THE OMAN LIQUEFIED NATURAL GAS PROJECT

L' USINE DE LIQUEFACTION DE GAZ NATUREL D' OMAN

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ABSTRACT

Oman Liquefied Natural Gas L.L.C. (OLNG) is a limited liability incorporated joint venture Company organised, since 1994, under the Laws of the Sultanate of Oman. It engages in the business of producing and selling Liquefied Natural Gas (LNG) and by-product Natural Gas Liquids (NGL's). The plant liquefies Natural gas using two identical process trains, with currently the single largest LNG production capacity of 3.3. mtpa in the world. Since the start in April 2000 the plant is now delivering LNG to Korea and Japan on a regular basis as well as spot cargoes to USA and Spain. The LNG plant has been successfully commissioned well within budget and on time due to the good collaboration between OLNG and its Contractors. Technically the plant is characterized by a very low specific capital cost, compared to other recent LNG projects. The paper describes the experience during engineering, construction and initial operation of the project characteristics that are new in the LNG industry and gives an overview of the key lessons learned.

RESUME

La societe Oman LNG LLC (OLNG) est une entreprise en coparticipation etablie en 1994 sous le regime du Sultanat d'Oman. Son activite premiere est la production et la commercialisation de Gaz Naturel Liquefie (GNL) et d'essence legere.

L' usine de GNL, comporte deux modules de liquefaction, chacun d'une capacite de 3,3 millions de tonnes par an qui sont actuellement les plus grands au monde de ce type.

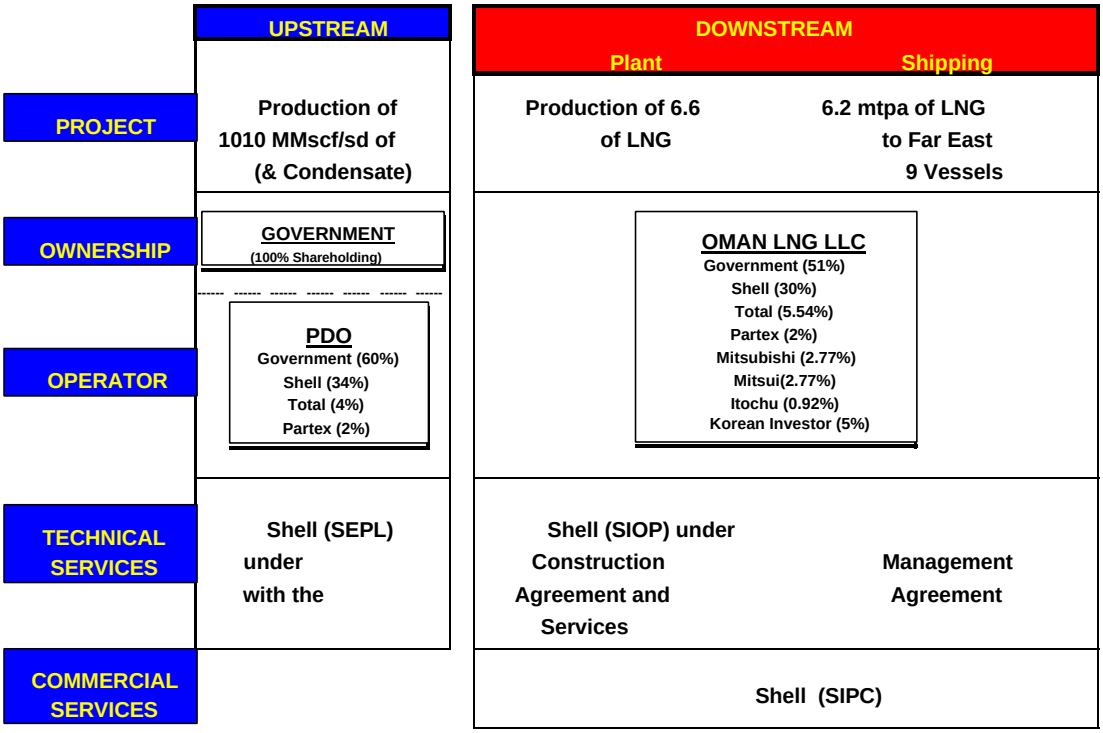
Depuis sa mise en route en Avril 2000, l'usine exporte le gas liquefie de maniere continue vers la Coree et le Japon ainsi que de maniere ponctuelle vers les Etats Unis et l'Espagne. L'ensemble du projet a ete couronne de succes, le calendrier d'execution a ete suivit de maniere rigoureuse et les couts on ete maintenus en deca du budget initial.

Ceci a pu etre obtenu en grande partie grace a une excellente co-operation entre OLNG et les entreprises d'inginierie et de construction. Une des caracteristiques importantes de ce projet est l'investissement financier specifique (raporte a la capacite de production) tres bas compare a d'autres projets similaires recents. Le document passe en revue les differentes phases du projet et l'experience acquise pendant la construction, la preparation a la mise en route et la phase initiale d'operation ainsi que les specifites particulieres du projet.

1.0 Introduction

Five years after substantial quantities of gas were discovered in Central Oman, the Oman LNG Project has established itself as the largest single Project in the Sultanate of Oman and a significant new source of Liquefied Natural Gas for the world's rapidly growing natural gas markets.

The Company was set-up by Royal Decree to handle the Downstream of this gas export Project, namely the liquefaction, transportation and sales of LNG. Following the provision of a small amount of equity to a Korean partner, the Shareholders are 51% Government, 30% Shell, 5.54% Total, 2% Partex, 2.77% Mitsubishi, 2.77% Mitsui, 0.92% Itochu and 5% to Korea LNG. The Upstream of the Project is 100% Government owned and is operated by Petroleum Development Oman (60% Government, 34% Shell, 4% Total and 2% Partex), with responsibility for field appraisal and development, gas processing and transport by pipeline to the liquefaction plant at Qalhat, near Sur. There is thus a commonality of Shareholding in those involved with both the Upstream and the Downstream, which makes for synergy.

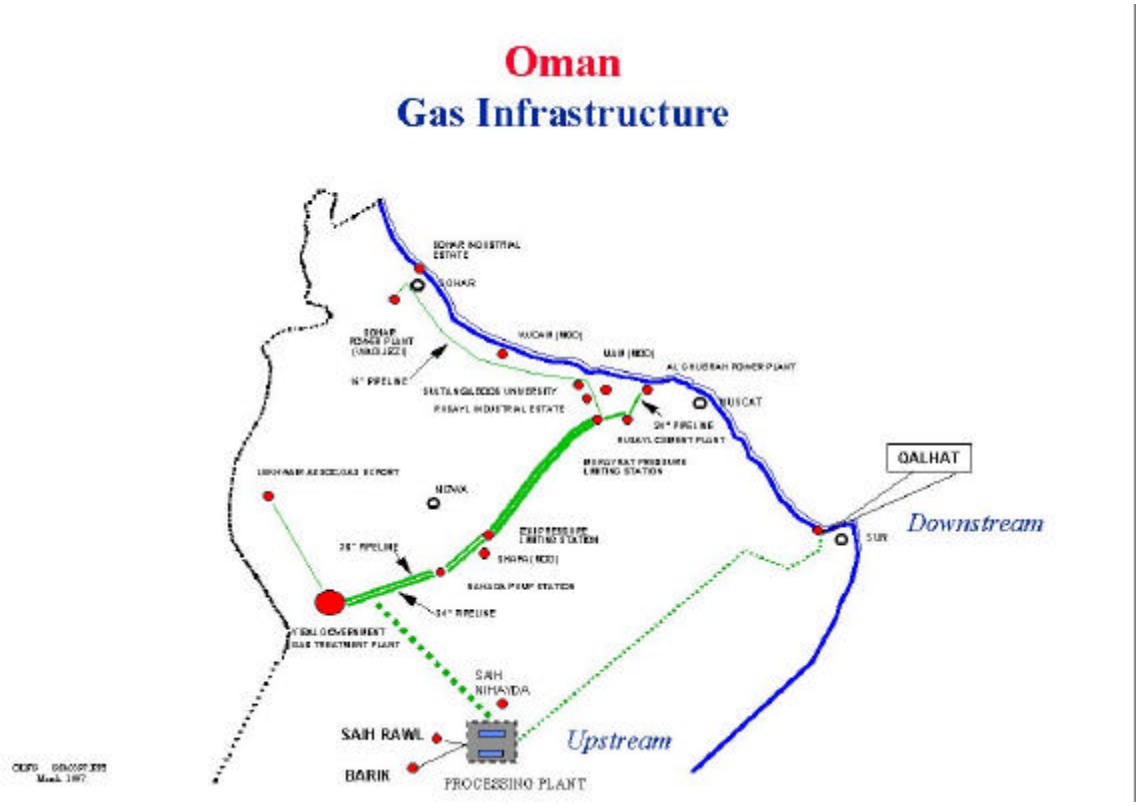


The basis for the construction of the plant was a Sales and Purchase Agreement (SPA) with Korea Gas Company in 1996 for an amount of 4.1 mtpa over a period of 25 years.

In between October 1998 and December 1999 long-term SPA agreements were signed with Osaka Gas of Japan and Dabhol Power Company in India. In order to optimize the initial period between the plant production capacity and existing long-term SPA's start short term SPA's were signed with US Company Coral Energy Resources L.P. and with Enagas of Spain for cargoes in 2000 and 2001. A SPA to sell more than 130,000 tons of condensate to Total for a period of 18 months was signed in June 1999 with first cargo lifted in May 2000.

2.0 Overall Gas Project

The Oman LNG Plant at Qalhat processes natural gas from the gas fields in Central Oman, after hydrocarbon condensate associated with the gas is removed by upstream treatment. The feed gas to Oman LNG is transported through a single gas pipeline, 360 kilometres long, to the Plant where it first undergoes treatment to remove impurities.



3.0 LNG Project Milestones

1989 & 1991: Significant volumes of non-associated natural gas discovered in central Oman.

January 1992: Shell Group's preliminary feasibility study on establishing an LNG project was accepted by the Government of Oman, and a Memorandum of Understanding signed.

June 1993: Shareholders' Agreement signed between the Government of Oman 51%, Royal Dutch/Shell Group 30% Total 5.54%, KOLNG 5%, Partex 2% Mitsubishi 2.77%, Mitsui 2.77%, Itochu 0.92%.

February 1994: Royal Decree issued to establish the Company.

July 1994: Oman LNG LLC registered as an Omani Company.

October 1996: Sale and Purchase Agreement (SPA) signed between Oman LNG and Korea Gas Corporation commencing year 2000.

November 1996: EPC contract signed between Oman LNG and Chiyoda/Foster Wheeler.

November 1996: LNG Plant Foundation Stone Laying Ceremony by HM Sultan Qaboos bin Said on site.

November 1996: Gas Supply Agreement signed between the Government of Oman and Oman LNG.

October 1998: SPA signed with Osaka Gas of Japan commencing November 2000.

December 1998:	SPA signed with the Dabhol Power Company of India commencing late 2001 – entire output of plant now sold on a long term basis.
June 1999:	SPA signed with Total of France for approximately 130,000 tonnes of natural gas liquids for an 18 month period commencing April/May 2000
November 1999:	SPA for short term sales of LNG signed with Coral Energy Resources L.P. of the USA for two cargoes of 125,000 cu m each for delivery during 2000.
December 1999:	First LNG production train ready for start-up.
January 2000:	SPA for short-term sales of LNG signed with Enagas of Spain for 17 cargoes of 125,000 cu m each for delivery during 2000 and 2001.
February 2000:	First LNG produced.
April 2000:	First export shipment of LNG to Korea.
May 2000:	Second LNG train started-up and producing
October 2000:	Official Inauguration of the Plant by his HM Sultan Qaboos bin Said on site.

4.0 Plant Description

The Oman LNG facilities consist of two Process Trains, each designed to produce a quantity of 10,200 t/d of LNG rundown, based on average design feed gas, equivalent to an annual production of 3.3 Million tonnes per train. The LNG trains are equipped with fixed speed Frame 6 and 7 gas-turbine drivers for the propane pre-cooling and mixed refrigerant compressors respectively. An endflash system has been provided to allow for nitrogen rejection and to maximise LNG production. The trains use once through seawater for cooling and HTF as a heating medium.

Main utility units are power generation, consisting of 4 Frame 6 gas-turbine generators, seawater cooling facilities, water distilling and treatment, instrument air and nitrogen units.

LNG from the two production trains is rundown to two LNG storage tanks, each with a net volume of 120,000 m3. Condensate produced is stored in two floating roof tanks.

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4.1. Rotating Equipment

4.1.1. Propane Compressor Train

The OLNG propane compressor train consists of a GE Frame 6 gasturbine, driving a four stage centrifugal compressor manufactured by Nuove Pignone. A 7.5 MW variable speed electric motor is coupled to the gasturbine/compressor train to provide starting power for acceleration of the machine and additional helper power during normal operation. Although the gasturbine speed can be varied over a small range it is being operated at fixed speed. The propane compressor is fitted with an anti-surge control and safeguarding system from Compressor Control Corporation (CCC). Original compressor power for average conditions is 35.65 MW. Due to a lower than expected compressor efficiency this figure was increased to 37.0 MW during detailed engineering.

4.1.2. MR Compressor Train

The MR compressor train consists of a GE Frame 7 gasturbine, driving an axial LP MR compressor and a two stage centrifugal HP MR compressor both manufactured by Nuove Pignone. Again a 7.5 MW variable speed electric motor is coupled to the gasturbine / compressor train to provide starting power for acceleration of the machine and additional helper power during normal operation. Similar to the propane compressor the MR compressor train is operated as a fixed speed machine. The LP MR compressor is fitted with variable stator vanes, allowing control of the compression ratio of this machine. Both LP and HP MR compressors are fitted with CCC anti-surge control. Overall power consumption of the MR compressor train for average conditions is 73.7 MW.

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4.1.3. Endflash Compressor

The endflash compressor is a three stage fixed speed centrifugal compressor, driven by an 11.8 MW electrical motor. The compressor is fitted with CCC anti-surge control.

5.0 Project Organisation

Three main activity centres were used during project implementation:

- Reading UK where the detailed engineering, procurement, commissioning and operating manual preparation, model review activities took place and where OLNG set up a Resident Engineering Team (RET),
- Muscat Oman where both CFW's and OLNG's Project Directorates were residing and where also local procurement was done,
- the Site, which was the domicile of the CFW and OLNG construction teams. Whilst the centre of gravity of project activities shifted from detailed engineering to construction/ commissioning, also project staff and responsibilities moved to Site and ultimately all project activities were undertaken / co-ordinated from the Site.

Company staff was recruited from shareholders, direct hires and local Omani graduates and trainees.

Whilst all Contractor staff were accommodated in a purpose built temporary camp adjacent to the construction site, Company initiated a temporary housing project in the town of Sur to accommodate its project staff. In excess of 60 existing properties were rented, refurbished and maintained to provide a recreation club, school, clinic, guest houses and bachelor as well as family accommodation. The permanent organisation operated on a rotational scheme (29/27) and this staff was accommodated in a complex purposely built by a third party for rental by OLNG.

6.0 Commissioning

Preparation for commissioning started at an early stage in Reading with the preparation of commissioning manuals, describing in a very detailed manner all activities from pre-commissioning, commissioning, functional testing to hand over procedures. This work was done by CFW monitored by OLNG start-up specialists assigned to the Resident Engineering Team at an early stage.

The concept of commissioning driven project scheduling defined during project specification stage was applied consistently throughout construction and commissioning.

During construction, the Complex including buildings, roads, jetties and telecommunication equipment, was broken down in parts resulting in an overall total of 610 Commissioning Systems, defining every part of the Complex.

QA/QC during start-up was performed by Company permanent organisation, based on the Company Quality System. Repetitive audits were done by CFW, witnessed by Company, to ensure that procedures were followed and corrective actions done to solve non-conformances. This led to improvements in working methods and systems.

In addition numbers of reviews, such as the Criticality and Integrity review during engineering; HSE reviews, Quality reviews, reviews by lead discipline engineers during construction/commissioning and Operational readiness review were done before Start-up.

Managing the interfaces between construction and commissioning was identified critical to the future operational success. Management of the interface between the different teams involved was greatly enhanced by “ICARUS” a responsibility matrix developed locally, giving a clear definition of the role and responsibilities for each individual in OLNG Teams.

A lot of work was done by all teams involved working with high spirit and strong motivation. As a direct consequence, commissioning of the LNG trains was completed on time and the facilities could be handed over by main contractor to OLNG several weeks ahead of contractual dates.

7.0 Start-up and Operation

The start-up of the liquefaction trains proved to be very successful and reliable LNG production was established several weeks ahead of initial schedule. First LNG was produced mid February and first shipment of LNG to Korea took place early April.

Overall, start-up was smooth, and a seamless transition from mechanical completion to steady operation of the plant was ensured. Operational and performance tests were done successfully. Initial operation was safe and reliable and all LNG cargoes were loaded on time according to the annual delivery plan and in addition some 6 spot cargoes to the USA and Spain were loaded.

Excellent co-operation by all teams involved in commissioning, start-up, trouble shooting, operation and maintenance resulted in efficient and enjoyable team work for the overall benefit of the project. Nearly all members of the start-up team transferred to the permanent organisation either in operations or engineering/maintenance keeping experience and expertise in the Company.

8.0. Plant Operation Tools

8.1. Conditioning and Performance Monitoring (CPM)

The Bruell & Kjaer CPM system was a “first” in a big scale project like Oman LNG and it proved to be a very good system. Initial set-up of the system to provide all data in a format as required by the rotating equipment group, took some time. Once set-up the system was reliable and extremely useful during start-up of equipment as it provides excellent base-line data for the machines. Fault analysis during upsets is also user-friendly.

8.2. Motor Control System (MCS)

For starting and stopping of normal pumps, mixers and motors, the system is an extremely effective tool. The operational feedback is good and there is also enough diagnostic information to the operator in case of hardware failure.

Due to the software link between distributed control system (DCS) and MCS (see above) there is an inherent time delay between initiation and execution of Start/Stop

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commands. For switching of standby pumps on speed-critical systems or on systems with safeguarding/interlocks this is not acceptable and during the commissioning phase several pump logic's had to be reworked to hardwired Start/Stop signals to improve the speed of response.

8.3 Operational Data Server (ODS)

The system has been available to the Operations, Engineering and Technology groups through out the start-up. It has proved invaluable in trouble shooting and process performance monitoring. Use of the system has facilitated the early completion of the Acceptance Test Runs as data was readily manipulated and verified. Use of the trending facilities greatly enhanced the cool-down as trending was more flexible and longer term than that available in the distributed control system (DCS).

8.4 Pacer

Pacer is a maintenance management system and although a system mainly used for the permanent organisation, the system has been used during the start-up. This to ensure that permits could be properly raised and all important history on equipment could be stored from an early stage of its intended lifetime.

8.5 Operations Training Simulator (OTS)

The OLNG simulator is the only one in the world that is so comprehensive. Units included in the simulator are the exact set up of one whole process train, there are: Acid Gas Removal, Dehydration, Scrub Column, Fractionation, Propane/MR Refrigerant Compressors system, Main Cryogenic Heat Exchanger (Treated natural gas is liquefied here to LNG), LNG stripper and its end flash compressor. In earlier models, different parts of the operations were split up, so that separate simulations were required to assess different parts of the process train. In this integrated system the impact of an incident in one unit on the others is visible immediately and clearly, giving trainees a complete picture of the working of the plant."

9.0 Summary

The story of Oman LNG is one of speed, low cost, successful start-up and till today excellent operation with limited problems. There has been an outstanding co-operation between the Government of Oman, private shareholders, buyers, and bank's and not to forget the EPC contractor and his (local) subcontractors.

Therefore the story of an expansion with at least one train is not a dream but under study today in a serious way and will hopefully materialise to the benefit of the country.