LNG journal

September/October 2002

Shell's first "equity-LNG" ship

Nigel Kuzemko , Shell Gas & Power

Unlike Shell's previous LNG carriers, the recently-named "Galea" is not committed to a specific project. Instead it will be used to facilitate the development of a portfolio of LNG projects worldwide

On 5 September Shell Gas & Power (Shell) named the first of its equity newbuild LNG carriers the "Galea" at the Mitsubishi Heavy Industries (MHI) shipyard in Japan.

The vessel is the first in a series of three that have been secured from this yard against the background of a growing portfolio of Shell LNG projects around the world which require shipping, and will help meet growing demand for LNG. The carrier can carry 135,000 m^3 of LNG and has the Moss (5 spherical tanks) cargo containment system. It is the sister ship of the Abadi, a carrier used in the transportation of Brunei LNG.

Shell's new LNG carrier, the Galea

Unlike any of the previous LNG vessels that Shell has commissioned, this carrier is not committed to a specific project. Instead it will be used to facilitate the development of a portfolio of upstream and downstream LNG projects in the Asia Pacific, Mediterranean and Atlantic Basin.

Shell has taken the step to construct the carriers in response to changes in the global LNG market place. These ongoing changes are numerous and include:

- The renaissance of the Atlantic Basin market. LNG has historically been concentrated in the Far East, which accounts for 70% of LNG sales. However, LNG trade in the Atlantic Basin is expected to grow by 10% p.a. over the next ten years, rising by 40 mtpa or more.
- Access to North American markets through capacity arrangements at the LNG terminals. Shell has acquired capacity at Cove Point and expansion capacity at Elba Island and is well positioned for further terminal opportunities on the East and West Coasts. Access to Shell shipping will facilitate sales into this Shell capacity.
- A move towards the sale of LNG equity shares of production on an equity basis.
- The availability of spare capacity in new LNG projects due to the slow build up of sales under long term contracts and the scope for these to flow into the Atlantic Basin.

In amongst these changes in the global LNG markets Shell is looking to be able to offer viable propositions to both Shell and non-Shell upstream and downstream businesses. For the producer or new LNG projects Shell can offer a link between the market and the producer so that incremental volumes may be placed (e.g. spot cargoes from Malaysia into Spain, NWS 'Wedge' volumes) or significant long-term commitments that support financing of projects (e.g. Nigeria LNG Trains 4 and 5, Mariscal Sucre in Venezuela). In addition, the business can offer FOB or CIF sales with the new Shell carriers and risk management products to supplement sales to new markets (e.g. USA, India) where the price exposure is more uncertain.

For the customer (of the LNG or of the re-gasified LNG) Shell can offer a delivered product at competitive and market related prices that is delivered from a portfolio of supplies.

Further value may be achieved for both customers and producers in the geographic spread of Shell's LNG portfolio through the development of swaps, even though this market is complex and not yet established. For example, a project such as Sakhalin, which is very close to Japan, need not rely only on demand growth in Japan. It can secure new demand in other markets, and then existing supplies to Japan could be diverted to those markets, and swapped for Sakhalin supply, allowing the logistic advantages of Sakhalin's proximity to Japan to be realised.

One year on from the tragedy of 9/11, there is a continued focus on the safety of LNG imports, especially into the USA. The tragedy led to the temporary closure of the Everett terminal in Boston in a response to safety fears. This derived from understandable concerns, which have been thoroughly studied and addressed. LNG may be risky for the project proponents in financial terms but, once established, LNG is in fact one of the safest of hydrocarbons, and has the record to prove it.

After a 2001 which saw the Arun disruption as well as the shocking events of 9/11, the relevance of the current situation to the security of any supply arrangement is a factor for each player to consider. The result could be a renewed focus on security of supply, which no doubt played a part in China's decision to purchase from Australia for its Guandong terminal.

Overall as the LNG market continues to develop it requires the players to respond. The Galea is an example of how Shell is responding to the customer and producer needs in the global LNG market. ■

Nigel Kuzemko is General Manager - Global LNG for Shell Gas & Power. He initially worked as a geophysicist for Ultramar and then moved to the commercial arena just before the LASMO takeover. Following this he worked for Atlantic Richfield as European Gas Manager and TXU before joining Shell in February 2000.

IN THIS ISSUE

LNG journal

Maritime Content Ltd
213 Marsh Wall
London E14 9FJ
UK

PUBLISHER
Stuart Fryer
Tel: +44 (0)20 7510 0015

EDITOR
David Roe
(MA, PhD, CEng, MIGasE)
Tel: +44 (0)20 8542 9637
roe.lng@lineone.net

ADVERTISING MANAGER
Eva Suminska
Tel: +44 (0)20 7510 0026
suminska@lngjournal.com

ADVERTISING EXECUTIVE
Dawn Carse
Tel: +44 (0)20 7510 0021
Carse@lngjournal.com

PRODUCTION
Vivian Chee
Tel: +44 (0)20 7510 0018
production@lngjournal.com

SUBSCRIPTION
1Year (6 issues) £198
Subscription Hotline:
Tel: +44 (0)20 7510 0015
Fax: +44 (0)20 7510 2344
Email:
subs@lngjournal.com

Marathon buys in to Elba Island

Marathon Oil has successfully bid to acquire Enron's right to deliver and sell LNG at the Elba Island LNG reception terminal in Georgia for $31.9 million. Under the agreement, Marathon can supply up to about 1.2 mta of LNG (58 Bcf/year of natural gas), for about 17 years, to El Paso Merchant Energy.

Enron's sale of its interest in the terminal was part of asset disposals associated with its bankruptcy proceedings.

Venezuela chooses offshore developers

Venezuela's Ministry of Energy & Mines has chosen preferred bidders for development of four blocks containing offshore gas reserves. Blocks 1 and 2 were awarded to BP and a BG/ChevronTexaco consortium. Both operate adjacent gas fields in Trinidadian territorial waters. Gas from Blocks 1 and 2 will be used as feed gas for the Mariscal Sucre LNG plant on the Paria peninsula, which is being planned by a venture of PDVSA, Shell and Mitsubishi.

Skansa client's CD enclosed

Korea Gas seeks more LNG

There will be a further delay in implementing the Korean Government's plans to privatise Korea Gas Corporation (KOGAS). The opposition Grand National (Hannara) Party secured a majority of seats following a by-election in August, and opposes the privatisation proposals, so it is most unlikely that the legislation will be passed by the current administration. Because of the delay the Korean Energy Ministry has authorized the negotiation of new supply contracts by KOGAS to meet the growing gap between future demand and contracted supplies. LNG demand is estimated to exceed current contracted supply by more than 0.85 mta by 2004, and a recent forecast from the Ministry predicted an LNG demand of over 28 mta by 2015, compared to the 2001 level of 15.6 mta.

Sakhalin approved

The Russian supervisory board for the Sakhalin II LNG project has approved the project's development budget of $8.5 billion after considering the matter for over a year. Negotiations are continuing with potential buyers in Japan and Korea, and Shell is considering committing to take some of the project's output for supply to world LNG markets. It is planned to take a final investment decision by the end of this year.

Williams sells Cove Point

On September 5 Williams Co. announced that it had completed the sale of its Cove Point LNG storage facility and associated 87-mile pipeline to a subsidiary of Dominion Resources Inc. for $217 million in cash. The sale also avoids the need for Williams to spend about $105 million that is needed to reactivate marine reception and expand the capacity of Cove Point over the next two years. The disposal is part of Williams' plans to raise $1.8 billion in asset sales to strengthen its balance sheet and restore a credit rating affected by the collapse of Enron and losses in energy trading

India's NTPC wants fixed-price LNG

In response to the invitation issued in March by the National Thermal Power Corporation (NTPC) of India, as many as 11 leading domestic and international oil and gas companies have expressed interest in supplying up to 5 mta of LNG to NTPC for its proposed gas-based power plants. NTPC is to invite bids by April 2003 for LNG supplies at a fixed price, not linked at all to crude oil or other fuels, with a target of $3/million Btu ex-regasification in mind. Several LNG suppliers have confirmed willingness to supply LNG on this basis.

NTPC is also looking to take a 26% stake in the LNG reception terminal, and is appointing consultants to advise them specifically on the procurement of LNG. NTPC is coming under political pressure to drop its plans to invite bids for LNG supplies, and instead to take LNG through the Petronet LNG project.

First LNG from Trinidad project expansion

Atlantic LNG recently delivered the first LNG cargo from Train 2, the first of its two-train expansion. The LNG was carried on the Methane Polar, on charter to BG, and was delivered to Lake Charles LNG terminal for BG LNG Services.

Train 1 was commissioned in 1999 as one of the largest single train facilities in the world, with a capacity of 3 mta. The terminal at Point Fortin included two 102,000 m^3 LNG storage tanks and marine facilities with a 700-metre jetty. Train 2 started construction in August 2000, and was completed in August 2002, two months ahead of schedule. The expansion project includes one 160,000 m^3 LNG storage tank and more ship-loading capacity. The expansion partners are BP (42.5%), BG Trinidad and Tobago (32.5%) and Repsol (25%).

The US market is set to receive about 38% of Train 2 production over a 20-year period. This is in addition to its 60% take of Train 1 production. The other 62% of Train 2 production is due to go to the Spanish market. Train 2 consumes about 500 million standard cubic feet of gas per day of which BG and BP each supply 50%. BG supplies gas from the Hibiscus Field in the North Coast Marine Area (NCMA) via a new pipeline. BP's supply comes via an existing pipeline from its South East Coast fields.

Atlantic shipped its 200 th cargo from Train 1 in June this year, 39 months after initial LNG production. The commencement of shipments from Train 2 will increase Atlantic's delivery of cargoes to approximately 120 per year, up from 60.

Train 3 will start up in the 2nd Quarter of 2003. BG and ChevronTexaco have been granted approval by the Trinidad authorities to develop their co-owned Dolphin Deep and Starfish fields off the east coast of Trinidad, which from 2005 will supply gas to the Train 3 expansion. LNG production from BG capacity in Trains 2 and 3 will be sold to El Paso Merchant Energy under a long term contract for import into the Elba Island LNG receiving terminal in Georgia, USA, from 2003.

Atlantic LNG is currently in negotiations with the Government of Trinidad & Tobago for the construction of Train 4, which at 5 mta is one of the largest LNG trains proposed worldwide to date.

The Atlantic LNG terminal.
New storage tank and trains 2 and 3 under construction (in foreground)

China selects Australian LNG
Tangguh is next

The North West Shelf (NWS) Venture in Australia has been selected as the preferred supplier of 3 mta of LNG over 25 years to Phase 1 of China's first LNG project at Guangdong, in South China. Subject to execution of the necessary agreements, deliveries will begin in 2005. The equal participants in the NWS venture are Woodside (operator), BHP Billiton, BP, ChevronTexaco, Japan Australia LNG and Shell. The NWS Venture is building a fourth train at its Karratha plant, and the deal with China will almost certainly mean that a fifth train will be built: a final investment decision is to be made next year.

China National Offshore Oil Corporation (CNOOC), the largest shareholder in the Guangdong LNG project, is likely to purchase about 5% of the North West Shelf gas resources, for a price of around US$ 320 million. CNOOC will also take a 25% stake in a new joint venture company China LNG, which will be set up to own the gas that the NWS project will deliver to Guangdong. The remaining 75% will be shared equally among the six NWS project participants.

The unsuccessful bidders for supplies of LNG to Guangdong were RasGas (Qatar) and the Tangguh project (Indonesia), led by BP and Pertamina. However, the Chinese government unexpectedly stated that the Tangguh project was the preferred supplier of 2.5 mta for 25 years to the next Chinese LNG terminal project, in Fujian province. Details of the supply agreement are being negotiated. CNOOC has recently signed an agreement with the Fujian provincial government; CNOOC would own 60% of the terminal and associated pipeline and the Fujian Investment & Development Co., Ltd. would own 40%. Construction of the first phase of the terminal, at Meizhou Gulf on the East Coast of the province, was scheduled to start in 2004, with first operations in 2006.

A consortium of China Merchants Group of Hong Kong, China Ocean Shipping (Group) Company (COSCO), and Australia LNG has secured the shipping franchise for the Guangdong LNG project. LNG will be sold on a FOB basis. It is reported that Hudong-Zhonghua Shipbuilding is to build two 145,000 m^3 LNG carriers for the project, for delivery at the end of 2005.

Bolivian LNG project delayed

The new Bolivian government, which took office on August 6 under the presidency of Gonzalo Sanchez de Lozada, has decided to review the feasibility and development plans for an LNG export project. Bolivia's Ministry of Hydrocarbons is appointing US consultants to undertake a study, funded by the U.S. Trade and Development Agency. Pacific LNG (a consortium of Repsol, BG Bolivia and BP-led Pan American Energy) had earlier undertaken a feasibility study, and signed a Memorandum of Understanding on LNG sales with Sempra Energy, who is planning an LNG reception terminal in Mexico for supply to US and Mexican markets. It had been awaiting a decision by the previous Bolivian government on the selection of the port that would export LNG from landlocked Bolivia. The options are a port in southern Peru, or in northern Chile, which would be lower cost because of the shorter distance to the Bolivian gas reserves, but politically sensitive since Bolivia still claims sovereignty over the coast lost to Chile during the war in 1879. A decision is expected by the end of the year.

Mexican regulations published

In August the Energy Regulatory Commission published environmental, safety, and technical regulations covering the siting, design, construction, and operation of LNG reception facilities. They are based in part on the US NFPA 59A LNG Code and in part on the European Community LNG standards. The first project to seek approval since publication of the regulations was a combined LNG terminal, 1000 MW power plant, and desalination plant near Tijuana, close to the US border on the west coast in Baja California. The project is being developed by Marathon (USA) in conjunction with Pertamina (Indonesia), Golar LNG (Norway) and Grupo GGS (Mexico). Other LNG terminals planned for Mexico's Baja California include those promoted by Sempra/CMS, by Shell, by El Paso/Phillips, and by ChevronTexaco. LNG projects planned for Mexico's Gulf Coast include the El Paso/Shell terminal at Altamira.

Egyptian LNG contract for Bechtel

The Egyptian LNG joint venture has awarded an EPC contract to Bechtel (USA) for the first train of the LNG plant at Ikdu. It is reported that Bechtel are to award a contract to Nuovo Pignone (italy) for compressors, and to Mitsubishi H. I. (Japan) and Petrojet (Egypt) for storage tanks. Gas will come from the offshore Simian/ Sienna fields being developed by BG and Edison, and the 3.6 mta train will use the Phillips cascade process, an improved version of that used in the Atlantic LNG project, Trinidad. The plant is scheduled to come into operation in 2005. Financing is also being arranged, including a $450 million loan from the European Investment Bank; the financial adviser is Societe Generale. Egyptian LNG is led by BG and Edison International; other partners are the Egyptian Natural Gas Holding Company, the Egyptian General Petroleum Corporation, and Gaz de France.

Union Fenosa seeks Partner

Union Fenosa of Spain is seeking a strategic partner for its growing gas business (its LNG business activities are described in an article on page 16 of this issue), and has appointed Goldman Sachs as advisor. Union Fenosa is looking to sell between 20 to 50% of its gas business to a strong international company with a good downstream marketing record, but would retain management control. It has an ambitious capital investment programme, and mounting debts; the strategic partner may be expected to share investment in Union Fenosa's LNG projects.

Stake in Depa for sale

The Greek government has formally invited bids from private downstream gas companies for up to 35% of Depa, whose net assets, valued at almost $935 million, include the Revithoussa LNG reception terminal. Depa is currently owned by the Greek state (65%) and Hellenic Petroleum (35%).

Depa has a long-term contract with Sonatrach of Algeria for the import of 0.4 mta. With further investment, and subject to market requirements, the terminal can be expanded from it current capacity of 1.5 billion m3/year (1.5 bcma, about 1 mta) to over 5 bcma (about 3.5 mta).

Another Italian terminal planned

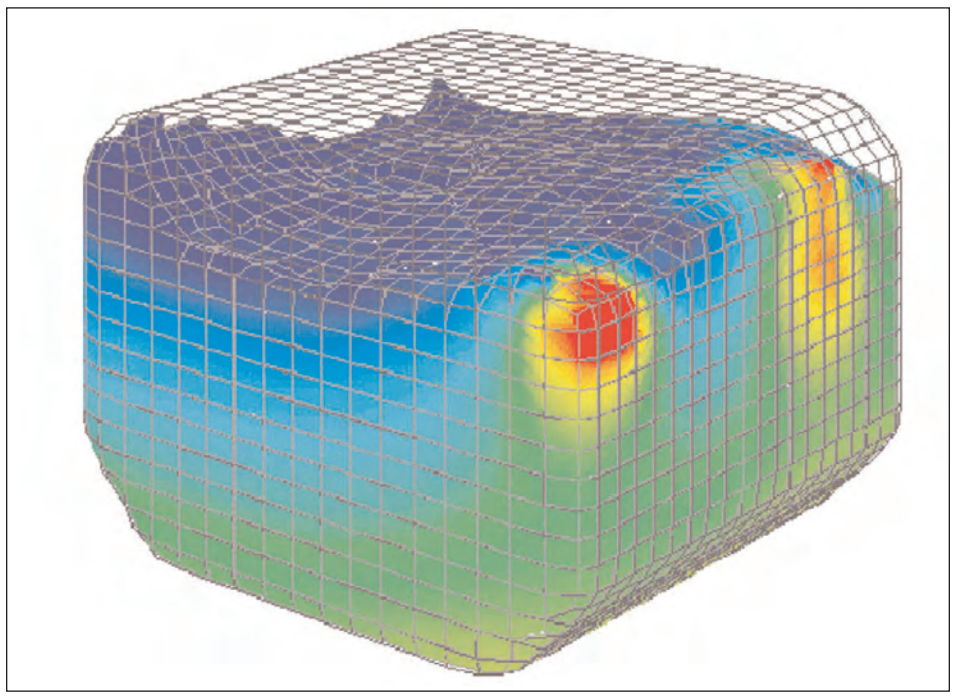
Edison of Italy is seeking approval of the Italian authorities for a second new LNG reception terminal, near Marittima in Tuscany. There are already plans for new LNG reception terminals at seven sites awaiting approval by the Italian authorities: one for BG (at Brindisi); three for Enel (at Taranto, Vado Ligure and Muggia); and two for Falck (on the southern Calabrian coast). Recently, Edison started construction of an LNG reception terminal 15 km offshore at Rovigo, on the Adriatic Sea; it is being developed with ExxonMobil.

Sloshing Simulation from ABS

A key aspect of transporting LNG is designing the tank and containment systems to withstand the dynamic loads and sloshing of the LNG cargo. This has taken on an even greater importance with operators seeking the operational flexibility of partial cargo loading in LNG carriers, and with the prospect of offshore floating LNG production and reception, when the cargo containment will be partially filled for considerable periods.

ABS (American Bureau of Shipping) can analyse the effect of the partially loaded tanks with its set of proprietary sloshing simulation software. The powerful 2 and 3-D computer modeling programs can pull from North Atlantic, route specific or site-specific wave databases to conduct a direct simulation on a particular LNG vessel. One difficulty is that there is very limited existing experience of partial load operation or of actual damage to containment systems that has occurred due to low filling conditions.

ABS is working with several clients conducting loading analysis for new LNG construction as well as retrofits. Further work by the ABS Corporate Technology Research Department has been extended to the review of model tests for sloshing pressure as well as impact strength tests. This 3-D sloshing research has led to recommendations for pump tower modifications as well as reinforcements to containment systems to handle the unique LNG loads.



Sloshing simulations conducted with ABS 3-D software

"LNG Today : The Promise and the Pitfalls"

This 90-page report by Andy Flower and Richard King is produced by the Energy Publishing Network in co-operation with Gas Strategies. It covers the LNG chain, project structures, sources of LNG, LNG markets, contractual arrangements and pricing, shipping, short-term trading and the outlook for LNG. It does not attempt to deal in any detail with LNG technologies, and there is no coverage of the topics of project development and financing, LNG safety, offshore LNG production and reception, nor the use of LNG for peak-shaving and satellite storage, nor as vehicle fuel. As to be expected from authors associated with the Gas Strategies team, the report provides an excellent basic understanding of the commercial aspects of international LNG trade, and is very readable, with high quality figures and maps, and with a good executive summary.

The report is available from the Energy Publishing Network: contact Paul Cassar - Tel. +44 1865 395826 or E-mail paul@energypublishing.com. Price: Electronic (pdf) version £350/$525/Euro525, electronic and printed versions £375/$565/Euro565. For further details please visit www.energypublishing.com

Lined Cavern Storage of LNG

Géostock (a subsidiary of BP, Totalfinaelf and Tractebel), and SN Technigaz (100% subsidiary of Bouygues Offshore) have jointly developed a new LNG underground storage technology. It consists of a mined cavern lined with a metal membrane as used by Technigaz in conventional LNG storage. The new technology is claimed to offer potential advantages in terms of safety, environmental protection, operational simplicity and cost effectiveness. Géostock and SN Technigaz have signed a Head of Agreement with SKEC (SK Engineering & Construction) to construct a pilot unit at Taejon in South Korea which will optimize the concept and demonstrate its technical and economical viability. The experimentation phase will last about two years. For further information contact : M. Jean-Michel Noé, Tél : 33 (0)1 47 08 73 31, E-mail : jmn@geostock.fr, or Mr. Woong Suk Yoo of SKEC : Tel : 00 82 2 3700 9230 . E-mail : wsyoo@skec.co.kr

New Microcell technology

Professor Robert Amin of the Curtin University of Technology, Western Australia, has won the Institution of Engineers' Australia Eureka Prize for Engineering Innovation. His prize-winning technology was the "LNG Microcell" liquefaction process, in which the carbon dioxide in the natural gas is separated as a solid using novel proprietary technology. It is claimed that when developed at a commercial scale this would reduce significantly the size of pretreatment plant for acid gas removal, and could be applied to liquefaction plants on LNG carriers. The inventors are approaching potential sponsors, including Shell and Woodside, with a view to establishing a larger-scale pilot plant.

Shell exits Namibia

Following the its recent decision to shelve plans for an offshore LNG project, because appraisals showed insufficient gas reserves, Shell has now decided to withdraw from its Kudu field operations. It will transfer its 75% share to its partners, ChevronTexaco, who will have 60% and Energy Africa, 40%. They will continue to explore potential markets in Africa for the gas.

Das Island refurbishment

In June Abu Dhabi Gas Liquefaction Co. (Adgas) installed and commissioned a new LNG loading arm at its Das Island LNG plant. The plan is to check its satisfactory performance over a 4-6 months period, before replacing all four 16-inch loading arms. The project is required because of the increasing frequency and cost of maintenance for the old arms, which require marine barges to be lifted from the jetty for workshop refurbishment.

CMS may sell Lake Charles

CMS Energy Corp is considering the sale of a number of pipeline and gas assets, including its LNG reception terminal at Lake Charles, Louisiana. The Federal Energy Regulatory Commission has given initial project and environmental approvals to CMS' plans to expand the Lake Charles terminal by 2005.

Dairy of events

2002

October 6-11 Course: LNG - The Commercial Imperatives, Oxford, UK (Alphatania Group. Tel. 44 (0) 20 7650 1402. Fax. 44 (0) 20 7650 1401. e-mail training@alphatania.com)

October 10-11 7th Gas Executives Summit Conference, Paris, France (ENSPM. Josée Foucault, Tel. 33 147 52 72 93. Fax. 33 1 47 52 71 09. e-mail josee.Foucault@enspmfi.com)

October 13-16 Gastech 2002, Doha, Qatar (Turret Rai. Rachel Borg, Tel: +44 1895 454545, Fax: +44 1895 454588, E-mail: info@gastech.co.uk)

November 4-6 European Autumn Gas Conference, Florence, Italy (Overview Conferences. Tel. 44 (0) 20 7650 1430. Fax. 44 (0) 20 7650 1431. e-mail events@economatters.com)

December 10-11 3rd Annual World LNG Summit, Rome, Italy (CWC Group, Elina Watson, Tel: + 44 20 7089 4187, e-mail: ewatson@thecwcgroup.com)
Also : **December 9**, Workshop - Understanding the LNG value chain. **December 12**, Training Course - Using energy derivatives to increase profitability on LNG projects

2003

January 13-24 Course : Gas Conditioning and Processing (LNG Emphasis), south-east Asia (J.M. Campbell & Co., Tel. 1 405 321 1383. Fax. 1 405 321 4533. e-mail registrar@jmcampbell.com)

January 20-31 Course : Gaz Naturel Liquéfié - in French, Paris, France (AFG. Tel. 33 (0) 1 44 01 87 51. Fax. 33 (0) 1 44 01 87 91. e-mail emmanuelle.holmiere@afgaz.fr)

March 25-28 Course : Technology and the LNG Chain, London, UK (J.M. Campbell & Co., Tel. 1 405 321 1383. Fax. 1 405 321 4533. e-mail registrar@jmcampbell.com)

March 30 - April 3 LNG Sessions at the 2003 Spring National Meeting of the American Institute of Chemical Engineers (AIChE, Chen-Hwa Chiu, Tel. 1-713-432-6922, Fax 1-713-432-6256, e-mail chiuch@chevrontexaco.com)

April 1-4 Course : Technology and the LNG Chain, Singapore (J.M. Campbell & Co., Tel. 1 405 321 1383. Fax. 1 405 321 4533. e-mail registrar@jmcampbell.com)

May 17-20 Course : Technology and the LNG Chain, Oman (J.M. Campbell & Co., Tel. 1 405 321 1383. Fax. 1 405 321 4533. e-mail registrar@jmcampbell.com)

June 1-5 World Gas Conference and Exhibition, Tokyo, Japan (IGU. National Organizing Committee. Tel. 81 3 3502 0620. Fax. 81 3 3502 0621. E-mail noc@wgc2003.gr.jp)

June 2-4 Course : Information sur le gaz naturel liquéfié - in French, Paris, France (AFG. Tel. 33 (0) 1 44 01 87 51. Fax. 33 (0) 1 44 01 87 91. e-mail emmanuelle.holmiere@afgaz.fr)

June 16-27 Course : Liquefied Natural Gas, Paris, France (AFG. Tel. 33 (0) 1 44 01 87 51. Fax. 33 (0) 1 44 01 87 91. e-mail emmanuelle.holmiere@afgaz.fr)

2004

March 21-24 LNG 14: 14th Int. Conference and Exhibition on Liquefied Natural Gas, Doha, Qatar (IGU/IIR/GTI. www.lng14.com.qa)

TotalFinaElf ship for Snohvit

Total Fina Elf has secured shipping to transport its 18.4% share of the output from Norway's Snohvit LNG project to its customers. It has time-chartered a 145,000 m^3 Moss-type LNG carrier from a Lief Hoegh/Mitsui OSK Lines joint venture. The vessel will be built by Mitsubishi H.I. of Japan for delivery in 2006, and will be a sister ship of the one being supplied by the same owners to Statoil for the Snohvit project. The delivered cost, including interest and other pre-delivery expenses, would be in the region of $190 million. The LNG carrier will be operated by Leif Hoegh (UK) .

Imabari to build LNG ships

Imabari Shipbuilding Co. of Japan has entered the business of building LNG carriers. It has prepared a dock at its subsidiary, Koyo Dockyard Co., in Hiroshima prefecture, with crane and equipment installed, suitable for building ships up to a capacity of 145,000 m^3. Imabari believes that it can be competitive on cost, and is now seeking orders.

New ship for Nigeria

In early September, Bonny Gas Transport Limited, a subsidiary of Nigeria LNG, took delivery of the second of the three new LNG carriers built by Hyundai H. I. of Korea. The 137,000 m^3 Moss-type LNG Sokoto will berth at the Bonny terminal in October ahead of the start up of the plant's third train in November.

Kvaerner Masa to build LNG ships again

Kvaerner Masa Yards of Finland, now owned by Aker Maritime of Norway, are planning to build LNG carriers once again. The yard built four LNG carriers in the mid-1990s for Adgas of Abu Dhabi. They are now seeking orders for LNG carriers up to 145,000 m^3 capacity, with "stretched" Moss-type tanks, and with fuel-oil driven propulsion systems and boil-off reliquefaction.

MISC's latest LNG Carrier

The first of the six new LNG carriers being built in Japan for Malaysia International Shipping Corporation (MISC) recently entered service. The 137,000 m^3 capacity Puteri Intan Satu arrived at the Bintulu terminal on September 8 to load cargo prior to its maiden voyage to Sodeguara, Japan. It is the 14th LNG carrier of MISC, the world's single largest LNG fleet owner and operator.

Whessoe SA contracts

Whessoe SA of Calais France reports several recent successful orders for its LNG storage tank instrumentation systems, including Level-Temperature-Density measurement gauges and LNG MANAGER, the PC based control platform. Orders include : Kogas (Tong Young) - two tanks; Kogas, Inchon - two tanks; Petronet LNG (Dahej); Enagas, replacing a non-Whessoe system on an existing tank.

For more information contact : Pieter Versluijs, e-mail pversluijs-whessoe@wanadoo.fr

Chicago Bridge film enclosed

Gas Turbines for LNG Ships?

Per-Erik Larsson, ALSTOM Power, Sweden

Will gas turbines eventually displace steam turbines as the preferred propulsion option in LNG ships ? ALSTOM, a supplier of both technologies, objectively assesses their relative merits

Steam turbines have been successfully used in LNG ships since the very birth of this ship type. Recently however new ideas about alternative propulsion options have been raised. Gas turbines have emerged as the most potent novel propulsion option for future propulsion of LNG ships. Turbine manufacturer ALSTOM in Sweden has been manufacturing steam turbines since 1893 and gas turbines since 1945, while ALSTOM Chantiers de l'Atlantique shipyard in France has built 14 LNG ships since 1971. ALSTOM in Sweden has delivered 29 steam turbines for LNG ships. With a proven track record in LNG technology and with both steam- and gas turbine technologies in its product portfolio, ALSTOM is in the unique position to objectively assess advantages and disadvantages of the two turbine technologies in LNG ships.

Gas turbines versus steam turbines

Both turbine technologies come with unique benefits and drawbacks. The issues worth mentioning in this context are fuel efficiency, length of operational experience and proven reliability as well as redundancy in case of failure. In the world of changing LNG and bunker prices and emerging spot markets fuel flexibility is also of importance. Engine room size and location and subsequent flexibility in general arrangement is also a very interesting issue worthy of consideration.

Both steam and gas turbines have been used for decades and both have very good track records

Fuel efficiency of steam turbines in today's LNG ships is approximately 30%. If gas turbines were to be used, electrical propulsion would emerge as the most economic alternative. In such a COGES arrangement (COmbined Gas-Electric Steam) the gas and steam turbines are connected to generators, which produce electricity. ALSTOM's GT35 gas turbine produces approximately 16.5 MW of electrical power and the comparable fuel efficiency of such a single cycle is approximately 32%. But as gas turbines dissipate lots of hot exhaust gases, this heat can be utilised to boil water. Water is boiled to steam, which can be used in a separate steam turbine that produces another 5.5 MW of electrical power. As the 22 MW of electrical power from the combined cycle is not quite enough to power a modern LNG ship, extra electricity can be produced by normal diesel generator sets, one or two of them. The total comparable fuel efficiency of this combined GT35 COGES and diesel-electrical machinery is up to 42%. This fuel efficiency easily beats steam turbine efficiency and is reflected positively in annual fuel oil costs.

If the ship size is increased and, as discussed later, the ship's cargo space is enlarged due to the smaller gas turbine engine room, a higher power will be needed to keep the ship's design speed. If such a new ship design is matched with a 2xGT35 COGES plant capacity the designer can be motivated to install a second gas turbine instead of the diesel engine as in the first alternative. Such an optimised COGES machinery will operate at an efficiency of around 40%.

Length of practical, in-service experience has to be regarded as a very important issue for LNG ship-owners. This is also a clear strength for both of the turbine technologies. Both steam and gas turbines have been used for decades and both have very good track records. As much as the shipping world desires only to use proven and tested technologies, both alternatives are on the same level in this respect. Operational reliability is an issue of course closely related to operational experience. The steam turbine has proven itself as a very reliable and trouble-free source of propulsion power. It can safely be said that the steam turbine has an excellent reliability record. The same however can also be said about the gas turbine. Gas turbine technology, although not yet that common in marine use, has been used in oil and gas fields for decades now. As is commonly known, gas turbines are used both in land based and offshore oil and gas fields with great success and an excellent reliability record.

But reliability is only part of the picture, so to speak. Irrespective of high reliability, if something were to go wrong, redundancy is what comes into play. Sufficient propulsion system redundancy ensures that in case of a single failure there is still enough propulsion power available to get to a safe place. It must be admitted that in the steam turbine machinery redundancy is scarce. All 100% of propulsion power can be lost due to a single failure in the steam turbine. But this is not the case with the three-or-four-component COGES and diesel-electrical machinery. In the turbine/diesel engine-based

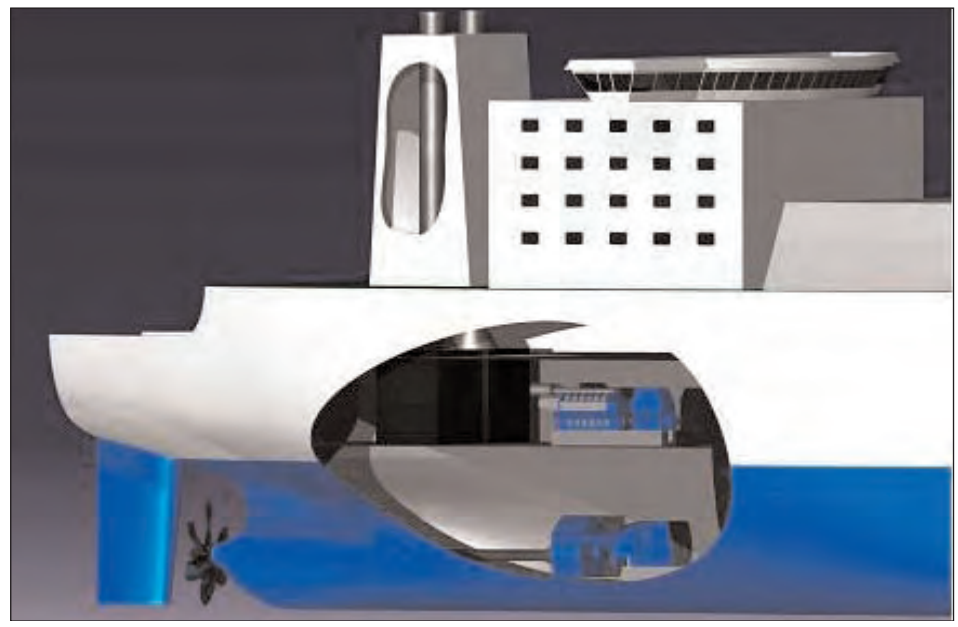


Figure 1: Typical LNG ship's engine room, with steam turbine propulsion

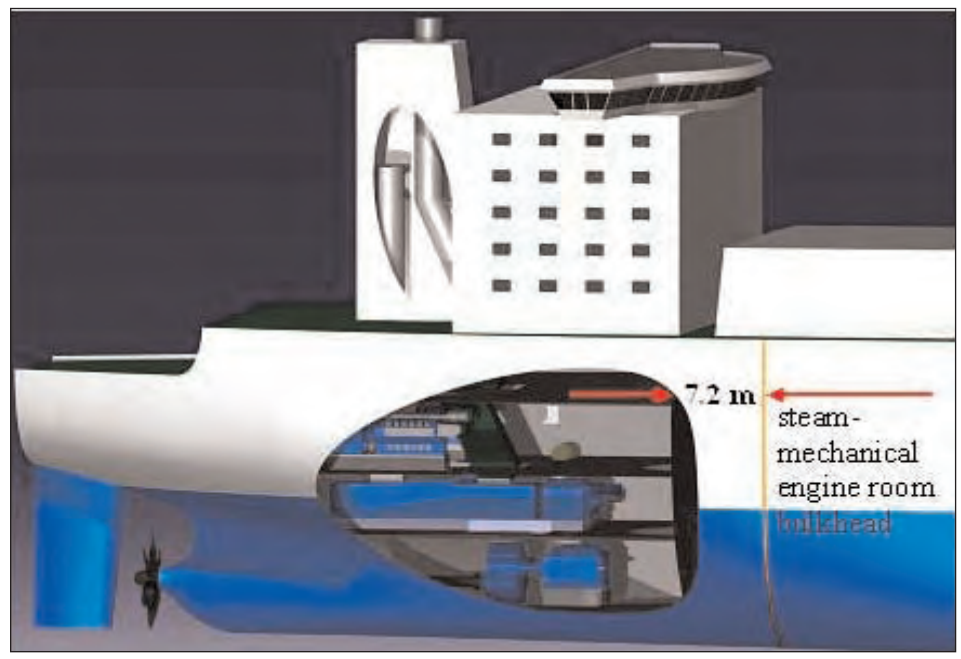


Figure 2: LNG ship's engine room, with one GT35 gas turbine in a COGES machinery and two diesel-generator sets; high speed electrical motor propulsion

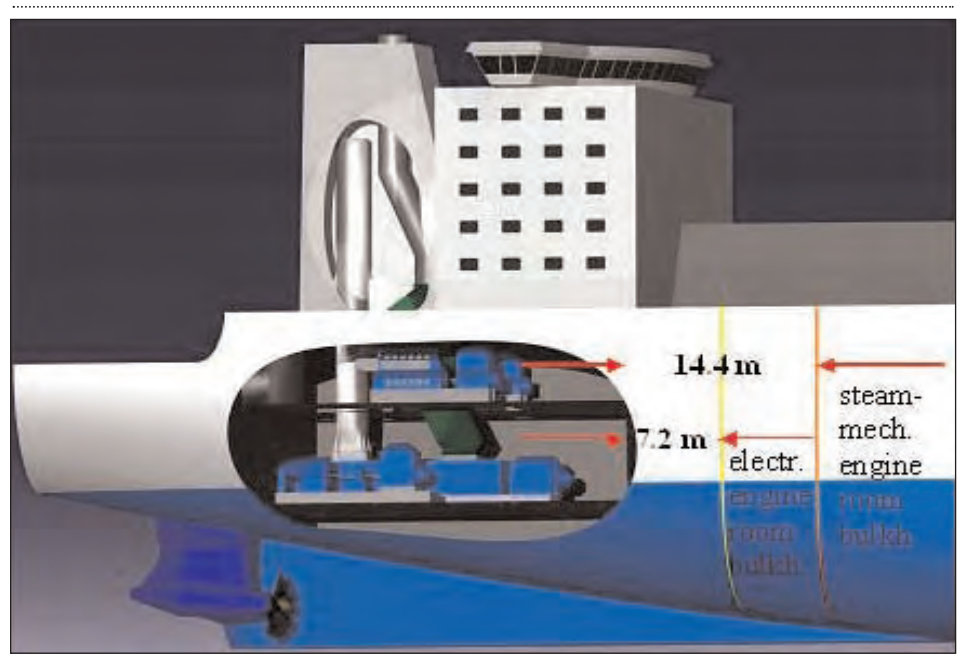


Figure 3: LNG ship's engine room, with one GT35 gas turbine in a COGES machinery and two diesel-generator sets; diesel-electrical twin podded propulsion

machinery there is always at least 30% of propulsion power available after a single failure in the power production machinery. COGES machinery produces the main bulk of the required power, while the one or two diesel generator sets also work as an emergency "take me home" power source. The diesel-electrical power alone is enough to give the fully laden ship a speed in excess of ten knots. For the COGES plant with two gas turbines the available power with one turbine stopped would be around 65% of the ship's required NCR (Normal Continuous Rating) power in a ship of optimised design.

Especially for spot cargo operators fuel flexibility should be a prime issue. This is also perhaps the strongest point on behalf of the steam turbine technology. The steam turbine machinery is able to take either 100% of LNG or 100% of bunker, or any combination in between. The steam turbine machinery thus has the ultimate fuel flexibility. Similar fuel flexibility is available with the GT35 COGES machinery since the dual fuel burners in the turbine can burn both LNG and bunker. With the COGES and diesel-electrical machinery this flexibility is compromised to some extent since the normal diesel engines are operated only on bunker oil. As this COGES cycle will produce about 70% of required power in today's size of LNG carrier, this is not enough to provide full fuel flexibility.

Machinery room size and location

As the steam turbine is mechanically coupled to the shaft-line rotating the propeller, the steam turbine's location in the ship is pretty much fixed. The steam turbine thus dictates the size and the location of the engine room. In typical LNG ships the length of the engine room is usually between 55 and 60 meters. This length also fixes the location of the engine room forward bulkhead, which separates the cargo area from the aft ship accommodation and engine room block. Figure 1 shows a 3-D view into a typical LNG ship's engine room. The ship pictured is of membrane cargo containment type, but an engine room with the same length can also be found onboard typical ships with a Moss type cargo containment.

However, in gas turbine based electrical machinery the power production does not need to be at the end of the shaft-line. The machinery producing electricity can be located in principle anywhere in the ship, wherever the most convenient location can be found. In practice, due to the gas turbine's low weight it is most convenient to raise the machinery's location by one deck and to move it towards the aft. In this way only the electrical propulsion motors are left on the double bottom and the engine room length can be reduced. Figure 2 shows a 3-D view into the same LNG ship, now equipped with one GT35 gas turbine in a COGES machinery and two diesel-generator sets. The engine room layout is not made any more compact in this arrangement, but the same spaciousness is kept as in the steam turbine machinery. As a result the engine room length is reduced by 7.2 meters. Propulsion is provided by two high speed electrical motors, connected to the single shaft-line through a reduction gear. The propulsion arrangement could also be made with two propellers and shaft-lines for still more redundancy.

Sonatrach - pls scan in hard copy

The pictured COGES- and diesel-electrical machinery with single screw electrical propulsion is comprised of well-proven technology and components with long track records. ALSTOM has supplied electric propulsion for more than 30 years now, with at least 250 references.

But if there is a desire to shrink the engine room still further, a step into more novel technology can be taken. With ALSTOM Mermaid podded propulsors the electrical propulsion motor and shaft-line can be eliminated and replaced by pods. The electrical motor is then located in the podded propulsor outside the ship's hull. The only remaining propulsion equipment with a set location inside the ship's hull is the Mermaid pod room in the aft. Figure 3 shows a 3-D view into this kind of COGES and diesel-electrical twin podded arrangement. As a result the engine room length is reduced by another 7.2 meters, for a total of 14.4 meters compared to the steam turbine machinery. At least the same reduction can be obtained with COGES-only machinery.

With gas turbines an unconventional and even more efficient location of the gas turbines would be to locate them on the main deck aft of the deckhouse. This is a realistic location due to the low gas turbine weight. With the gas turbines on the main deck, the engine room length could be still further reduced and the limiting factor would then become arrangement of accommodation. Figure 4 shows a photograph of such a GT35 installation on the main deck onboard the Leadon FPSO.

Figure 4: GT35 gas turbine installation on the main deck onboard the Leadon FPSO

Use of heavier fuels

One of the clear advantages with steam turbines is their ability to utilise heavy fuels. In general gas turbines are not associated with this feature. This mainly stems from the fact that the majority of gas turbines in marine use are of the aero-derivative type. These aero-derivatives usually burn distillate fuels, either marine diesel oil (MDO) or marine gas oil (MGO). Both of these fuels carry a price premium over heavy fuel oil (HFO), which is the liquid fuel commonly used in LNG ships. The price premium between HFO and MDO has been between 40 and 100 US$/tonne, and the premium between MDO and MGO another 10 to 20 US$/tonne, depending on year and location of purchase.

Unlike aero-derivative gas turbines, ALSTOM's industrial type gas turbines have a long track record of burning heavier fuels

Unlike aero-derivative gas turbines, ALSTOM's industrial type gas turbines have a long track record of burning heavier fuels. Due to its more robust fuel system and fuel burners, roomy combustion chambers and robust turbine design, the GT35 can also burn HFO. A typical aero-derivative gas turbine has a number of small sophisticated burners, narrow combustion chambers and sensitive film cooled turbine blades which require rather light fuels to operate. Figure 5 shows combustion chambers of GT35 and a typical

Figure 5: Combustion chambers of GT35 (right) and a typical aero-derivative gas turbine (left) of the same power output

aero-derivative gas turbine of the same power output.

Heavier fuel thus can be and is burnt in GT35 gas turbines. Four GT35 gas turbines in Saudi-Arabia have burnt crude oil as their primary fuel during their duration of operation. After being commissioned in 1997, they have accumulated a total of 18 operating years in crude oil operation. Burning of crude oil requires some periodic cleaning of the turbine section, but the heavier fuel has not posed any problems in operation. Operational reliability above 99.8% and operational availability above 98% have been reached.

ALSTOM's GT35 gas turbines have also been installed for marine use. There are two units in operation onboard fast ferry Luciano Federico L, built in 1997 and currently operated between Buenos Aires and Montevideo. Another two units are onboard the 1997-completed fast ferry Stena Carisma, which is operated by Stena Line in traffic between Sweden and Denmark. The vessel was originally designed for MDO operation, but has subsequently shifted to heavier fuels, Since 2001 an intermediate fuel known as IF30 has been used, which is a mixture of MDO and HFO, with HFO being the main component at 65-70%. Burning of IF30 has been very successful in Stena Carisma. From a fast ferry operator's point of view it is more attractive than HFO. IF30, which is nearly as cheap as HFO, can be treated onboard almost as MDO without additional heavy and bulky ancillary systems. If the slightly cheaper HFO were to be burnt, it would require installation of some additional ancillary systems, like pressure boosted fuel heating units. Onboard LNG ships, on the other hand, space is available for ancillary systems and HFO can be utilised. Fast ferry operation is probably the toughest marine operation and as the turbines prove reliable in this service, the LNG industry can trust that the GT35 machinery is fully capable as a marine power plant.

As gas turbines in general are designed to burn gas, natural gas is also one of the basic fuels burnt in GT35 gas turbines. At the moment there are over 150 GT35 gas turbines in operation around the world and approximately one third of them are burning natural gas as their primary fuel. About another 15% of GT35s currently in operation are dual fuel machines and can operate on both gas and liquid fuel. Dual fuel operation requires nothing special of the turbine and the mixture of natural gas and liquid fuel can be altered freely as in steam turbine machinery.

Conclusion

Gas turbines emerge as potentially very attractive power production devices in LNG ships. Electrical gas turbine machinery beats steam turbine machinery in fuel efficiency, in redundancy and in compactness. Greatly improved fuel efficiency is directly visible in annual bunker costs and subsequently in the ship operator's bottom line. Enhanced redundancy improves the ship's survivability in case of a failure in the power production machinery. With gas turbine based electrical machinery the engine room length can be reduced. This length reduction, applicable to membrane as well as Moss type ships, can be utilised as additional cargo space or as reduced ship's length.

Proven reliability and the length of in-service operating experience are strong points for both steam and gas turbines, which have both been used in power production, in land and at sea, for decades. Ability to accept heavier fuels has usually been associated only with the steam turbine machinery, but is applicable to ALSTOM's GT35 gas turbine as well.

Gas Turbines emerge as potentially very attractive .... in LNG ships. Electrical gas turbine machinery beats steam turbine machinery in fuel efficiency, in redundancy, and in compactness

The only issue in which the steam turbine is clearly superior is fuel flexibility. The steam turbine machinery is able to burn any combination of LNG and bunker, but the COGES and diesel-electrical machinery is able to burn from only 30% to 100% of bunker due to the limitation of the diesel engine. To take full advantage of the fuel flexibility of GT35 gas turbines a second turbine should be installed in COGES-only machinery instead of diesel engines. The modification of the ship design to make use of the additional available cargo space could also involve a "size up" elongation of the ship to match two turbines full load at ship's MCR (Maximum Continuous Rating) operation. The power can also be used for increased speed if this is desired.

The expected fuel cost saving using the GT35 gas turbine based machinery is in the US$ 0.7 million range or more per ship annually. The ship can with little modification take more payload with unchanged manning, and other operational expenses are also very low. In ALSTOM's view the total economy with the new ship design is a clear indicator that steam plant LNG carriers will be replaced with the new technology in future new contracts. ■

Per Erik Larsson, M.Sc, worked from 1960 to 1963 at General Electric, USA. Since 1963 he has held various management posts in the marine turbine field at Alstom Power (previously called STAL-LAVAL), and since 1983 he has been Senior Application Engineer, working first with stationary steam turbines and since 1995 with gas turbines

The Liquefin Process

Béatrice Fischer, IFP, and Pierre Boutelant, Axens, France

Liquefin is an exciting new dual mixed refrigerant liquefaction process from IFP, which is claimed to offer significant advantages in efficiency, simplicity, and overall cost-effectiveness

Since the LNG plant accounts for about half the cost of the whole LNG chain, a most effective way to reduce the overall cost is to improve the cost efficiency of the liquefaction process. The liquefaction process requires simple and robust concepts, ease of operation and a high availability factor. The equipment incorporated should also be inherently safe, well proven and widely available.

The Liquefin® process has been developed by IFP to meet these requirements, in close connection with a major oil and gas operator, with equipment vendors and engineering contractors, and is commercialized by Axens. The Liquefin process presents major advantages in terms of compactness, economics and operability, and can also be applied for building large trains in the range of 6 million tonne per annum (mpta) and larger.

Process description

The Liquefin process is a dual mixed refrigerant cycle process. The basic principle can be described by referring to the simplified flow scheme in Figure 1.

The pre-refrigeration of the gas is achieved using a mixed refrigerant instead of propane. In this process, the pre-refrigeration cycle is operated at a much lower temperature than in a conventional dual-cycle process: the temperature is decreased down to about -60 °C (-75 °F). This pre-refrigeration temperature is adjusted so that the power of both cycles is identical.

At this temperature, the cryogenic mixed refrigerant can be completely condensed. The overall necessary power is decreased, as the quantity of cryogenic mixed refrigerant is lower, and because a good part of the energy necessary to condense it is shifted from the cryogenic cycle to the pre-refrigeration cycle.

The mixed refrigerant is condensed and vaporized at different pressure levels in each section, without any phase separation or fractionation

In the Liquefin process, both mixed refrigerants are used in the same way as pure components. The mixed refrigerant is condensed and vaporized at different pressure levels in each section, without any phase separation or fractionation.

Main features

Liquefin has all the positive features of the cascade process with a much better efficiency and a smaller number of rotating equipment:

No integrated cascade.

As the mixed refrigerant of the second cycle is fully condensed, the two mixed refrigerants can be used in a similar way as the pure refrigerants used in the cascade process.

Balanced power

The process is easily adjustable to obtain the same power for each cycle, thus allowing the use of two identical gas turbines.

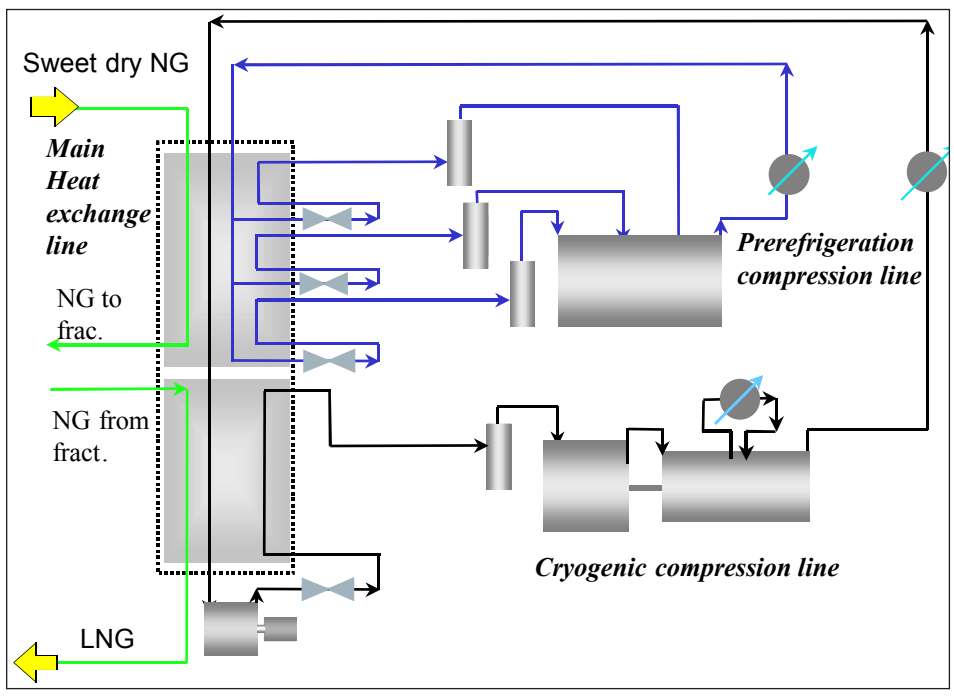


Figure 1: Liquefin general scheme

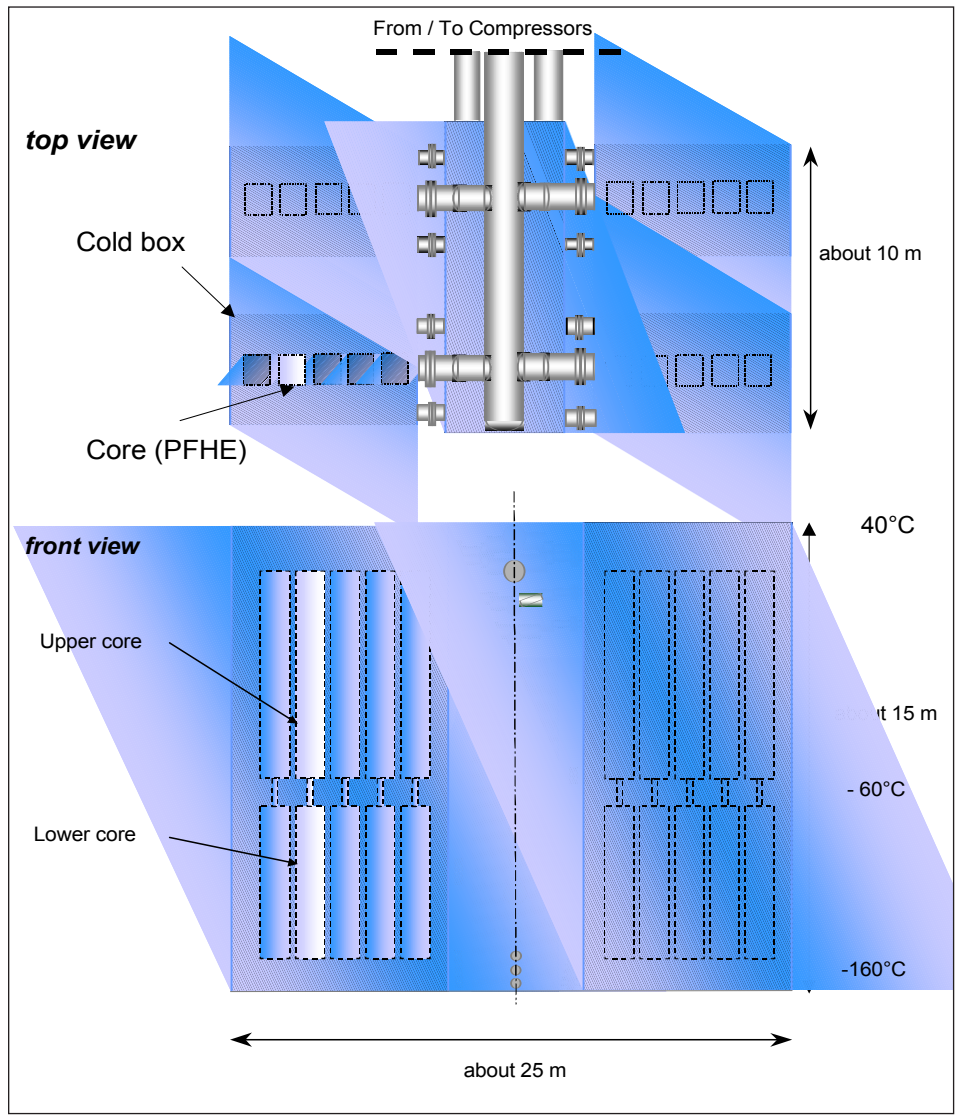


Figure 2: Typical cold box arrangement

Compact heat-exchange line

The Liquefin process has been designed to make the best use of plate-fin heat exchangers (PFHE). A single heat exchange line is used to cool gas from ambient temperature down to cryogenic temperatures. The process has been conceived to make the exchange line simple and compact. All the exchanges between the natural gas and the two mixed refrigerants (and between the two mixed refrigerants) are done in a single exchange line, made of plate fin heat exchangers inside a few cold boxes (see Figure 2).

- The main heat exchanger design has been based on a minimum number of cold boxes each compactly laid out to minimize cryogenic pipe runs. Inside the cold boxes, the piping between cores is also minimized.
- All fluids are distributed in single phase between the cold boxes and between the cores inside the cold boxes. After J-T valves, two phases are generated. There will be one J-T valve per cold box with a small distributor drum inside the cold box, which separates liquid and vapor before distributing them separately between the cores. They are then re-mixed inside the cores with a special device proprietary to each vendor.
- IFP/Axens have worked closely with selected PFHE manufacturers (Chart Marston, Nordon Cryogenie and Kobe) to derive a main heat exchanger line with a similar architecture of PFHE inside the cold boxes. Thus, the cold boxes can now be purchased from any of the three vendors without impacting the plant design or the P&I diagrams.

The main exchanger line arrangement is at the heart of the liquefaction technology

- This exchange line is modular: each cold box will contain several parallel lines of two cores in series. The number of cores and cold boxes will depend upon the

capacity of the unit and of the site conditions (roughly 1-1.5 mtpa per cold box).

- With the modular concept, all limitations in size that exist for the spiral-wound exchangers are removed.

The main exchanger line arrangement is at the heart of the liquefaction technology. A substantial effort has been made to assure the optimal and foolproof operation of the assembly. Extensive fluid dynamic and mechanical studies were performed, to ensure optimal overall fluids distribution, thermal performance and also resistance to thermal stresses.

A specific model was developed, to calculate the flow-rate to each core of the cold box as a function of the header/manifold arrangement, pipe dimension, fittings and taking into account the core pressure drop. This model has been linked through a visual Basic interface to the HTFS simulator, MULE, that allows calculation of the thermal performance and associated pressure drop starting from the flow-rates generated by the IFP model.

Stress analysis in the cores was achieved by using a novel homogenisation method with 3-dimensional finite element analyses. This method provides a relationship between the stresses at the core scale and the stresses at the fin scale. With this calculation method, any possible temperature profile can be analysed, either in normal, transient or emergency operation.

Process Benefits

Efficiency

The first advantage of the process is the high efficiency: comparing like for like, the process will produce about 6-15% more LNG with the same gas turbines than any other established liquefaction processes. This efficiency improvement is related both to the use of mixed refrigerant for the pre-cooling and to the use of plate-fin heat exchangers.

- The very low temperature difference all along the cores between the hot and cold side brings an improvement of the exergy efficiency and hence the power consumed per ton of LNG is lower (or for the same gas turbines, the quantity of LNG produced is higher).
- The cryogenic mixed refrigerant enters the cryogenic section in a fully liquid state, so that no energy of this cycle is wasted in condensing the mixed refrigerant. The quantity of cryogenic refrigerant is much lower than in the C3/MR process (roughly 1 mole of cryogenic mixed refrigerant for 1 mole of natural gas), thus overall efficiency is improved.
- The pressure drop is very low on both the hot and the cold side of the PFHE, whereas in spiral wound exchangers, the pressure drop is low on the shell side, but very high on the tube side. This brings an additional efficiency advantage.
- As the process is not submitted to the manufacturing limits of main heat exchangers, the efficiency can be as good for very large capacities as it is for smaller ones.
- Liquid turbines, which are now proven and widely used in LNG plants, will bring a higher capacity increase, as the total cryogenic mixed refrigerant passes through the turbine instead of the liquid fraction only, as in the C3/MR process.

EPC schedule

In conventional LNG plant projects, the critical long-delivery items are the gas turbines/compressors, the spiral wound heat exchanger and the storage/export system. Pre-ordering of compressors/drivers is

usual in LNG projects so that the critical path is shifted to the main heat exchangers and the LNG storage/export system. The shorter fabrication schedule for PFHE-based cold boxes permits significant reduction in overall LNG project schedule for new plants provided an appropriately innovative LNG tank construction contract is deployed. As a minimum, it enables the deferral of a large capital cost item of the main heat exchanger and provides additional time to firm up the design of the LNG process. For LNG plant expansions where additional tankage is not required, the schedule benefits can be easily captured.

Layout

The use of cold boxes allows a more efficient use of space and reduction in the plot area. As shown in the 3-D view in Figure 3, the liquefaction unit is limited to refrigeration compressors, air-coolers, the heat exchanger cold boxes and the scrub column. The common facilities such as pretreatment, fractionation and flash gas sections are not shown. The reduced space necessary for all the heat exchange line is clear to see. This results in significant reduction of cryogenic piping when compared to plants with large kettle chillers and the spiral wound exchanger.

Large Capacity

One of the major factors in LNG plant cost reductions has been the capacity of the liquefaction unit. In the last 10 years, the LNG train size has increased from about 2.5 mtpa to 4.8 mtpa. This has been the dominant factor in reducing LNG plant unit costs by approx. 50%. The capacity is limited mainly by:

a. the maximum size of the gas turbines in mechanical drive (the largest up to now is the GE Frame 7 - about 80 MW),
b. the maximum size of the spiral wound exchanger used in most large base-load plants.

The Liquefin process has many features that make it possible to build larger capacity LNG plants and hence significantly reduce costs:

- There is a single compact heat exchange line made up of several PFHE in a cold box. The PFHE have large heat exchange area per volume unit (up to 2000 m^2/m^3), and low approach temperatures can be obtained with a relatively small exchanger volume. Furthermore, as the cold boxes are modular, there is no size limitation for the heat exchange line. More cores per cold box, or more parallel cold boxes allow the capacity to be increased at will.
- The power on both refrigeration cycles is balanced. Thus, the power of two large turbines, such as GE Frame 7, can be fully used without any drawback on operation or efficiency. There is also the possibility of using two or more parallel lines of gas turbines or electrical motor driven compressors of equal power that would give increased capacity and potentially better availability. Configurations with 4 GE Frame 6, 4 Trent DLE or large electrical motors have been studied, the objective being an LNG train that would never completely stop producing.

Thus, capacities of up to 6 mtpa can be reached with 2 Frame 7 gas turbine drives and available gas compressors. With parallel compression lines for each mixed refrigerant and/or some compressor development, this limit can be pushed even further.

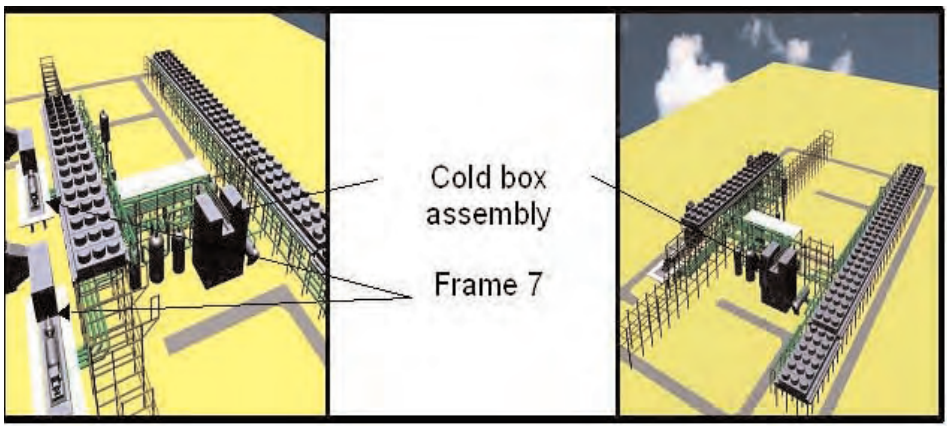


Figure 3: 3D view of the liquefaction section

Cost

Several factors previously mentioned lead to potential cost reduction with the Liquefin process:

- The ability to increase plant capacity, which has a significant bearing on unit cost of LNG production
- The single PFHE exchange line that replaces the costly spiral-wound heat exchangers and the large kettle chillers
- Reduced, compact plot area, which reduces large runs of low temperature pipework
- Reduced size of air-cooler condensers
- Multi-sourcing of all equipment including the main heat exchange line

Studies have shown that the cost of the liquefaction unit itself can be decreased by up to about 15%. Overall, including utilities, pre-treatment, storage, etc, the difference is reduced to something around 7%, but with the increased capacity for the same gas turbines, the cost per ton of LNG is lower by up to about 20% when compared with competing processes.

Operability

A previous study done with the help of a major engineering company had investigated the operability and reliability of the Liquefin technology. P&I diagrams and operating procedures (start-up, shutdown, warm-up, turndown) were developed. Potential hazards and operational upsets were examined to confirm that the process could handle these. This analysis confirmed the advantages of the technology in terms of operability and reliability. Furthermore, the process offers more flexibility to adapt to different process conditions and to temperature variations. The process has many adjustment parameters: the pre-cooling temperature and the compositions of both mixed refrigerants.

The concept of building an LNG plant that is capable of increasing production capacity in a "modular" manner is.. attractive

Modularity

The trend of increasing LNG plant capacities now poses problems in finding a ready market for the large amount produced by a new big train. The concept of building an LNG plant that increases production capacity in a "modular" manner is therefore attractive. It would enable projects to get off the ground with fewer customers. Such a development concept is now possible with the unique features of the Liquefin Process. All heat exchange for liquefying gas to LNG is in one assembly of PFHE in cold boxes. It is thus now possible to design a liquefaction unit with a series of "natural gas liquefier units", or NGLU, consisting of such cold boxes. Thus, expansions can now be possible with addition of more modules of NGLU's combined with expansion of refrigerant supply and feed gas treatment. Furthermore, each of the NGLU can be delivered to the plant site as a complete pre-assembled unit ready for tie-in, commissioning and start-up. This permits significant reduction in cost and schedule, with increase in safety and the first year's reliability.

Conclusion

The Liquefin process is a simple and very cost-effective solution for natural gas liquefaction. It produces more LNG at a reduced cost, and incorporates well-proven, widely available equipment. Large commercial Liquefin projects are presently being investigated at the FEED or pre-FEED stage. IFP-Axens have recently been attributed the 2002 IChemE Award for the Liquefin process, clearly showing the engineering profession's recognition of this technology. ■

Beatrice Fischer has been a Principal Research Engineer in a development division of IFP since 1996, working on the development of new gas processes and in particular, natural gas liquefaction. She joined IFP in 1977 as a process engineer, and in 1989 became process group leader (catalytic reformer group).

Pierre Boutelant, formerly Vice President Gas with Total, spent the bulk of his career in natural gas, mainly NGL and LNG. Contracted by Axens nearly a year ago, he is in charge of promoting and developing the IFP-Axens liquefaction process, Liquefin®.

Union Fenosa's Linked Chain Natural Gas Project

Miguel E. Jimenez-Gonzalez and Alejandro Sanchez-Gestido, Union Fenosa Gas S. A., Spain

Union Fenosa describe how in just two years they have advanced rapidly in the LNG business with a fast-tracked export project in Egypt, new shipping, LNG reception projects in Spain, and LNG supplies from Oman

The announcement in July 2000 of the signing of a Natural Gas Sales and Purchase Agreement (SPA) between the Egyptian General Petroleum Corporation (EGPC) and the Spanish Utility Company Union Fenosa (UF) had an important impact in the LNG industry. In fact, the fast tracking of this "five star" project for the Country and for the Spanish Company represented the first main step of the increasing investment of UF in the natural gas chain.

The intention of the present article is to demonstrate the presence of UF in the LNG business, including the recently signed agreement with the Government of the Sultanate of Oman, as well as the development of the first LNG project in Egypt and other important projects. All steps included here were achieved during the 24-month period from the announcement of this SPA.

Background

With a very stable and growing Spanish economy, a rapid growth in demand within the Spanish Energy market is expected for the next years. Figure 1 shows the economic, electricity, energy and natural gas growth in the last ten years in Spain. Natural gas demand for the Spanish market has trebled in this period. The expectations for the future trend of the market are quite similar to the evolution in the last ten years. Figures from the Ministry of Economy of Spain confirm the forecast of the Spanish Energy companies. The demand for electricity and natural gas will grow significantly, with the latest forecast showing that demand is expected to be doubled in five years time.

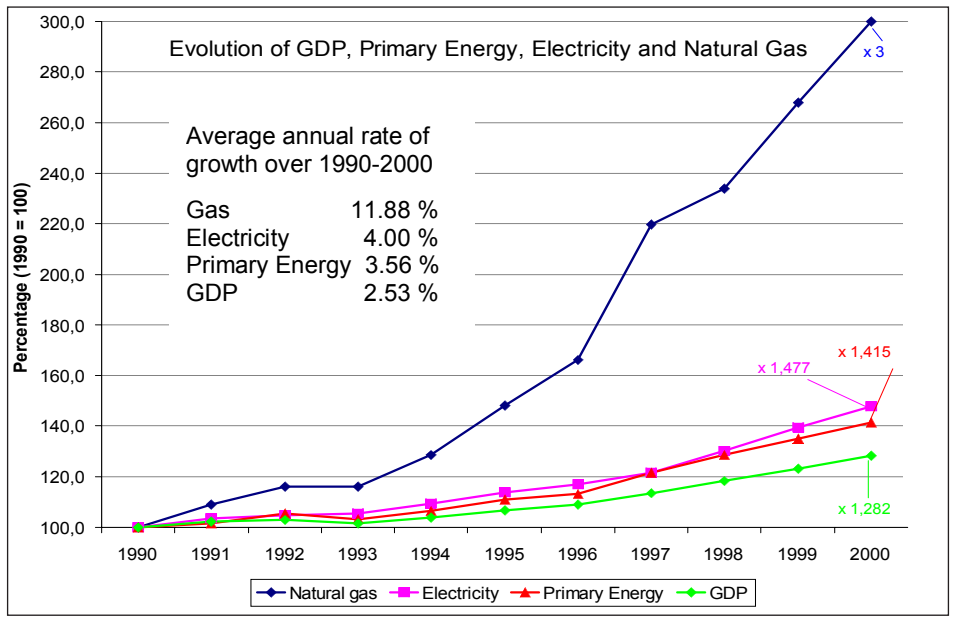


Figure 1 - Evolution of GDP, Primary Energy, Electricity and Natural Gas in Spain

Nowadays, installed power plant capacity and the natural gas framework and infrastructures are not sufficient to meet future demand in the country. Therefore, additional power generation capacity and natural gas infrastructures will be necessary to satisfy such high demand. The trend world-wide in the power generation market is to install additional capacity with Combined Cycle Gas Turbines (CCGT), using natural gas as fuel, instead of the traditional oil and coal-fired power plants, for both environmental and economic reasons.

Applications for more than 25,000 MW of CCGT power plant capacity have been made to the competent Spanish National regulatory bodies and authorities. Although not all of such capacity will be finally installed, UF expects to have around 3,000 MW CCGT generating capacity by the year 2006. The Company also holds sites for developing up to 7,000 MW.

UF strategy

UF's strategy was defined on the basis of the necessity for fuelling CCGT as well as taking into account the important increase foreseen for the industrial and domestic natural gas market.

The Company went to the Producer State in order to control and assure a stable and competitive procurement of natural gas. The point of view of the Company on the natural gas business was that the involvement in all steps of the natural gas chain business would also increase the value of the Company. The creation of their subsidiary Company Union Fenosa Gas S. A. (UFGas) was a clear mark that the natural gas business is a very important issue within UF activities. This Company is responsible for the purchase and sale of large quantities of natural gas, sale in the Spanish and International markets and involvement in new infrastructures to be developed.

UF is therefore deeply involved in all steps of the natural gas chain business: from the gas purchase at source, liquefaction plant, maritime transport, regasification plant, gas pipeline and national and international purchases. Each step is taken into account within the Company as a business by itself.

Egypt Project

The Company signed in August 2000 an Agreement with the EGPC for sale and purchase of 4 billion m^3(st) per year (bcma) for 25 years, starting 2004. UF has the option to extend the quantity agreed to 8 bcma and to extend the period another 25 years. Since the delivery of the product was, under the terms of the agreement, in the gaseous state in Damietta, the Company had the commitment of building a liquefaction plant. Two LNG Carriers were necessary for delivery of the agreed quantity of LNG to Spain. Involvement in LNG regasification terminals and gas pipelines was considered due to under-capacity of such infrastructures in Spain.

Oman Project

In addition to the Egyptian project, the Company reached an agreement in May 2002 with the Government of the Sultanate of Oman (GOSO) for:

- Long term LNG supply of 2.2 bcma delivered ex - Ship for 20 years, starting in year 2006
- Development of the third train of the Oman liquefaction plant. UF will take a stake in such a train.
- In addition, GOSO will also take a stake in the gas infrastructures of UF in Spain, mainly the Sagunto terminal

Figure 2: One of the LNG Carriers under construction for the Egypt project : Status of NB 103 for UF at IZAR - Puerto Real in June 2002

- A possible Joint Company is also envisaged for trading 2.2 bcma of the third train in international markets
- Short term LNG supply from the first and second train of Oman liquefaction terminal, for the years 2003 to 2005

The UF - GOSO agreement has strengthened the UF Gas strategy of diversification of LNG sources of supply.

Other Supplies

UF is nowadays supplying natural gas to its current industrial customers in Spain. Since the Egypt and Oman projects will not come on stream until 2004 and 2006 respectively, UF reached an agreement to take a stake in the Algerian gas coming to Spain through the Maghreb pipeline. UF successfully participated in the bid made under the de-regulation terms of the Spanish market for such gas. This supply came on stream in December 2001. Algerian pipeline gas will be followed by the short-term supply of LNG from Oman, covering the period until the LNG Projects developed by UF will come on stream. Additional LNG short term cargoes would also be bought by UF in this period.

Damietta liquefaction plant

This will be the first LNG project to come on stream in Egypt. It will start operations in the fourth quarter of 2004. The liquefaction plant is located at the port of Damietta, on the Egyptian Mediterranean coast 40 km west of Port Said. The area of the site is 120 hectare (1.2 million m^2). In addition, a jetty shall be constructed within the existing port facilities to be used for LNG ship loading activities. On 26 November 2001 the Company awarded the Engineering Procurement and Construction (EPC) Contract to a consortium consisting of Halliburton KBR with Japan Gasoline Company Co. (JGC) and Tecnicas Reunidas. The Contract provides for the construction of the first train and an option for a possible second train that could be built about three years later. Under the terms of this award the companies mentioned also assume responsibility for supplying materials and commissioning the plant.

In addition to the negotiation for the selection of the EPC contractors, UF had been securing the delivery on time for the main equipment of the plant. Gas turbines (General Electric), with a delivery period of 14 months, were reserved at the end of year 2000 for delivery in October 2003. The Cryogenic exchanger (APCI technology - 5 mtpa), with a 23 month period for delivery, was awarded in June 2001 for delivery in May 2003. The most critical equipment, the LNG tanks, were awarded to Technigaz - Bouyges in August 2001 for delivery in July 2004.

All actions were taken in order to achieve the target of start up at the end of the year 2004.

Technical Description of the Plant

Gas will arrive at the site from the new gas fields through the Egyptian national gas network next to the area of Damietta. The capacity of the LNG Plant is based on two trains, with an estimated LNG annual production of 5 million tons (6.89 bcm) each. Each LNG train will have the following stages: feed gas metering and reception, gas compression, gas cleaning (mercury, water and sulphur removal), heavy hydrocarbons removal and gas fractionating for refrigerants extraction, liquefaction (propane precooled/Mixed Refrigerant

cycle), and LNG discharge to storage tanks.

LNG produced by each train is stored in two double containment LNG storage tanks (steel inside and reinforced concrete outside) of approx. 150,000 m^3 net capacity each (78 m diameter, 55 m height) and subsequently exported to a dedicated ship loading facility. A collection and compression system will be provided for the LNG tanks to recover boil-off gases produced during storage and loading activities, thus allowing their use for internal plant consumption and/or their introduction into the liquefaction process.

In the layout, two tanks are considered for the first train and enough free space for two additional tanks of the same capacity should a second train be built. The tanks will be located parallel to the dock line, where the jetty will be erected. The LNG train area is located as close as possible to the tanks, in order for the pipe length to be as short as possible, necessitating less equipment. The purpose of this is to attain the simplest and safest design possible.

Refrigerant gases, ethane and propane, will be obtained from the process itself. The additional quantities required will be imported and stored to make up for the consumption generated during the process.

The plant scheme is based on the use of gas turbines as refrigerant compressor drivers and for power generation in open cycle. Diesel engine units will be used as a backup for the start-up process. The heating source for those plant sub-processes requiring it will be oil, heated by the gas turbines' exhaust waste heat. The cooling media used in the heat exchangers will be air, driven by approx. 320 fans of 3 m diameter each. This solution offers higher flexibility of operation and maintenance. This selection, after the corresponding technical study, confirms the existing technology trend toward this cooling option.

The LNG plant is like a completely independent city. It has its own desalination plant, power generation facilities, fire fighting station, medical center, canteen, training center and administrative buildings

Impact on the Egyptian economy

UF's Damietta LNG Plant is one of the most important single projects of a private Company in Egypt. It is important because it will be the first LNG Project to come on stream in the country and it will be the 'tool' to monetize the proven gas reserves of the country. The operation of the plant will increase the maritime activities and income of the Damietta Port. 75 LNG Carriers per liquefaction train will call at the port every year. Several local Egyptian companies

continued on page 20

Table 1 - Technical Characteristics of UF LNG Carriers

	IZAR NB 103	DAEWOO NB 2209
Capacity	138,000 m^3	140,500 m^3
Gross Tonnage (GT)	93,450	96,000
Deadweight Tonnage (DWT)	68,200	71,060
Length overall (Loa)	284.4 m	279.8 m
Length between perpendiculars (Lpp)	271.0 m	268.8 m
Beam	42.5 m	43.4 m
Depth to main deck	25.4 m	26.0 m
Draft (Design)	11.40 m	11.40 m
Endurance	20,000 n.m.	13,000 n.m.
Boil off rate (%/day)	0.15	0.15
Service Speed	19.5 knots	19.5 knots
Bulbous Bow	Yes	Yes
Cargo Transfer rate	12,000 m^3/h	12,000 m^3/h
Bow Thruster Power	2,500 kW	2,500 kW
Containment System	GTT No 96 E	GTT No 96 E

Figure 3: First test mooring at Reganosa Terminal

The World will be as One

LNG information & trading website

LNG OneWorld.com

LNG JAPAN CORPORATION 14th Floor Roppongi First Bld., Roppongi 1-9-9, Minato-ku, TOKYO, JAPAN 106-0032 T:+81-(0)3-6229-3449 F:+81-(0)3-3586-1094 Homepage: http://www.lngjapan.com Email: info@lngjapan.com

Sagunto Terminal

continued from page 18

will be involved in the construction of the plant (representing an estimated 20% of the total investment); 6,000 people will work during the construction phase of the plant, and an estimated 270 people during the operation phase.

LNG Shipping

Under the terms of the SPA signed with EGPC, two LNG Carriers were necessary for transport of 4 bcma from Egypt to Spain. Therefore, UF decided to time-charter, for a period of 25 years (with an option for 5 additional years) two new-built vessels. UF awarded the contracts to the Shipowners Naviera F. Tapias (one vessel built in Daewoo Shipbuilding and Marine Engineering Co. in Korea) and a Joint Venture between Knutsen OAS Shipping and WW Marpetrol (one vessel built at the Spanish shipyard of IZAR - Puerto Real). Both will be delivered during the summer of 2004. The Technical Description of the vessels is given in Table 1. The status of the newbulding for UF at IZAR - Puerto Real as at June 2002 can be seen in Figure 2.

Both vessels will be technically compatible with the jetty of Damietta and with the main loading and unloading terminals of the Atlantic Basin (including the two terminals where UF has a stake: Ferrol - Mugardos and Sagunto). Each vessel would need 15 days to complete a round trip between

continued on page 21

Miguel E. Jimenez-Gonzalez is Director of Maritime Transport & Logistics in UFGas. He is a Naval Architect, MSc of Business Management and MBA. He was Member of the Board of Barreras Shipyard and Commercial Attaché of the Finnish Embassy in Spain. He joined Union Fenosa in 1989, spending more than 9 years as Chief of Staff of the C.E.O of the Company.

Alejandro Sanchez-Gestido is a Naval Architect , graduating from Madrid University and Maritime Transport from the Maritime Institute of Spain. He was involved during two years in the Hydrodynamics R&D Team of IZAR Group before joining Union Fenosa Gas. He has been specialising in the LNG Business for the last two years.

GASTECH 2002 set to be a success

Gastech 2002, the 20th international Conference & Exhibition for the LNG, LPG and Natural Gas Industries, will take place in Qatar, one of the fastest growing gas producing nations. It can rightly claim the largest recoverable natural gas field in the world, with an estimated 370 trillion cubic feet. If everything goes to plan Qatar will, by the year 2008, become the largest LNG exporter in the world. It is not surprising then that the Gastech 2002 conference programme is heavily weighted toward LNG and its associated technologies.

As pre-Conference delegate bookings run at a record level, the Gastech 2002 Conference & Exhibition looks set to become the biggest event in its history. The programme, put together by Conference Director Bob Lakey, consists of 100 speakers, covering 12 sessions over a four-day period.

The Conference will be opened by HH Sheikh Hamad Bin Khalifa Al-Thani, Emir of the State of Qatar. There will be a Welcome Address by HE Abdullah Bin Hamad Al-Attiyah, Minister of Energy and Industry, who will later open the Exhibition, and Addresses by the Petroleum/Energy Ministers from Saudi Arabia, Iran, and Venezuela. There will follow Keynote speeches delivered by Harry J Longwell, Director & Senior Vice President, ExxonMobil, Thierry Desmarest, Chairman, TotalFinaElf and Linda Cook, Chief Executive Officer, Shell Gas & Power. They will set the scene on the first day of an event that the Organisers say is designed to bring together key people from all sectors of the industry to discuss current trends and future patterns.

The Conference and Exhibition takes place at the Qatar International and Exhibition Centre, and at the nearby Sheraton Hotel in Doha, Qatar's largest city with almost 80% of the population.

The parallel Gastech 2002 Exhibition has attracted almost 120 exhibitors which means that it will be the biggest gathering of LNG companies under one roof since LNG 13 in South Korea, and certainly it will be the largest until LNG 14 in 2004. The Organisers claim that all of the exhibition space was sold over three months ago, which indicates that the industry still remains positive about future trade and new projects.

Subjects include

World Gas Supply and Demand ◆ Safety Security & Training ◆ Natural Gas Utilisation ◆ LNG Facilities ◆ Gas-To-Liquids ◆ Offshore/Floating LNG & LPG Facilities ◆ Natural Gas/LNG - New Supplies, Emerging Markets ◆ LNG Shipping ◆ Technical Developments - Equipment and Process ◆ Changing Markets & Business Strategies ◆ Outlook for Natural Gas/LNG ◆ Technical Developments - Project Based, Energy Transport and Offshore

The Sheraton Doha hotel, "Pyramid of the Gulf"

Qatar's LNG Activities

Qatar owes its economic prosperity to oil, first discovered in 1939, and more recently to natural gas. Qatar General Petroleum Corporation (QGPC) is a state-owned corporation responsible for all phases of the oil and gas industry in Qatar. There are two LNG export projects, with the liquefaction facilities located side-by-side at the purpose-built Ras Laffan industrial port. Both projects are supplied with gas from the huge reserves of the offshore North Feld.

Qatargas is a joint venture of QGPC (65%), Exxon Mobil (10%), TotalFinaElf (10%), Mitsui (7.5%), and Marubeni (7.5%). The first two trains came into operation in 1996, supplying Chubu Electric of Japan, followed by the third train in 1998, supplying a consortium of seven Japanese buyers. Surplus LNG has also been sold on a short-term basis to buyers in Europe, USA, and Asia. A major four-year debottlenecking project started in April 2002, which will raise capacity from over 7 mta to 9.2 mta. Last year Qatargas signed contracts to supply Gas Natural of Spain, the first medium-term contracts between a supplier east of Suez and a European buyer. Two further trains are under study.

The second LNG project, RasGas, is a joint venture of QGPC (63%), ExxonMobil (25%), Itochu (4%), Nissho Iwai (3%), and Korea Gas Corporation (5%). The first train came into operation in 1999, with the second in 2000, the LNG being sold under long-term contract to Korea Gas Corporation. In January this year work started on the construction of a third train; the 4.7 mta expansion project, RasGas II, is being implemented by a joint venture of QGPC and Mobil QM Gas, an affiliate of Exxon-Mobil Corporation. All the output of the new train is sold to Petronet LNG of India for its Dahej terminal under the terms of a 5 mta 25-year sales contract. A fourth train is planned, also to supply Petronet LNG.

For complete details of the Gastech Conference and Exhibition visit www.gastech.co.uk
For exhibitor enquiries contact: Hugh Braithwaite on +44 1895 454581.
For conference enquiries contact: Gastech Secretariat +44 1895 454561

continued from page 20

Damietta and Ferrol, which is at the western end of the north Atlantic coast of Spain. Should Sagunto (located on the eastern Mediterranean coast of Spain, 30 km north of Valencia) be the unloading port, the round trip will be reduced by 5 days. Therefore, a minimum of 25 round trips per year will be completed by one vessel.

LNG Regasification terminals

The demand of natural gas in Spain in the next few years is expected to rise from 16.9 bcm in the year 2000 to more than 30 bcm in a central scenario in 2005. Due to the fact that the production of natural gas in Spain is negligible (less than 0.15 bcm in the year 2000), Spain is a net importing country of natural gas. In the year 2000, LNG represented 50% approx. of the total imports of natural gas to Spain. It will be increased to more than two thirds (67%).

There are three LNG receiving terminals that operate today in Spain: Barcelona, Cartagena and Huelva. The Ministry of Economy estimates that a maximum demand of less than 25 bcma can be satisfied with the current infrastructures (pipeline and LNG receiving terminals). Several natural gas companies operating in Spain have seen it as an opportunity to invest in LNG receiving facilities. Three terminals are under construction in Spain: Bilbao, Ferrol and Sagunto. It seems that a portfolio of 6 regasification terminals in Spain will fulfil the requirements of the natural gas demand in the country. In particular, UF is involved in two new projects: the Reganosa terminal and another at Sagunto. UF is the leader of the latest project.

Reganosa Terminal

The terminal is located in Ferrol - Mugardos. Union Fenosa is one of the main shareholders in the plant, having a 21% stake. Other partners include Endesa (21%), Tojeiro Group (18%), Sonatrach (10%), Galician Government (10%) and Galician Financial Institutions (Caixa Galicia - 10%, Banco Pastor - 5%, Caixanova - 5%). The first test mooring of a gas carrier on the purpose built mooring dolphins of the jetty was completed on September 2000 (Figure 3). The plant is designed to accommodate large LNG tankers.

During the month of June 2002 two major milestones were completed: authorisation from the Government and preliminary awarding of the EPC contract to a consortium consisting of Chicago Bridge International (CBI) with Tecnicas Reunidas and NECSO. The construction is expected to start shortly after this summer. The target for start-up operations is during winter 2004.

In a first stage, the plant will have two LNG storage tanks, each of 150,000 m^3 capacity. Design pressure is 290 mbar(g). The terminal is designed for a 12,000 m^3/hour unloading rate. The basic regasification capacity will be 320 tons/hour (3.6 bcma). It is envisaged to upgrade the terminal with the construction of two additional 150,000 m^3 storage tanks. The terminal will have three vaporisation lines (two submerged combustion plus one seawater), each 160 tons/hour capacity. In a second stage it will have another two seawater vaporisation lines, each 160 tons/hour capacity. Therefore, the regasification capacity will be increased to 480 tons/hour (5.4 bcma).

The operation of the plant will increase the maritime activities and income of the

Port of El Ferrol. The current traffic of goods of this port will be increased by more than one third due to the activation of the terminal.

Sagunto Terminal

The terminal is located in the Port Enlargement of the Mediterranean Port of Sagunto (Figure 4). Union Fenosa is the main shareholder of the plant, having a 50% stake and leading the project. Other partners include Iberdrola and Endesa. UF will build close to the site of the plant three 400 MW groups of CCGT in a first stage (plus 3 x 400 MW in a second stage), minimising the cost of transporting natural gas from the receiving plant to the consumer centre. That concept is defined as an "energy centre", and will be promoted by the Company in Huelva and Ferrol too.

The Company expects to award the EPC contract during the summer of 2002. The construction of the plant is expected to start shortly after, in the fourth quarter of 2002. The target for start-up operations is during the first half of 2005. In a first stage, the plant will have two LNG storage tanks, each of 150,000 m^3 capacity. The terminal is designed for a 12,000 m^3/hour unloading rate. The basic regasification capacity will be 5.25 bcma. It is envisaged to upgrade the terminal with the construction of one additional 150,000 m^3 capacity storage tank in the second phase plus an expansion of the regasification capacity up to 8.75 bcma. In the first phase, the terminal will have three vaporisation lines (seawater), each 160 tons/hour capacity plus one additional submerged combustion vaporisation line of 120 ton/hour. In the second phase it will have another three more vaporisation lines: two seawater lines (160 ton/hour) plus one submerged combustion line of 120 ton/hour .

The operation of the plant will increase the maritime activities and income of the Port of Sagunto. The current traffic of goods of this port will be increased by one half due to the activation of the terminal. 2,000 people will work during the construction phase of the plant (3 years), and an estimated 80 people during the operation phase : this number will increase to 300 - 500 during the programmed maintenance phase.

Conclusion

UF has taken a position, in a 24-month period, in all links of the natural gas chain business: from agreements for a diversified portfolio of supply (Egypt, Oman, Algeria), LNG liquefaction (Damietta and Qalhat) and regasification (Sagunto and Ferrol) terminals, Maritime Transport (IZAR - Knutsen/Marpetrol and Daewoo - Tapias LNGC), International Trading activities (Oman agreement) and commercialisation of natural gas to the final customer (at the moment, Spain). Diversification factors were taken into account in all steps taken by the Company.

Moreover, the Company business plan states that UFGas will be a Company commercialising between more than 6 bcma by 2006 (4 bcma from Egypt plus 2 bcma from Oman) and 10 bcma by 2010. That will represent a stake in the natural gas Spanish market of more than 15% in the year 2006 and more than 20% in the year 2010. This goal will be achieved through control over the origin of the gas and a strong presence of the Company in all links of the gas chain. ■

The Development of the LNG Industry in Japan

Part 3

Seiichi Hirakawa, Professor Emeritus, University of Tokyo, Japan

The third in a series of articles from one of the founders of the LNG industry in Japan looks at overland transportation and satellite terminals, whose growth is helping to extend the use of LNG in Japan's changing LNG market

The emphasis in the first part of this article (*LNG Journal*, November/December 2001) was on Japan's involvement in the series of international LNG conferences, and on Japan's LNG imports and natural gas market. The second part (LNG Journal March/April 2002) dealt with the ordinary LNG chain from an industrial aspect and the LNG cold-utilization industry. This part deals with the overland transportation and satellite terminals that are the atypical elements in the Japanese LNG chain.

Introduction

The LNG industry with marine transportation is characterized by a highly complex system composed of interrelated functional factors. In 1987, the author illustrated the case study of LNG import total system with the project between Pertamina and Tohoku Electric Power Co., Inc[1]. This LNG total system concept is synonymous with the concept of the LNG chain described in the 1990s.

Imported LNG is distributed by gas pipelines and LNG tank trucks from LNG receiving terminals in Japan. Negishi terminal introduced LNG jointly from Alaska in 1969, which was the first LNG project in Japan. Regasfied LNG from this terminal is supplied to the power station of Tokyo Electric Power as fuel for power generation and to the metropolitan supply areas of Tokyo Gas as city gas, after calorific adjustment. In 1970, the first LNG satellite supply by tank trucks was in operation from Negishi receiving terminal to a satellite terminal in Hitachi, 130 km north of Tokyo. In 1999, the author presented the developed status of the LNG overland transportation system in Japan [2].

Meeting City Gas Demand

The Japanese government has joined the gas industry in sponsoring several ongoing studies, and in urging distributors to introduce LNG through the Center for Promotion of Natural Gas (CPNG) founded in August 1985. Commissioned by MITI (the government), the Center made several studies of the possibility of joint introduction of natural gas to meet actual conditions of regional gas companies. These studies included the following major topics:

- estimation of natural gas demand for selected 18 local area blocks covering all of Japan
- evaluation of various transportation possibilities (small-size 18,000 m^3 type LNG tankers, local terminal ports, port facilities, gas pipelines, overland tank trucks, satellite terminals)
- comparison of total cost analysis, and
- making recommendations to MITI and the gas industry in Japan.

Following CPNG's study results, several small-to-medium sized Japanese gas companies decided to import LNG directly. Furthermore, the CPNG's studies were highly regarded with a sharp increase in the amount of transportation of LNG by tank trucks.

At present, the electric utilities are the largest consumers of primary energy in Japan. Some LNG-fired power plants are located next to LNG receiving terminals; others are a few kilometers away. City gas utilities do not own such extensive pipeline networks in Japan as in Europe and the USA. Cities and industrial areas have been developed along the coast, and pipeline networks for city gas have been constructed mainly around the cities within the supply areas of existing gas undertakings in order to cope with the demand. Tokyo Gas completed "loop trunk pipelines" which go around the Tokyo metropolis and connect three LNG receiving terminals. Osaka Gas also has the same scale gas trunk pipelines around large servicing areas. It is necessary to install inter-city and inter-industrial area pipelines in order to expand LNG demand for industrial and other uses.

Overland Transportation

LNG for satellite terminals is transported by LNG tank trucks from major LNG receiving terminals. Tank truck capacities originally started at 6.0 tons, but have now increased to 9.8 tons. For example, a 6.0 ton single-chassis type truck has a double wall cylindrical LNG tank (the material of the inner tank is stainless steel, SUS 304). The insulation type is vacuum insulation with perlite powder. The tank truck size is 11.3 m in length, 2.5 m in width, and 3.0 m in height. Since 1988 transportation capacity has been expanded by introducing 8.6 ton trailer-type tank trucks in addition to the existing 6.0 ton single-chassis type trucks. Deregulation in Japan would lead to a variety of tank trucks in loading capacity and gross weight. The high pressure gas control law regulates the capacity, and the road transport vehicle law governs the length, weight, maximum safe inclination angle, and so on.

In Japan, there seem to be few troubles with overland transportation by gas pipelines and LNG tank trucks in regard to technical aspects, but the largest obstacles preventing their expansion are legal and economic. In addition, an LNG tank container transportation system combining trailer and rail transport has been launched [3], and this is attracting attention as a safe and economical way of transporting LNG over long distances regardless of weather.

LNG Satellite Terminals

Before 1985, the following satellite supplies came into operation: from Sodegaura to Hitachi (distance 170 km, starting year 1976), to Washinomiya (130 km, 1976), to Shoei (140 km, 1976), and to Miho (105km, 1977); from Negishi to Hitachi (197 km, 1970), to Washinomiya (100 km, 1971), to Shoei (105 km, 1976) and to Kofu (150 km, 1981); from Chita LNG joint terminal to Kani (84 km, 1984).

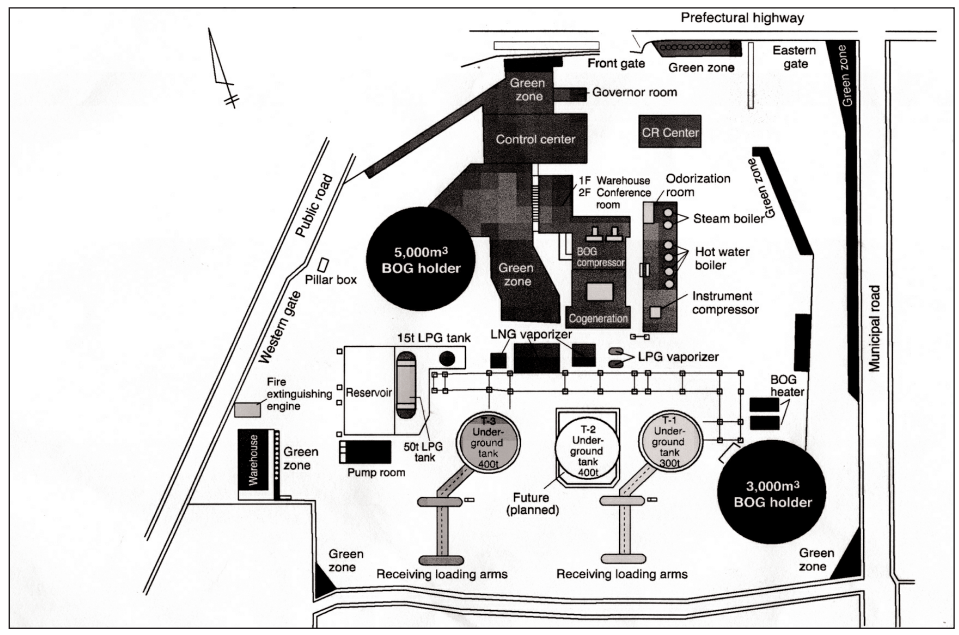


Figure 1 Layout of Kofu satellite terminal

In the current era (from 1993 to the present), the number of LNG satellite terminals has increased from 19 to about 40. The distance from LNG receiving terminals to satellite terminals ranges between 50 km and 380 km.

Hitachi satellite terminal

In 1986 the Hitachi satellite terminal had base load LNG facilities and peak shaving SNG (synthetic natural gas) facilities to produce city gas. The LNG facilities consist of four unloading facilities for tank trucks, two LNG tanks and four vaporizers. One of the LNG tanks is a flat bottom, double-wall aboveground tank whose capacity is 1,400 m^3, and the other is a cylindrical tank whose capacity is 54 m^3. LNG is vaporized by means of three hot water bath type vaporizers and one air-fin type vaporizer. LNG is sent to the calorific value control unit, where LPG and boil-off-gas are mixed. Then gas is supplied to city gas pipelines.

Kofu satellite terminal

The current diagram of the Kofu satellite terminal layout after remodeling in 1988 is shown in Figure 1. The key dimensions of the main facilities are as follows:

- LNG tank (inground type) 1 x 650 kl. 1 x 870 kl
- LNG vaporizer : (open rack) 2 x 84,829 m^3/d. (air fin) 1 x 27,357m^3/d (hot water circulation) 1 x 28,276 m^3/d
- LPG tank 1 x 35 kl. 1 x 118 kl
- PG vaporizer (vapor heating) 2 x 10,800 m^3/d

LNG is vaporized, and LPG is added to adjust the heating value of city gas to be supplied at 11,000 kcal/m^3.

Hiroshima : Hatsukaichi terminal and Bingo satellite terminal

From 1993, LNG supply to the regional gas companies has been transported by smaller LNG tankers such as the 18,000 m^3 type, due to economic and geographical reasons, as shown in Table 1 (overleaf).

For example, the LNG project of Hiroshima Gas is outlined as follows;

- Contracting parties. Seller: Pertamina. Buyer: jointly Hiroshima Gas and Nippon Gas (Kagoshima)
- Sales contract. About 200,000 tonnes per year for 20 years
- Loading and unloading ports. Bontang (East Kalimantan) and Hatsukaichi

Figure 2 The Bingo satellite terminal

Regional city	Utilities	Year of introduction
Fukuoka	Saibu GAS	1993
Shizuoka	Shizuoka Gas	1996
Hiroshima	Hiroshima Gas	1996
Kagoshima	Nippon Gas	1996
Sendai	Gas Bureau, City of Sendai	1997

Table 1 LNG supplies to Regional Gas Companies using smaller LNG tankers

(Hiroshima)

- Shipping. LNG tanker (19,000 m^3 capacity) with three Moss-type spherical tanks. Voyage 14 days (6 days for one-way voyage of distance 4,500 km)
- Storage and vaporization. LNG tank (in-pit type) 1 x 85,000 kl. LNG vaporizer (air fin) 2 x 4 t/h

Full-scale operation of Hatsukaichi LNG terminal commenced in March 1996, following delivery of the first tanker shipment of LNG in the same month. Hiroshima Gas supplies city gas to about 400,000 customers in 5 cities and 5 towns in Chugoku districts. Gas from Hatsukaichi terminal is supplied by pipelines to urban areas of Hiroshima. LNG from Hatsukaichi terminal is supplied by LNG tank trucks to large commercial or industrial customers, and to Bingo satellite terminal (travelling distance 87 km, starting year 1999), where the LNG is stored and revaporized for use on the customer's site and the satellite terminal site.

The dimensions of main facilities in Bingo satellite terminal (Figure 2) are as follows:

- LNG tank (cylindrical aboveground tank) 2 x 600 kl
- LNG vaporizer (air fin) 3 x 2 t/h (hot water circulation) 2 x 1.5 t/h
- LPG tank 2 x 15 t

Gas is supplied from Bingo to the cities of Mihara and Onomichi.

Marine satellite terminals

Osaka Gas, Nippon Steel Corporation and three other companies have reached an agreement on plans for the domestic supply of LNG from LNG reception terminals to marine satellite terminals, using a small LNG coastal tanker (approximately 85 meter length overall, 2500 m^3 capacity [4]) with the start time targeted for about August 2003. The project is outlined as follows;

- Contracting Parties

Sellers: Osaka Gas, Nippon teel Corporation and Kitakyushu LNG

Buyers: Shikoku Gas and Okayama Gas

- Contract Quantity

About 90,000 tonnes per year for Shikoku Gas and about 50,000 tonnes per year for Okayama Gas.

Concluding Remarks

The use of LNG in Japan is becoming more widespread through the growth of overland transportation and satellite terminals. Another example of the continued willingness in Japan to study and implement new LNG applications is the use of LNG as vehicle fuel. A proto-type LNG vehicle of JGA (the Japan Gas Association) was completed in 1999. LNG vehicle studies are making good progress with new technologies under research and development, taking into consideration the codes and regulations which apply to LNG vehicles in Japan, such as Road Transport Law, High Pressure Gas Control Law and so on.

The second part of this arti-

cle showed how the development of LNG use in Japan has shown remarkable technological progress; this is illustrated by the 30-year history of the LNG storage tank in Japan, where there are four types in use. LNG's extremely low temperature and high flammability require that careful attention be given to the design and construction of the storage tanks. Engineers in Japan analyze seismic activity and other environmental conditions to determine the most suitable materials and structural design for tanks and their foundations. The first LNG in-ground tank at Negishi receiving terminal, with a capacity of 10,000 m^3, was completed in 1970. The author acted as specialist adviser to a review in 1972 of the feasibility of a larger size, 60,000 m^3 in-ground LNG tank. Many other LNG tanks were subsequently constructed with still greater safety, reliability and economy [5][6][7], and inground tanks have now been built of 200,000 m^3 capacity, and aboveground tanks of 180,000 m^3 capacity.

The conclusion of the first part of this article was that LNG will continue to play an important role as a key energy for Japan. Safety and security of the LNG chain have been the top priority, and new technologies and cost reduction in the LNG chain are very important for the future development of the LNG industry in Japan. ■

References

1. *Hirakawa, S. (1987) Case study on LNG transportation in importing total system. Proceedings 17th Internation al Congress of Refrigeration (Vienna) Vol.A, pp.181-186.*
2. *Hirakawa, S. (1999) Review and discussion on LNG aspects in Japan with special reference to LNG importation and overland transportation system. 20th International Congress of Refrigeration (Sydney) Proceedings (CD-ROM) T1.5. Paper No.079, pp.1-7.*
3. *Toyosaki, M. (2001) Japex's satellite activities. The LNG Journal, Sept/Oct 2001.*
4. *Murakami, A. and Kobayashi, K. (2001) Large and Small Ships: Latest Developments. LNG Journal Nov/Dec 2001.*
5. *Hirakawa, S. (1981) LNG Storage and its handling at LNG receiving terminals. 7th International Congress of Chemical Eng., Chemical Equipment Design and Automation (Prague) Congress Paper G.3.23, pp1-5.*
6. *Hirakawa, S. Kamigaito, O. and Tsuji, S.(1983) Cellular glass insulation of LNG storage facilities. Proceedings 16th International Congress of Refrigeration (Paris)*
7. *Hirakawa, S. and Yamazaki, J. (1995) Prestressed concrete technology on LNG storage tanks. 19th International Congress of Refrigeration (The Hague) Congr. Proceedings, Vol.3b, pp.1195-1202*

Dr. Hirakawa is Emeritus Professor of Petroleum and Natural Gas Engineering at the University of Tokyo. He is Chairman of the Japanese National Committee of the International Conference on LNG. He was a chairman of CPNG's research committees from 1985 to 1994, and served to promote the introduction of natural gas for small-to-medium scale gas utilities. From 1976 to the present, he has served as a member of commission A2 of IIR (International Institute of Refrigeration).

Acknowledgments

The author expresses appreciation to the Japanese National Committee of the International Conference on LNG and also wishes to acknowledge the cooperation of all past and present members of the secretariat, in particular, Mr. Seiji Tateishi, Mr. Yoshihisa Yamaguchi and Ms. Kayo Teramoto.

Nigeria LNG on main CD - please drop in - is zipped up

LNGOneWorld

Combining Contemporary technology with a Conservative Business sense

The LNG industry is a sunrise industry with a bright future, but involving a complex interplay of various variables, that makes uncertainty a constant companion for decision makers. However, high stakes inherent to the industry critically requires best interpretation of the complex scenario that would ultimately distinguish the 'winners' from the 'losers'. The need thus arises of up-to-date, accurate and reliable business intelligence information from providers who are experts and leaders in the field.

Also, the rapid growth in LNG sourcing options, 'fragmentation', and growth of speculative (not committed to any particular project) ordering of LNG shipping tonnage offers increased flexibility such as spot or short term LNG trading for various players.

LNGOneWorld is a well thought out pioneering venture aimed at providing LNG trade and transport related business intelligence information as well as trading opportunities for the LNG spot trade. More than just merely leveraging web-based technologies, the most important strength of the portal is that it is promoted and supported by entities that are respectively one of the largest global trading entities and one of the leading providers of research and consultancy services to the LNG transportation industry.

What business intelligence information would be provided by LNGOneWorld?

The LNGOneWorld portal is essentially a business-to-business portal. The information provided is specialised in nature for professionals involved in the LNG trade. These include entities involved in both upstream and downstream aspects of the LNG chain - oil and gas majors, LNG upstream infrastructure /equipment providers, governments of LNG exporting/importing countries, companies involved in developing infrastructure and equipments for liquefaction/re-gasification terminals, LNG shipping companies, shipyards, LNG traders and power sector utility companies. The portal is also a boon for legal entities, financial institutions and various kinds of intermediaries who are essential to support the LNG business.

LNGOneWorld provides a single content-rich information source; covering the global LNG markets in terms of production, consumption, pricing, infrastructure, trade and shipping. It combines daily industrial news with topical editorial features, as well as supplying the latest data on energy, trade and shipping. There is also a unique discussion forum, where LNG professionals can share and debate the latest developments within the industry, and a member's directory where personal and company details can be logged.

LNGOneWorld would allow company internal resources to focus on strategy, interpretation and analysis, rather than data mining

The focused coverage, coming from specialists in the field, is comprehensive and selective yet at the same time provides clarity and only the necessary detail for speed, accuracy and exclusivity, handing decision makers valuable lead time to benefit and profit by. In summary, LNGOneWorld would allow company internal resources to focus on strategy, interpretation and analysis, rather than data mining.

What is LNG trading?

For more than twenty years LNG projects were funded by long-term, inflexible contracts due to the major investment needed. These are described as traditional LNG contracts. However, today's intense international competition in the LNG supply domain and demand fluctuations due to deregulation and the liberalization of the energy sector, coupled with a growing LNG fleet and more trading opportunities, means that the traditional structure of the LNG industry is gradually being broken down to be replaced by more flexible arrangements. A new concept or type of contract is being called for by the market- the so called non-traditional LNG contract, with more spot and short term contracts, encouraging speculative ventures and new entrants into the market.

The first milestone in LNG trading-LNG swaps

LNG users should be able to vary the supply of LNG to match their variable energy demands by swapping almost full shiploads of LNG with other user (s) who have an almost equal but opposite demand requirement. To facilitate swap arrangements efficiently and quickly, the LNG trade will have to exchange information about their supply / demand requirements on a timely and regular basis with each other.

LNGOneWorld believes that an increase in user to user 'cargo swaps' would be the first actionable step in the direction towards a liquid market for the spot trading of LNG. The portal thus seeks to be the medium through which the LNG trade can regularly and on a timely basis exchange information and facilitate an efficient swap market and eventually a liquid spot market for LNG.

Contemporary technology with a Conservative Business sense

In some cases, where the inherent business model of electronic trading platforms have been sound, they were backed by companies trying to register unsustainable sky-rocketing growths. An example here is that of the unfortunate fall of Enron- even though the Enrononline business model with a conservative backing has still many possibilities.

LNGOneWorld has an advantage in being promoted and developed by entities that have an in depth and practical understanding of the nuances of both the conservative energy trading domain as well as shipping markets. LNGOneWorld's strategy seems to be to iteratively gain sustainable user confidence and foster a community building exercise as the market readies for spot LNG trading.

Promoters and Participants of LNGOneWorld

LNGOneWorld has been created by LNG Japan Corporation and North South International Ltd. LNG Japan Corporation was established in September 2001 as a joint venture between Nissho Iwai Corporation and Sumitomo Corporation. The core mission of the venture is to focus on, and expand its LNG related activities and hence become one of Japan's leading energy companies. North South International Limited is a London and Oslo based corporate finance and strategy advisor specialising in the shipping industry. Day to day content of the site will be managed by London based Drewry Shipping Consultants, a company with three decades of experience of covering the international LNG markets.

Time frame for the development of the portal

The first phase of the LNGOneWorld portal, providing critical business intelligence information to the LNG industry players is already functional and located at http://www.lngoneworld.com. The second stage, envisaging an electronic trading platform for LNG, is proposed to be developed by the year 2004. ■

Membership Structure

The portal has a four-level membership structure as follows:

1. **Non-registered: Available to all interested parties**
2. **Level One [Complimentary]: Available to registered individuals**
3. **Level Two [Associate Membership]: Available to companies with an interest in the LNG industry. Associate membership at USD 750 per year will allow single user login.**
4. **Level Three [Full Membership]: Available to core LNG participants such as consumers, producers, importers, exporters, shippers and traders, etc. Full membership at USD 2000 per year will allow each corporate member 5 user logins for their key staff.**

Each membership retains different levels of access to the site contents and membership is strictly controlled by LNGOneWorld in order to maintain the highest standards for core LNG industry players.

Liability for Marine Casualties

Philip Weems and Kevin Keenan, King & Spalding, USA

This article is the second in a series by the same authors. It analyses the wide diversity of regimes for limiting liability in the event of a major LNG shipping accident, and suggests there is a need for change

"When I lost my rifle, the Army charged me 85 dollars. That is why in the Navy the Captain goes down with the ship" [1]. Indeed, given the inherent perils of the sea, losses resulting from maritime casualties can lead to substantial liabilities. Since the middle 1700s, vessel owners have lobbied successfully to limit their liability to third parties for damages to property and for injuries to and death of individuals. Consequently, several regimes for limiting liability of shipowners (and, in some cases, charterers, operators, salvors and insurers) have been developed -- some through international conventions and others through local laws -- and are currently implemented in various jurisdictions throughout the world. The adopted liability regimes, however, represent a wide spectrum of economic and legal frameworks and, therefore, produce dramatically different results.

This article will briefly examine a number of different limitation of liability regimes. The regimes discussed will be limited to those in effect (or, in a couple of cases, proposed) in jurisdictions having existing or proposed LNG liquefaction or regasification facilities. We have, for the sake of argument, assumed that a catastrophic marine casualty involving third-party property damage and loss of life occurs in Algeria, Belgium, Norway, the United States, Russia, Japan and Indonesia. These countries have been chosen and are discussed below only because their respective limitation of liability regimes offer for the reader an interesting and, we hope, informative study in contrasts. For purposes of this article, we have also assumed that the international conventions discussed below, except as otherwise noted, have been ratified in the respective countries without reservation and that such conventions are in full force and effect [2].

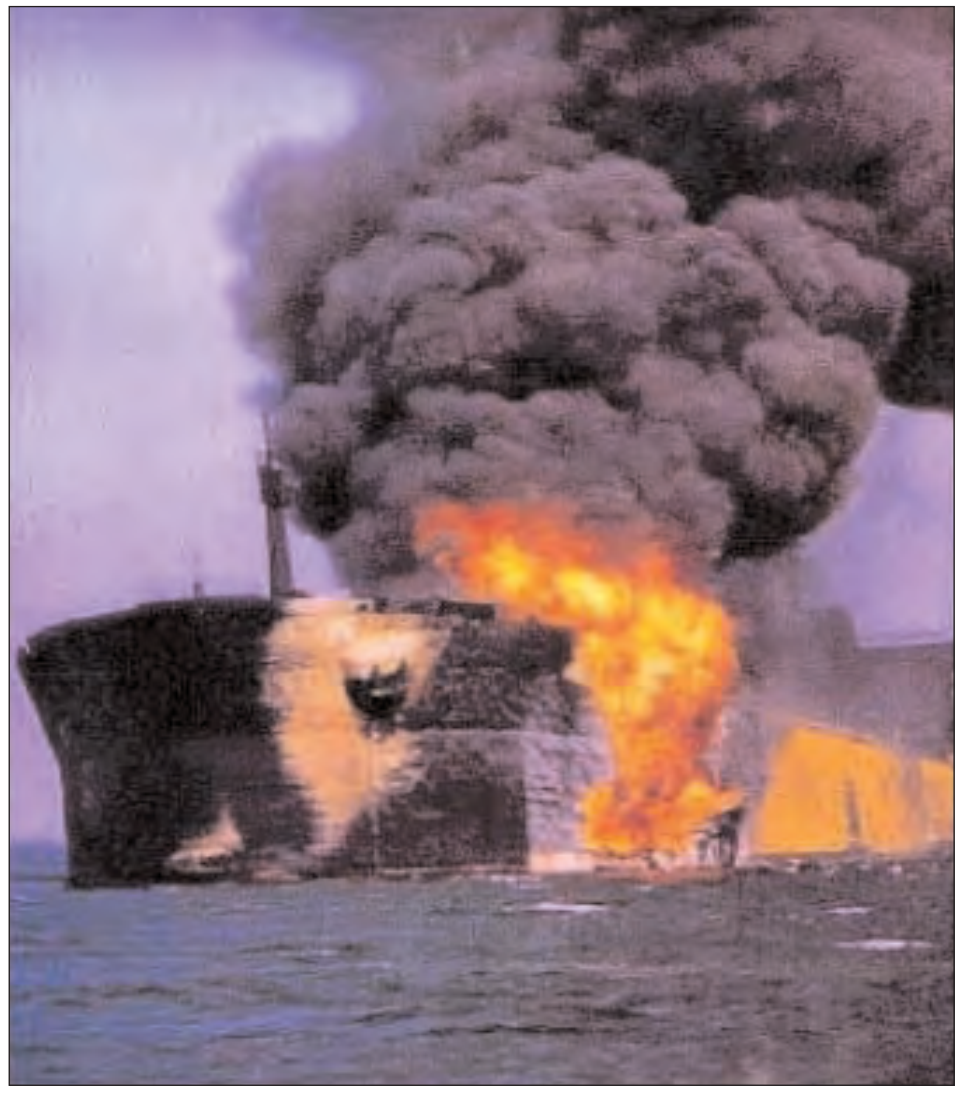
The nature and properties of LNG, advances in technology, and an industry-wide emphasis on safety have enabled the LNG industry to develop and maintain an enviable safety record. Although little debate exists today concerning the safety of the LNG industry, it is arguably in the industry's best interest to ensure that adequate funding is available to compensate victims of an LNG-related casualty. Unfortunately, depending on where the casualty occurs, compensation available under prevailing legal regimes could fall short of what might at the time be considered fair in the affected community. To illustrate this point, we present the Janus, a hypothetical 138,000 m^3 LNG tanker (net tonnage of 48,000 tons; gross tonnage of 96,000 tons). For the sake of illustration, the reader should assume that the Janus suffers a catastrophic casualty involving the partial breach of her containment system, the ignition of boil-off gases, the partial loss of her cargo, significant collateral property damage, and loss of life in each of the locations and jurisdictions discussed below. In addition, the reader should assume that the owner of the Janus has not acted in a manner which would render inapplicable the liability regimes discussed below [3].

1. **Skikda, Algeria** -- International Convention Relating to the Limitation of the Liability of Owners of Sea-Going Ships (Brussels, 1957)

Algeria ratified the above-noted convention (the "Brussels Convention") in 1964. Under the Brussels Convention, the owner, charterer, manager and operator of the Janus, as well as her master, members of her crew and servants of her owner, may limit their liability in regard to a casualty in Algerian waters (including claims for both personal injury and property damage) to a maximum of 3,100 francs for each ton of the Janus's net tonnage. While there are allocation rules within this limit that deal with amounts available for personal injury versus property damage, ultimately the vessel owner's liability is by law capped at 3,100 francs per net ton.

While the 1979 Protocol to the Brussels Convention later introduced the Special Drawing Right established by the International Monetary Fund (the "SDR") in order to ease conversion of the liability limits to member state currencies, Algeria has yet to ratify the 1979 Protocol. Thus, limitations of liability for events occurring in Algerian waters would, as the above discussion suggests, be determined using the "franc" as the unit of measure -- a unit consisting of sixty-five and one half milligrams of gold. At today's prevailing gold price, this leads to a very interesting, and possibly unintended, twist.

Had the Janus suffered a casualty in 1978, the limitation of liability in Algeria under the Brussels Convention would have been approximately US$10 million [4]. The next year, based on the value of the SDR in 1979, the Janus's limitation would have been approximately US$12.8 million. [5] -- a significant increase and quite likely one of



the driving forces behind the 1979 Protocol. However, while the currencies comprising the SDR left the gold standard behind, Algeria's failure to ratify the 1979 Protocol kept the gold standard alive, at least in this context, and in so doing effectively increased its liability limits beyond those contemplated in the more recent iteration of the Brussels Convention.

Thus, while liability limits under the 1979 Protocol for the Janus would be approximately US$13.1 million. today [6], limitations today under the Brussels Convention, sans the 1979 Protocol, would be somewhere in the neighborhood of US$97 million. [7].

2. **Zeebrugge, Belgium** -- International Convention on Limitation of Liability for Maritime Claims (London, 1976)

The above-noted convention (the "London Convention"), which serves as the basis for the maritime liability laws of thirty-seven countries [8], was ratified by Belgium in 1989. Aside from liability limits which were intended to be (and but for today's price of gold would be) higher than the Brussels Convention, one of the most important changes brought about by the London Convention is that liability limitations are extended not only to shipowners, charterers [9], operators, managers and salvors (and those persons for whose actions the shipowner or salvor is responsible), but also to all of their insurers [10].

Limits of liability for claims governed by the London Convention are also stated in SDR. Like the Brussels Convention and its 1979 Protocol, limits of liability under the London Convention are based on the ship's tonnage (albeit gross rather than net tonnage) and, in particular, are dependent upon whether the claim involves personal injury or whether it involves property damage only.

Based on the current value of the SDR, the limitations of liability applicable to the owner, charterer, operator, manager and salvor of the Janus (and each of their insurers) would be approximately US$50 million in respect of claims for personal injury and property damage. Like the Brussels Convention, the London Convention also makes a clear distinction between claims for personal injury and claims for property damage, with an allocation between the two taking place inside that US$50 million limit.

3. **Melkoya Island, Norway** -- 1996 Protocol to the Convention on Limitation of Liability for Maritime Claims (1976)

Like Belgium and some thirty-five other nations, Norway ratified the London Convention and made it a part of its Maritime Code of 1994. However, Norway also ratified the 1996 Protocol to that Convention (the "1996 Protocol"). Although not yet in effect, the 1996 Protocol raises the limits of liability for maritime claims above those established by the London Convention [11]. Under the higher limits, a casualty involving the Janus in Norwegian waters would result in liability limits in the neighborhood of US$80 million. for claims involving personal injury and US$40 million. for claims involving damage to property, for a total aggregate limitation of liability equal to approximately US$120 million. It is widely expected that the 1996 Protocol will come into force within the next few years.

4. **Lake Charles, Louisiana, U.S.A**. -- Limitation of Vessel Owner's Liability Act (1851)

The United States is not a party to any of the international conventions governing limitation of liability for maritime casualties. Instead, limitation of liability in the United States is governed by the Limitation of Vessel Owner's Liability Act, 46 U.S.C. §§ 181 et seq. (2001) (the "Act"). Originally passed in 1851, the Act provides that a shipowner may be entitled to limit his liability to the "amount or value of the interest of such owner in such vessel, and her freight then pending" [12]. The point in time where the owner's interest in the ship and freight pending is to be determined is the termination of the voyage on which the loss or damage occurs [13]. The U.S. Supreme Court has long held that where a ship sinks following a collision, not only is the sinking the termination of the voyage for purposes of the Act, but the value of the vessel -- and thus the limitation of the shipowner's liability -- is measured by the value of whatever is saved prior to the sinking [14]. Moreover, hull and machinery insurance has no bearing on the determination of value for limitation purposes [15].

While the master of the Janus may not have to go down with his ship following a casualty in U.S. waters, he may indeed, oddly enough, have a pecuniary disincentive to ensure that she stays afloat immediately thereafter. Clearly, to the extent that she is totally destroyed, the vessel owner's potential liability for third-party losses is severely limited. Paradoxically, following a breach of her containment system causing a catastrophic casualty, the Janus could in theory retain significant value (for purposes of comparing limitation regimes, we have assumed as much as US$100 million. based on the present value of newbuild LNG vessels). Thus, while the United States may have the lowest liability limit among those discussed in this article, it could theoretically have one of the highest. Depending on the extent of the casualty, the owner [16] of the Janus may be entitled to limit his liability to an amount ranging from zero (following the Janus's total destruction) up to the Janus's fair market value (assuming little damage to her hull and machinery and the ability of her containment system to be repaired), plus her pending freight.

One unique twist of which the shipowner should be aware is that limitation of liability is an action in its own right under the Act, rather than a defense to an action for damages. In other words, the Act requires a shipowner to initiate a limitation action by petitioning the appropriate federal district court, within six months of the initiation of proceedings elsewhere, to stay those proceedings. In addition to and concurrently with the filing of the limitation action, the shipowner must either surrender the vessel to the court or establish a limitation fund in the amount of her value plus her pending freight.

5. **Sakhalin II, Russia** -- The International Convention on Liability and Compensation for Damage in Connection with the Carriage of Hazardous and Noxious Substances by Sea

The above-noted convention (the "HNS Convention") was ratified by Russia in

2000. Although not yet in force, the HNS Convention is the first liability convention to deal specifically with LNG. The HNS Convention introduces strict liability for the shipowner, establishes higher limits of liability, creates a fund for compensating victims when damages exceed limitations, and includes a system of compulsory insurance.

Like the London Convention, the HNS Convention calculates the shipowner's liability in SDR. Limitations under the HNS Convention are the same whether the claim is made in respect of property damage or for personal injury. For a vessel like the Janus, having a gross tonnage equal to 96,000 tons, liability of the shipowner under the HNS Convention would be capped at 98.56 million SDR or approximately US$129 million. This is considered the "first tier" of liability limitation under the HNS Convention. To help ensure that shipowners are capable of meeting their first tier obligations, the HNS Convention makes mandatory for all vessels registered in a member state the procurement of insurance coverage in amounts not less than the limitations provided.

The "second tier" under the HNS Convention offers a further layer of protection to victims of marine casualties. To the extent that damages incurred in connection with the Janus's casualty exceed US$129 million, or if the shipowner is incapable of meeting that obligation (a risk that is significantly mitigated by the compulsory insurance requirement discussed above), claimants may be entitled to compensation from a fund established under the HNS Convention (the "HNS Fund") up to a maximum of 250 million SDR (approximately US$327 million), inclusive of the shipowner's first tier contribution, if any.

A discussion of the particulars of the HNS Fund is beyond the scope of this article. Suffice it to say that contributions to the separate LNG Account established thereunder are made annually by all persons holding title to LNG immediately prior to its discharge. Thus, for FOB sales of LNG, buyers will be liable for the annual contribution to the HNS Fund in the applicable member state. For DES sales of LNG, sellers will make the applicable contribution.

6. **Yanai, Japan** -- London Convention Augmented with Social Responsibility Insurance

Japan ratified the London Convention in 1982. While limitations of liability for marine casualties occurring in Japanese waters would be governed by the London Convention, and while traditional P & I cover is procured on that basis, Social Responsibility Insurance evolved in the early 1980s in response to a Japanese concept -- albeit unofficial and legally non-binding -- which ascribes liability to persons thought to be in breach of the social contract (i.e., the responsibility of citizens to be socially responsible in the communities in which they operate and to assume responsibility for their failure to exercise prudent judgment and reasonable care). Where a breach of social responsibility occurs, the community affected by the breach may seek to impose sanctions on the person or entity whom they perceive to be the perpetrator. In most cases, the party perceived to be responsible is the local company in its capacity as LNG buyer -- since the community affected has little knowledge of the shipping interests involved in transporting

LNG but significant knowledge, for obvious reasons, of the local company importing it. Although sanctions may vary, sometimes consisting only of an official request for a public apology, payment of money to compensate individuals and public authorities affected can also be required from time to time. Such sanctions, if not complied with, may be enforced by significant and concerted disruptive action against the non-complying business.

In order to insure against the financial costs potentially associated with such sanctions, Japanese LNG buyers have required that shipowners procure policies covering "non-legal liabilities." Social Responsibility Insurance, therefore, provides coverage for potential payments -- some have called them "sympathy payments" -- to victims of marine casualties without the need to admit or establish liability. Shipowners have been known to procure policies of Social Responsibility Insurance covering non-legal liabilities in Japan up to US$150 million.

Thus, in addition to the limits set forth in the discussion of the London Convention above, the owner of the Janus would likely be liable -- albeit unofficially, without the force of legislation, and without admitting liability -- for compensating victims of a catastrophic casualty. As a result, Social Responsibility Insurance is widely procured by vessel owners whose LNG tankers trade in Japanese waters.

7. **Arun/Bontang, Indonesia** -- Omnibus & Waiver Agreements and Conditions of Use

Indonesia is not a party to any of the foregoing international conventions and has adopted its own liability regime, presently set forth in its Commercial Code. However, that liability regime is largely academic at Arun and Bontang, where LNG tanker owners find their liability governed by the Omnibus & Waiver Agreements and the Conditions of Use (collectively, the "Port Liability Agreements") -- contractual documents entered into by and among the master of the vessel, the vessel owner, the vessel operator, the terminal owner, and the LNG buyer and seller.

The Port Liability Agreements provide a quid pro quo that, although not yet tested in any court of law because of LNG's envious safety record, appears to be an acceptable allocation of liability to the shipping and insurance industries. In exchange for a strict liability regime which ascribes liability to visiting LNG tankers and their owners regardless of fault (except if damages arise from the terminal owner's gross negligence or willful misconduct), the terminal owner grants to the tankers and their owners a limitation of liability equal to US$150 million [17]. In addition, the Port Liability Agreements provide that the full US$150 million must be covered by the vessel's P&I Club and the certificate of entry must include therein a specific reference to such agreements. Vessels calling at Arun or Bontang also waive all rights to limit liability under international conventions. Personal injury claims are handled on a knock-for-knock basis, with each party responsible for damages incurred by its own personnel.

Thus, if the Janus were to suffer a catastrophic casualty at Arun or Bontang, assuming the terminal owner is not found to be grossly negligent or guilty of willful misconduct, the shipowner would be

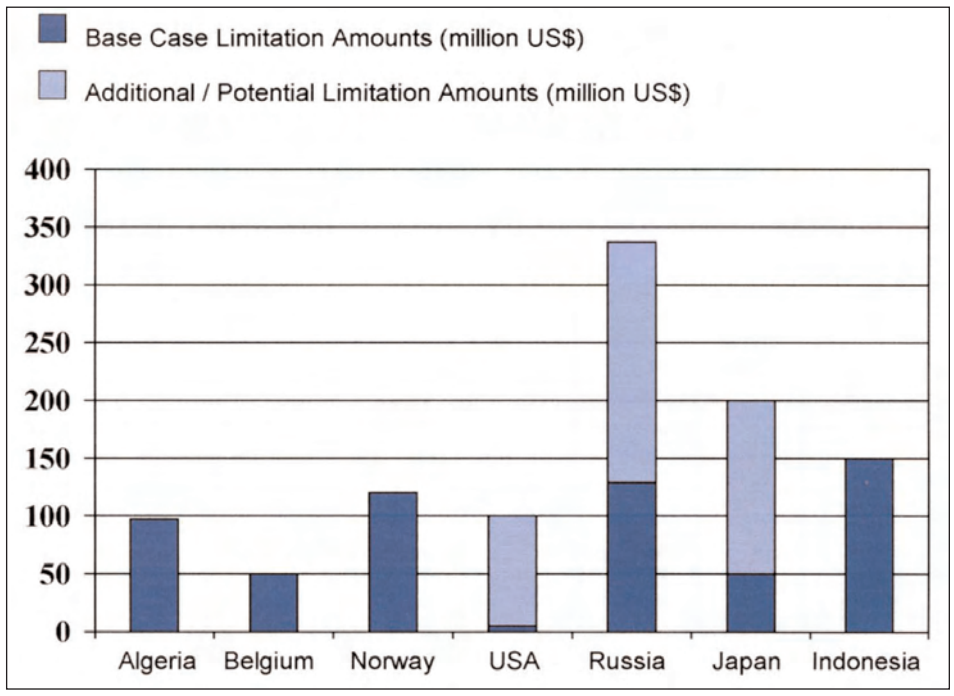


Figure 1 - Comparison of limits across selected jurisdictions

strictly liable for all damages occasioned by its use of the harbor, regardless of fault, up to a maximum of US$150 million.

Is a Voluntary LNG Liability Scheme Advisable?

As can be seen from this overview, limits of liability are far from uniform and lead ultimately to a wide range of available compensation for third-party damages. Without a doubt, the public image of the LNG industry will be adversely affected by an accident following which victims go uncompensated due to what might, under the circumstances, be perceived as unreasonably low limitations of liability under existing regimes. Perhaps the time has come to address the disparity and take steps to ensure the industry retains, even in the face of a catastrophic accident, its record of responsible management and concern for public health and safety. To maintain the status quo is to risk a public outcry and the specter of adverse governmental action following such an event, either of which could be far more costly to the industry.

Concerns as to adequate levels of compensation for LNG-related casualties have been articulated for at least twenty years. In fact, at an International Bar Association conference on LNG in 1982, Dr. D. W. Abecassis, Head of LNG Shipping at Shell International Marine Ltd. in London, presented a paper in which he argued that present legal regimes limiting shipowner liability are inadequate and that the LNG industry should "club together" to create a scheme of voluntary acceptance of strict liability, similar to TOVALOP and CRISTAL (both of which served as interim liability regimes pending the widespread adoption of the 1969 Civil Liability Convention and the 1971 Fund Convention). In his presentation, Dr. Abecassis stated that "not only in the interests of those who might suffer loss or damage from an accident, but also in the long term interests of the LNG business, the LNG industry should [create a scheme of voluntary acceptance of strict liability]" [18].

The questions raised by Dr. Abecassis seem to us to be as valid today as they were in 1982. The limits that would be provided by the 1996 Protocol to the London Convention are still arguably too low in the LNG context and the HNS Convention may not come into effect for many years, if at all [19]. To be sure, the LNG industry enjoys an excellent safety record, but it is in everyone's best interest to ensure that victims are adequately compensated in the event an LNG carrier is involved in a serious casualty. Failure to do so could lead to strict liability or over-relaxation of liability limits (or even abandonment of such limits altogether). Enviable and excellent though it might be, LNG's record will one day be called into question. After all, "[a] ship in port is safe, but that's not what ships are built for" [20]. ■

IKPT film enclosed (can you pls enlarge to fit this space?)

"To be sure, the LNG industry enjoys an excellent safety record, but it is in everyone's best interest to ensure that victims are adequately compensated in the event an LNG carrier is involved in a serious casualty."

Kevin D. Keenan, a senior associate with King & Spalding in Houston and soon to be resident in their recently-announced London office, specializes in downstream energy-related transactions, including oil, gas and LNG.

Philip R. Weems, a partner with King & Spalding in Houston, specializes in the legal aspects of developing, marketing and operating LNG and cross-border natural gas projects.

Endnotes

1. *Dick Gregory (comedian, author, political activist).*
2. *For example, the HNS Convention, by its terms, requires ratification by twelve nations prior to its coming into effect. While only Russia and Angola have ratified the HNS convention as of August, 2002, this article discusses the HNS convention prior to its effectiveness because it is the first liability convention to specifically address LNG. In addition, the 1996 Protocol to the London Convention is addressed here because it is widely believed that it will enter into force in the near future.*
3. *For example, Article 4 of the London Convention, entitled "Conduct Barring Limitation," declares that "a. person shall not be entitled to limit his liability if it is proved that the loss resulted from his personal act or omission, committed with the intent to cause such loss, or recklessly and with knowledge that such loss would probably result."*
4. *Gold (US$34.95/troy oz.) (1978 Average).*
5. *SDR = US$1.29200 (1979 Average). IMF Yearbook, p. 439 (1981).*
6. *SDR = US$1.31909 (July, 2002).*
7. *Gold (US$310.50/troy oz.) (July, 2002).*
8. *Other current and potential LNG nations which have ratified the London Convention include Australia, The Bahamas, Egypt, France, Japan, Mexico, Spain, Turkey, the United Arab Emirates, the United Kingdom and Yemen.*
9. *While the decision of the English Admiralty Court in The Aegean Sea, 2 Lloyd's Rep. 39 (Q.B. 1998), has been interpreted by some commentators (and it is feared will be interpreted by other courts) to suggest that the London Convention does not afford charterers the right to limit liability, the rule in that case appears only to proscribe attempts by charterers to limit liability as between charterers and shipowners (i.e., limits that are more appropriately set out in charterparties themselves).*
10. *London Convention, Art. 1(6).*
11. *996 Protocol, Art. 3(1).*
12. *46 U.S.C. § 183(a).*
13. *Place v. Norwich & N.Y. Transp. Co., 118 U.S. 468 (1886).*
14. *Dyer v. National Steam Nav. Co., 118 U.S. 507 (1886).*
15. *Place v. Norwich & N.Y. Transp. Co., 118 U.S. 468 (1886).*
16. *Unlike the Brussels and the London Conventions, the Act does not extend its liability limitations to parties other than the shipowner and bareboat/demise charterer.*
17. *The US$150 mill. limit was set almost twenty years ago and has come under review at least once since then in an effort to determine whether it should be increased.*
18. *The Special Problems of Liquefied Natural Gas, International Bar Association conference on LNG (1982).*
19. *It should be noted that LNG is but one of more than 3,000 substances covered by the HNS Convention. Given the breadth of the HNS Convention and the fact that its practical workings result in perceived cross-subsidization among industries (especially toxic chemicals) and across national boundaries, its fate is far from certain.*
20. *Grace Murray Hopper (military leader, mathematician, educator).*

3rd Annual
World LNG Summit

"Where the LNG industry meets to do business"

Rome Cavalieri Hilton Hotel – Rome, Italy

Summit: 10-11 December 2002

Pre-Summit Workshop: 9 December 2002

Post-Summit LNG Training Course: 12 December 2002

Distinguished speakers include:

Muri Muhammad, President, **The Malaysian Gas Association**

Ting Lee, Secretary General, **The Gas Association of The Republic of China**

Javier Estrada, Commissioner, **Comission Reguladora de Energia – Energy Regulatory Commission, Mexico**

Junichi Namiki, Senior Manager, Project Development and LNG Transportation, Gas Resources Department, **Tokyo Gas Co., Ltd.**

Betsy Spomer, CEO/VP, **BG LNG Services/Global LNG, BG Group**

Elías Velasco García, Chief Executive Officer, **Unión Fenosa Generación**

Miguel Angel Remón, Vice President Exploration and Production, **Repsol YPF**

Sveinung J. Støhle, Executive Vice President, **Golar LNG**

Topics

- New dynamics in the LNG trade
- Securing stable and economical supply of city gas feedstocks
- Projected demand for LNG
- Spot market vs long term contracts
- Innovative shipping contracts to reduce costs and increase flexibility
- Floating LNG: feasibility, costs and safety
- Case studies of Japan, US, China, Italy, Spain, Brazil, Turkey and Portugal

SPONSORED BY: GE Power Systems Oil & Gas · LANNER the value of knowing · TAYLOR - DEJONGH

Pre-Summit Workshop
Understanding the LNG value chain

&

Post-Summit LNG Training Course
Using energy financial tools to increase project returns

For further information, please contact
Paul Morris at CWC Europe Limited on tel: **+ 44 20 7089 4183**,
fax: **+44 20 7089 4201** or e-mail: **pmorris@thecwcgroup.com**

the cwc group
cwceurope limited

www.thecwcgroup.com/conferences

Invar Membranes for LNG Tankers

F. Hannon, F. Duffaut and M. Leroy, IMPHY UGINE Précision, France

The Invar membrane system is one of the world's leading LNG cargo containment technologies. IMPHY describe the details of the technical development of the material, its testing and successful application

By conception, membrane-type cargo tanks are integrated with the ship's double hull, enabling optimum use of available space. In order to line the insulated tank with its leakproof metal membranes, the solution is to use flat sheets made from a material with an expansion coefficient close to zero, so that the thermal strains and stresses between -160 °C and ambient temperature become negligible.

Original Features of the Invar® Membrane Technique

The main feature is the use of the same metal - Invarâ - for both the primary and secondary membranes (Invar® is a registered trade-mark of IMPHY UGINE Précision). The insulation is comprised of two layers of perlite-filled plywood casings, fixed to the hull with the aid of welded mechanical couplers. The Invar® membranes are composed of strakes, sheets 0.7 mm thick and 530 mm wide, with upturned edges, placed side by side and resistance welded. The tongues are fitted into slots in the plywood casings in such a way as to allow relative sliding between the membrane and the casings without creating shear stresses. Moreover, the joints formed between the strakes act as bellows, absorbing any small residual thermal strains and compensating for variations in the hull dimensions due to the loads exerted by the cargo.

Apart from thermal stresses, since the membranes are linked to the structure of the ship at their ends, they are subjected to the same types of deformations as the vessel as a whole, which is loaded in bending to different degrees, depending on the state of the sea. These conditions are cyclic in nature and the ship's design life is based on the assumption of 108 cycles. Fatigue strength is therefore an important factor for all the components and joints in the membrane and insulation system.

The Initial Choice of Invar®

The principal alloy characteristics initially considered necessary for the manufacture of a flat membrane were :

- A low mean coefficient of thermal expansion (CTE) between ambient and -163° C
- Complete absence of brittleness at low temperature
- Stable properties after long exposure at low temperature and after thermal cycling
- Good bendability
- Good weldability

Based on these criteria, in January 1963, the research and studies performed by IMPHY UGINE Précision led to the choice of an Invar® -type iron-nickel alloy containing 35-36 % Ni, and designated as Invar® M63.

Industrial Development of LNG Grade Invar®

Verification of the basic properties

In the early 1960's, a program was established to determine the basic properties of samples of Invar® M63 alloy.

Expansion behavior and thermal stresses

The expansion properties were measured on samples taken from both semi-products and cold rolled strip of various thicknesses, from several melts representative of the full range of compositions envisaged. These tests showed an average CTE of $1.5 \pm 0.5 \times 10^{-6}$/°C between 0 °C and -180 °C. The maximum value of 2×10^{-6}/°C, together with an average Young's modulus of 140 000 MPa and a temperature amplitude dT of about 180°C (between ambient temperature and -163 °C), leads to a theoretical thermal stress equal to :

$CTE \times E \times dT = 2 \times 140\,000 \times 180 \times 10^{-6} = 50$ MPa.

In the transverse direction of the strakes, this low thermal stress is attenuated by the flexible joints. In the longitudinal direction, it is transferred to the ship by the system of mechanical connections.

Mechanical properties

The mechanical properties of Invar® M63 were explored and validated by tensile and fatigue tests on smooth and notched specimens, together with impact and bending tests. The conclusions were as follows:

- The turned-up strake rims can be formed without problem to the required bend radius
- When the temperature is lowered from 20 °C to -163 °C the yield and ultimate tensile strengths are doubled, while the elongation to failure remains close to 40%
- In the same conditions, the 108 cycle endurance limit is multiplied by 1.7 in the base metal and by 1.2 in the TIG welded lap joints
- The impact strength at liquid temperature is high, with typical Charpy values of 200 J/cm^2, and no notch weakening is observed in tensile tests
- Specimens exposed for 1000 hours at -196°C show no change in either structure or properties.

Furthermore, it has been verified that these characteristics are isotropic in the plane of the strip. These good properties are due to the stability of the austenitic structure, the Ms point (temperature under which the martensitic structure appears) being below liquid hydrogen temperature. However, it is well known that the Ms point can be raised by cold work. The alloy chemistry has been balanced so that a strain of at least 20 % is necessary before small amounts of martensite are observed.

Industrial feasibility

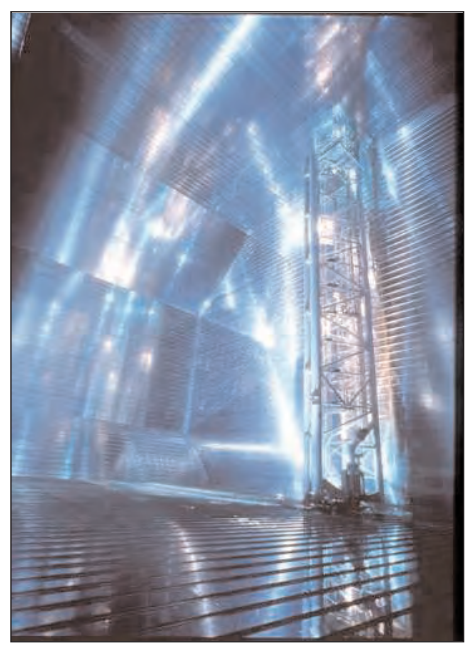
Until the creation of InvarâM63, Invar® was essentially a metrological alloy, for which the only application involving significant volumes was as the passive component of thermostatic bimetals. Its conversion to a "structural" material implied not only the evaluation and validation of numerous hitherto undetermined properties, but also the definition and implementation of an industrial manufacturing route, starting from ingots of sufficiently large dimensions and finishing with 530 x 0.7 mm cold rolled strip. The strip lengths had to be capable of producing 30 to 60 meter strakes. The challenge was taken up and successfully met.

Straightness of the strips

Each strip delivered is converted to a strake by turning up the edges with the aid of a roll-forming machine. The resulting strakes must be perfectly straight to be able to be inserted without deformation between two tongues. The edge straightness must be better than ± 0.5 mm per meter and non cumulative. This was achieved and guaranteed by using an original adapted process.

Welds

Tank construction involves numerous welding operations of different types, on assemblies of various thicknesses. These include both homogeneous (Invar®/Invar®) and heterogeneous (Invar®/stainless steel) joints, automatic and seam welds. The validation tests performed on these weld joints, including micrography, fatigue, and thermal expansion measurements, were used to optimize the welding parameters and to determine safety factors for each type of joint, depending on the weld dimensions.



The Invar membrane containment system

The stability of the austenitic structure of Invar® M63 at all temperatures leads to a certain tendency for solidification cracking. From the first few industrial heats, this tendency was counteracted by improving the melting practice, particularly with regard to the sulfur content, and no problems of this sort were encountered in practice, in either TIG or resistance welds. The case of reheating cracks is more complex. Cracking of this type is liable to occur during repair of a weld seam or at the junctions between two crossed beads. The fusion zone on the first bead is reheated during the second welding pass and, in addition to temperature gradients, is subjected to both applied and residual mechanical stresses. In all ships this problem is overcome by controlling the constraining forces and welding power, and by the skill of the welding operators.

Corrosion resistance

Although Invar® is far from being a stainless steel, its corrosion resistance is vastly superior to that of mild steel. Simple precautions during storage and onboard handling have enabled perfectly bright membrane surfaces to be obtained, and this condition is preserved during the life of the ship by maintaining an inert nitrogen atmosphere in the insulation spaces.

Today's Material - Invar® M93

In 1980, Nakagawa et al (1) made a significant contribution to the problem of reheat cracking by proposing the "cross-bead test". This test can be used to determine the stress level at which reheating by a second bead does not cause cracking in the fusion zone of the first one. A new grade, with the

residuals controlled to the above maximum levels, is the Invar® M93 developed by IMPHY UGINE Précision, and employed for all the orders of tankers. Its use in several shipyards has already confirmed the complete absence of welding problems. A further consequence is that welds requiring filler metal, including multipass welds in large thicknesses, can be performed with Invar® M93 wire.

Tomorrow's Material

With a view to helping the shipyards in LNG carrier construction, IMPHY UGINE Précision is working on a new Invar® MXX, whose corrosion resistance and weldability are improved still further. Furthermore this new product, quite compatible with both Invar® M63 and Invar® M93, allows tank repairs to be carried out on the existing LNG carriers.

The quantity of Invar® used in a standard 138 000 m^3 capacity four-tank vessel is about 400 tons, with a total primary and secondary membrane area of about 25 000 m^2. About 90 % of the 110 km welds involved are made with automatic equipment.

Experience in LNG Tankers

The Invar® M63/M93 membrane systems have proved, since the first LNG tankers, to be reliable and safe. The oldest vessels have been in service for more than 25 years, and no major problem has arisen due to the cargo system. This confirms the good fatigue resistance of the membranes under both the mechanical stresses imposed by loading and unloading operations and by the movements of the ship at sea, and the partial or complete thermal cycles corresponding to either the differences in temperature during voyages under load and ballast or to programmed technical overhauls. Reclassification requests have been submitted to the regulating bodies to allow the service life of the most meritorious tankers to be extended to 35-40 years.

Conclusions

The Invar® M93 grade is the outcome of long studies carried out by IMPHY UGINE Précision to meet the specific requirements of LNG tankers with the main double-hull Invar® M93 insulation system. This material meets also the requirements of the one-membrane newly developed insulation system CS1, the new GTT technology for gas transportation.

Invar® M93 is being promoted in about 25 shipyards licensed to build membrane tankers throughout the world. Furthermore, Invar®-based insulation systems are also being envisaged for land-based cryogenic storage tanks, as well as future developments for new cryogenic applications.

IMPHY UGINE Précision has proven long experience of supply to worldwide shipyards, and is the world leader in the production of Invar® M93 membranes. Its Invar® (M63)/M93 material has been delivered to seven shipyards for the construction of more than 50 LNG carriers all over the world : this includes 5 LNG carriers by Chantiers de l'Atlantique for the shipowner Petronas, one by Hanjin and one by Fincantieri, two by Japanese shipyards, the first 10 by the Daewoo shipyards, and 5 by IZAR. ■

Reference

1. Nakagawa H., Matsuda F., Nagai A., Sakabata N. (1980). Transactions of JWRI 9, n° 2 : 55-62.