LNG journal

November/December 2002

The changing world of LNG

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The LNG business is continuing to change, with new projects and markets, lower costs, new players, and more short-term LNG trade. Andy Flower reviews recent developments

In our book 'LNG Today: The Promise and the Pitfalls'* my co-author Richard King and I described the development of the LNG business from the first cautious steps in the 1960s to a $20 billion business today. In the final chapter, we looked at how the business was changing from a very conservative activity based on long-term relationships into one where the advent of new players and the increase in short-term trading seemed likely to ensure that LNG would remain one of the fastest growing sectors of the energy industry. Although it is only just over six months since we completed the book a lot has happened to make now an opportune time to look again at the prospects for the future taking into account developments this year.

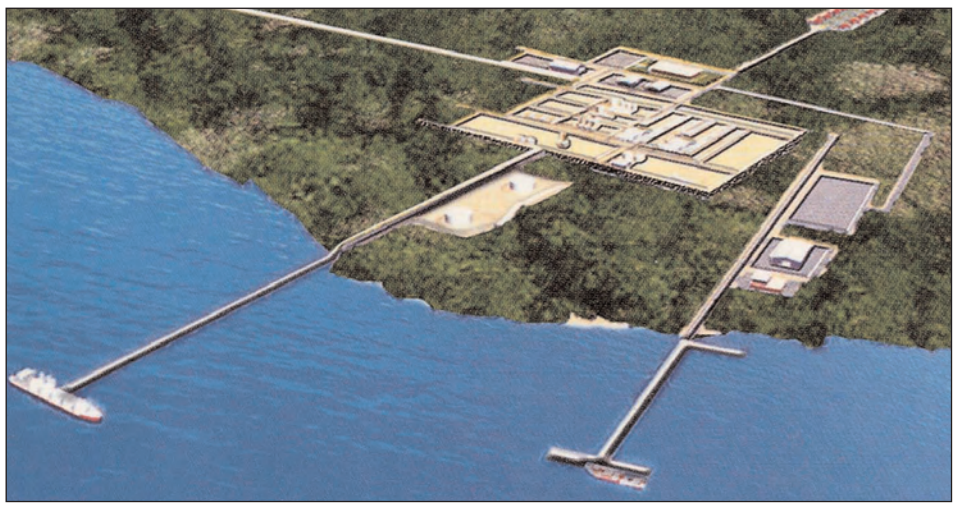
As we entered 2002, LNG seemed poised for a new leap forward with more new liquefaction plants and LNG receiving terminals planned than ever before and bulging order books for new LNG ships. The main question mark over how fast LNG supply and demand would grow was the rate at which markets would develop. As we approach the end of 2002, that still seems to be a key issue.

The Asia-Pacific LNG Market

On the positive side, China has made a major step forward towards joining the ranks of LNG importers with the selection of the supplier for not one but two LNG import terminals at Guangdong and Fujian. The deals that have been done with the Australian North-West Shelf project and the Tangguh project in Indonesia show the strong position that Buyers currently enjoy. The prices in the new agreements are at a significant discount to the prevailing level for existing buyers and CNOOC (China National Offshore Oil Company) was able to purchase a share in upstream gas reserves at a very competitive price.

The LNG prices achieved by the Guangdong and Fujian terminals are likely to have a lasting impact on the LNG market. The existing buyers in Japan, Korea and Taiwan are well aware of the new prices and can be expected to use the information in future negotiations with LNG sellers. However, the push for lower prices is only one of the requirements that existing buyers in Asia are looking for. Others include increased flexibility in contract terms with much reduced take-or-pay levels, shorter duration contracts and, particularly in the case of Korea, 70% or more of the annual contract quantity delivered in the winter months to help manage seasonal demand swings.

It is probably true to say that the prices agreed for Guangdong and Fujian supplies will have the effect of accelerating the process of price reduction rather than being the main reason for change, since the pressures were already evident from buyers facing the challenge of liberalising markets. The decline in prices will inevitably increase the drive to maintain the downward trend in costs of gas production, liquefaction and shipping.



The Tangguh project, Indonesia - to supply Fujian, China

India is the other new market in Asia that has taken much longer than expected to realise the hopes of LNG sellers. The debacle of the Dabhol project further delayed the development of LNG imports and provides a lesson to LNG sellers that you have to understand your buyer and its customers. It is no good relying on a take-or-pay contract when the contract prices bear no relation to the needs of consumers downstream of the LNG receiving termi-

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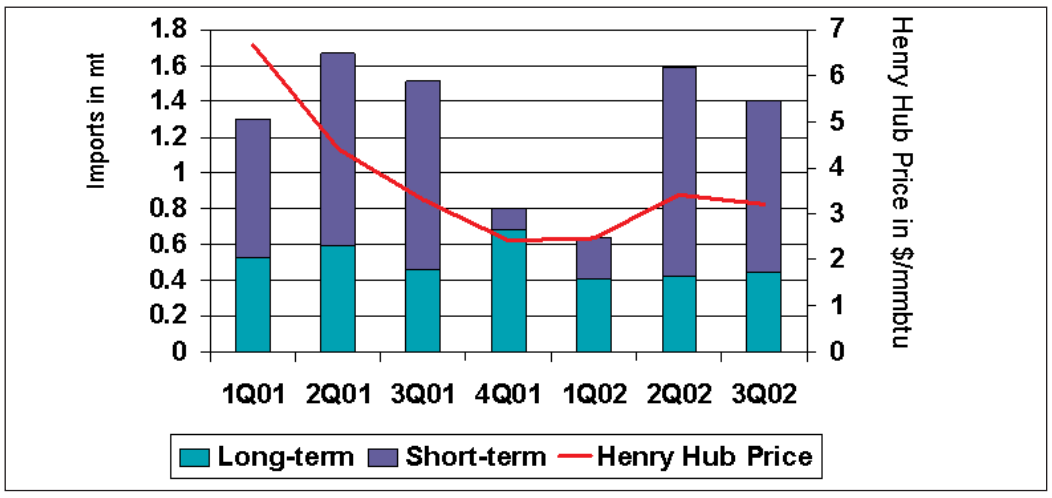

Figure 1: Quarterly US LNG imports and Henry Hub prices 2001-02

nal. Hopes in India are high again with construction of two new terminals, the Petronet terminal at Dahej and Shell's Hazira project, well advanced. However, in neither case have contracts yet been signed for the sale of regasified LNG so question marks remain over just how fast the LNG market in India will develop.

LNG demand in Asia's main established markets was subdued over the first 8 months of the year with Japanese imports down by over 5% and Korean imports only 1% up on the previous year. However, the last 4 months of the year should be more interesting with Japanese power utilities looking for additional LNG supplies to replace a shortfall in nuclear power following the closure of over 12 GW of capacity for inspection. They are running up against competition from Korea Gas, which is facing its usual problem of meeting increased gas demand in the domestic and commercial sector over the winter months. However, this year the situation looks worse than in previous years with long-range weather forecasts suggesting that temperatures will be lower than 12 months ago and the power companies consuming more gas than expected. Korea Gas says that it needs 30 to 35 cargoes (1.8 mt to 2.1 mt) of spot cargoes this winter. This is welcome news for producers in S. E. Asia, Australia and the Middle East, who had seen buyers exercising downward flexibility to reduce offtake during the first half of the year.

The Atlantic Basin LNG Market

The liberalisation of European natural gas markets continues to create opportunities for LNG sellers, particularly in southern Europe, where LNG is supporting the entry of new downstream gas marketers. A number of new LNG terminals are under construction or at the advanced planning stage in Spain, France and Italy and even in the UK, which last imported LNG over a decade ago. However, questions are now being asked as to whether some of the more optimistic demand projections in Europe will be achieved, which could mean that some markets will find themselves oversupplied with natural gas in the medium-term.

The strengthening of natural gas prices in the USA and forecasts of a supply shortfall as demand increases and domestic production, at best, remains flat produced a flurry of announcements of plans to develop new LNG receiving terminals in the USA, Canada, Mexico and the Bahamas in 2000 and 2001. Although few of the more than 20 projects announced over the last two years have been officially cancelled, progress has been slower than expected and final commitment has not yet been made to the development of North America's first new terminal since the 1970s. This is partly as a result of the financial uncertainty that many of the US companies who are planning terminals have faced in the aftermath of the Enron collapse, and scandals over trading practices. There has been more activity in the ownership of existing LNG terminals and in the companies controlling access to their capacity. All four of the existing terminals have seen their ownership change in the last few years and in mid-2002 the Cove Point terminal changed hands for the second time in as many years. Access to the existing terminals has proved to be a valuable asset with Enron and El Paso receiving significant cash payments for capacity at the Elba Island and Cove Point terminals respectively.

Natural Gas prices in the US market have been on something of a roller-coaster ride this year. They remained below $2.50/MMBtu throughout much of the first quarter. At this level, most of the world's LNG suppliers cannot make an acceptable return selling LNG into the US market and short-term imports almost dried up. Both the Lake Charles and Elba Island terminals remained unused throughout the first three months of the year. Only the Everett terminal remained active, receiving a single cargo from Algeria and nine from Trinidad, the two closest suppliers to the US.

US prices began to rise in mid-March and were well above $3 by early April. LNG producers reacted rapidly to strengthening prices by delivering 1.6 mt in the second quarter and 1.4 mt in the third quarter compared with only 0.6 mt in the first three months of the year. Figure 1 shows how the level of US LNG imports has moved with natural gas prices over 2001 and 2002. Quarterly LNG imports, split into those under short-term and long-term agreements are plotted against the average Henry Hub gas price for the quarter. Malaysia, Brunei, Nigeria and Qatar joined Algeria and Trinidad as suppliers during the second quarter of 2002 and Oman delivered a cargo in the third quarter. It was the first time that Brunei has supplied the US and it now means that all of the world's LNG producers, except Libya and Alaska, have now delivered LNG to the Lake Charles terminal.

New Liquefaction Projects

It is not surprising, given the current level of activity and interest in European and US markets, that all the commitments to new liquefaction capacity made this year have been targeted at these markets. Final investment decisions have been made for about 20 mtpa of new capacity as listed in Table 1.

Egypt deserves a special mention since only a few months after the start of construction of its first project at Damietta, commitment has been made to a second development at Idku. The only new LNG production to have come on stream in 2002 is the second train at Atlantic LNG in Trinidad and Tobago that delivered its first cargo to the US market in August. It will be joined before the end of the year by Nigeria's third train.

Project	Design capacity in mtpa	Markets
Nigeria Trains 4 & 5	8.2	Spain, Italy, Portugal, USA
Norway (Snohvit)	4.0	Spain, France, USA
Egypt (Idku)	3.6	France
Qatar - RasGas Train 4	4.7	Italy
Total	**20.5**	

Table 1: New LNG Capacity Committed in 2002

The list in Table 1 represents the projects that have passed the important threshold of a final investment decision. They represent only a small fraction of the projects at the planning stage, which have, as always, experienced their ups and downs over the last few months. Only one project, Namibia's Kudu project, has disappeared from the list but others such as Bolivia and Sunrise (Australia) have gone back in time. The projects that have made progress this year include Tangguh and Australia North West Shelf train 5, both of which have secured sales contracts with China.

LNG Shipping and Offshore LNG

The level of orders for new LNG ships in 2002 is down on the previous two years when scarcely a week seemed to go by without the announcement of a new order, resulting in a record of over 60 ships on order. However, 12 new ships have been ordered in 2002 and a number of companies are in discussion with shipyards.

An analysis of the ships on order shows that the capacity they will add to the LNG fleet is well in excess of that needed to transport the LNG from the new liquefaction capacity under construction. This suggests that, as the new ships are delivered into service, they will loosen the constraints that a lack of uncommitted ships has placed on the trading of LNG on a short and medium-term basis. The first eight ships ordered in the last few years were delivered from the yards during the second half of 2002 and some are already being put to work to help solve short-term problems. Three of the new ships will be delivering LNG from Qatar, Oman and Australia to Japan and Korea this winter, meeting the short-term needs described earlier in this article. In 2003, a further 19 ships are scheduled to be delivered from the yards adding additional flexibility to the fleet.

A new development in LNG shipping in the last few months has been the announcement by El Paso of their Energy Bridge project to regasify LNG on board the ship and transmit natural gas to shore by pipeline. One advantage is that the system will replace the need for new onshore LNG receiving terminals and avoid the protests that are likely to accompany plans for such facilities in the USA. El Paso's plans have been greeted with some scepticism by established LNG players but initial economic analyses suggest that the cost of receiving and regasifying LNG will be competitive with conventional onshore terminals.

The Energy Bridge represents yet another attempt to move LNG technology offshore. Delays in permitting the pipeline connection to the gas grid are currently stalling the development of the world's first offshore gravity-based LNG receiving terminal at Rovigo in Italy. Plans for floating liquefaction facilities have been continually in the news in 2002 but moving from the planning stage to development is

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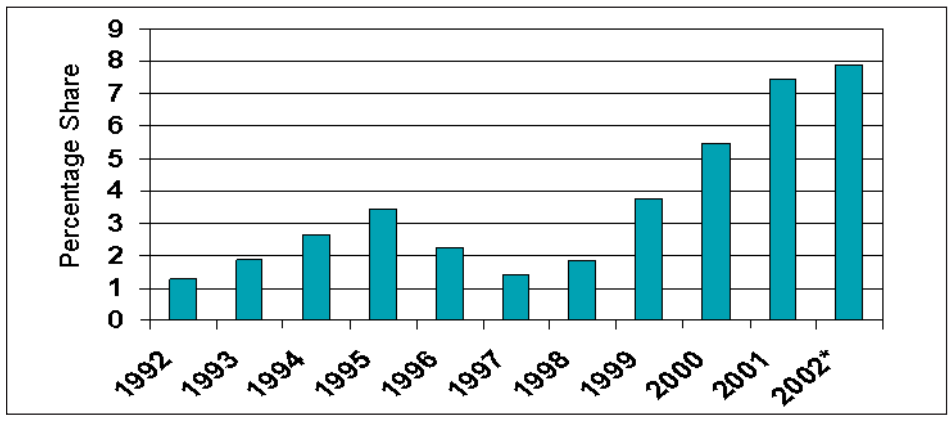

Figure 2. LNG short-term trades - percentage share 1992 to 2002

taking more time and proving more difficult than anticipated

Short-term LNG trade

The short-term trading of LNG continues to be a topic of major interest. Our LNG book* was completed before final figures for short-term trading in 2001 were available. As Figure 2 shows its share of total LNG trade continued on the upward trend that started in 1997. However, it still represented only just over 7% of the total. Actions by Japanese and Korean buyers to offset the effects of the shutdown of Indonesia's Arun plant for nearly 6 months in 2001 resulted in Asia taking over from the US as the largest market for short-term cargoes last year. Initial figures for the first half of 2002 suggest that Europe, and in particular the Iberian Peninsula, is now the main focus for the marketing of short-term cargoes. However, there may well be a swing back to Asia in the last few months of the year as Japan and Korea seek to solve their current supply problems.

Overall, total world LNG supply and demand in the first half of 2002 hardly grew compared with the same period of 2001. However, activity continued to move from the Asia-Pacific region to the Atlantic Basin. LNG demand in Asia was down by about 3.5% while it increased by around 6% in the Atlantic Basin. Short-term trading in the first half of 2002 was just under 8%, a similar level to that in 2001 as a whole. ■

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Copies can be purchased online at www.energypublishing.com

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LNG spot cargoes for Korea

Korea Gas Corporation (Kogas) has been taking steps to secure an additional 30 cargoes of short term LNG supplies between December 2002 and March 2003 to meet its peak winter demand. This is 8 cargoes more than last year, due to increased demand for LNG use in power generation resulting from higher prices of fuel oil. Short term LNG supplies have been secured from RasGas and other suppliers with which Kogas has long term contracts. Also, Australia's North West Shelf venture has signed a sale and purchase agreement to supply 0.22 mt LNG; this comprises one spot cargo to be delivered in December and three cargoes that will be redirected from existing buyers and delivered in December and January. The first of BP's new LNG carriers, the 138,000 m^3 British Trader, will be chartered for this trade.

Kogas is still seeking an additional 2 mta of medium-term LNG supplies starting next year from 5 to 10-year contracts, and has announced plans for further expansion of LNG storage at the Pyongtaek terminal, with four new 140,000 m^3 tanks.

LNG terminal in Korea for POSCO

POSCO of Korea is to build a 1.7 mta LNG reception terminal at Gwangyang, which is due to come into operation in June 2005. There will be two storage tanks each of 100,000 m^3 capacity, and marine facilities able to receive 138,000 m^3 ships. The main construction work will be undertaken by Daelim Industrial, and the port construction will be handled by Daewoo Engineering and Construction.

South East Asian LNG suppliers cooperate

At the end of October Brunei National Petroleum Co., Petronas of Malaysia, and Pertamina of Indonesia signed a memorandum of understanding on cooperation in LNG transportation, plant capacity and LNG supply. The agreement is intended to help them deal with the spot LNG market and the increased flexibility on deliveries required by long-term customers in Japan and Korea.

Pertamina is asking Petronas and Brunei LNG to help cover a shortfall of 3 to 5 LNG cargoes from the Bontang plant that have to be supplied to Korea Gas Corporation by December. The shortfall is due to a temporary reduction in gas supplies from TotalFinaElf's Tunu and Peciko fields offshore, caused by temporary shut ins while new wells are brought on stream and compression facilities installed, and the need for repair of some pipelines.

Domestic demand for Indonesian LNG

Pertamina has acknowledged the need to seriously consider domestic demand for LNG. Some Indonesian fertilizer and petrochemical companies are facing shortages of feed gas. PLN, the Indonesian state electricity company, is interested in purchasing LNG from the Tangguh project to help supply rising demand for gas-fired power generation on the islands of Java and Bali.

Change to marketing of Indonesian LNG?

Indonesia is considering how it should best expand and market its LNG supplies to meet future potential requirements of both overseas and domestic buyers. Pertamina is seeking Government approval to once again take sole responsibility of marketing LNG from Indonesia. Previously, BP has taken the lead on marketing LNG from Tangguh, but the project now proposes a Tangguh Marketing Board, comprising BP, Pertamina and BG. The Government may set up a single entity for marketing Indonesian LNG (similar to Australian LNG).

Recently, Inpex Corporation of Japan has announced a major discovery, with more than 4 TCF of gas, in the Masela block in the Timor Sea between Indonesia and Australia. Inpex believes the reserves could support a new LNG export project.

Nuclear power problems in Japan cause extra LNG demand

In September Tokyo Electric Power Company (TEPCO) had to shut down nine of its 17 nuclear power plants for emergency inspections, following revelations of irregularities in reporting of structural faults found in earlier routine maintenance. To help cover the power shortage, TEPCO has increased output from LNG fuelled power plants, and needs to obtain over 1 mt of additional LNG this year. A total of 0.12 mt of LNG was obtained on a spot basis from Oman, for delivery in October and November. Kyushu Electric, Kansai Electric and Tokyo Gas have also helped by reallocating to TEPCO several cargoes - a total of 0.2 mt of LNG - imported under long-term contracts. TEPCO is restarting its idle 175 MW Kawasaki LNG-powered unit. TEPCO is also to bring online in August 2003 a new 380 MW LNG-fired power plant in Shinagawa, 3 months ahead of schedule, and two Futtsu units with a total capacity of 760 MW, over a year earlier than planned.

Chubu Electric Power Co has also secured additional LNG cargoes from its long-term suppliers to make up for a power shortfall caused by the temporary shutdown of its nuclear power plants.

Taiwan Power tries again

Taiwan Power Corporation invited bids on November 5 for a 25-year LNG supply to its planned Da Tang power plant in northern Taiwan. The tender will close in March next year. The selected bidder will need to establish an LNG reception terminal by 2008, and supply an initial 0.69 mta of LNG, building up to 1.68 mta from 2011 onwards. Taipower on two occasions in the past two years has invited bids to supply up to 2 mta, but insufficient bids were submitted to meet the minimum legal requirement. The differences on this occasion are that an extra 4 years have been allowed for construction of the terminal, and the LNG supplier is no longer required to supply gas-oil to the power plant if the LNG terminal is not ready before the power plant starts operation. Meanwhile, Tung Ting Gas of Taiwan, one of the previous bidders, is building a new LNG reception terminal at Taoyuan in the north-west, which is planned to be operational in late 2005. The main contractor is Chiyoda of Japan.

Other news from Japan

- Osaka Gas is planning from March 2003 to reduce the calorific value from 46.05 MW/m^3(st) to 45 MW/m^3(st) of the city gas that it supplies; this will reduce substantially the quantity and cost of LPG which it adds to re-vaporized LNG to control calorific value, and will lead to a reduction in the gas price to consumers.
- Because of falling electricity prices, Tokyo Gas and Shell are to abandon their plans for a joint business to construct a LNG-fuelled power plant in Tokyo and retail power to the Tokyo government, hospitals and offices. Tokyo Gas is still pursuing its own power generation projects, and plans to construct 4 more LNG-fired plants in Chiba and Kanagawa prefectures by 2010.
- The liquid cargo handling business of Niigata Engineering, Japan's leading manufacturer of LNG marine loading arms, is in financial difficulties and is to be acquired by Nippon Sharyo Ltd. and Tokyo Boeki Ltd. They have agreed with Niigata Engineering's business administrators to take over its production facilities at its Nagaoka plant and intellectual property rights.

India - LNG struggling to find markets

The Petronet LNG project is facing difficulties because although it is committed to import LNG from RasGas it has still not agreed sales of the revaporized gas to end customers. It has sought to renegotiate price terms with RasGas, and is seeking Government support. Iffco-Kribhco, the fertiliser combine, is discussing with Petronet its taking of a 20% equity stake in Petronet LNG in return for having direct access to imported LNG.

The Indian Government is preparing an integrated natural gas policy, which will remove the existing price caps on domestically produced natural gas and encourage use of imported LNG. India's Petroleum Ministry has developed a draft regulation that allows sellers to bundle imported gas with cheaper domestic supplies in sales to fertilizer manufacturers and possibly electricity generators. Power and fertiliser companies buy 80% of the natural gas sold in India and these industries face financial difficulties and are unable to pay for imported LNG. Low import duty and local taxes on LNG were also being sought by the Ministry. The full (unbundled) price of gas from LNG to the customer would be about $4-$5/million Btu, based on a cost of LNG imported by Petronet of about $3-4 per million BTU (at crude oil prices of $16-24 per barrel) plus regasification and transportation costs. This compares with current subsidized prices of domestic gas of about $2.5/million Btu. The pooling mechanism would allow Petronet to sell gas from Dahej LNG for about $3-$3.5/million Btu. The pricing proposal appears to disadvantage private developers of LNG projects such as Shell (Hazira) which do not have access to domestic gas supplies, unlike Petronet participants such as GAIL.

In late October Reliance of India reported a major gas discovery offshore India's east coast : over 7 TCF in-place and 4 TCF of recoverable gas reserves in the Krishna-Godavari basin off Andhra Pradesh. The prospect of additional domestic gas supplies in a few years time has called into question the economic viability of some planned future LNG import projects, particularly those on the east coast. However, the Kakinada LNG terminal project (a consortium of Indian Oil Corporation, Petronas and BP) has stated that it would continue with the development of the project.

NWS project signs up to China deal

On 18 October a contract was signed by the six participants in Australia's North West Shelf (NWS) project and representatives of the Chinese buyer for the 25-year sale of 3.3 mta of LNG, starting in 2005. Nine companies will invest in a Chinese Joint Venture Company which, when formed, will be the buyer of LNG received at a terminal to be constructed near Shenzhen, in Guangdong Province. These companies are China National Offshore Oil Company (CNOOC), BP Global Investments Limited (BP), and seven Chinese companies which will buy re-gasified LNG for use in power stations and for pipeline distribution to consumers in Hong Kong and Guangdong. The Joint Venture Company will be formed after the Chinese government has formally approved the project.

On 21 October an agreement was signed whereby CNOOC will acquire 5.56% of the NWS gas reserves, and will take a 25% stake in a new joint venture called China LNG (CLNG), which will own the gas to be processed and supplied to the Guangdong LNG terminal. The six existing NWS participants will each hold 12.5%. CNOOC will pay around $US320 million for its interest in the NWS project. It is reported that CNOOC has subsequently been negotiating to increase its equity stake in the project's gas reserves to around 6%: this increase corresponds to the difference between the final agreed LNG sales volume and the earlier 3 mta on which initial terms were based.

Australia is setting up a AUS$25 million Australia-China Technology Partnership Fund, which would subsidise the training by NWS participants and associated companies of Chinese gas workers through workshops and exchanges.

The North West Shelf's LNG export terminal

CNNOC of China invests in Tangguh

The partners in Indonesia's Tangguh project, led by Pertamina and BP, have signed heads of agreement to supply up to 2.6 mta to a planned LNG terminal at Fujian in China, starting in 2007. There are three production sharing contracts (PSC), and CNOOC have agreed to pay BP $275 million to acquire up to 12.5% in the gas reserves. Before this deal, the PSC interests were BP 50%, Mitsubishi 16%, Nippon 12%, BG 11%, KG (Kanematsu Corp, Japan National Oil Corp and Overseas Petroleum) 10%, and Nissho Iwai 1%. Following wide consultations, Indonesia's Environment Ministry has approved an environmental impact study for the Tangguh project. The project is now expected to invite bids for the LNG terminal EPC contract before the end of the year, and to start construction after the end of the first quarter 2003.

Another Qatargas expansion proposed

TotalFinaElf, which has a 10% stake in Qatargas, has proposed a major investment in a new 5 mta expansion train at the Qatargas plant, with an option for a second expansion train. TotalFina Elf has proposed taking responsibility for marketing the LNG output, part of which would go to its own markets in Europe, and part to other buyers. ExxonMobil are already studying the feasibility of Qatargas expansion trains, with the UK market in mind.

Trinidad plans train 4

The victory of the People's National Movement in the Trinidad elections in early November ended 10 months of political uncertainty following an inconclusive result in the previous election last December. The Prime Minister, Patrick Manning, has publicly stated that he wishes to see higher returns to the country arising from the terms under negotiation with Atlantic LNG for a fourth LNG train expansion.

Increased demand for Shinko LNG pumps

The internals of the Shinko Nishishiba SM type single-stage submerged LNG cargo pump, as displayed on Shinko's exhibition stand at the Gastech 2002 Conference. 100 of Shinko's SM and SMR (removable type) LNG pumps have been supplied for LNG carriers in service, and a further 82 are being supplied in 2003 for LNG carriers being built by Daewoo, Mitsubishi H.I. and Kawasaki H.I. They include eighteen 1650 m3/h pumps for Daewoo, the first of Shinko's largest capacity pumps (model SM350, up to 2000 m^3/h) supplied for operational service. Contact: e-mail hiro-terao@shinkohir.co.jp

LNG Vehicle Fuel News

- Cummins Westport Inc., a joint venture of Cummins Inc. (USA) and Westport Innovations Inc. (Canada), has obtained US$477,000 in funding from the U.S. Department of Energy to improve heavy-duty vehicle fuel pump and storage technology for LNG use in heavy-duty trucks and buses. A goal of the one-year program is to develop and demonstrate an advanced-design integrated fuel tank and pump system for vehicles fueled with LNG.
- Chart Industries' Nexgen Fueling business unit has obtained California Weights and Measures approval for its new LNG fueling dispenser, the only one to be officially approved. It uses a submerged LNG meter, incorporating temperature and density compensation and measurement of methane content.

New Hamworthy KSE pumps

Hamworthy KSE Svanehoj A/S of Denmark has developed a range of LNG cargo pumps that are are claimed to be an economic alternative to the current type of in-tank cargo pumps for use on small-scale LNG Carriers. They are based on the design of the Company's well-known multi-stage deepwell cargo pumps for LPG and Ethylene. They have standard EX motors fitted on the deck of the LNG carrier, thus avoiding power cables penetrating the cargo tanks.

For more information contact : e-mail elindkvist@hamworthykse.com

More LNG from Oman

Tractebel of Belgium announced on 14 November that it has agreed with Oman LNG to buy 0.6 mt of LNG on a FOB basis, with the LNG delivered over an 18 month period from the first quarter 2004 to markets in North America, Europe and Asia. Tractebel will use the LNG carriers Hoegh Galleon (87,000 m^3) and Excalibur (138,000 m^3), which it has chartered. About half of the LNG will go into the Lake Charles LNG terminal : the LNG has too high a heating value to go into Tractebel's Boston LNG terminal. Also, in early November TotalFinaElf of France signed a contract with Oman LNG for the purchase of 0.6 mt (six cargoes) of LNG on an ex-ship basis, to be delivered by the Lakshmi.

The Oman LNG plant is to be debottlenecked, which will increase output by 10% to 7.2 mta. The joint venture Chiyoda Foster Wheeler, EPC contractors for the first two trains, has been confirmed as EPC contractor for the 3.2 mta third train expansion; a $600 million contract is to be awarded. Work is due to start in the first quarter of next year. Negotiations are taking place over participation in the train 3 expansion: Union Fenosa (buyer of half of the output) is likely to take a stake of between 5 and 10%. Oman LNG has been offered an increased stake of 40%, with the Oman Government taking the remainder.

RasGas expands again

On 14 October RasGas signed a heads of agreement with Eni of Italy for the supply of 0.75 mta of LNG to Spain on a FOB basis over 20 years. A sales and purchase agreement is expected to be signed soon. The LNG will come from spare capacity on trains 1 and 2.

The consortium of Chiyoda, Mitsui, and Snamprogetti, EPC contractors for the RasGas II train 3 expansion that started construction at the start of 2002, has been confirmed as the EPC contractors for the Train 4 expansion. Train 4 will be 4.7 mta capacity, like train 3. It is scheduled to come into operation in 2005. J. Ray McDermott Middle East are the appointed EPC contractors for the necessary upstream facilities. Train 4 will supply 3.5 mta for RasGas' 25-year contract with Edison of Italy. The total cost of trains 3 and 4 is reported as $2,400 million. Work is currently being funded from equity, and RasGas II plan to seek about $ 1 billion of project finance in the first quarter 2003.

Nigeria LNG's train 3 starts operating

Train 3, the first phase of Nigeria LNG's expansion of the Bonny LNG plant, has come into operation. The first shipment of LNG from Train 3 is planned to be loaded in December for delivery to Gas Natural at the Huelva Receiving Terminal in Spain. Nigeria LNG is finalizing arrangements for the total of over $2 billion required to finance the Train 4 and Train 5 expansion (the NLNG Plus project). A $800 million syndicated loan is being arranged by Citigroup/ SSSB, BNP Paribas, Credit Lyonnais, Mediocredito and WestLB. Two loans have already been secured : $100 million from the African Development Bank and $160 million from six domestic Nigeran banks. The project partners are contributing $900 million of equity.

Enagas terminals expand again

Enagas of Spain has approved plans for a fifth storage tank, of 150,000 m^3 capacity, and a 16% increase in throughput capacity at its Barcelona LNG terminal. Also, the Cartagena LNG terminal is to be expanded, with a third storage tank, of capacity 130,000 m^3, and an increase in throughput capacity

Egyptian LNG project underway

On October 14 the partners in the Egyptian LNG venture ratified a sales and purchase agreement with Gaz de France who will buy the total output of the first train, 3.6 mta, for a 20 year term on a FOB basis. There was also a participation agreement signed, under which Gaz de France will acquire a 5% equity stake in Egyptian LNG; BG and Edison International will each hold 35.5%, and Egyptian Natural Gas Holding Company and Egyptian General Petroleum Company will each hold 12%. Construction on site started on October 16, under the EPC contractors, Bechtel; a $68.7 million contract has been awarded to a consortium of Mitsubishi H.I. (Japan) and Vinci Construction (France) for the two 140,000 m^3 storage tanks.

BG is continuing to market to potential buyers in the USA and Europe the output from the planned second 3.6 mta train, which would use gas from the Sapphire field.

Diary of events

2003

January 14-15 Course : LNG Training Seminar (LNG Vehicle Fuel), Burnsville, MN, USA (NexGen fuelling. Tel. 1 952 882 5225. Fax. 1 952 882 5172. e-mail kristi.reker@nexgenfuelling.com)

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)

January 23 Seminar : Construction of Gas Carriers and Gas Transportation, Bilbao, Spain (International Trade Fair Bilbao. e-mail apalencia@feriadebilbao.com)

January 28-29 3rd Annual LNG : Economics and Technology, Houston, Texas, USA (SRI. Tel. 1-888-666-8514. e-mail abenedict@srinstitute. com)

March 11-12 8th Asia LNG Markets, Singapore (CMT. Cynthia Yeo Tel. 65 6346 9132. Fax. 65 6345 5928. e-mail cynthia@cmtsp.com.sg)

March 12-14 New Frontiers in LNG Shipping (Conference) and Trends in LNG Shipping Contracts (Workshop), London, UK (GTI, colleen sen : Tel. 1-847-768-0512. Fax. 1-847-768-0842. e-mail colleen.sen@gastechnology.org)

March 12-14 LNG - When East Meets West, Los Angeles, USA (Zeus, Mark Voss, Tel. 1-832-200-3701, e-mail mvoss@LNGExpress.com)

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 11-16 Course : Liquefied Natural Gas - The Commercial Imperatives, U.K. (Institute of Petroleum. Tel. 44 (0)20 7467 7100. e-mail lthwaite@petroleum.co.uk)

May 24-27 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)

October 19-24 Course : Liquefied Natural Gas - The Commercial Imperatives, U.K. (Institute of Petroleum. Tel. 44 (0)20 7467 7100. e-mail lthwaite@petroleum.co.uk)

2004

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

Approval for BG's Italian terminal

On 18 November, the Italian authorities approved BG's planned LNG reception terminal in Brindisi Port, which will receive LNG from BG's Egypt project . The first phase of the terminal, with a capacity of 3 mta, will be constructed before the end of 2006; the second phase will take the total capacity to 6 mta. There have been recent proposals for two more new LNG reception terminals in Italy : a total of eight are already planned. Italian gas company OLT Offshore has signed a preliminary agreement with the city of Livorno to build a 2.2 mta LNG terminal some 15-20 km offshore. Gioia Tauro Oil of Italy is seeking approval to build an LNG terminal in the southern port of Gioia Tauro in Calabria.

Planned LNG terminals in the UK

Lattice Group plc has submitted an application for planning permission to the local authority for the establishment of an LNG reception terminal on its site at Isle of Grain, Kent, on the Thames estuary. The proposal is to install LNG marine reception facilities capable of receiving LNG carriers up to 145,00 m^3 capacity, with a 1 km pipeline to transfer LNG to the four existing 50,000 m3 storage tanks at Lattice's existing LNG peak-shaving installation on the Isle of Grain. Additional vaporizers would be installed to increase total capacity to between 12 and 18 million m^3(st)/day. The terminal could be in operation by 2005.

Petroplus has completed its feasibility studies and submitted an application for planning permission to establish an LNG reception terminal at its site in Milford Haven, Wales.

BP buys LNG for Spain

BP has recently concluded agreements with two LNG suppliers to buy surplus LNG for the Spanish gas market. Abu Dhabi Gas Liquefaction Company (Adgas) has signed an agreement with BP Gas Marketing for the FOB sale of up to 0.75 mta of LNG from the Das Island plant. The agreement runs from January 2002 until March 2005, with an initial volume of 0.3 mta, and an option to extend until 2007. Three cargoes of LNG, totalling 170,000 tonnes have already been delivered under the agreement.

Qatargas has signed an agreement with BP for the supply of 0.75 mta of LNG on a FOB basis over a three period starting in the third quarter of 2003. The LNG will be transported by BP's British Merchant, one of three 145,000 m^3 membrane-type LNG carriers being built for BP by Samsung H.I.; the ship is due for delivery in March next year. Another of these ships, the British Innovator, is to be used on Abu Dhabi LNG trade.

Tokyo 2003 : the 22nd World Gas Conference

The General programme and registration handbook has now been published for the World Gas Conference (Tokyo 2003) to be held in Tokyo, Japan from June 1-5, 2003.

His Imperial Highness the Crown Prince has accepted the position of President of Honour for Tokyo 2003. In June this year, Mr. Hiroshi Okuda, Chairman of the recently established Japan Business Federation, became the Honorary Chairman of the National Organizing Committee of the Conference, with Mr. Kunio Anzai, Chairman of The Japan Gas Association, becoming the Chairman of the Committee.

Tokyo 2003 is held under the auspices of the International Gas Union (IGU), which has ten Working Committees that actively study various sectors of the gas industry. LNG is covered by the Working Committee on Liquefied Gases, WOC3, which is currently chaired by Angel Travesset of Spain. The report of WOC3 will be presented at Tokyo 2003 in two Working Committee sessions, one on liquefaction plants and one on regasification plants; and in three Technology Forums : "safety and environmental management in LNG plants"; "operational know-how in LNG terminals"; and "ageing of LNG import-export installations and its technical countermeasures". Elsewhere in the programme there will be a strategic round-table, "New LNG Markets - Leader's Forum", and a session on "Pipelines vs LNG in developing makets : Competition or cooperation".

As LNG imports are the source of most of the gas used in Japan, LNG will also feature strongly in the parallel World Gas Exhibition at 'Tokyo Big Sight' - the Tokyo International Exhibition Center. The planned area of the Exhibition is 26,600 m^2 and as at October 1 the number of exhibitors already committed was nearly 150, including many big names in the LNG industry.

For further information about Japan 2003, please visit the organizers' web-site : http://www.wgc2003.com, or e-mail-noc@wgc2003.gr.jp , or Tel. +81 3 3502 0620.

Darwin site approved for Bayu-Undan project

On 13 November Australia's Northern Territory Government granted Phillips Petroleum an exceptional development permit for the construction of an LNG plant at Wickham Point, Darwin for the Bayu-Undan LNG project. Before it can proceed, it must await the ratification by Australia and East Timor of the Timor Sea treaty regulating exploitation of oil and gas resources in the region. The outcome may also be affected by the choice of onshore or offshore LNG development options for Greater Sunrise gas in the Timor Sea.

Statoil buys US import rights from El Paso

Statoil of Norway has reached an agreement with El Paso of the USA to acquire its rights to one-third of the LNG import capacity for 20 years at the Cove Point LNG terminal in Maryland. Statoil has also taken over El Paso's 17-year contract to purchase 1.8 mta of LNG, starting 2006, from Norway's Snohvit LNG project, led by Statoil. The price paid to El Paso is $210 million. This deal is claimed to ease El Paso's financial situation, and to be in line with Statoil's strategy to develop its international LNG business and gain access to US markets.

Meanwhile, Statoil has made certain management changes on the Snohvit LNG project, because of a budget over-run of some 7% early in the project. Extra costs are partly due to an underestimate of material requirements for the LNG plant, and partly due to the delay in project start-up. Work is underway at the plant site on Melkoya Island, where a 2.5 km road tunnel is being constructed under the sea o allow easier construction access. The site is to be levelled and a dry dock excavated to receive the barge carrying the process plant.

IHI - stainless steel for cargo containment

IHI Marine United has obtained principal approval from classification societies ABS, DNV and NK for its SPB (self-supporting prismatic-shape IMO Type B) cargo containment system made of stainless steel (SUS 304). Approvals are expected soon from Lloyd's Register and US Coast Guard.

The conventional material for such cargo tanks is aluminium alloy or 9% nickel steel. The advantages which IHI claim for the use of stainless steel are : price competiveness and a more stable material market; weldability comparable to steel; and multi-cargo loading is possible, such as LPG and Ammonia as well as LNG. IHI is to propose the use of the SPB system in stainless steel for offshore floating and gravity-based LNG facilities and for LNG carriers.

Other shipping news

- Mitsubishi Corporation has bought half of Shell's 50% stake in Brunei Shell Tankers; the other 50% is owned by the Brunei Government. Brunei Shell Tankers owns a fleet of seven 75,000 m^3 capacity LNG carriers, operated by Shell International Trading and Shipping Company, which transport 6 mta of LNG between Brunei and Japan.
- The major partners in Greenfield Shipping - Mitsui OSK Lines (40%) and the Oman Government (40%) - have offered to buy the 20% stake held by Shipping Corporation of India (SCI), who want to withdraw from the venture. SCI is seeking Government approval. Greenfield Shipping was originally set up to supply LNG from Oman to the now-suspended Dabhol Power Company LNG terminal, and owns the 138,000 m^3 LNG carrier Lakshmi.
- On October 29 Malaysia International Shipping Corporation (MISC) took delivery of the Puteri Delima Satu, built by Mitsui. This is the second of the six new Puteri class LNG carriers being built in Japan for MISC. A $820m loan, supported by Japan Bank for International Cooperation, has been arranged by six banks, ANZ, Bank of Tokyo-Mitsubishi, Mizuho Corporate Bank, SocGen and Mitsui Banking Corp, to finance these newbuildings.
- ENI of Italy has decided to reduce the size of its shipping business, and is inviting bidders for its fleet of crude and products tankers. The winning bidder will take over long-term technical management of ENI's four LNG carriers : the 40,000 m^3 LNG Palmeria and LNG Elba, and the 65,000 m^3 LNG Portovenere and LNG Palmeria.
- Exmar's first LNG carrier, the Excalibur, was delivered towards the end of October by Daewoo. The ship is chartered to Tractebel.

Samsung's new Panamax LNG carrier

Samsung Heavy Industries of Korea has developed a design of 100,000 m^3 class Panamax LNG carrier with optimized ballast arrangements to achieve the necessary stability at the limited breadth of only 32.3 m. It has membrane-type cargo containment and dual-fuel diesel-electric propulsion This is intended to be of use for transport of LNG from Trinidad and other Atlantic Basin LNG plants through the Panama Canal to future U.S. and Mexican west-coast reception terminals. Previously the largest Panamax LNG carriers were 70,000 m^3 capacity.

Mexican LNG imports

Mexico's Federal Electricity Commission is to invite bids to supply the equivalent of 3.3 mta of revaporized LNG to power plants in north-western Tamaulipas state. The winning bidder would build an LNG reception terminal near Altimira on the Gulf of Mexico, where Shell and El Paso are planning a 6 mta terminal. The environmental agency Semarnat has denied an environmental permit for a 10 mta terminal planned by El Paso and Conoco at Rosarito, near Ensenada in Baja California. Semarnat said that the site violated an urban environmental plan for Rosarito.

Kvaerner Masa's new LNG Carrier Concept

Kvaerner Masa-Yards of Finland has introduced a new design concept for a spherical tank LNG carrier, in which the tank cover extends over all cargo tanks and is an integral part of the hull's longitudinal strength. The design provides an elegant appearance and gives an improved hull form, resulting in 10% less propulsion power. It eliminates the structural disadvantages of large deck openings associated with spherical tanks, and avoids the need for extra thick steel plates and deck strengthening . The weight of steel used is less, and the design is claimed to significantly reduce construction costs and to make more feasible larger size LNG carriers, which will always have a stiff and light construction regardless of size.

The new design, showing the tank position within the integrated cover

Bolivia reviews LNG project

The Bolivian Government have appointed US consultants Global Energy to undertake a study of the proposed project for export of LNG to Mexico based on Bolivian gas reserves. The US Trade Development Agency has given a grant of $386,000 to help fund the study, which will review the whole project scope and costs, and the best option (either Chile or Peru) for the location of a port for the LNG export terminal. The study will be completed by February 23, 2003. Because of this delay, Pacific LNG, the project developer, no longer has an exclusive agreement to deliver LNG to Sempra (US) in Mexico, and alternative buyers are under consideration.

New LNG version of WISE Cargo

A new LNG carrier model has been added to the range of models available for the WISE Cargo Liquid Cargo Handling Simulator. WISE is based on the SafeCargo Liquid Cargo Simulator developed by Ship Anaytics International (USA) with Warsash Maritime Centre (UK). The LNG model is based on a 135,000 m^3 Moss type carrier, with a version for a 138,000 m^3 membrane-type LNG carrier available in December this year. The software enables all operations conducted on an LNG carrier to be simulated in real time, and is designed to run on Windows-based desktop or laptop computers. This training tool is claimed to give considerable cost-savings.

For more information contact : Ray Gillett, Tel. 44 (0) 1983 567608. e-mail pchemx@interalpha.co.uk

US terminal news

- In early October The Federal Energy Regulatory Commission (FERC) gave final clearance to the planned expansion of the Cove Point LNG terminal, recently sold by The Williams Cos. to Dominion Resources.
- On November 20 FERC gave preliminary approval on non-environmental issues to El Paso's plan to expand its Elba Island LNG receiving terminal.
- Senior representatives of the US LNG Industry have urged FERC to review the system of regulation of LNG import terminals in the USA. In particular, FERC's policy of open access LNG terminals was criticized as inhibiting the establishment of new LNG terminals, to the detriment of the industry and customers.
- The U.S. Coast Guard has published in the Federal Register (October 11) proposed new rules governing LNG carriers in Boston Harbour. The proposals are to make permanent the expanded safety and security zones around LNG carriers that have been in place temporarily since the Everett terminal came back into operation following suspension of activities after September 11 last year.
- On 14 November the U.S. Senate approved the Maritime Security Act, which introduces new legislation to increase security of US ports and ships serving them. It also creates a regulatory system governing safety and security of US offshore LNG terminals.

John M. Campbell LNG Courses

Two LNG training courses are scheduled in the months ahead by John M. Campbell & Company (JMC): G-4 LNG - 13-24 January 2003, Southeast Asia - This is the LNG version of the standard G-4 Campbell Gas course. It is directed towards technical, production and processing personnel and has been presented in five of the world's base-load LNG plants.

G-9 LNG Short Course "Technology and the LNG Chain". This course combines LNG technology with information on LNG commerce and the LNG chain. It is being held in three locations : London, UK (25-28 March 2003); Singapore (1-4 April 2003); and Oman (24-27 May 2003). In-house versions of both courses can be scheduled. Information on the full range of Campbell Gas courses is available at www.jmcampbell.com or registrar@jmcampbell.com.

Submarine collides with Norman Lady

On November 13 the US nuclear-powered submarine, Oklahoma City, was in collision when surfacing with the Leif Hoegh's LNG carrier Norman Lady in the straits of Gibraltar. The Oklahoma City sustained damage to its periscope and control tower. The Norman Lady suffered some dents in the outer hull below the water line, with minor cracking allowing leakage of seawater into the double bottom of the hull structure. The Norman Lady was in ballast while sailing from the Barcelona LNG reception terminal to Trinidad. There were no casualties nor environmental hazards. As at November 20 the Norman Lady was at anchor off Gibraltar while being gas freed prior to sailing to dry dock in the region.

New technology facilitates small-scale LNG production

Kjartan Skeie and Inge L. Nilsen, ABB Gas Technology AS, Norway

There are a large number of potential uses of LNG produced on a small scale. In order to improve the economics of specific applications, ABB and SINTEF have developed a lower cost, more efficient mixed refrigerant liquefaction process for plants under 20 tonne/day

Applications of Small-Scale LNG Production

Low cost and ease of operation are the main benefits from a new small-scale LNG plant developed by SINTEF Energy Research AS and ABB Gas Technology AS (ABBGT). The key to reduced costs is the use of standard components and a modular design.

Small-scale production and transportation of LNG can be particularly feasible in areas where natural gas is available, but where pipeline gas distribution to remote areas is not economically favourable. Such concepts typically involve low-capacity liquefaction units, simple storage facilities, and road- or sea transportation of the LNG product to industrial areas or to one or more remote communities.

The use of LNG as fuel for vehicles is growing worldwide, and the need for LNG fuelling stations is increasing. Small-scale LNG technology is well suited for this application, as it can be installed directly at such facilities, connected to a domestic gas grid.

The use of LNG as fuel for vehicles is growing worldwide, and the need for LNG fuelling stations is increasing

LNG evaporating from the cargo tanks of LNG carriers is traditionally used as fuel to run the steam propulsion system. In the shipping industry there is a tendency to move from steam propulsion systems to diesel engine systems. This makes it interesting, both from an environmental and an economic point of view, to use a small-scale LNG plant to recover boil-off gas from the cargo tanks.

Other applications are re-liquefaction of boil-off gas and displacement gas from large LNG storage tanks and the recovery of associated gas from production and refining of oil and gas.

Traditionally, the relatively small number of low-capacity plants built have been based on modified base load designs or nitrogen turbo expander cycles. This causes relatively high engineering costs and involves expensive equipment such as plate-fin heat exchangers and turbo machinery. In

Figure 1: Small-scale LNG pilot plant

Process description of small-scale LNG plant

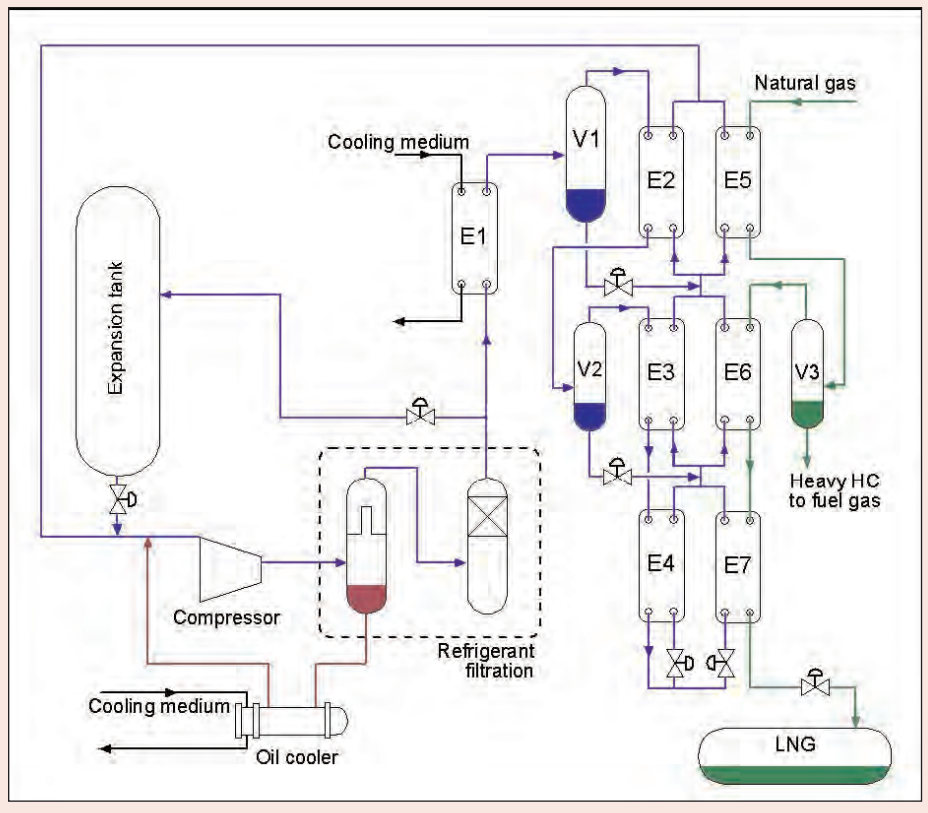
Compressed refrigerant is partly condensed by heat exchange with air or a cooling medium (E1) and gas and liquid are separated in V-1. The vapour is cooled and partly condensed in heat exchanger E2, while the liquid flashes across a level control valve before being mixed with the cold refrigerant stream from exchangers E3 and E6. The pressure drop across the level control valve is associated with an instantaneous temperature drop (known as the Joule-Thomson effect). Along with the cold refrigerant stream from exchangers E3 and E6, the flashed liquid provides the refrigeration duty to exchangers E2 and E5.

The partially condensed refrigerant leaving heat exchanger E2 enters separator V-2. The vapour leaving V-2 is further cooled and condensed in exchanger E4 and sub cooled in exchanger E6 prior to throttling to a low pressure resulting in an instantaneous temperature drop, giving refrigeration duty to heat exchangers E6 and E7. The cold refrigerant streams from heat exchangers E6 and E7 are then mixed with the liquid phase from separator V-2, which has been reduced in temperature due to the pressure drop across the level control valve. The refrigerant flow is then distributed to heat exchangers E4 and E5.

The natural gas is pre-cooled in heat exchanger E3, condensed in E5 and sub cooled in E7. For most sales gas qualities removal of the heavy fraction of the gas is needed in order to avoid freezing of heavy components in the natural gas condenser and sub-cooler. Depending on the amount of heavy components in the feed gas, these must be removed upstream of the condensation section. Further removal of C2+ can be facilitated by a simple separator (V-3) installed downstream of the natural gas heat exchanger E5. The liquid phase from this separator can typically be evaporated and used as fuel for a gas engine or a gas turbine used for power generation, or for heat generation.

During normal operation the low-pressure mixed refrigerant leaving heat exchangers E2 and E5 is pure gas containing no liquid droplets. Any unforeseen liquid entrainment will be separated from the gas in the compressor suction line accumulator (not shown on the simplified process flow diagram). This pot protects the compressor by keeping the flow of liquid entering the compressor well below acceptable limits. During compression the gas temperature will increase to about 85 °C, and virtually no refrigerant can accumulate in the lube oil system.

At base load plants, using mixed refrigerant, a shutdown normally causes refrigerant to be vented to avoid over pressurizing the system as liquefied refrigerant evaporates due to heat input from the environment. As refrigerant is lost it might take a long time before the plant is stable again, and on-off operation is no option. The new small-scale LNG plant therefore includes an expansion tank in order to avoid over pressurizing the refrigerant circuit due to shut down. As no refrigerant is lost, on-off operation



Simplified process flow diagram

is possible. This is a feature primarily seen only on nitrogen expander cycles.

The expansion tank is designed not only to avoid over pressure, but also to keep the pressure low enough for the refrigerant to be in the gas phase after plant shut down. This makes start-up and stabilisation of the plant easier, and a start-up time of approximately 1 hour has been demonstrated.

Removal of CO_2 and water from the feed gas is required in order to avoid freezing in the condensation and sub cooling section. The technology of choice for gas pre-treatment will depend strongly on feed gas quality and site infrastructure. Molecular sieves and amine systems are the most likely alternatives. Mercury and small amounts of sulphur can be removed on impregnated activated carbon or other metal oxide processes. ■

addition, most small-scale LNG plants have not been very energy efficient, typically between 0.6 and 1.0 kWh/kg LNG produced. Due to this the relative investment costs for small-scale LNG liquefaction plants increases significantly with decreasing production capacity.

The new technology is intended for production capacities well below 100 tonnes LNG per day, more likely in the range of 2 - 20 tonnes per day. It is focused on low investment costs and high energy efficiency. The power consumption will typically be between 0.5 and 0.6 kWh/kg LNG produced.

The Liquefaction Concept

The liquefaction concept was developed and patented by SINTEF Energy Research AS. A co-operation between SINTEF Energy Research AS and ABBGT was established for further development, and a licence agreement was signed. Through this agreement ABBGT is licensed to commercialise and sell the concept worldwide.

The new natural gas liquefaction concept is based on the use of standardised refrigeration components such as oil lubricated screw compressors and copper brazed heat exchangers. By using "off-the-shelf" equipment and a high degree of standardisation and modularisation, a low-capacity liquefaction plant can be built and installed at significantly lower costs than for conventional technology.

Oil lubricated screw compressors are commonly used in refrigeration service due to outstanding robustness and low investment costs. These machines are easily available for the duties relevant to low-capacity LNG plants, and the investment costs are about one third of the costs for turbo machinery of similar capacity. By proper separation and filtration/adsorption the challenge associated with lube oil carryover and entrainment is overcome, and the technology can safely be suited to cryogenic service.

Copper brazed plate heat exchangers show superior temperature approaches and are well suited for boiling and condensing fluids. By configuring the exchangers in a cascade, many of the features of a multiple stream plate-fin exchanger can be achieved. Combined with a mixed refrigerant based on nitrogen and hydrocarbons, high energy efficiency can be obtained.

Pilot plant

Figure 1 shows a pilot plant designed for liquefaction of 50 kg/h of natural gas that is built and installed in the test laboratory of SINTEF Energy Research in Trondheim, Norway. The design is identical to the full-scale design as described above. During the test periods, methane has been liquefied, and the tests have provided valuable input to the design of the full-scale plant.

Cost-effective modularised plant

A fully automated plant with 100% integrity and unmanned operation will provide a cost-effective solution for several applications in remote areas. Unmanned operation and simple on-off operation is also advantageous on sites with existing processing facilities, as the new unit can easily be monitored and controlled with a marginal amount of additional resources.

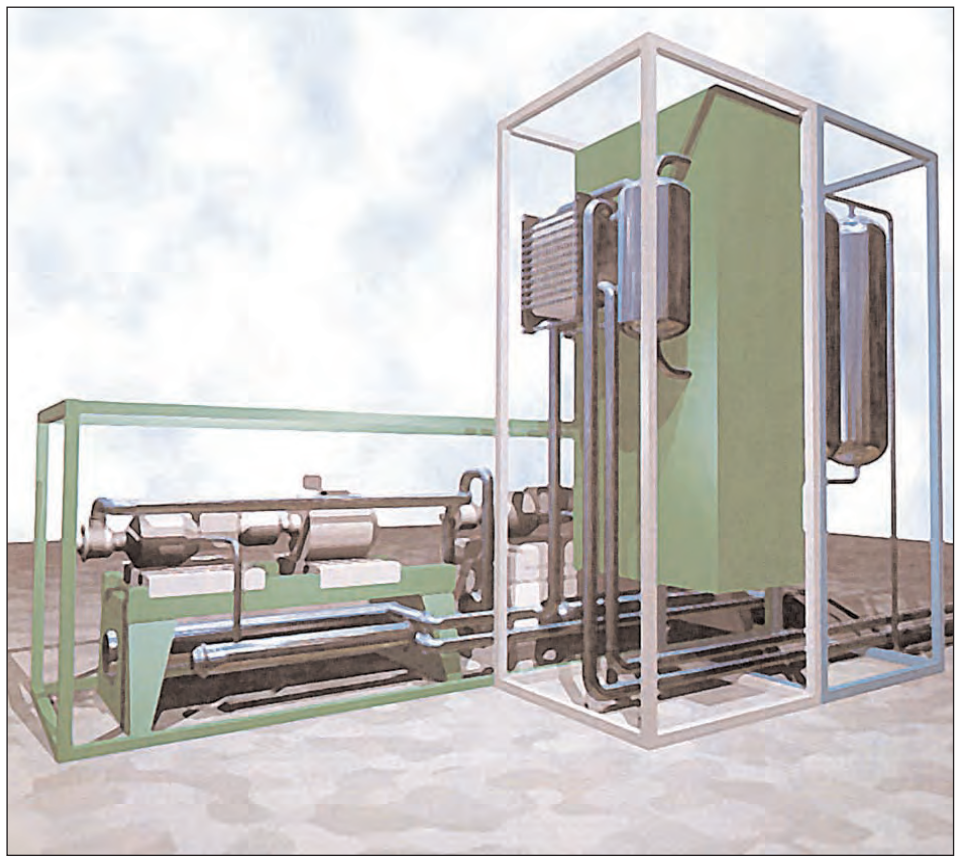


Figure 2: Typical plant layout for the cold box and the compressor skid

Standardisation of the plant layout and comprehensive use of modularisation will facilitate low purchasing costs as well as reduced installation costs. It is thus intended to supply the liquefaction plant, including feed gas pre-treatment, as standard capacity units. This will minimise engineering costs and thus purchasing costs.

The condensation unit will be constructed as a cold box containing the heat exchangers and the gas-liquid separators. The box is filled with a suitable insulation material. A slight overpressure with nitrogen avoids air getting into the cold box. The module will also contain the expansion tank, refrigerant filter, refrigerant cooler and the first refrigerant liquid separator. The refrigerant compressor will, due to the size and weight however, be supplied as a separate skid-mounted unit. A typical layout of the cold box and the refrigerant compressor skid is shown in Figure 2.

Standardisation of the plant layout and comprehensive use of modularisation will facilitate low purchasing costs as well as reduced installation costs

As for the condensation unit, the use of conventional packaged systems of standard capacity will minimise costs and simplify installation for the pre-treatment unit.

The estimated investment costs of a small-scale LNG plant with a production capacity of 50 tonne LNG/day is potentially 30 % less compared to plants of the same size based on conventional technology. The estimate includes pre-treatment and condensation units. ■

Kjartan Skeie is a Process Engineer with ABB Gas Technology AS, Bergen, Norway. He has been working in developing small-scale LNG technology, with other LNG projects in Norway, and with gas processing and VOC recovery. He has an MSc in chemical engineering from the University of Bergen, Norway.

Inge L. Nilsen is a Senior Process Engineer with ABB Gas Technology AS, Bergen, Norway. His background includes natural gas processing, gas purification and combustion engineering. He received an MSc in mechanical engineering from the Norwegian Institute of Technology, Trondheim, Norway.

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Fieldbus Technology for the LNG Process - A Viable Option?

David S. Lancaster, Bechtel, USA and Brian Parkes, Bechtel, UK

Fieldbus is a new, fully digital control system technology. One of the leading EPC contractors explains the potential benefits and implications of its use in LNG process plants

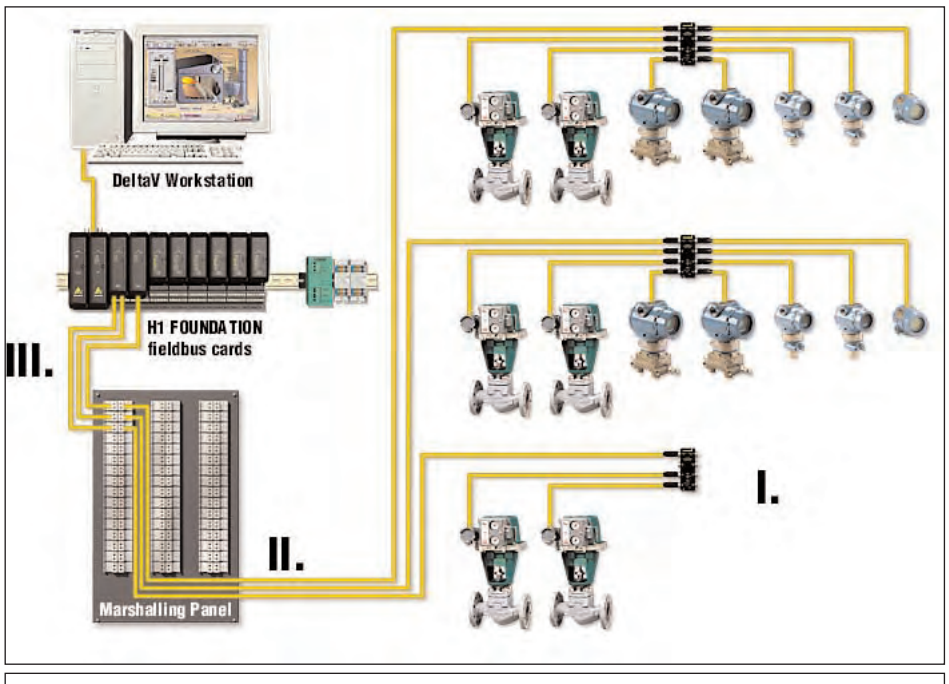
Recent developments in control systems and field instrument technology have created opportunities to review the basis of process control design philosophies required for LNG plants. Fieldbus is a fully digital technology that connects field measurement and host control equipment via a serial, two-way communications system. It offers potential paybacks in the form of reduced life cycle costs with savings in installation, commissioning, maintenance and improved access to information.

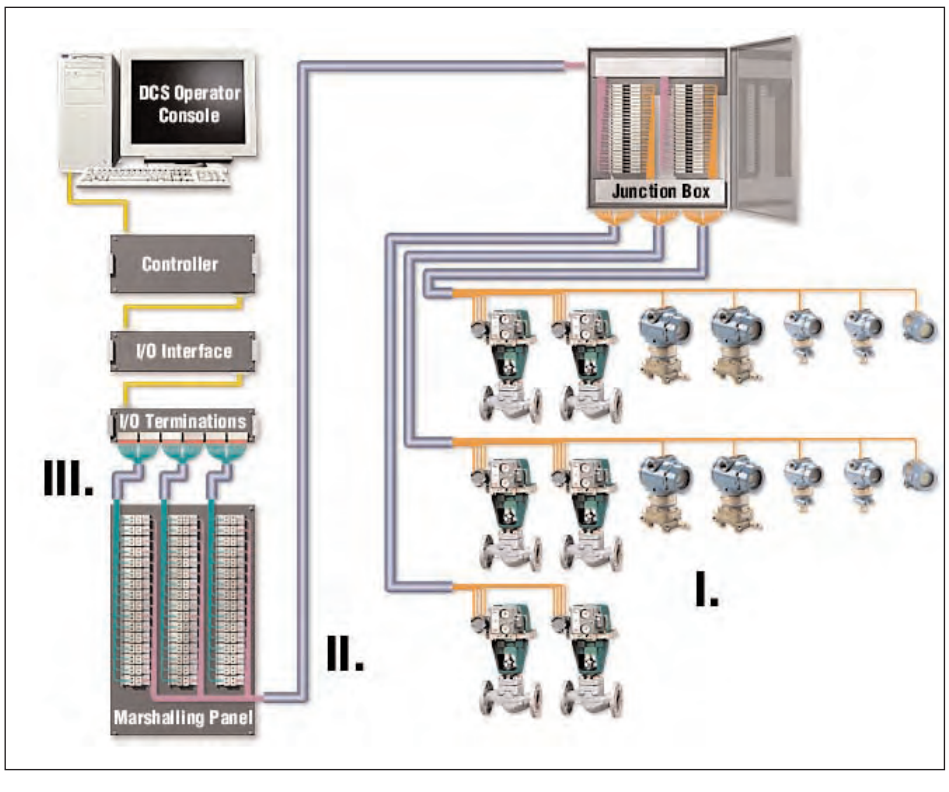
For process control applications two main Fieldbus technologies have evolved that dominate the process control industry, PROFIBUS PA and Foundation Fieldbus (FF). PROFIBUS PA has been implemented widely in Europe, however FF is rapidly gaining acceptance worldwide with control system and instrumentation manufacturers positioning themselves for the demand in product functionality.

The Oil, Gas and Petrochemical industries have been slow to realise the economic and enterprise benefits of FF. However, the level of advancement has been dramatic over the past two years with more and more Owner/Operators now realising the longer-term benefits. With the maturing of the developing Fieldbus technology and its greater acceptance in the marketplace, Engineering and Construction Contractors are rapidly gaining expertise and incorporating Fieldbus engineering, design and installation experience into their portfolio. Teamwork involving Owner/Operator, E&C Contractor, and the Vendor is key for successful implementation of Fieldbus on projects.

Until recently, the concerns about safety and reliability of a new technology in LNG process applications have been of concern. Given the current status of the technology and the broad base of successful installed systems, these concerns have been alleviated and in fact, with predictive maintenance capability, Fieldbus can add to the overall reliability of the Control System. The benefits to the Owner/Operator therefore, offer significant reasons to use Fieldbus technology in the LNG process.

Figure 1 : Comparison of Typical Architectures - Above : Foundation Fieldbus, Below : Conventional





Why Fieldbus?

The same question was probably asked when electronic transmission began to replace pneumatics. The answer is also probably the same: technology opens new horizons that cannot be realised if it is not implemented.

We live in a digital world. All around us is the application of digital technology and without it we could not enjoy the benefits of modern living. Implementing Fieldbus technology adds new horizons to the business domain. Control methodologies, engineering implementation, business integration, and information availability all become easier and more flexible, which can reduce Life Cycle Costs.

The methods for control strategies available to the engineer become more numerous, more varied and easier to implement. For the Owner/Operator, there is now a wealth of information available throughout the enterprise that can be used as knowledge to optimise the process, and for predictive maintenance and information management applications to add value for strategic advantage.

Is Fieldbus safe, reliable and suitable for LNG?

LNG projects take anywhere from 5 to 10 years to implement from conception to operation, so any decision at the conceptual stage should take into account the rapidly progressing and expanding Fieldbus technologies for control systems. Any Fieldbus implementation for LNG plants must take into consideration the unique requirements for this type of plant. Aspects that need to be considered are:

1. Is Fieldbus safe? Safety is paramount in the LNG process. Fieldbus promises safer, and robust microprocessor technology hardware with the application of computerised quality control standards for manufacture. Fieldbus uses well-established techniques for design and certification for instrumentation in hazardous area locations, which have proved in the past to be acceptable and safe for conventional electronic analog instrumentation.

2. Is Fieldbus reliable? Fieldbus by its nature relies on a bus for communication with the central control system (host). Failure of a bus segment can result in failure of all devices on that segment. This is an area that is of concern to all control technologists. However with duplication of power supplies and Host interface cards the issue becomes less of a problem. Concerns with field termination, short circuit protection and surge suppression have been addressed. With Foundation Fieldbus, the use of back up Link Active Schedulers and "control in the field" allows continued operation of the field loops without any interruption when there is a communication failure between the network (or segment) and the Host. Also, for critical applications, duplicated instrumentation and duplicated bus segments can be considered as a final solution. Diagnostics of course allows the monitoring of the state of the device and the implementation of predictive maintenance, which will enhance reliability and decrease spurious plant trips and plant downtime.

3. Is Fieldbus ready? Although Fieldbus continues to be developed, the technology has been put to use at many operating facilities in the Petroleum and Chemical Industry. It offers easy expandability and a digital environment with the opportunity for a Total Solutions Concept to plant design. Fieldbus products include smart instrumentation, cable connection systems, segment design tools and Host systems that can manipulate and present the measured information.

4. Where can Fieldbus be applied? There are many types of instruments that are fieldbus ready including analysers, pressure, flow, level, temperature transmitters, valve positioners, multivariable transmitters, Coriolis, Ultrasonic and Swirl flow meters, with more continually being added to the list. Fieldbus encourages the move away from switches (pressure, flow, level, temperature, valve position) to transmitters for the benefits that bus technology can offer, with fewer instrument types and less unique spares. The diagnostics and information at the instrument that are available will allow greater predictive maintenance and loop performance in critical areas such as JT valves and heat exchangers.

Fieldbus is finding applications in most industries for continuous, discrete and sequential control. It is being used for Intelligent Motor Control Centers but is not currently accepted for use in Safety Systems, Fire & Gas Systems and special package control systems such as Gas Turbine controls, Anti-surge compressor control systems, performance controllers and Machinery Condition Monitoring systems. In the short term these systems can still be integrated into the main control system and in due time there will be a trend to use Fieldbus for them.

There is a move by Owner/Operators to integrate package control systems into the Main Plant Control System. This involves more effort during design; how-

ever it moves the Plant Control System closer to a Total Solutions Concept with all the advantages that this offers. If Fieldbus is being considered for packages then it should be looked at from all aspects to ensure that the benefits provide the justification. Forcing package Vendors to revise their standard design in order to use Fieldbus may not be technically or economically justifiable.

5. Will it last? Fieldbus enables the collection of total process plant data and if this data is used to convert into knowledge, then a true understanding of the operation and behaviour of the process can be gained and used for life cycle benefit. It enables thorough diagnostics, pre-incident information and more efficient plant maintenance. It enables control to be distributed in the field allowing faster loop control, enhanced control strategies and knowledge-based decisions for plant operation. It is a technology that will continue to be developed for many years to come. Safety and reliability will continue to be featured high on the manufacturers' agenda and on the list of User requirements. Manufacturers will be driving for cheaper solutions with greater plug and play functionality.

Fieldbus considerations and options

In general, for projects where Cost of Ownership (Life Cycle Costs) and a harsh or remote environment is of concern there could be maximum benefit from the implementation of Fieldbus technology with functionality such as remote diagnostics, predictive maintenance, Internet connectivity and remote reporting technology providing the opportunity to drive down long-term costs. From the Total Installed Cost point of view alone, it can be more complex to make a case for the use of Fieldbus technologies, due to variables such as the requirement for additional engineering, cost of smart instrumentation, software licenses and wire and cable systems.

Figure 2 : Comparison of 256 I/O Equipment - Left : Conventional, Right : Foundation Fieldbus

How does Fieldbus affect Front End Design?

The important design decisions made at the Front End of the project ensure that the Owner/Operator and E&C Contractor have a common expectation of the project scope and deliverables, and that detail design has a firm foundation for progress. Of the many variables to be considered of primary importance is the functional specification, which will be used as a basis for the selection of the Host System.

A successful Fieldbus project depends on the following:

- Education of all parties involved in the design, construction and operation as to the advantages, disadvantages and constraints of Fieldbus systems
- Early definition of
  - documentation requirements (P&IDs, wiring, loop or segment drawings,etc.)
  - Host system requirements and selection
  - the control philosophy (location of PID function, cross segment communications, etc.)
  - third party equipment interface requirements (indication/control redundancy requirements (controllers, communications, power supplies and sources, etc.)
  - wiring methodology (including topology used, wire types and termination requirements)
  - field instrument requirements and function block capability
  - field instrument locations (segment design)
- Appropriate training for engineering, construction/start-up, operations and maintenance personnel
- Host approved listings for third party interoperability for third party field instruments
- Alarm management requirements
- Device alert requirements and associated configuration
- Early agreement on FAT/SAT procedures (different methods for different Fieldbuses)

Other engineering disciplines' input and work methodology would be affected. The successful Fieldbus project requires careful consideration of electrical control and indication requirements, HAZOPs issues, documentation requirements, and maintenance requirements/expectations, among others.

The key issue in the Front End Design is that the expectations and assumptions of all parties match. The availability of options is much greater than with conventional systems. Therefore, scope agreement and detailed specification development is vitally important for bidding purposes, especially for Lump Sum, fixed price projects.

How does Fieldbus affect Detailed Design?

The use of Foundation Fieldbus requires more detailed design earlier in the project. The biggest change is to develop the segment design at an early stage to facilitate the enquiry for the Fieldbus system. It requires a definition of the necessary field instrumentation and the location for these instruments, which is required to carry out the necessary analysis of the segment.

Another significant issue is the impact of a Fieldbus design on HAZOPs and reliability calculations. Although the safety systems remain unaffected by the use of Fieldbus technology, the basic process control system does not. There are new "what if" scenarios to be considered when it comes to segment loading, "control in the field", redundancy and communications in general. Many of these issues do not exist with conventional instrumentation. It will become necessary to analyse segment design failure on the control system from a safety and reliability perspective and conduct alarm management reviews to ensure that alarms are necessary for efficient plant operation and prioritised for reporting.

Changes are all too common to the instrumentation design resulting from process additions/ deletions, mechanical packages and changes to the P&IDs. These changes will have a major effect on the Fieldbus system design if the design methodology does not take account of change management. The benefits of a Fieldbus system are that it can be easily expanded. This advantage has to be used to maximum effect when designing it.

Effects on construction and commissioning

Fieldbus is based on the segment/network concept with the ability to also use remote I/O in the field. These concepts can have a significant effect on Construction and Commissioning strategies and schedules. Construction schedules can be reduced because Fieldbus is simpler and easier to install and commission. Savings in the following areas may be realised:

- The overall cable and wiring scenario could be less with fewer or smaller multiconductor cables from fewer field junction boxes to the main control room. Depending on the field cable system selection there could be fewer wiring terminations and more plug and socket connections. There could be less cable trenching and smaller main cable tray sizes.
- There should be less system hardware and therefore smaller control equipment buildings.
- Low power devices coupled with less equipment could lead to smaller HVAC in buildings and smaller UPS systems.
- The use of windows technology and remote diagnostics facilitates loops to be commissioned faster with little need for conventional point to point wiring checks.

The Fieldbus approach is different and if maximum benefit is to be gained suitable training and familiarisation must be provided for construction and commissioning teams so that they can understand the concepts and gain maximum advantage from the new technology. The Fieldbus Supplier should be fully involved during construction, checkout, commissioning and start-up, as well as during the engineering phase.

Construction and commissioning may take less time; however, this could be offset to some extent because the design for a Fieldbus system may take longer. Construction and commissioning strategies should take this into account possibly delaying instrument installation as late as possible when the plant is at a more complete state of readiness.

The Owner/Operator and Fieldbus Supplier will be key to the system completion and acceptance. Involvement by the Owner/Operator at every stage of

design/construction and commissioning will reap benefits for engineering, maintenance and operations with associated Life Cycle benefits.

Maximise contractor and supplier experience

From the User perspective, the emphasis should be to identify and document achievable goals and expectations for the use of Fieldbus technology on the project and its control system. A thorough understanding of potential Host systems and field instrument capabilities is required for a successful project.

Foundation Fieldbus seeks to offer the same sourcing strategies as traditional analog systems with the interoperability concept, which enables field instruments from different Suppliers to be compatible with other Suppliers' Host systems. Interoperability is certified by the Foundation Fieldbus organization and is manifested on the instrument as a tickmark-approved product. The preferred approach is to appoint a Main Instrument Vendor (MIV) that is responsible for supplying the complete instrument system including field devices. The technical expertise of the MIV can then be used to benefit the final system design. This approach naturally offers single point responsibility for the Fieldbus system operation and guarantee.

Effect on project and delivery schedules

Traditional DCS systems relied heavily on hardware. Configuration required specific system knowledge and implementation relied heavily on Supplier expertise. Fieldbus shifts the scales so that hardware becomes less critical and the skills required are software related to system integration and configuration.

Fieldbus technology would not apply to Safety Related, Machinery Condition Monitoring, Anti-Surge Control, Gas Turbine Control, Fire and Gas systems. Although technology is advancing in these areas, integration of these systems offers the best solution.

During detailed Engineering additional effort will be required for implementing Fieldbus. System hardware utilises industry standard off the shelf products to a large extent. The deliveries of these are not critical. However the major effort is in the engineering, configuration and interface design with third party systems.

Depending on the Host system selected, the reliance on proprietary Supplier systems for the configuration and control strategy development has significantly decreased. This allows more freedom to produce the design and to some extent, control strategy and third party interface verification, in a "desktop" environment, independent of the hardware schedule.

By integrating the MIV with the Design Contractor's efforts, the schedule for the engineering and configuration can be dovetailed to the overall project design schedule.

Effect on CAPEX

The most important decision relating to CAPEX that the User has to make relates to a "Total Solutions Concept" (TSC). The TSC relates to all the control and monitoring systems and the definition of digital functionality with all the consequential benefits relating to measurement and control. The TSC will propel the User to consider the following that will reduce or increase CAPEX in the implementation of Fieldbus technologies:

- For maximum benefit they have to be considered for a true fully digital architecture.
- They are developing rapidly and execution strategies at design must be driven by the required functionality to achieve lower implementation costs.
- They can result in less hardware, and reduced cabling, control building, HVAC, UPS, installation, commissioning, training, and spares, thereby reducing the overall CAPEX.
- Different strategies have to be considered for system definition, system Supplier selection, engineering design implementation, change management and construction/commissioning.
- New opportunities are opened up for use of smart field instrumentation with new considerations for Intrinsic Safety and the use of Fieldbus components for cabling and wiring connections, all of which will lead to higher CAPEX.

Without a definitive analysis it would be difficult to quantify a cost impact of using Fieldbus. However, an overall CAPEX reduction would be expected (or at least be cost neutral) provided a structured approach was taken with project development changes made in the early life of the project as opposed to later after engineering and Fieldbus system design is well advanced.

Effect on OPEX

When considering operational expenditure, account must be taken of not only the direct costs but of the hidden lifetime benefit costs of using Fieldbus. Identifying the direct costs should not be difficult; these are encountered with conventional control systems and include labour, operational, maintenance, support, management, and consumable costs, etc. The lifetime benefit costs are not so easy to calculate and can be considered to best support the operations and maintenance philosophy of minimum maintenance, high system integrity and minimum intervention.

Fieldbus has prompted Host systems to use windows technology with drag and drop principles for set-up and configuration. Training is easier as a result, and utilisation of database structures offers data manipulation for easier analysis and presentation. The use of windows technology will require less system specific training, easier system configuration, less maintenance, greater flexibility, and fewer, but highly competent employees.

Fieldbus has brought about the concept of Asset Management, which enables the optimisation of OPEX costs with a focus on efficiency, reliability, safety and availability, and offers the toolset for analysing and monitoring the data that digital Fieldbus systems make available. When coupled with an "Open Architecture" Host system, communications with Owner/Operator business systems becomes much easier, making more information available to the enterprise, which can be utilised for cost saving strategies.

Fieldbus has enhanced the concept of diagnostics for definitive operation and maintenance, providing an expanded view of the process for the operator and reduced maintenance through predictive strategies. Diagnostics are a direct consequence of the data available from Fieldbus field instrumentation devices. Device and process diagnostics, and trouble shooting, all become realisable benefits for operations, maintenance, engineering and management.

Fieldbus provides more information that leads to the concept of a more expanded view of the process, which results in better knowledge for control, monitoring and alarm management possibilities. More data gives more information enabling reduced process variability, closer control and better process availability.

Fieldbus is reliable and accurate resulting in reduced spares usage and increased plant uptime. It provides a digital environment with plug and play functionality and inherent documenting facilities. Adding and deleting to a Fieldbus system should therefore be easier, quicker and simpler. ■

The benefits of a Fieldbus system are that it can be easily expanded. This advantage has to be used to maximum effect when designing it

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Speeding the Growth of LNG

Harvey Harmon, El Paso Global LNG, USA

El Paso describe the resurgence of the North Amercian LNG market; existing and potential future U.S. LNG reception terminal activities; and their new Energy Bridge floating regasification system

The worldwide LNG business is expanding rapidly and has become one of the fastest growing markets in the global energy industry. LNG industry growth in the nineties was about 7% annually. Projections for continued growth in the LNG market are exceptionally bullish. Some forecasts have predicted the total market's compounded annual growth rate between the years 2000 and 2007 to be as much as 10 percent, with corresponding incremental volume growth over the same period of 12 billion cubic feet per day (Bcf/d), equivalent to about 90 million tonne per year.

Figure 1: Elba Island, Georgia

The key driver for growth in the LNG business is the choice of natural gas as the favored fuel for power generation. This is producing a huge increase in global gas demand, an increase that cannot be met by traditional supply sources. This demand growth has resulted in a reexamination of non-traditional supply sources and a corresponding increase in the number and variety of LNG projects.

Perhaps as importantly, the market structure of the LNG business has changed dramatically in the past decade. New players like El Paso have entered the sector, resulting in increased competition. New technologies have decreased the cost of the LNG delivery chain. Increasingly sophisticated approaches to identifying and exploiting embedded optionality and managing risk have introduced liquidity into the marketplace. These forces are causing a restructuring of worldwide LNG activities similar to those caused by deregulation in North American energy markets. The development of a growing LNG spot market in recent years is just one example of the effect of this worldwide restructuring.

North America: the re-emergence of a market

LNG is not a newcomer to North American shores. The LNG option has been available as a component in the continent's supply mix for many years. What's changed to cause LNG's new attractiveness? A confluence of factors is helping to push LNG to the forefront as a viable supply alternative in North America.

U.S. demand for natural gas continues to increase. In the second half of 2001, prices were lower due to mild weather and a weaker U.S. economy combined with reaction to September 11th. Last winter was the 5th warmest winter on record. In fact, the November through January period was the warmest for 123 years of recorded data. In spite of that, natural gas demand and prices are up in 2002 compared with 2001 due to the new demand for gas-fired power generation, which itself is driven by the demand for more electricity.

Natural gas has become a preferred fuel for electric generation for several reasons. Considerable regulatory pressure continues to be exerted toward reducing pollution such as nitrogen oxide (NOx) and carbon dioxide (CO_2), particularly for electric generators. Natural gas is a much cleaner fuel than coal or oil with regard to both of these pollutants as well as sulphur dioxide (SO_2). A new gas-fired combined cycle plant can be built for less capital and less time than a similarly sized coal plant, which improves the economics of the gas-fired facility. As a result, more than 91% of the power projects under development in the U.S. will use natural gas as a fuel. Last year there was 404,000 MW of new U.S. power plants under development compared to the total installed U.S. capacity of 805,000 MW in the year 2000. Even if only one third to one fourth of the planned capacity is built, the incremental amount of MW developed will be a huge number. In a recent report a leading consultant projected a total of 115,000 MW will be built during 2002 and 2003.

This huge jump in the demand for natural gas to fuel electric generation is increasing the stress on domestic supply sources. Historically, North American supply, including the United States, Canada, and Mexico, has remained relatively flat since 1995, with production hovering around 71 to 72 Bcf/d. Significantly, production output has not budged despite dramatic increases in the gas-directed rig count over the past five years. Many North American producers are running on a supply "treadmill." As basins have become more mature, more wells are needed to keep deliverability at the same level. Average active gas drilling rigs in the United States have moved from lows in the early 1990s of about 350 to highs of nearly 950 in 2001 while production has remained at or slightly above 50 Bcf/d. Against the backdrop of this steady-state supply history, demand is projected to soar. The Cambridge Energy Research Association predicts U.S. demand rising from levels of 71 Bcf/d in 2000 to over 90 Bcf/d in 2010.

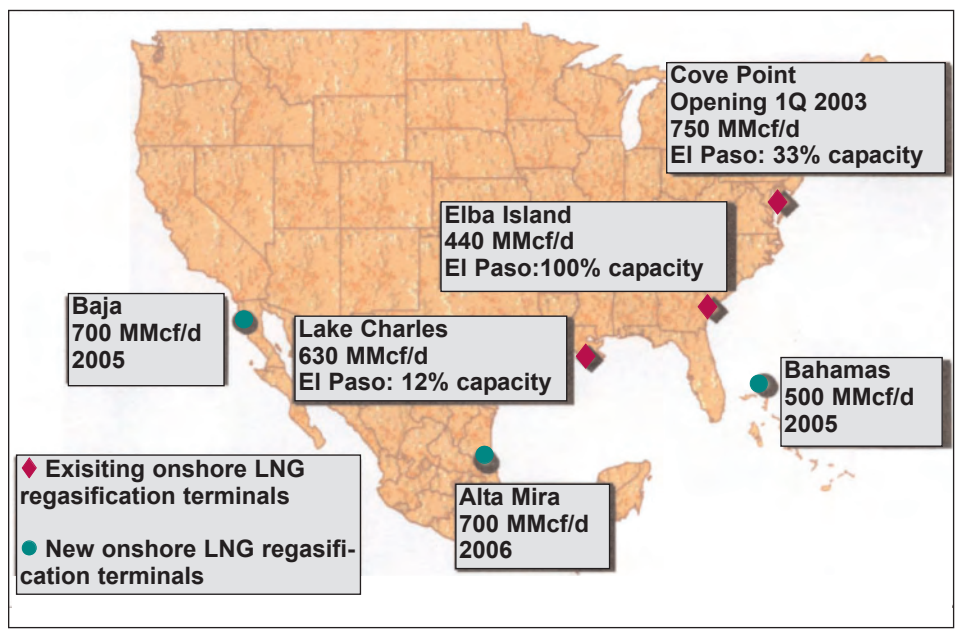
Another factor is that costs across the LNG production stream, from liquefaction to regasification, have been reduced significantly. Exploration and productions costs are down due to improved technologies such as 3-D seismic, directional drilling, and improved sub-sea facilities. Shipyard expansions in East Asia and increased competition have lowered LNG tanker costs by 40% from their peak. Liquefaction costs have been lowered by as much as 33% through economies of scale. Design efficiencies, technology improvements, and innovative financing have all contributed to improved project economics.

How will the North American LNG business develop? Gas demand growth is expected to occur in the coastal regions of the United States. In fact, fully 50 percent of the demand growth between 1998 and 2005 is on the U.S. coasts, particularly the east coast where demand is expected to increase by 3.3 Bcf/d over that time period. LNG is uniquely suited to serve this demand growth scenario.

Table 1 A summary of European import terminal development

Country	Expansions	Planned New Terminals
Italy		Rovigo (a permitted floating terminal near the Po river delta), Muggia, Taranto, Vado Ligure, Brindisi, Lamezia and Corigliano Calabro
France	Fos-sur-Mer II	Le Verdon
Spain	Barcelona, Cartagena and Huelva	Sagunto (permitted), Mugardos (permitted) and Bilbao (under construction)
Portugal		Sines (under construction)
UK	Isle of Grain,	Milford Haven

Figure 2: El Paso LNG Capacity Positions and Terminals



Europe: aggressive capacity expansion

LNG imports have also been a long-standing component of the European gas market. Belgium, France, Spain, Italy and Turkey - all fast growing gas markets, as well as being 5 of the 8 largest gas markets in Europe with a total consumption of around 15 Bcf/d in 2001 - have operational import terminals today. New terminals or expansions to existing terminals are planned for sites in Italy, Spain, France, Portugal and the UK.

A summary of European import terminal development is shown in Table 1.

Activation of Elba Island terminal

There are four existing regasification terminals in the United States. Three are currently operating and the other one is scheduled to return to service by the spring of 2003. The latest terminal to re-open is the Elba Island terminal in Georgia. This facility was constructed in 1978 by Southern Natural Gas Company, an El Paso affiliate, and is shown in Figure 1. It was shut down in the 1980s due to low demand and it was re-opened in October 2001. It has three storage tanks with a total capacity of 4.0 Bcf (186,000 m^3 LNG). The vaporization capacity is 675 MMcf per day (about 19 million m^3(st)/day).

An open season to expand the terminal by 360 MMcf/d and add 3.3 BCF of storage was held last year. The results were announced earlier this year with the expansion being fully subscribed for a 30 year term. The planned in-service date for the expansion is June 2005.

Other land-based LNG terminals

El Paso also has capacity rights at two other U.S. terminals. El Paso owns 12% of the 630 MMcf/d capacity at the Lake Charles terminal in Louisiana and 33% of the 750 MMcf/d capacity at the Cove Point terminal in Maryland. The Cove Point terminal is projected to be reactivated in the second quarter of 2003.

El Paso is actively developing terminals in Mexico, the Bahamas, and Baja California. At Altamira in the Mexican state of Tamaulipas, El Paso and partner Shell Gas & Power have obtained a site and plan to make a regulatory filing later this year. Commercial operation is expected to begin in the first quarter of 2006. In the Bahamas, El Paso has obtained a site; an affiliate, El Paso Pipeline, plans to construct a pipeline to Florida. Commercial operation is expected to begin in the second quarter of 2005. In Baja California, El Paso and partner Phillips Petroleum have obtained a site. Commercial operation is expected to begin in the third quarter of 2005. All of these terminal locations can be seen on the map in Figure 2.

New U.S. land-based LNG terminals unlikely

In the United States, areas with the greatest demand have dense population. It has been difficult to site any energy facility in these densely populated regions. No new LNG receiving terminals have been built in the United States since 1980. NIMBY (Not In My Back Yard) issues may delay or derail potential projects. Substantial costs will be associated with permitting new developments. On the west coast, heightened environmental sensitivity and a time-consuming regulatory approval process have traditionally made facility siting difficult.

Also, viewpoints have changed since September 11th last year, giving heightened security concerns in the aftermath of the terrorist attacks on the United States. The disruption of LNG operations at the Everett terminal in Boston Harbor and issues surrounding the reactivation of the Cove Point terminal demonstrate that security concerns have become a major and potentially costly issue.

Similar NIMBY issues to those faced in the U.S. are also likely to impact development activity in Europe, particularly in Italy which has the most aggressive expansion plans for terminal development and a history of difficult planning processes for LNG import terminals.

El Paso Energy Bridge

El Paso Corporation's EP Energy Bridge™ system is an attractive alternative to land-based terminals with lower capital requirements and flexible delivery options.

Developed by El Paso Global LNG Company, EP Energy Bridge combines LNG shipping and regasification on a single ocean-going vessel. No new technologies are incorporated in the design. It is an innovative application of proven technologies that allows natural gas to be delivered directly to coastal natural gas markets. With this new system, scheduled delivery of natural gas from remote regions takes place on either a baseload or a seasonal basis using a highly reliable offshore mooring system and subsea pipeline to shore.

Figure 3 is an artist's rendering of what an EP Energy Bridge vessel might look like. A new design is not required, simply a modification of an existing LNG carrier design. Shown are some of the innovative components such as on-board vaporizers and a view of the turret, with the docking buoy attached, that make up an EP Energy Bridge vessel.

The Energy Bridge interconnection design uses the APL Submerged Turret Loading system, whose docking buoy provides a single-point mooring system with high reliability, for the offshore unloading of LNG vessels. The APL Submerged Turret Loading system has been proven in the harsh North Sea environment. North Sea connections have been made in sea states over 5 meters and operational loading in the North Sea has taken place in sea states over 13 meters. By contrast, most Energy Bridge sites have sea states less than half of the North Sea environment.

There are currently 19 APL buoys in service, used for traditional oil and gas production operations. Over 1,400 connections have been made to date in the North Sea with a 100% success rate. Current APL technology users include Shell, BP, and the Norwegian government-owned energy company, Statoil.

Figure 4 shows the general Energy Bridge System layout. A fleet of specially equipped EP Energy Bridge ships brings LNG to market. Upon arrival at the terminal area, an EP Energy Bridge ship con-

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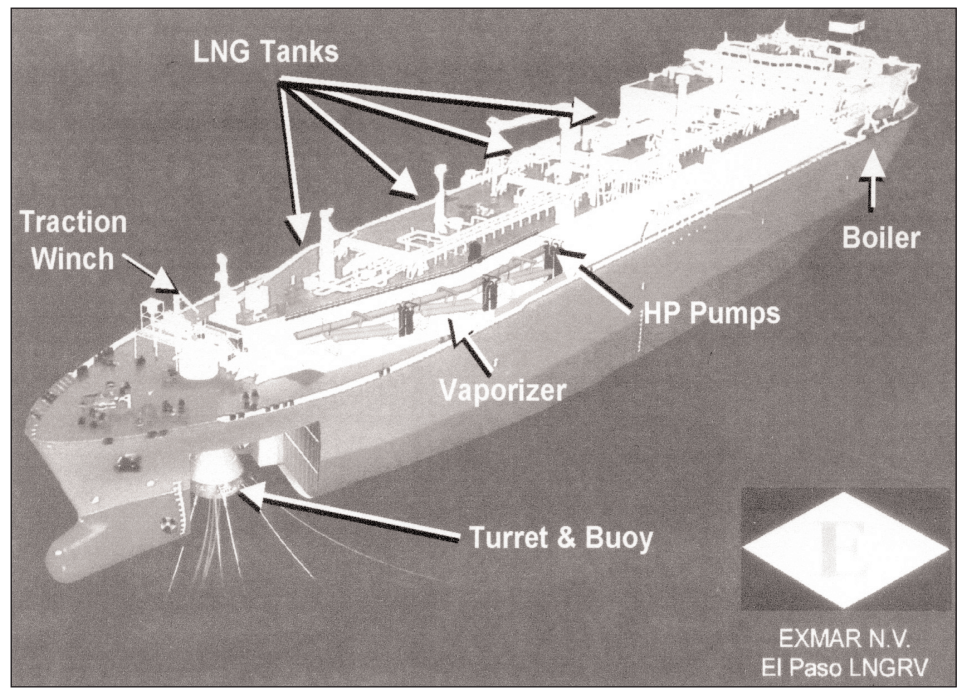

Figure 3: Typical Energy Bridge Vessel

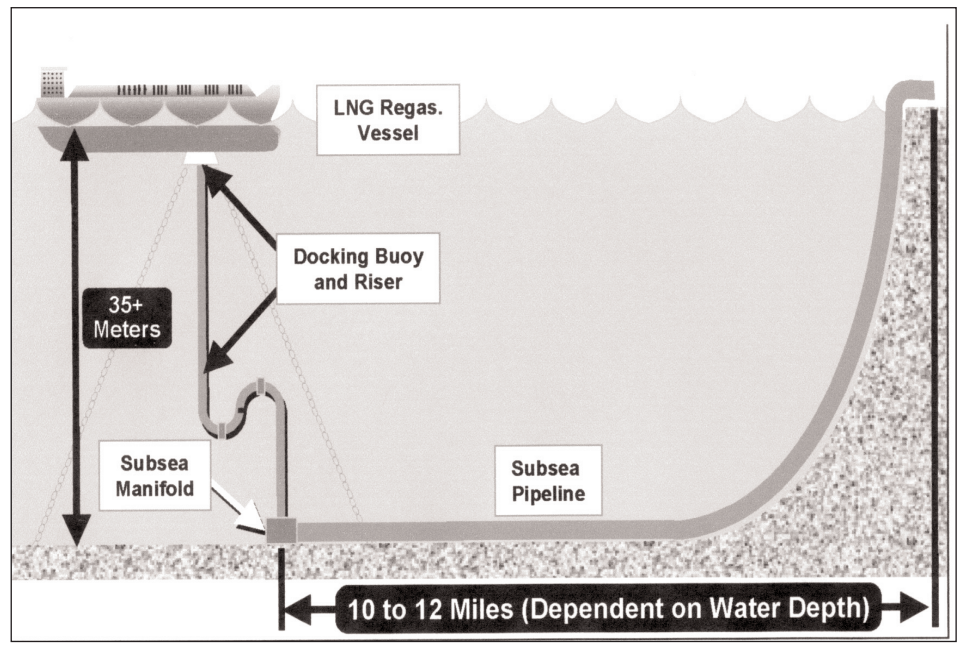

Figure 4: Energy Bridge general system layout (not to scale)

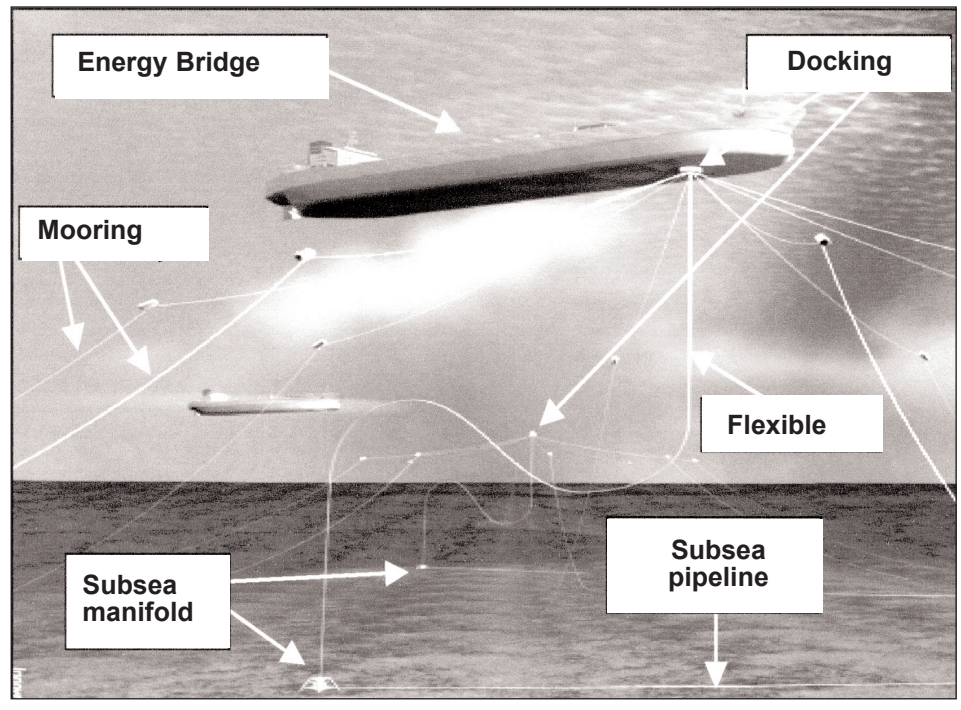

Figure 5: Energy Bridge ship during offloading operations

Harvey Harmon has over 20 years experience in the energy industry with most of his effort focused on natural gas pipeline and market issues. In 1986 he joined Tennessee Gas Pipeline. He has performed multiple studies of electricity demand and the need for gas fired generation. In 2001, he joined the Global LNG unit of El Paso and is responsible for planning and analysis. He holds Bachelors and Masters degrees in Ocean Engineering and a M.B.A.

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nects to a submerged offloading system, which safely moors the vessel and connects it to an offload pipeline. This operation takes place well offshore and typically over the horizon. Once connected to the offload pipeline, the EP Energy Bridge ship begins onboard regasification to provide safe conversion of the LNG to natural gas vapour at pressures up to 1,400 psi (about 97 bar). The gas is sent through the offloading system and riser to a seabed pipeline that leads to an onshore customer facility or to a nearby gas transmission pipeline. At the conclusion of the transfer, the ship releases the offloading system to its idle position safely beneath the surface of the sea, where it remains until the next EP Energy Bridge ship arrives. Each EP Energy Bridge ship carries approximately three billion cubic feet of natural gas (138,000 m^3 LNG) and will typically offload in seven to ten days.

Figure 5 shows how the system will look when gas is being offloaded. The APL system is suitable for water depths of 35 meters to more than 100 meters. Once the ship is connected to the mooring buoy, the ship freely weathervanes, thus mitigating much of the stress on the mooring lines. As stated previously, an Energy Bridge ship can safely dock in seas with heights of 4-5 meters. Once connected, the send-out to shore can occur in seas of 10-11 meters in height providing for high reliability. The typical offshore gas installation will have two offloading buoys and risers so that as one ship concludes transfer, another can begin delivery, assuring continuous flow.

In the United States, El Paso is working with the U.S. Coast Guard, Department of Energy, Federal Energy Regulatory Commission and the Minerals Management Service in regards to EP Energy Bridge technology and has received favorable responses in these discussions.

In Europe, El Paso has commenced a review of possible applications for EP Energy Bridge to the major gas markets. This will involve liaison with both EU regulatory bodies and individual country marine, environmental and energy regulators.

There is ample reason to be truly optimistic about the new LNG industry

Conclusion

There is ample reason to be truly optimistic about the new LNG industry. The industry worldwide will grow five to six percent per year with growth occurring fastest in the United States. Traditional supply sources are being stressed to meet demand, particularly in North America. With a rising U.S. gas price environment, LNG is the ideal solution to the demand/supply imbalance with extremely favorable economics in the global marketplace. LNG's ability to serve coastal markets effectively and to provide peaking services for power generation makes it a great supply match for today's developing demand centers. EP Energy Bridge will be an innovative way of using proven technology to solve the U.S. LNG terminal bottleneck and an effective way to increase the linkage between European and U.S. gas markets. ■

GASTECH2002
THE 20TH INTERNATIONAL CONFERENCE & EXHIBITION
FOR THE LNG, LPG AND NATURAL GAS INDUSTRIES
QATAR 13-16 OCTOBER 2002
QATAR INTERNATIONAL EXHIBITION CENTRE, DOHA • SHERATON HOTEL, DOHA

The Gastech 2002 Conference

David Roe, Editor (UK)

The successful recent Gastech 2002 Conference in Qatar was attended by 1350 delegates, with a large parallel exhibition. The emphasis was on LNG production, shipping and trade. This report summarizes the Conference sessions, highlighting the new developments presented and the important issues discussed

In terms of attendance, Gastech 2002 was one of the most successful Gastech Conferences ever, with 1350 delegates and double that number of persons attending the opening ceremony (guests and exhibitors). There was an impressive parallel exhibition, with some 140 exhibitors, occupying the whole of a 10,000 m^2 exhibition hall.

In general, delegates benefited from good administrative support from the organizers, Turret Rai, and enjoyed the generous hospitality of the hosts, Qatar Petroleum, and several other major sponsor companies. Many of the keynote speeches and presented papers were good. However, there were some disappointing aspects of the technical programme. With up to three parallel sessions, delegates cannot attend every presentation, so it is regrettable that some presenters do not produce a proper written paper. Some session chairmen were excellent, but some made little effort to stimulate discussion and in some cases blatantly promoted their own company.

Gastech conferences traditionally cover both LNG and LPG, and aspects of natural gas (such as Gas-to-Liquids); however, Gastech 2002 departed from previous practice in having no specific LPG sessions, so LNG dominated the Conference. The emphasis was on LNG production, shipping and trade: this bias may have been deliberate, to reflect the fact that the Conference was held in an LNG-producing country and Gastech always has a strong shipping content. There was not one keynote speech on behalf of a major LNG buyer, and there were few papers on LNG reception, storage and specific markets. Also, delegates from Asian LNG importing companies were a bit thin on the ground. The geographic breakdown of delegates was: Qatar and the Middle East - 37%; Europe - 31%; USA and the Americas - 14%; Asia (excluding Japan) and Australasia - 8%; Japan - 6%; Africa - 4%.

Opening

The Conference was formally opened by His Highness Sheikh Hamad Bin Khalifa Al-Thani, Emir of the State of Qatar. A speech was also given by H.E. Abdullah Bin Hamad Al-Attiyah, Minister of Energy and Industry, and Chairman of Qatar Petroleum. He announced that the door is open for foreign investors to submit any reasonable offer for new projects using gas as feedstock. As well as Qatar's plans to increase its LNG producton and to become the world's largest LNG exporter by 2010, with 45 mta, the country is to supply gas by pipeline to neighbouring countries, and is also planning several new Gas-to-Liquids and gas-based petrochemical plants.

There was also a message conveyed by Bob Lakey, Conference Director, who was unable to attend owing to illness.

The Emir addressing the Opening Ceremony

Shipping

Charles Piele of LNG Shipping Solutions presented an analysis that showed there was little spare yard capacity before 2005, but the current capacity of 25 ships/year was adequate to meet future project developer's needs for shipping to serve long-term contracts. The economic situatuion in 2002 had meant a slight reduction in long-term charter rates to $63,000/day, equivalent to a new ship price of around $155 million. However, there continued to be a shortage of ships to service short-term LNG trade and peak winter demand in Korea (it has been reported that Kogas has paid over $100,000/day to charter Shell's "Galea" for the coming winter). About one third of ships on order for delivery between 2003 and 2006 were not so far committed to a long-term trade.

Yasushi Yamawaki of NYK Line stressed the challenge facing shipping companies and ship owners in meeting the need for more flexible shipping arrangements in the present Buyer's market. ***Mohammad Souri of the National Iranian Tanker Company*** described studies of potential participation in the provision of LNG carriers to support Iran's ambitious plans for major LNG exports from 2007.

Kimball Chen of Energy Transportation Group (ETG), with co-authors from the Guangdong LNG Transportation Project Office (GLTPO) presented a good account of the process for establishing LNG shipping for China's first LNG project. ETG is the advisor to GLTPO, set up by China's leading shipping companies, China Ocean Shipping Co. and China Merchants Holding, which has selected the Hudong Shipyard of Shanghai as the preferred Chinese shipyard to build the LNG carriers. GLTPO is also to conclude an agreement with a foreign shipping partner, the final negotiations having been delayed until after the recent selection of the LNG supplier, the North-West shelf project of Australia.

Jon Anreassen of Leif Hoegh and Sverre Valsgaard of Det Norske Veitas presented a most comprehensive paper describing in detail the repair and refurbishment of the 87,500 m^3 capacity Hoegh Galleon and her sister ship the Norman Lady. These were the first Moss-type ships, built in the early 1970s, and the only ones with 9% Ni-steel cargo tanks. Leif Hoegh, the ship managers, acquired the Mystic Lady (subsequently renamed the Hoegh Galleon) from the Japanese owners, who had decided she should be scrapped after the discovery in 1998 of extensive hair-line cracking in the vicinity of the welds, caused by hydrogen induced stress corrosion. After extensive studies and a pilot project, Leif Hoegh, in conjunction with DNV and CBI, had all the cargo tanks repaired and rewelded. The ship was extensively refurbished and independently verified to continue in LNG service for a further 20-30 years. Leif Hoegh's Norman Lady was found not to have such extensive cracking, and cracks were repaired by grinding only, without re-welding. The Hoegh Galleon had been long-term chartered to Enron, but this summer the U.S. Bankruptcy Court approved the acquisition by Tractebel LNG (London) of the charter rights. The charter expires at the end of 2018 and has a 10-year option to extend.

The second session on LNG shipping reflected the present interest in novel propulsion systems, with no less than seven papers on this subject. Two LNG ships are now being built by Chantiers de l'Atlantique in France with diesel-electric propulsion, instead of the steam turbine system commonly selected for LNG carriers. The session Chairman, ***Chris Clucas of Dorchester Maritime***, conducted a "straw poll" amongst the audience, asking which systems were thought to have a potential application to LNG Carriers ordered in future. 75% voted for dual-fuel diesel electric propulsion; 50% for gas turbine propulsion; and 45% for slow speed diesel propulsion with boil-off reliquefaction. Interestingly, no-one thought that steam propulsion had any potential application for future LNG Carriers.

In this session ***Karim Chapot of Gastransport and Technigaz (G.T.T.)*** presented details of the new G.T.T. CS1 containment system for LNG carriers, using an invar membrane primary barrier and reinforced polyurethane foam insulation.

LNG Trade

Several speakers addressed recent developments in LNG trade (an article on this subject by Andrew Flower appears in this issue).

The panel session "Changing Markets and Business Strategies", was chaired by ***Kathleen Eisbrenner of El Paso Global LNG***. The panelists were ***Mohamed Althani of RasGas, Yashikazu Koyama of Osaka Gas, Jean-Pierre Mateille of Total-FinaElf, Simon Bonini of BG Group, and Doug Rotenberg of BP.*** Each gave a presentation, which left insufficient time for an in-depth discussion to develop. Points made included

- No speculative LNG plants were forecast (without firm buyers), although the trend would continue of starting construction of plants with a proportion of the output unsold. There was a trend towards "branded LNG", i.e. LNG bought by traders with no particular market specified, or sold with no particular source specified
- Important attributes of successful short-term LNG traders included possession of shipping capacity and access to terminals; the ability to develop new markets

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- Improve the security of your company's LNG terminals by hearing where some of the weak links are

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and tailor supplies to the customer's requirements; and experience and skill in market trading. Personal contacts and established relationships were important, and future trading through an Internet portal was unlikely

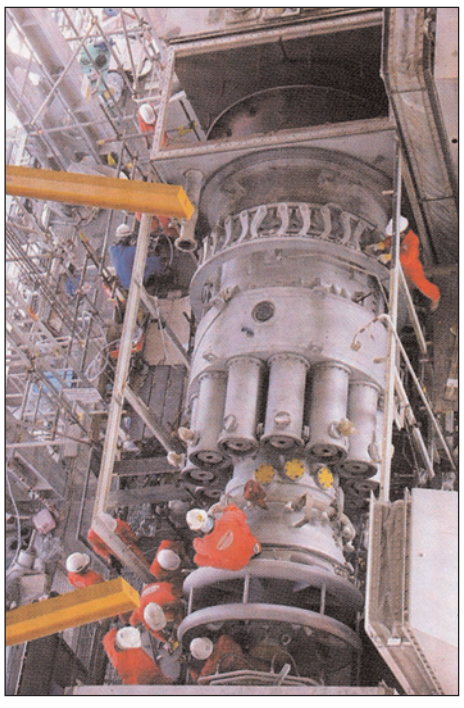
- It was unlikely that development of a west coast US/Mexico LNG market would have a significant impact on Asian LNG trade, because of the distance between the two markets.
- Although El Paso is soon to be seeking approval for an application of its Energy Bridge shipboard regasification system in the Gulf of Mexico, the first worldwide project is likely be in Korea, at the end of 2004
- Opportunities for cost saving in LNG schemes would lead to an extra 12 mta of LNG demand in Japan by 2010, compared with the official MITI forecast. (In discussion after a later presentation, ***Rodney Schmidt of Petroleum Finance Company*** also expressed the view that larger than forecast LNG market growth would occur in Asia, for the reason that deregulation would result in competition and innovative developments)
- The base LNG price in a new contract would increasingly be set by LNG supply and demand considerations in a Buyer's market, although the changes to LNG prices would continue to be linked to oil price changes.

In a final session ***James Ball of Gas Strategies*** pointed to the fact that in Spain and elsewhere new long-distance pipeline supplies were having difficulty competing with more flexible LNG projects. Because of the commercial advantage to the buyers of controlling shipping in a more flexible LNG market, since 1995 over 80% of new sales contracts in Asia have been FOB, whereas before 1995 over 80% were ex-ship.

LNG Supply Projects

An impressive presentation by ***Jerry Wolahan of RasGas*** described the expansion of Qatar's RasGas LNG project. Trains 1 and 2 currently produce 6.6 mta, and an EPC contract was awarded this year to a Chiyoda-led consortium (CMS-A) for the 4.7 mta third train, to supply Petronet of India. It is scheduled to start up in early 2004. The same consortium had just been confirmed as EPC contactors for a fourth train, of the same size. Train 4 will require construction of an extra marine berth, and will use acid gas re-injection offshore, which will then be retrofitted to train 3. An extra 140,000 m^3 storage tank will be provided for trains 3 and 4.

Debottlenecking the Qatargas plant



Phil Hunter of Bechtel described progress on the Atlantic LNG project two-train expansion in Trinidad. There had been four LNG cargoes transshipped to date from train 2, and just two days before the Conference the contractors, Bechtel, had handed it over to the operators. Like the first train, the expansion trains use the Phillips optimized cascade process, but use Frame 5D instead of Frame 5C gas turbines to help achieve a 10% increase in capacity to 3.3 mta. Train 3 was forecast to come into operation in August 2003, ahead of schedule. Train 4 would be 4.8 mta capacity, using the same process. Train 1 is being upgraded to increase its capacity to 3.3 mta.

The project for debottlenecking the 3-train QatarGas plant was presented by ***Jean Greffioz of QatarGas.*** The nominal capacity was 6 mta, but the actual capacity could be increased to 7.7 mta without modifications. To increase the capacity to the maximum set by the capacity of the feedgas sea line, 9 mta, a debottlenecking EPC contract was awarded to Chiyoda-Technip. The main work is the replacement of propane compressors, and the upgrading of gas turbine and mixed refrigerant systems, being undertaken by GE/Nuovo Pignone. The three gas turbine sets on Train 1 were replaced by new units in April and May of this year, with no disruption to the LNG delivery schedule. The total cost of the debottlenecking is $200 million; it is scheduled for completion in 2005.

Mohammed Al Mukhainy of Oman LNG and co-authors described the successful commissioning, start-up, performance and maximum capacity testing of the Oman LNG plant. Problems that had to be overcome included operation of the new dry low NOX technology on the process gas turbines, where special procedures had to be followed. Also, there were problems with vendors' over-protection of their equipment packages, irrespective of their criticality in the overall process. ***Agnus Cassens of Oman LNG*** gave a polished presentation about the plans of Oman LNG, which include debottlenecking the plant, leading to a 15% increase in LNG capacity, and adding an expansion train.

Progress on the BG/Edison Egyptian LNG project was presented by ***Arshad Sufi of BG Egypt***. The first train will be 3.6 mta, based on the Phillips cascade process. There will be two 140,000 m^3 storage tanks. Site preparation has begun, and Bechtel was appointed the EPC contractor in May, and given notice to proceed in September. The output of the first train has been sold to Gaz de France, who signed a sales and purchase agreement on October 12 this year. Financial closure is expected in the first quarter, 2003. BG Egypt claim that this will be the fastest LNG project to be developed: 6 years from first gas discovery to first LNG produced. A second 3.6 mta train is scheduled to follow a year later.

At the RasGas exhibition stand

Andrew Jamieson of Nigeria LNG described latest developments on the project. The pre-treatment unit of the third 2.95 mta train was being commissioned; it would produce first LNG in November. A third 77,000 m^3 storage tank had been constructed. Three new LNG carriers, built by Hyundai H.I., are to service this expansion. The EPC contract was awarded earlier this year to the TSKJ consortium (contractors for the first three trains) for the "NLNG Plus" train 4 and 5 expansion, totaling 7.5 mta. Sales of LNG have been agreed with Shell (2 contracts), ENEL, Transgas, ENI, and Iberdola. Eight additional LNG carriers are being acquired : 4 new-builds from Hyundai, and 4 chartered from Bergesen. First LNG is scheduled for production in 2005. Unlike the first three trains, the NLNG Plus expansion is to seek project finance. A sixth, 4 mta train, is currently under study.

Allyn Risley of Phillips Petroleum outlined the Darwin LNG project based on Bayu-Undan gas reserves between East Timor and Australia. It will be a single 3.3 mta train plant at Wickham Point near Darwin. 3 mta has been committed to Tokyo Electric (2 mta) and Tokyo Gas (1 mta), on a FOB basis. It is scheduled for first LNG production in 2006.

The design basis for the Snohvit LNG plant, now under construction, was presented by ***Roy Scott Heiersted of Statoil.*** The selected process for the 4.3 mta, barge-mounted single train is the Statoil-Linde proprietary Mixed Fluid Cascade process, with five LM 6000 aero-derivative turbo-generators providing electric power to drive the refrigerant compressors and for other plant uses.

Nanung Untung of Pertamina described the progress on the Bontang train I expansion project. This is to be 2.95 mta, and steam-turbine driven, a copy of Train H. EPC bids have been received and a contract is expected to be awarded later in 2002, with first LNG produced in mid 2005.

Reception Terminals and LNG Markets

Paolo Bergamaschi of Edison Gas presented the design of the Edison Gas offshore LNG reception terminal, which will be 17 km off the coast of Porto Levante in the North Adriatic Sea. It will be a gravity-based structure located on the sea bed at 28 m water depth, comprising two adjoining modules of cellular prestressed concrete, each having an LNG storage capacity of 125,000 m^3. LNG carriers up to 147,000 m^3 can berth alongside. Negotiations are taking place prior to an award of an EPC contract. The project is still delayed, awaiting final approval from the Italian authorities.

David Haynes of Advantica talked broadly about potential applications of optimization studies to LNG trade. His paper presented examples of the applications of Advantica's reliability and availability optimization package, OPTAGON, in particular to Lattice's plans for conversion of the Isle of Grain peak-shaving installation in the UK to a marine reception terminal.

Technical Developments

Everett Hylton and Hans Kimmel of Ebara International Corporation presented the new "third generation" of liquid expander technology. It is an LNG Exducer turbine, which operates at constant speed, avoiding the need for transformers and frequency converters required for the previous variable speed design. The new design is a hybrid combining a radial inflow reaction turbine with a variable pitch blade axial propellor turbine. The blade pitch is electrically adjustable to deal with variable mass flow and differential pressure. The LNG Exducer turbine can also be operated as a two-phase expander, which is of particular benefit in nitrogen removal.

Doug Yates of Phillips Petroleum showed how simple comparisons of the thermal efficiency of alternative liquefaction processes can be highly misleading. The overall thermal efficiency of a liquefaction terminal depends on many factors and design features, from the inlet pipeline to the ship loading interface, and involves a trade-off between capital and life-cycle costs. Different technologies or plant designs cannot be compared or benchmarked on thermal efficiency unless the unique differences each project brings to the evaluation process are understood and compensated for.

Jeff Sawchuk and co-authors from BP reported results from their "Big Green Train" design studies. The objective was to design a single train of up to 8 mta capacity with a lifecycle cost 25% less than for the Trinidad train 1 plant (i.e. $135/tonne/year), and with CO_2 emissions 50% less. Studies were based on the Liquefin process. It was concluded that trains up to 8 mta were technically feasible using Frame 9 gas turbine drivers, but the preferred technology was the use instead of four large electric motors equipped with variable frequency drive for four parallel refrigerant compressors. A large CCGT power plant would provide the electric power.

A new liquefaction process was described by ***Mark Roberts and co-authors from Air Products and Chemicals.*** With the standard APCI C3-MR process, train sizes greater than 5 mta are difficult to achieve without developing new designs for the increased size of some of the major equipment items. The new proprietary AP-X Hybrid LNG process differs in that it uses a simple efficient nitrogen expander loop to provide the LNG subcooling instead of using mixed refrigerant. Using similar sized equipment as in the C3-MR process, it is claimed that train sizes of 8 mta can be achieved.

Max-Michael Weiss of Lurgi described how Lurgi, BASF and Zeochem had combined forces to offer LNG plant developers a single package for gas pre-treatment. This avoids the need to select and combine several different licenced technologies for gas purification, acid gas removal and sulphur recovery. The overall process offers 99%+ recovery of all sulphur, through use of a PURISOL unit for recovery of the mercaptans and their processing to elemental sulphur in a modified Claus unit with a unique Lurgi Kombi burner system.

Mohamed Djeuna of Sonatrach reported on the repair of the outer shells and roofs of three LNG storage tanks at the Arzew liquefaction complex in Algeria. It was decided not to warm up and decommission the tanks, because of the potential adverse effect of excess perlite compaction, nor to attempt live welded repairs on the operating tanks, for safety reasons. All repairs were undertaken using patch plates fixed using epoxy adhesive.

Offshore LNG

One Conference session covered offshore LNG schemes, in which SBM, FMC, and the French team of TotalFinaElf, Gaz de France, and Eurodim all presented updates on their previously published developments of offshore mooring and LNG transfer. All are developing cryogenic swivels for combined LNG and vapour return transfer for offshore applications. Both FMC and SBM offer a design of soft-yoke mooring system using articulated

transfer arms.

Technip-Coflexip have developed a flexible LNG transfer hose, and have combined with ASB-Amri and Eurodim to develop a design of a suitable connecting system for the flexible pipe - "Amplitude LNG Loading System". A prototype will be tested early in 2003. At the Gastech Exhibition, information was available on another flexible cryogenic hose system developed for offshore LNG transfer by the OCL Group; tests were completed in the summer of 2002. Also, ExxonMobil presented its new flexible LNG hose developed in conjunction with Senior Flexonics.

The classification societies are now increasingly involved in the safety of liquefaction plant through their work on the hazard assessment and design classification of offshore LNG facilities. Relevant papers were presented from DNV, RINA and ABS.

Safety and Security

The emphasis was on the safety and security of LNG shipping, ports, and offshore LNG facilities: the safety of onshore LNG plants and storage was rarely addressed.

In a keynote address ***Paul Pluta of the U.S. Coast Guard*** outlined the response to ensure the security of liquefied gas carriers serving U.S. ports following the terrorist incidents of September 11 last year. To increase the security of ships and ports worldwide, the International Maritime Organization (IMO) has prepared proposed amendments to SOLAS (Convention on Safety of Life at Sea) covering security, and a proposed new mandatory Code: International Ships and Port Facility Security. An IMO Conference is to vote on these proposals in December this year, and if approved, the changes to SOLAS would be fully enforceable by mid-2004. ***Martin Brooking of Lloyd's Register of Shipping*** stressed the need for a three-pronged approach to the security of LNG carriers: (a) prevention, with actions by Governments and authorities to combat terrorism, and greater security awareness amongst personnel on ships and in ports; (b) assessment of vulnerability and consequences, with risk mitigation measures taken as necessary; (c) emergency response planning. ***Bill Lewis of Project Technical Liaison Associates*** addressed the perceived and actual risks posed by land-based LNG facilities in the USA, and advocated security and hazardous risk audits.

John Gyles of SIGTTO presented his organization's approach to advising on safety of LNG shipping and terminals, with the development of a suite of core documents. ***Niall Ramsden of Resource Protection International and Roger Roue of SIGTTO*** described a forthcoming new SIGTTO report, "Liquefied Gas Fire Hazard Management", due to be published before the end of 2002.

With ever-increasing calls for greater knowledge and awareness amongst ship's crews of safety and security matters, a timely paper was presented by ***Jeffrey Albone of Golar Management Ltd.,*** on future manning requiements. With the numbers of operating LNG carriers increasing by nearly 50% in the next five years, there is a shortage of officers and ratings. The LNG Shipping industry has to address as a matter of importance the issue of recruitment of the necessary personnel, and their training and retention (through appropriate motivation, working environments, terms and conditions). ■

Naturgass Vest's LNG project at Kollsnes, Bergen

Anton Hellesøy, Naturgass Vest, Norway

In Norway, the use of LNG as industrial and transport fuel is growing. A new project is under construction that will produce LNG and transport it by sea and by road to several locations in the Bergen area

Naturgass Vest is a gas distribution company based in Bergen in Western Norway. The company was established in the early nineties after it was decided that gas from the Troll field would be landed at Kollsnes, about 60 km north-west of the city (see Figure 1). In 1996 the Troll field started its deliveries to Continental buyers via Kollsnes Gas Treatment Plant (GTP), and in early 2000 Naturgass Vest started up its first deliveries to customers in Bergen, based on Troll gas.

The CNG-based market in Bergen

Gas distribution is an infant industry in Norway and everywhere one has to start from scratch. In Bergen we have based our first deliveries on CNG (compressed natural gas). As we see it, CNG is a relatively cost-effective distribution system when we are dealing with distances that are not too long, and with customers that are not too big and are relatively spread out. This was exactly the situation in Bergen, and in addition we had an important customer that actually wanted the gas as CNG, namely the local bus company. The bus company and the local authorities had decided some years before that when natural gas would be available in Bergen, they would convert a number of buses to CNG. So they were actually our first customers, and today there are about 60 CNG buses in Bergen, contributing to a cleaner and quieter city centre.

Gas distribution is an infant industry in Norway and everywhere one has to start from scratch

In addition to delivering CNG to buses, we have now set up a number of smaller receiving terminals in Bergen to which CNG is brought by trailers and converted to low pressure gas (pressure reduction from up to 300 bar and down to 4 barg) and distributed further to customers. Our biggest customer is the regional hospital which is using gas for heating and steam; a number of housing cooperatives, each with its own centralized heating, are using gas for heating and hot water (all together 2 200 flats in Bergen); a few municipal homes for elderly people are using gas for the same purpose and a printing house is using gas for high speed drying of colour printing. In addition we have a few customers on the island west of Bergen, almost on the route from Kollsnes to Bergen. Altogether we are now supplying about 10 million m^3(st) a year as CNG and have replaced about 15% of the gas oil use in the region with the much cleaner natural gas.

Our plan for gas distribution in Bergen has been to build up a market based on CNG and when it has reached a certain size, to replace the trailer transport from Kollsnes to Bergen with a pipeline. This is still our aim, but we are not there yet. Meanwhile we have been looking for other ways of expanding our market, and that is where LNG is coming into the picture.

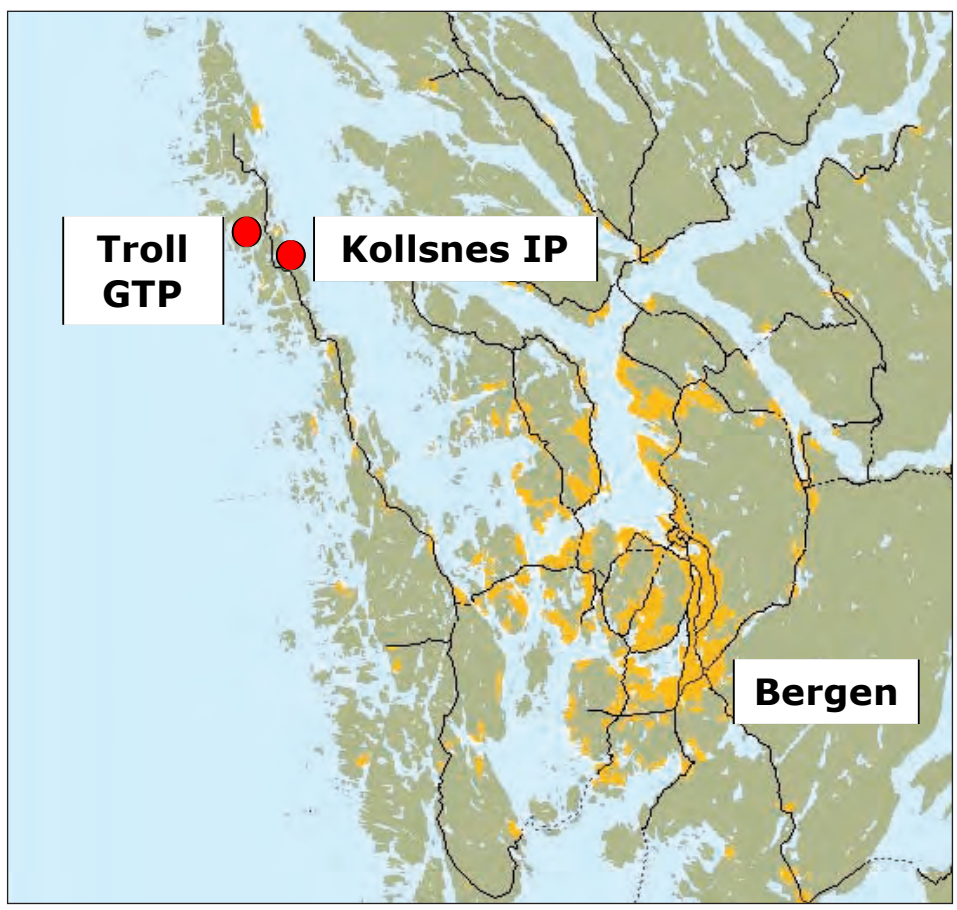


Figure 1 Location of Kollsnes Gas Treatment Plant and Industrial Park

Plans for an LNG Project

It all started with a discussion about how to get natural gas to ferries in Norway. Western Norway, as is well-known, more or less cut into pieces by fjords and islands that make a lot of road communications dependent on ferries (on stretches that are too far for bridges). These ferries are an important source of NO_x-emission, which is considered the main local polluter (sour rain). But, since it is so important, it is also here we find the main potential for a reduction. When a diesel driven ferry is replaced with a ferry driven by natural gas, the NO_x-emission is reduced by up to 95%. These ferries are spread along the coast of Western Norway, and we very soon realised that to get natural gas to where the ferries are, it has to be transported as LNG: pipelines are definitely not viable, and the routes by road are too long and difficult for CNG.

There is also another characteristic feature of Western Norway that is favourable to the use of LNG. One of Norway's most important industries is the process industry: based on one or other raw material, it is utilising the abundant availability of electricity to make different metals: aluminium, nickel, titanium, etc. These plants are located along the coast and in the fjords in a number of small industrial communities more or less dependent on a particular plant. As electricity is becoming more and more expensive in Norway, there is a growing need for alternative energy. Up till now, this has been met mostly by oil, but also by LPG at some places. So this was the starting-point of our plans to build an LNG plant at Kollsnes.

The selection of a turn-key plant contractor

Our first serious contact was during summer 2001 with an American company. This company had a long experience in building cold-boxes of the smaller size we were looking for, but since they would only deliver the liquefaction part of the system, we needed someone to do engineering of the civil works. So we engaged the local branch of a big international company to do a pre-engineering study to estimate the costs of a complete plant.

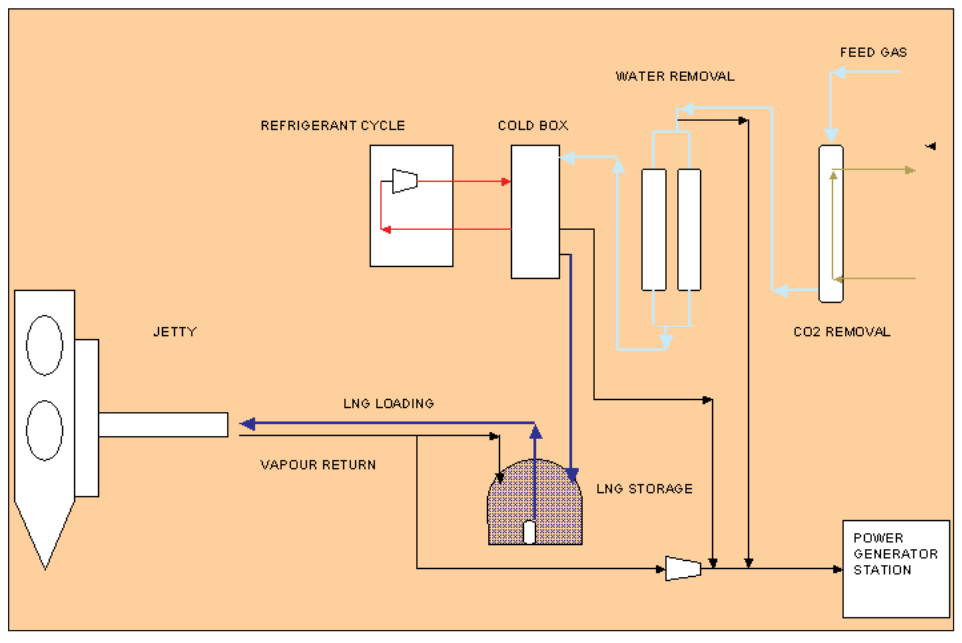
Then a UK company made contact with us and wanted to offer its services. They impressed us with their experience and professionalism, and we wanted to see more closely what they had to offer. Since we wanted to keep both the American and UK company interested, we gave them both a budget and asked them to come up with design and costs for a turn-key plant within three months time. When the time limit had run out, neither of the companies were able to deliver a full cost estimate for a turn-key delivery, possibly because they had too strict a time limit.

At this time, we contacted a German company that was well known in Norway from before and had done similar, but much larger projects for Statoil. We contacted them and asked if they could be interested in submitting a bid on a small LNG plant. Actually, we had had some brief contact with the company at an early stage, without getting them particularly interested. Something must have changed their mind, since now they were very keen to bid.

So now, we had three seriously interested companies, and we found it was time to go and ask for a final offer. We gave all the three parties two months to come up with a design and a price for a turn-key delivery of a plant with a capacity of 120 tons of LNG per day and located in Kollsnes Industrial Park.

The German company Linde AG came

Figure 2 . Process schematic of the LNG terminal



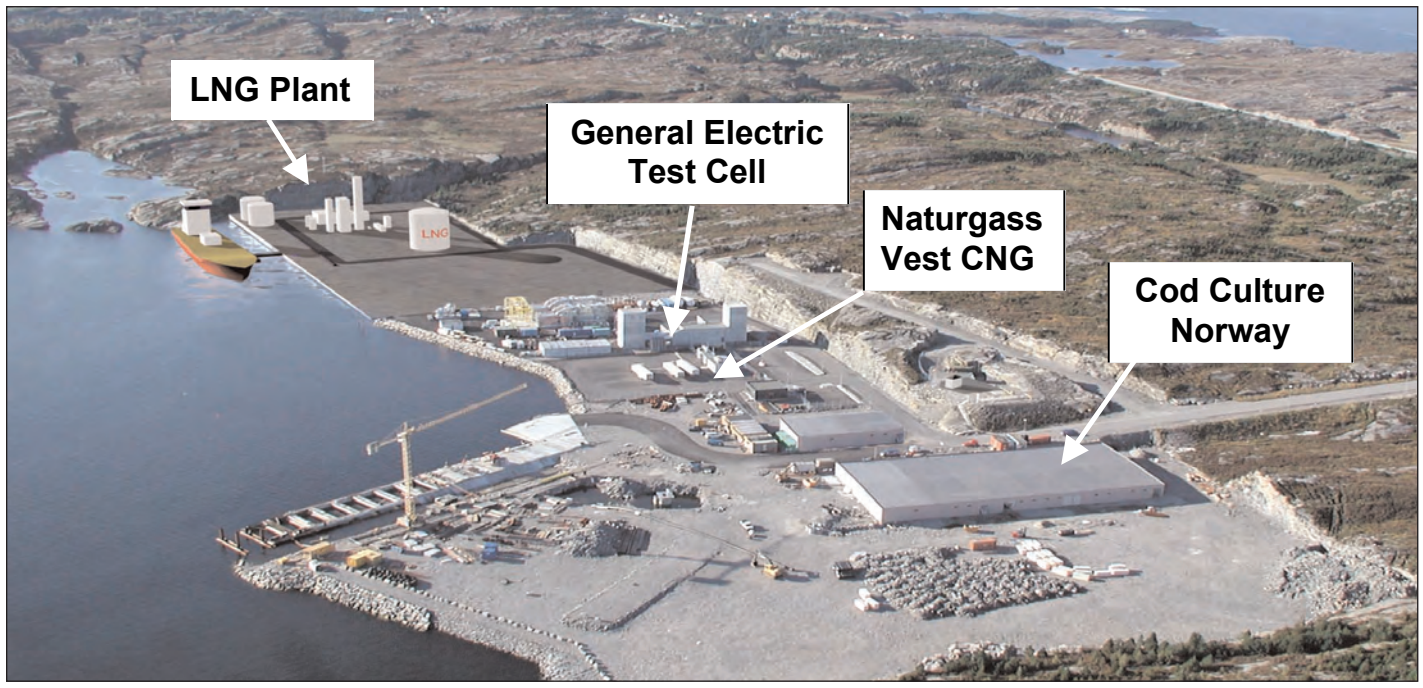


Figure 3. Appearance in 2004 of Kollnes Industrial Park

out with the winning bid, and we signed the contract with them in March 2002. At this time, they had already been awarded two big contracts by Statoil: an NGL treatment unit at Kollsnes and the LNG-project in Northern Norway (Snøhvit).

Description of the LNG Project and Facilities

When we chose Linde, we of course also chose a concept that was well proven. The plant is based on a Mixed Refrigerant Cycle process using LNG and propane as the refrigerant (see Figure 2, showing a process schematic of the LNG terminal).

The input gas will in some cases contain slightly too much CO_2 for the cold-box, particularly when other fields than Troll will be delivering gas to Kollsnes GTP. We therefore have to install an amine-based CO_2-remover.

After the CO_2-remover, where the gas has become saturated with water, is the water-removal unit. This consists of two mole-sieve-based adsorbers. At any time one stream of wet gas is passing through one of the adsorbers, while the other is being regenerated by using heated boil-off and tail gas. Every 8 hours the two streams are switched around. After the gas has been dried in the adsorber, the stream is sent through the cold box where it is liquefied and sent into the storage tank. The storage tank is 2000 m^3 capacity.

The gas that has been used for regenerating the adsorber is too wet to be put back in the gas stream, but is quite acceptable for being used in a gas engine. So the local utility company, BKK, is setting up a small heat-and-power plant (3.5 MW output) just a few hundred meters away from the LNG plant. They buy this gas cheap from us and use it to make electricity, which is sold back to us on favourable terms. The waste heat from the engine is recovered and will be sold to a land-based fish farm established just nearby in Kollsnes Industrial Park. Figure 3 shows the Kollnes Industrial Park as it will appear in 2004, with the LNG terminal added to the existing industrial facilities.

Transportation

The LNG will be exported from Kollsnes mainly by ship. Naturgass Vest has chartered from Knutsen OAS a small LNG tanker (1000 m^3 capacity) on a 15 + 5 year term (see Figure 4). The ship is now being built in Holland and will be ready by September 2003, a month before the plant comes into operation. The ship has two 500 m^3 pressure vessels and a dual fuel based propulsion system (natural gas and diesel).

We will also buy two or three LNG-trailers which will be used for bringing LNG into Bergen and to smaller customers in the region that can be reached easily by truck. The first one has been ordered from Chart Ferox and will be delivered by March 2003.

The Customers

So far we have signed up contracts for deliveries of LNG of more than half of the yearly capacity, and we are about to finalize discussions with a number of customers for the rest.

The customers we have signed contracts with are:

- Hydro Aluminium, Sunndal: 8,700 tons per year for smelting, etc.
- Statoil, Ågotnes: 8 000 tons per year for two supply ships
- Sør-Norge Aluminium: Husnes, 3,000 tons per year for smelting, etc.
- BKK Varme, Bergen: starting with 500 tons per year, rising to 10,000 after 8 to 10 years
- Haukeland regional hospital, Bergen: up to 3,000 tons per year, for heating and steam raising

Figure 4: The 1000 m^3 capacity LNG carrier to be used on the project

At each of the customer's sites, a terminal has to be installed, consisting of one or more LNG tanks (each up to 450 m^3) and a vaporizer. The tanks will be supplied as turn-key deliveries by Aga Cryo of Sweden and Chart Ferox of Czechia, and are all vacuum insulated pressure vessels. All customers will receive the LNG by ship except the two in Bergen, which will receive it by truck. For those who will receive LNG by sea, we normally only have to modify existing marine reception facilities. In one case, though, we will have to construct a new jetty dedicated to LNG off-loading.

The price to the customer is normally referred to ex-vaporizer (except to the supply ships where it is ex-quay).

The total investment for the LNG plant plus all the customer terminals has a budget of about NOK250 million (EUR35 million).

So far the project is on schedule, both concerning time and costs. We hope this also will be the case when we come to October 2003. ■

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Integrated Natural Gas Liquefaction and Liquids Recovery

John Wilkinson, Hank Hudson, Richard Pitman, and Kyle Cuellar, Ortloff Engineers, Ltd., USA

This article describes the importance in LNG production of proper process selection for the natural gas liquids recovery stage and its heat integration with the liquefaction stage. A considerable reduction in power consumption can be accomplished.

In LNG production, regardless of the method used to liquefy the natural gas stream, it is common to require removal of a significant fraction of the hydrocarbons heavier than methane before the methane-rich stream is liquefied. The reasons for this hydrocarbon removal step are numerous, including the need to control the heating value of the LNG stream, and the value of these heavier hydrocarbon components as products in their own right. Unfortunately, little attention has been focused to date on the efficiency of the hydrocarbon removal step.

Ortloff has been developing technology for recovering liquids from natural gas for nearly 30 years [1]. Throughout this time, the governing principles for Ortloff technology have been higher recovery, better efficiency, greater simplicity, and better reliability than the processes offered by other companies and organizations. As a result, the Ortloff processes for liquids recovery are generally acknowledged as the state-of-the-art around the world.

During the past few years, much of the development effort at Ortloff has focused on extending this natural gas liquids recovery technology to allow efficient liquids recovery in conjunction with liquefaction of natural gas. This work has shown that careful integration of the hydrocarbon removal step into the LNG liquefaction process can produce both LNG and a separate heavier hydrocarbon liquid product using significantly less energy than reported in the literature for current processes. The remainder of this article presents the results of a study conducted by Ortloff to determine the recovery and efficiency performance of the new liquids removal technology when applied to a typical natural gas stream.

Study Parameters

A typical natural gas stream containing about 9% of hydrocarbons heavier than methane was selected for the study. The pressure of the gas stream was assumed to be 65.5 bar(a) (950 psia) after treating and dehydration. Water cooling to 35°C (95°F) was assumed for cooling and condensing of the refrigerant streams.

The LNG production rate for each case examined was set by assuming that two General Electric MS7001EA gas turbine drivers provide the refrigeration for the liquefaction cycle, with the power available based on 38°C (100°F) ambient air. No power recovery from the waste heat in the gas turbine exhaust was assumed. (Approximately 30-35 MW of power per gas turbine could be generated using an absorption refrigeration system, a closed-loop hydrocarbon refrigeration cycle, or a simple steam cycle, but no credit has been taken for this in the specific power consumption values given later.)

The liquid co-product produced for each of the cases in the study varied depending on the desired level of liquids removal. For cases producing C_2+ NGL (natural gas liquids), the C_1:C_2 ratio in the liquid was controlled to a typical NGL specification. For cases producing C_3+ LPG (liquefied petroleum gas), a C_2:C_3 ratio consistent with producing commercial-quality propane in downstream fractionation was used. Similarly, for cases producing condensate (butanes and heavier), a C_3:C_4 ratio consistent with producing commercial-quality butane in downstream fractionation was used.

Process Description

A block diagram for the Ortloff integrated LNG and liquids recovery process is shown in Figure 1. To simplify the process simulations used for the study, a relatively simple dual mixed refrigerant (DMR) cycle was used for all of the cases studied. However, the Ortloff liquids recovery technology can be integrated easily into any of the LNG liquefaction cycles commercially available today.

Depending on the particular process configuration used in the liquids recovery section and the desired recovery level for the co-product liquid stream, the treated and dehydrated natural gas feedstock was cooled using a combination of high-level mixed refrigerant, a slipstream of low-level mixed refrigerant, and/or process streams, followed by processing for liquids recovery. The resulting methane-rich residue gas then flows to the liquefaction section at relatively low temperature to be liquefied to form the LNG stream.

The degree of subcooling of the high pressure LNG stream was adjusted so that the flash gas formed during the pressure reduction step (to storage pressure) could supply most of the fuel required for the gas turbines driving the mixed refrigerant compressors. After compression to a suitable pressure for use as turbine fuel, the flash gas was mixed with a small supplemental stream of methane-rich gas from the liquids recovery section as needed to balance the turbine fuel requirements. (In practice, a gas recovery system would also be needed to capture the boil-off vapor from the LNG storage tanks, but this detail was not included in the process simulations for this study.) The power required for flash gas compression (as well as any miscellaneous rotating equipment in the liquids recovery section) is included in the specific power consumption values given later.

A mixed refrigerant stream in a closed vapor-compression refrigeration cycle was used to supply low-level cooling for the liquids recovery section and the LNG liquefaction section. A second mixed refrigerant cycle was used to supply high-level cooling for the liquids recovery section and pre-cooling of the low-level mixed refrigerant. The mixed refrigerant streams used in the simulation models were multi-component mixtures of nitrogen, methane, ethane, and heavier hydrocarbons. The particular compositions (as well as the number of components) were adjusted as needed to achieve a good match between the condensation of the process streams and the evaporation of the mixed refrigerant streams.

For most of the process configurations used in the liquids recovery section, a slipstream of low-level mixed refrigerant was used to supply a portion of the process cooling. For some of the configurations, one or more of the process streams generated within the liquids recovery section were used to cool low-level mixed refrigerant rather than supply process cooling directly. At the lower recovery levels there was generally a surplus of cooling available from the liquids recovery process, which was used to supplement the pre-cooling of the low-level mixed refrigerant.

Study Results

Six different cases were modeled with varying levels of co-product liquid recovery to show the impact on the overall cycle efficiency. Two were NGL recovery cases - ultra-high (95%) ethane recovery and medium (80%) ethane recovery. Similarly, two were LPG recovery cases - ultra-high (99%) propane recovery and medium (85%) propane recovery, and two were condensate recovery cases - high (90%) butane recovery and low (70%) butane recovery. The results of the cases are summarized in Table 1. (The annual production rates in Table 1 are based on operating 8,760 hours per year. Although it is typical to de-rate the production capacity, the assumed on-stream factor for LNG plants appears to

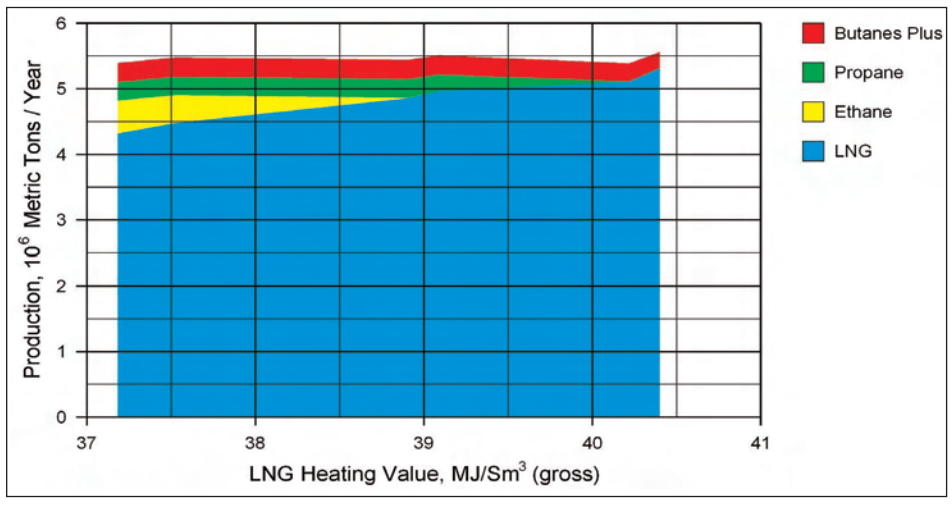

Figure 2 - Liquid Production Rates

Figure 1 - Block Diagram

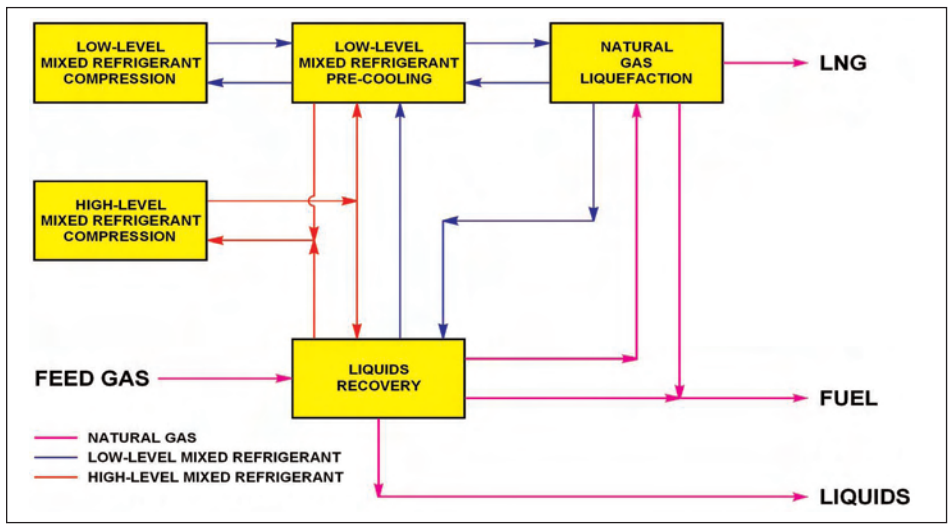

Table 1 Case Study Results

	Ultra-Hi C_2	Medium C_2	Ultra-Hi C_2	Medium C_2	High C4	Low C4
C_2 Recovery	95.0%	80.2%	---	---	---	---
C_3 Recovery	100.0%	96.4%	99.2%	84.9%	---	---
C_4 Recovery	100.0%	98.9%	100.0%	99.9%	90.5%	70.4%
C_5+ Recovery	100.0%	99.8%	100.0%	100.0%	99.2%	95.4%
Feed Gas,Mt/y (10^6 t/y)	5.91	6.00	5.95	6.02	5.90	6.08
LNG, Mt/y	4.32	4.48	4.86	4.97	5.11	5.32
Liquids, Mt/y	1.07	1.00	0.58	0.54	0.28	0.24
Total Liquid, Mt/y	5.39	5.48	5.44	5.51	5.39	5.56
LNG HHV, MJ/m^3(st)	37.2	37.5	38.9	39.1	40.2	40.4
Specific Power, kW-h/t	2231.3	227.7	229.5	226.7	231.8	224.7

vary from company to company. For ease of reference, no such de-rating was included in the study results.)

With proper selection of the liquids recovery process and careful integration of liquids recovery into the overall liquefaction cycle, the specific power consumption for producing LNG and a heavier hydrocarbon liquid co-product stream using Ortloff technology is relatively independent of the amount of heavier hydrocarbons removed. For the assumed gas turbine drivers, the total liquid production ranges between 5.4 and 5.6 million tonnes per year (5.4-5.6 Mt/y) depending on the makeup of the liquid co-product and the corresponding heating value of the LNG product as shown in Figure 2.

The relatively constant total liquid production, regardless of the degree of heavier hydrocarbon removal, is not so surprising considering that all of the gas stream must be liquefied as either LNG or liquid product. In past installations, however, the processes used for liquids recovery have not been particularly efficient and have not allowed for good heat integration with the liquefaction cycle. The Ortloff liquids removal technology addresses both of these limitations.

Conclusions

The specific power consumption of LNG plants is reported to range from 276 kW-h/t to 300 kW-h/t [2,3]. With proper process selection and heat integration between the liquids recovery and the liquefaction steps, a considerable reduction in the power consumption can be accomplished. As shown in Table 1, the specific power consumption using the Ortloff liquids recovery technology ranges from 225 kW-h/t to 232 kW-h/t depending on the type of liquid co-product produced in tandem with the LNG. These values are based on a relatively simple DMR liquefaction cycle, and could be further reduced using a more sophisticated DMR cycle, cascade refrigeration, or some of the other more recent developments in liquefaction technology.

Process configurations are available to provide maximum efficiency for a given product, or to allow efficient adjustment of the product recovery levels if the product consumption and/or economics are variable. The process efficiency and heat integration provided by the Ortloff liquids recovery technology allows choosing the appropriate recovery level with minimal impact on the overall power consumption, providing the following benefits:

- Lower specific power consumption means that larger train sizes are possible for a given driver selection. With inlet air chilling on the gas turbines, the train size could be as large as 7.5 Mt/y using a pair of Frame 7 drivers.
- The co-product liquid stream can be tailored to optimize the cash flow for a particular project by producing an NGL stream, an LPG stream, or a condensate stream to serve as feedstock for chemical manufacturing, domestic heating fuel, or liquid fuel refineries.
- Changes in feed gas composition have much less impact on the liquefaction section because the liquids recovery section can maintain its removal efficiency over a wide range of compositions.

The Ortloff liquids removal technology can be integrated into any type of natural gas liquefaction cycle. This means that all of the liquefaction cycles in use today can benefit from this technology, and that the choice of liquefaction cycle can be made independently of the recovery level desired in the liquids recovery section. This degree of flexibility should help to simplify the design and optimization of new LNG plants. It is also likely that existing LNG plants can be retrofitted to use Ortloff technology to raise the liquids recovery efficiency, increase plant throughput, or both. ■

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Ortloff Engineers, Ltd. (www.ortloff.com) is a process engineering consulting and licensing firm based in Midland, Texas specializing in cryogenic gas liquids recovery, sulfur recovery, and sour gas processing.

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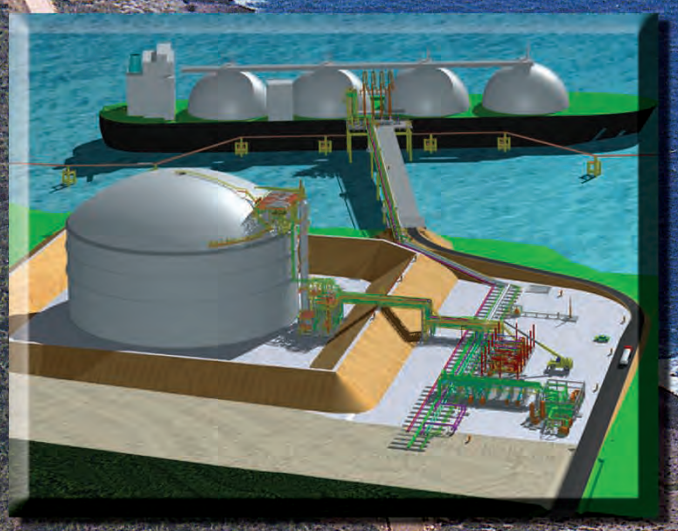

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