd: offsetting

Verwijderd: dung or

Verwijderd: reduces