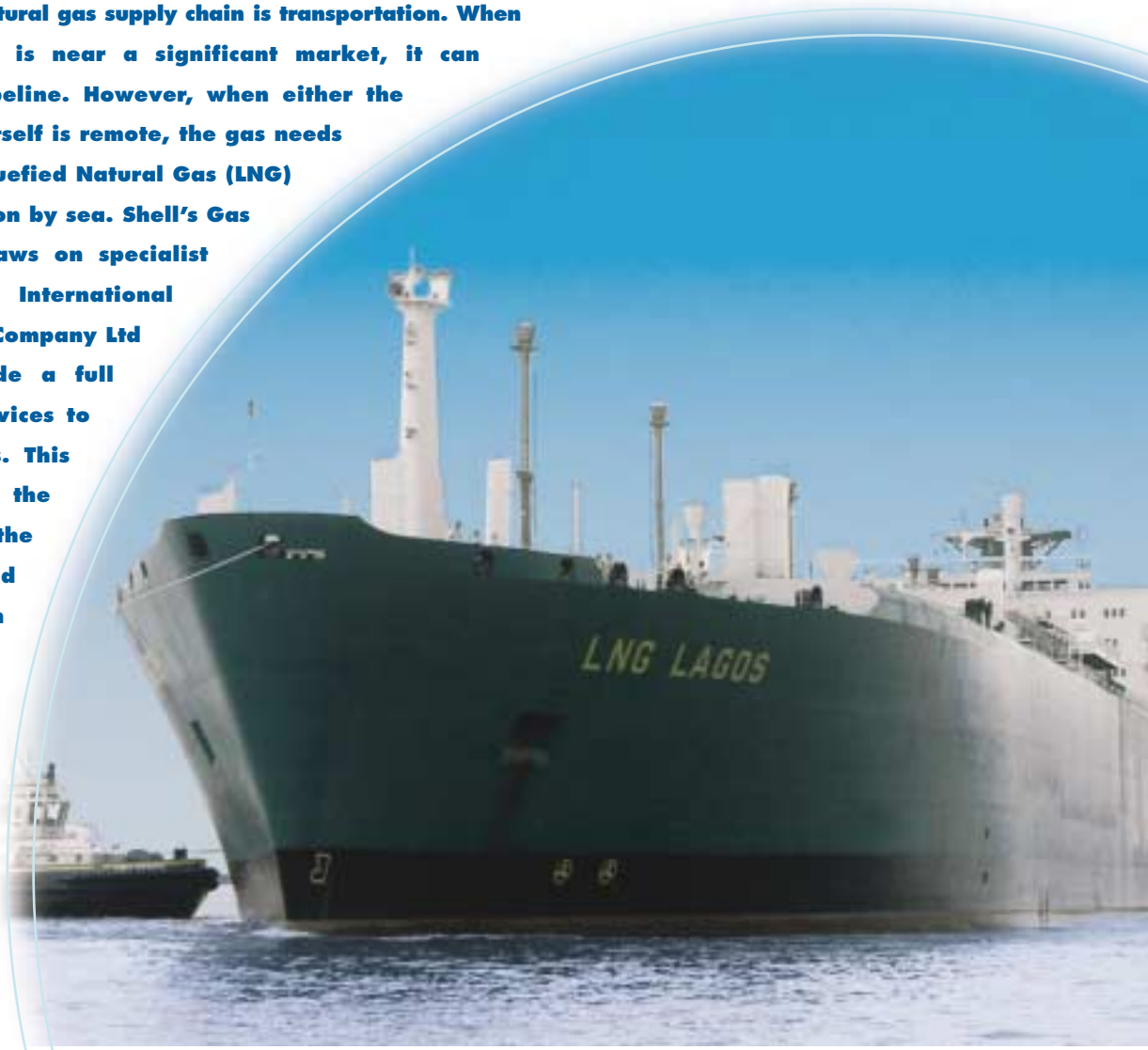
LNG Shipping

Taking Gas and Power Further

Shell Gas & Power

TRANSPORTATION OF NATURAL GAS BY SEA

A critical part of the natural gas supply chain is transportation. When a natural gas source is near a significant market, it can be transported by pipeline. However, when either the source or the market itself is remote, the gas needs to be converted to Liquefied Natural Gas (LNG) for viable transportation by sea. Shell's Gas & Power business draws on specialist support from Shell International Trading and Shipping Company Ltd (STASCO), who provide a full range of shipping services to Shell and its partners. This brochure explains the specialist nature of the shipping activity and how it has become an integral part of Shell's LNG knowledge base.



LNG Lagos, owned by Bonny Gas Transport, a 100% subsidiary of Nigeria LNG (in which Shell has a 25.6% equity holding)

LEADERS IN GLOBAL LNG SHIPPING

Expansion in the Liquefied Natural Gas industry is bringing new opportunities for Shell. Natural gas is becoming an increasingly important source of cleaner energy, making liquefaction and marine transportation a fast growing activity. In 1991, 65 LNG vessels were in service across the globe. In 2002 there are 130 vessels in service with significant numbers on order. As the global LNG fleet expands and new players enter the market, experience in LNG shipping will allow Shell to harness opportunities for its customers and co-venturers.

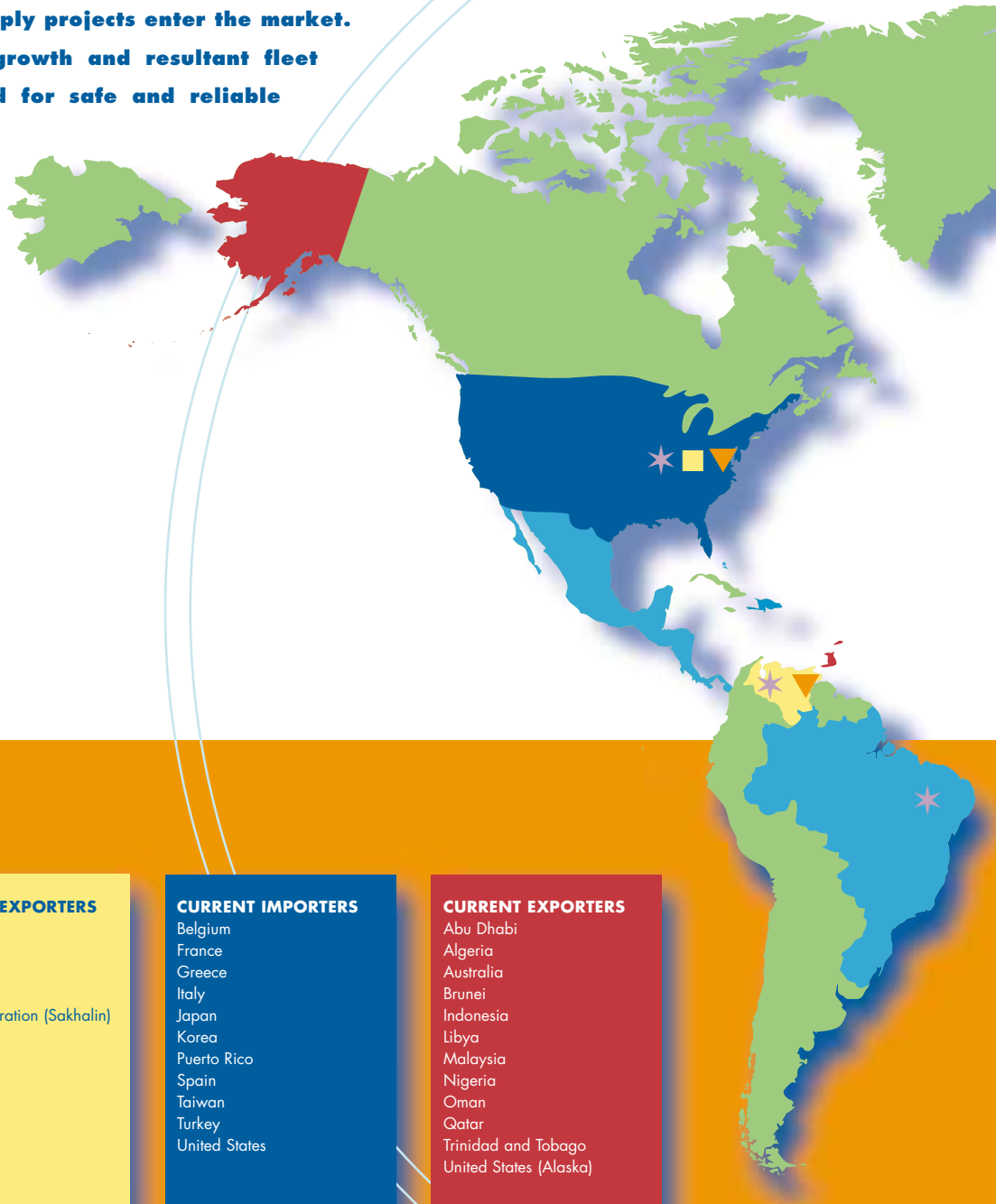
Shell's leadership dates back to 1964, when serious interest in the liquefaction of gas within the market began. Since the maiden voyages of the *Methane Princess* and *Methane Progress* in 1964, Shell has shipped over 8,500 cargoes without loss. As a result of this early involvement, Shell has developed specialist knowledge in the shipping of LNG to a variety of markets in Asia Pacific and the Atlantic Basin. With participation in the management, manning, or construction supervision of over 15% of the world's fleet, Shell is one of the largest LNG vessel operators in the world.

As the LNG shipping industry has developed over the decades, STASCO has provided a wide range of shipping services for joint ventures. These services have included feasibility studies, port and terminal expertise, technical consultancy, financing advice, fleet operations and vessel procurement. Through the breadth of these services, Shell can today bring credibility to an LNG project in the eyes of suppliers, financiers and customers alike, supporting the successful realisation of a project on the best possible commercial terms.

Methane Princess, one of the first LNG carriers managed and operated by Shell. Drawing on experience from a worldwide pool of marine professionals, Shell has provided LNG shipping solutions to a variety of customers and projects for over 40 years

WORLDWIDE LNG TRADE

A number of new supply and import terminal projects are currently under construction or consideration. This is a reflection of increased demand for LNG and as a consequence, the ordering of new LNG vessels has recently increased. Historically, LNG demand and hence shipping activity has been mostly focused in the Asia Pacific region largely due to Japanese import requirements, which account for approximately 40% of the world's LNG trade. Today, the Atlantic Basin is also a significant region of LNG activity and it is anticipated that trade flows will continue to grow and change as demand and supply projects enter the market. This high level of projected growth and resultant fleet expansion re-focuses the need for safe and reliable shipping as a key component in meeting the aspirations of LNG buyers and sellers alike.



WORLDWIDE LNG TRADE MOVEMENTS

PLANNED IMPORTERS
Bahamas
Brazil
Central America
China
Dominican Republic
Finland
India
Jordan
Lebanon
Mexico
Portugal

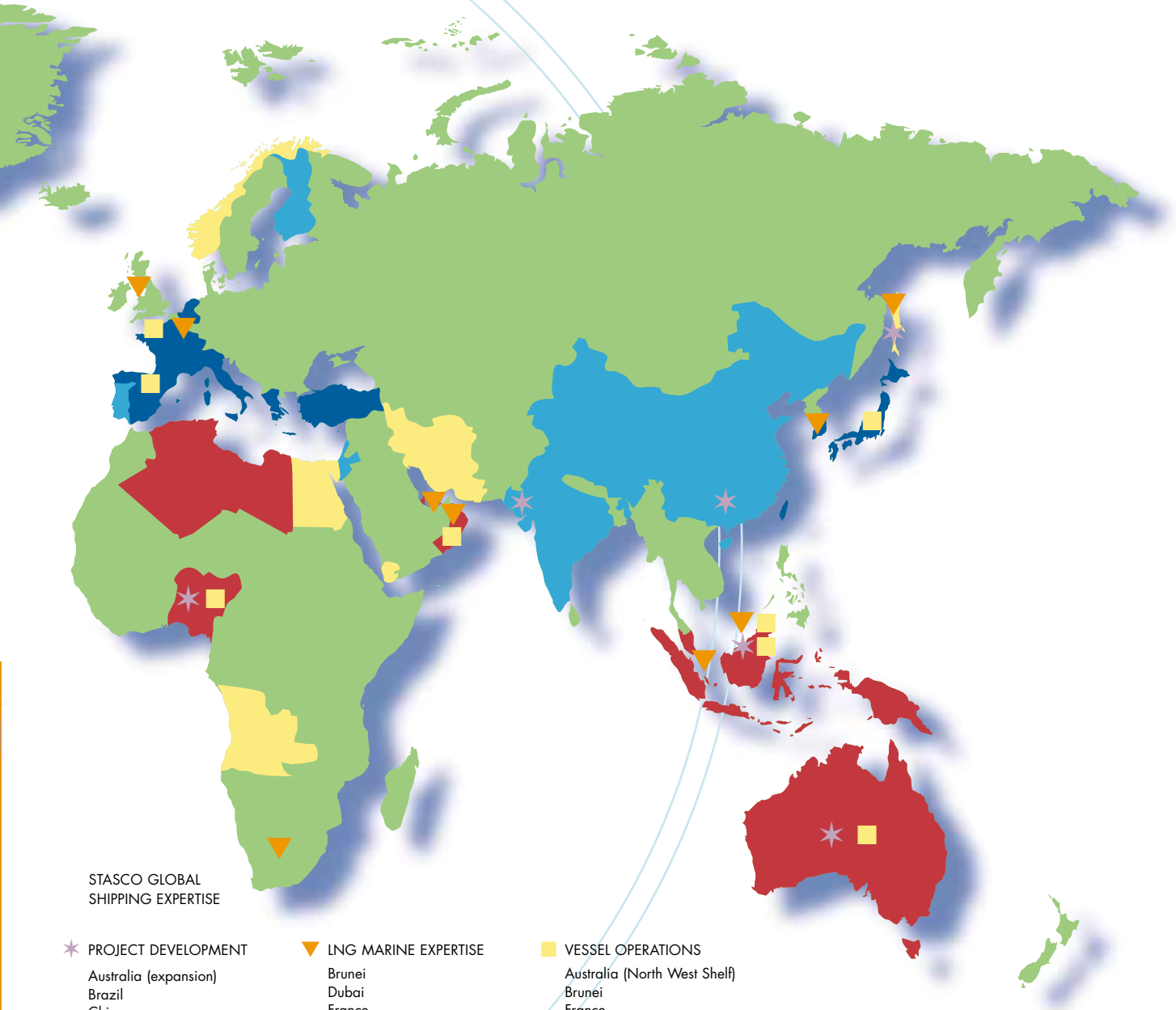
PLANNED EXPORTERS
Angola
Egypt
Iran
Norway
Russian Federation (Sakhalin)
Venezuela
Yemen

CURRENT IMPORTERS
Belgium
France
Greece
Italy
Japan
Korea
Puerto Rico
Spain
Taiwan
Turkey
United States

CURRENT EXPORTERS
Abu Dhabi
Algeria
Australia
Brunei
Indonesia
Libya
Malaysia
Nigeria
Oman
Qatar
Trinidad and Tobago
United States (Alaska)

STASCO SHIPPING OPERATIONS

Through management or manning, STASCO is involved with approximately 15% of the world's LNG fleet, representing one of the largest operators in the business. Shell's expanding gas and power business aspirations provide STASCO with an opportunity to continue to support Shell's equity gas sales and exercise its ability to meet ship requirements in quality and reliability to a wide spectrum of customers.



STASCO GLOBAL SHIPPING EXPERTISE

✶ PROJECT DEVELOPMENT

Australia (expansion)
Brazil
China
India (west coast)
Malaysia (expansion)
Nigeria (expansion)
Russian Federation (Sakhalin)
United States
Venezuela

▼ LNG MARINE EXPERTISE

Brunei
Dubai
France
Korea
Oman
Russian Federation (Sakhalin)
Singapore
South Africa
UK
USA
Venezuela

■ VESSEL OPERATIONS

Australia (North West Shelf)
Brunei
France
Japan
Malaysia
Nigeria
Oman
Spain
USA

SHIP MANAGEMENT

The LNG shipping industry as a whole has enjoyed an excellent safety record since its inception, delivering cargoes without loss since 1964. Nevertheless, LNG is a technically demanding cargo that requires sophisticated vessels manned and operated by qualified, experienced staff. Ship managers face many challenges to ensure that an LNG cargo is delivered in the safest and most efficient manner.

Maintaining operational excellence relies on the co-operation and partnership between ship staff and those on shore. The strong emphasis on safety and reliability in LNG shipping will continue to have a key role in the management of vessels as LNG enters into a period of expansion. Some of the considerations in ship management are shown below:

- Manning
- Training
- Technical support
- Emergency Response
- Dry docking
- Insurance
- Day-to-day operations
- Technology transfer
- Reactivation
- Modernisation

As with oil shipping, the LNG shipping industry standards are monitored through the International Maritime Organisation (IMO) regulations and Flag State control. In addition to their legal obligations, owners and managers have their own systems of Emergency Response, quality and HSE management.

STASCO ship management personnel based in London

SHELL AND SHIP MANAGEMENT

In total, the Shell Group employs over 2,000 maritime staff. This figure includes over 85 qualified ship captains and 120 office-based staff worldwide. These staff contribute to the smooth running of a growing portfolio of 25 LNG vessels managed, manned and operated by STASCO. Professional ship operation and management has resulted in an enviable operating record within the industry. It is only through setting high standards that STASCO and its predecessor organisations have been able to play a leading role in serving their shipping customers since the first cargoes of LNG were delivered in 1964.

The management and manning operation includes the recruitment, selection and training of qualified officers and crew. Human resource best practice ensures that all employees are monitored and appraised regularly, helping them to fulfil their potential. In addition, STASCO's fleet provides a training ground for future superintendents to oversee technical and operational management of vessels.

EMERGENCY RESPONSE AND SAFETY

Our vessels operate to a Safety Management System which in 1995 was among the very first to be approved under the requirements of the ISM (International Safety Management) Code. STASCO's safety performance is amongst the best in the industry.

STASCO's safety routine incorporates a 24 hour callout, a detailed infrastructure and full logistical support.

A dedicated Emergency Response casualty centre in London is maintained with the expertise and resources necessary to support a swift and effective response worldwide. Emergency scenarios are exercised on a regular basis and emergency drills are part of a weekly safety routine on board.

Lifeboat drill on board the *Northwest Seaeagle*

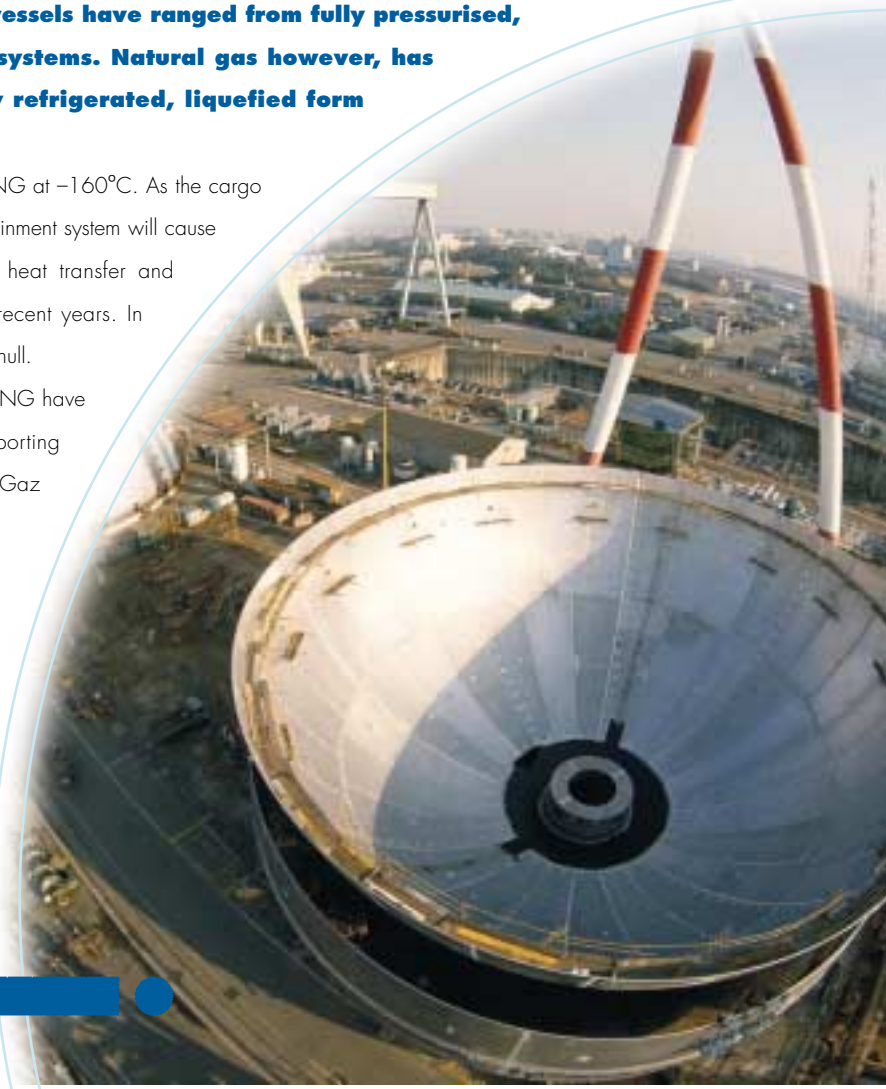
LNG SHIP DESIGN AND CONTAINMENT SYSTEMS

Several types of ship have been developed over the years to carry butane, propane, ethane, ethylene and natural gas in liquid form. These vessels have ranged from fully pressurised, through semi-pressurised to fully refrigerated systems. Natural gas however, has only ever been shipped commercially in a fully refrigerated, liquefied form at low (essentially atmospheric) pressure.

All LNG hulls require specially designed insulation to carry LNG at –160°C. As the cargo is at its boiling point, any heat flow from the outside into the containment system will cause evaporation, or 'boil off'. Insulated tanks therefore minimise heat transfer and development in this field has reduced boil off significantly in recent years. In addition, the insulation protects the integrity of the outer mild steel hull.

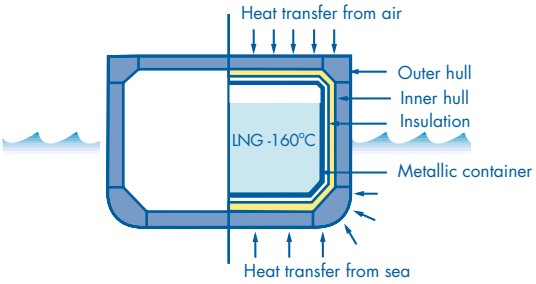
Since the mid 1960s, two main designs for the transport of LNG have emerged and remain predominant – the single barrier, self-supporting Moss system and two membrane systems, Technigaz and Gaz Transport.

Free-standing Moss ship under construction at Hyundai Heavy Industries, South Korea



LNG tanks under construction at Mitsui Shipyard, Chiba, Japan. The tanks have been installed on LNG carriers for the North West Shelf project in Australia

INSULATION AND BOIL OFF

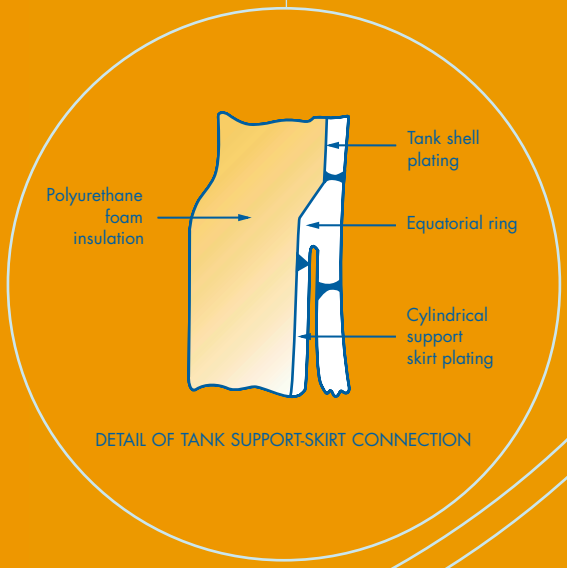


Purpose of insulation
– to protect hull steel from low temperature embrittlement
– to limit heat transfer and boil off from cargo

Purpose of metallic container
– to contain the LNG cargo
– to protect the insulation

FREE-STANDING CONTAINMENT SYSTEMS

Free-standing systems are built as self-supporting tanks and can either be prismatic or circular spheres built as a separate unit to the main hull. The artist's impression below shows the design of a Kvaerner-Moss five tank free-standing system, currently being built by Mitsubishi Heavy Industries for Shell.

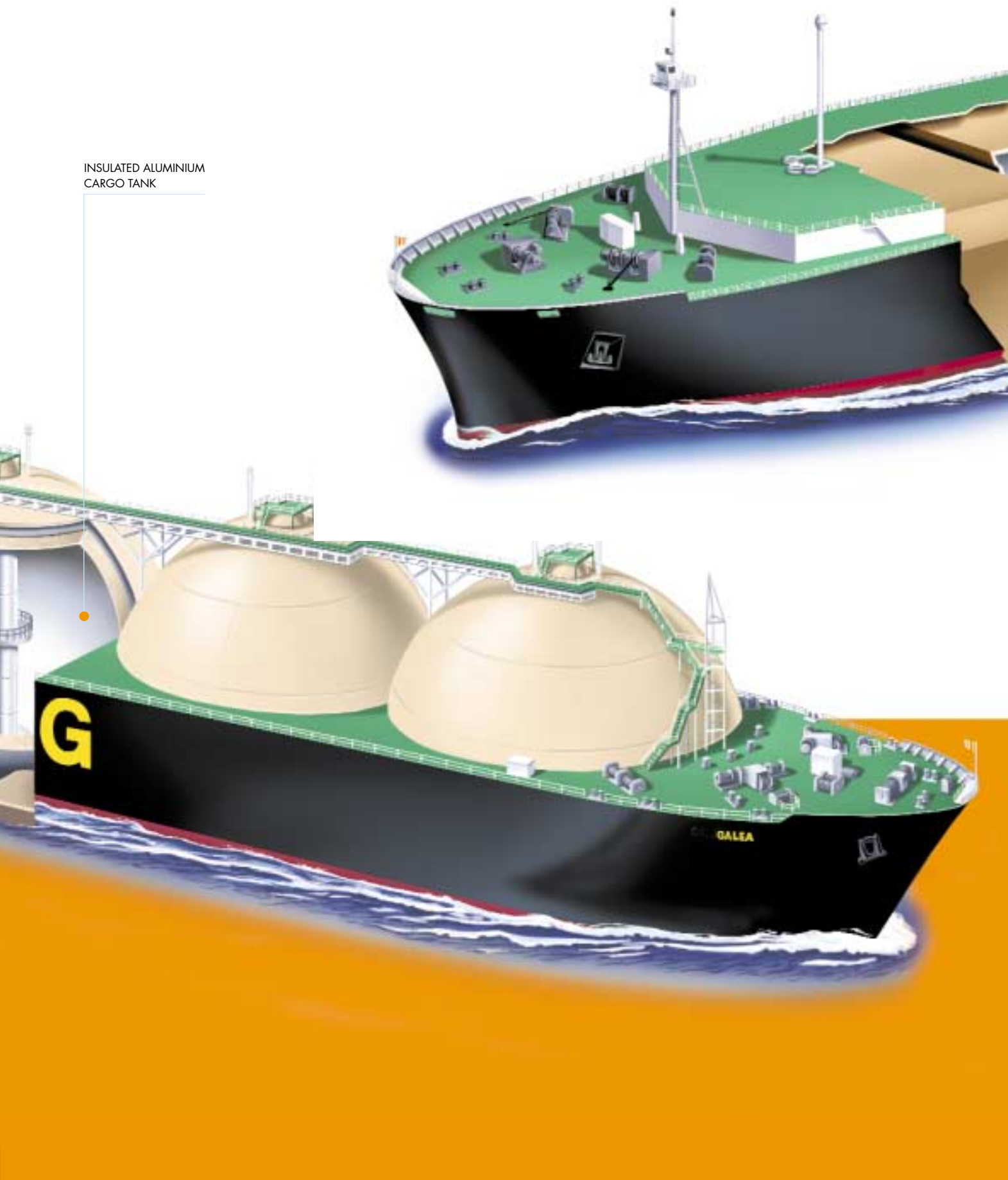


DETAIL OF TANK SUPPORT-SKIRT CONNECTION

PRINCIPAL VESSEL CHARACTERISTICS

Length overall	290m
Breadth	46m
Depth	25.5m
Design draft	11m
Deadweight	67,300t
Cargo tanks at -163°C	135,000m³
Fuel oil tanks	2,700m³
Diesel oil tanks	200m³
Water ballast tanks	53,450m³
Boil-off rate	0.15%
Engine power	21,320KW
Speed	19 Knots
Type of cargo tanks	Independent spherical tanks
Number of tanks	5

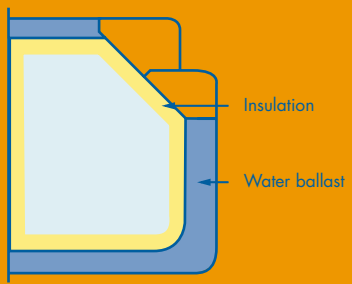
MEMBRANE CONTAINMENT SYSTEMS

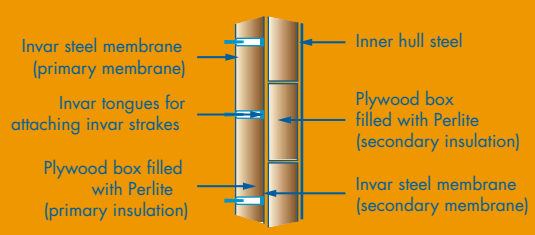


Membrane systems developed predominantly by Technigaz and Gaz Transport incorporate tanks integral to the design of the whole vessel. Technigaz use stainless steel while Gaz Transport use Invar (36% nickel steel alloy). This optimises the use of the hull space which otherwise remains redundant in free-standing systems. The artist's impression above shows a cut-away section of the membrane tank containment system.

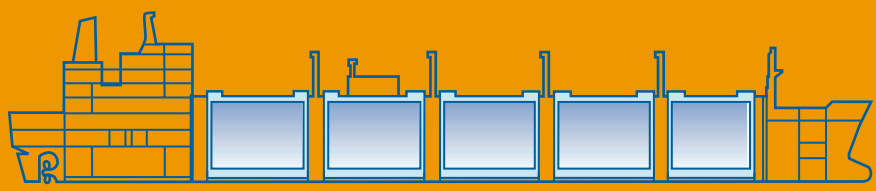
The engine room of a Moss ship under construction at Hyundai Heavy Industries, South Korea

A TYPICAL GAZ TRANSPORT MEMBRANE TANK SYSTEM





PROFILE



PROPULSION SYSTEMS

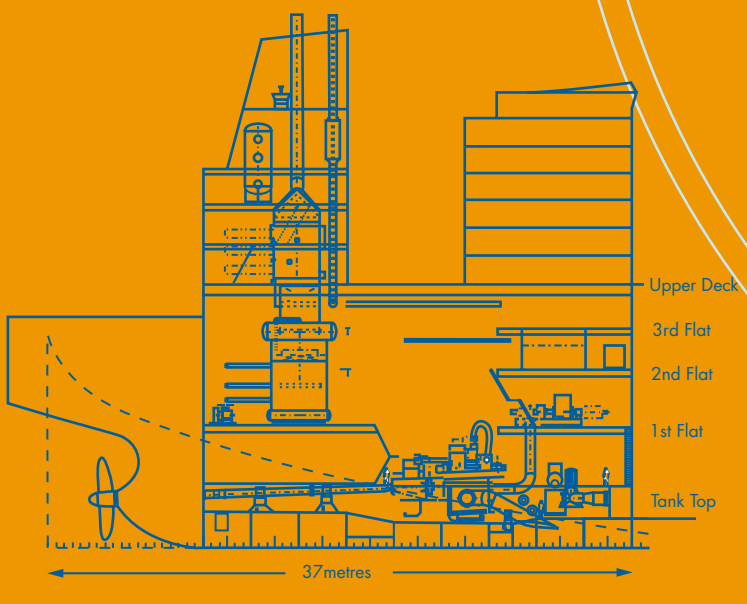
LNG vessels have traditionally employed steam turbine propulsion systems. These systems have given a high degree of reliability and this, coupled with the ease with which they can handle the use of boil off gas as fuel, has resulted in steam turbines being the first choice for all large LNG ships to date. It is acknowledged however, that the steam turbine has almost entirely been replaced in other merchant shipping sectors by the diesel engine. The diesel engine offers significantly better fuel consumption but technical considerations arise with the use of boil off gas as fuel in large diesel engines. These have not been resolved in LNG vessels to date, hence the continuing dominance of the steam turbine in LNG ships.

ALTERNATIVE PROPULSION SYSTEMS

Even though steam turbines have been the preferred method of propulsion in LNG vessels, they suffer from high fuel consumption. Several alternative designs have therefore been considered. One option currently under consideration is a dual fuel diesel-electric system. This offers advantages in the degree of redundancy and flexibility, as demonstrated in the cruise liner industry.

Gas turbines are a second alternative. Proven in warships, this system offers a high power to weight ratio and increasingly high reliability, together with a significant reduction in the size of the engine room. Looking further ahead, the advances in fuel cell technology may provide an opportunity for a viable LNG propulsion plant.

A TYPICAL STEAM TURBINE PROPULSION SYSTEM



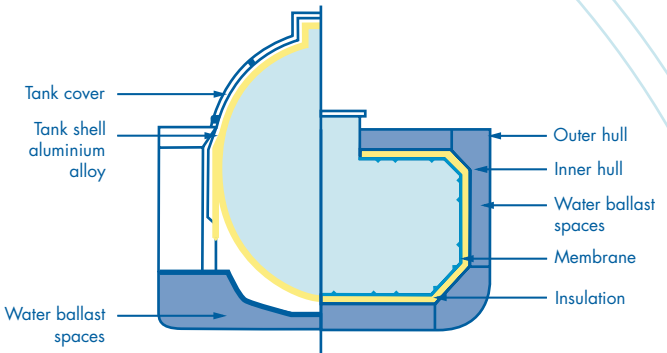
Spherical tanks are employed in some designs, while the remainder are based on rectangular or trapezoidal flat walled structures, tailored to closely fit the ships' hold spaces. Membrane systems fit efficiently into the hull shape, while spherical tanks inevitably result in some inefficient use of hull capacity.

Large spheres are constructed from aluminium alloy plates using special techniques. Spherical tanks are produced to a high degree of accuracy and are tested thoroughly with methods such as ultrasonics and X-rays to detect potential defects.

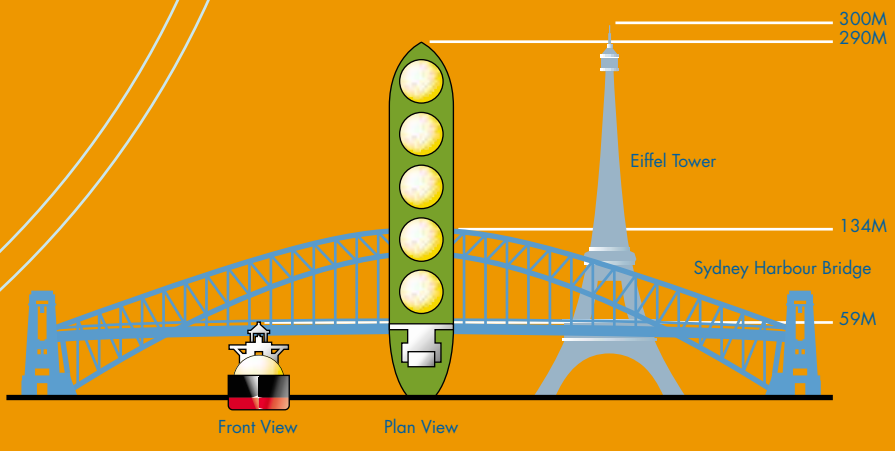
Examples of spherical tanks under construction are shown in the photographs opposite. The inset picture shows the foremost part of a free-standing Moss Ship being built, with part of the spherical tank ready for installation. This particular vessel will be assigned to the Nigerian LNG project and is expected to enter service towards the end of 2002.

All the ships employ double hulled structures with the space between the hulls being used to carry ballast water on return journeys. Out of the 130 gas carriers currently in existence, approximately 66% use the Moss spherical system, while 28% use the membrane system. The remaining 6% is taken up by other designs. Considerations such as ship-to-shore compatibility, weather conditions, project specific requirements and commercial aspects will determine the selection of the most appropriate containment system for the customer.

CONTAINMENT SYSTEMS: MAIN DESIGN FEATURES



SELF SUPPORTING TANKS	MEMBRANE TANKS
Tank: Heavy rigid metallic High material and fabrication cost	Tank: Specialised light construction High material and fabrication cost
Tank capacity: 125,000m^3 Ship tank material weight: 4,000 tons	Tank capacity: 125,000m^3 Ship tank material weight: 400 tons
Insulation: Non-load bearing Relatively cheap	Insulation: Rigid load bearing over whole surface Relatively expensive



GLOBAL PARTNERS IN JOINT VENTURE AND SHELL PROJECTS

STASCO and its predecessor organisations have maintained continuous involvement in LNG shipping for over 40 years, securing the safe delivery of over 8,500 cargoes worldwide. During the period 1990 to 2000, the business successfully completed over 450,000 million tonnes sea miles of LNG transportation for a wide variety of customers, representing LNG sellers, buyers, charterers and vessel owners.

Support to Shell Gas & Power's interests have included:

BRUNEI

In 1972, the Brunei LNG trade to Japan commenced with the first of seven ships, the result of a joint venture agreement between Shell and the Brunei government. Shell provided assistance in the design, construction supervision and acquisition management of the vessels whilst they were being built in France. In the early 1990s, Shell supervised and conducted a life extension study on the fleet, which resulted in an agreement with the Japanese buyers to utilise these vessels for the foreseeable future. The eighth vessel, the newbuilding *Abadi* joined the fleet in 2002.

MALAYSIA

STASCO has provided manning services for Malaysian International Shipping Corporation and Petronas since 1982, when the Malaysian LNG Satu project delivered its first cargo to Japan on board a *Tenaga* class vessel. Since 1994, a similar service has been provided to the Malaysian LNG Dua Project, which commenced delivery of LNG to Japan, Korea and Taiwan using the *Puteri* class of LNG vessels.

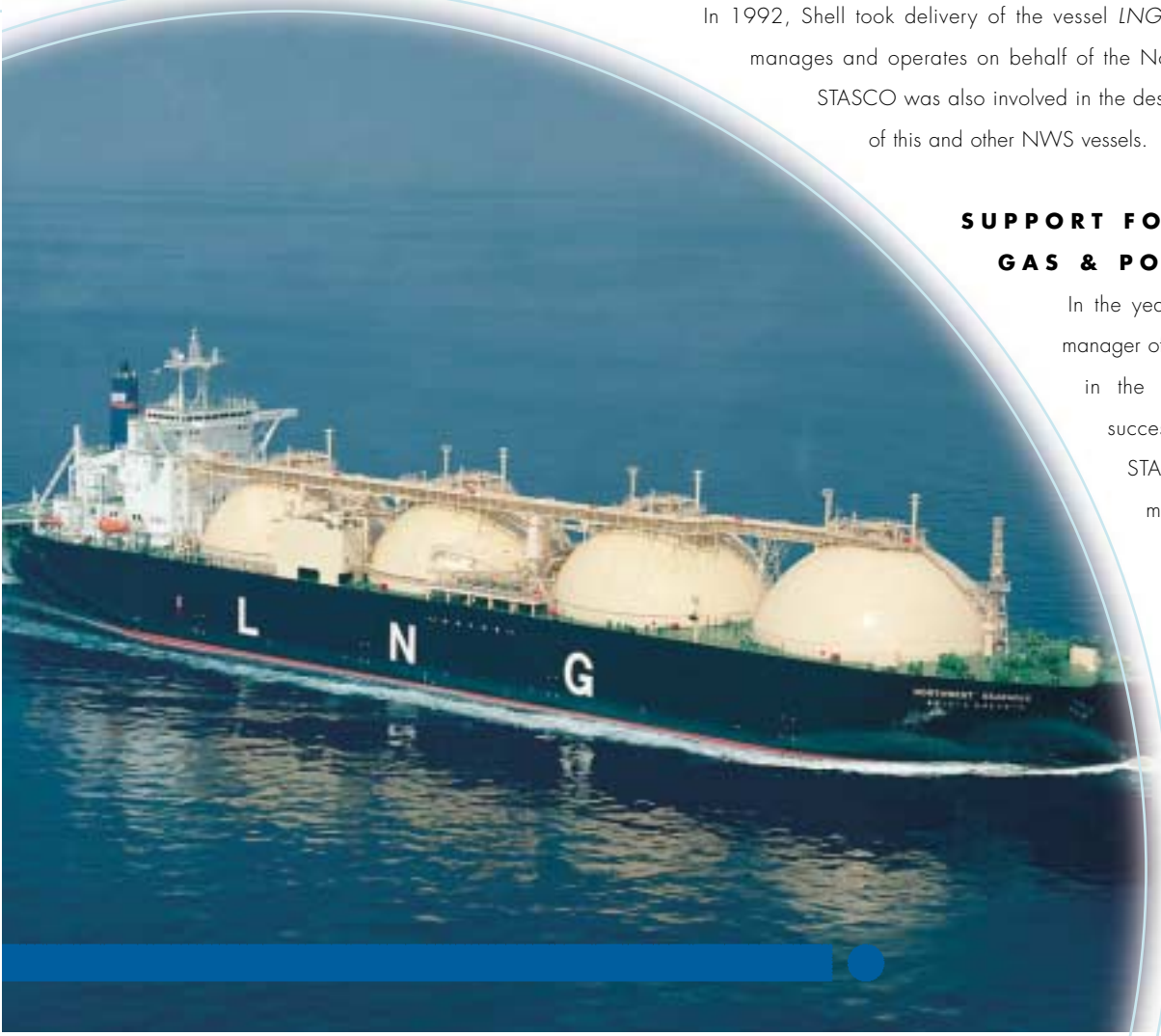
NIGERIA

The vessels *LNG Bonny*, *Finima* and *Port Harcourt* were reactivated for commercial use in the early 1990s by Bonny Gas Transport. They were placed under the management of STASCO prior to the commencement of the Nigeria LNG project. The fourth Bonny Gas Transport vessel, *LNG Lagos*, was refurbished in 1999 and the newbuilding *LNG Rivers* joined the fleet in 2002 with a further two newbuildings for delivery in 2002/3. All vessels are managed and operated by STASCO.

Brunei Shell Petroleum recruiting cadets at the Bruneianisation Road Show

AUSTRALIA

In 1992, Shell took delivery of the vessel *LNG Northwest Seaeagle*, which it manages and operates on behalf of the North West Shelf (NWS) Project. STASCO was also involved in the design and construction supervision of this and other NWS vessels.



The *Northwest Seaeagle*, operated by STASCO is employed on the North West Shelf project carrying LNG on the Australia/Japan route

SUPPORT FOR SHELL GAS & POWER

In the year 2000, STASCO became the manager of *LNG Delta*, a vessel reactivated in the United States, which is now successfully trading for Nigeria LNG. STASCO has also become the manager of its sister ship, *LNG Galeomma*. This vessel entered active service in the same year, with the loading of a cargo of Oman LNG for delivery on behalf of Coral Energy L.P., USA, to Lake Charles. In September 2002, Shell Gas & Power took delivery of the new LNG carrier *Galea* to facilitate the shift to increasing global trade in LNG.

With three new vessels currently on order, Shell will continue to strengthen its leadership position in LNG shipping in preparation for a range of portfolio opportunities worldwide.

SHIPPING SERVICES

Effective management of commercial arrangements and LNG shipping projects is of key importance to our customers. To support this, Shell is able to call on a unique and diverse range of skills and experience in shipping in both technical, operational, strategic and commercial aspects, ensuring that the best possible service is given to those requiring assistance with LNG shipping.

The STASCO operations unit is able to offer the services required for the day-to-day operation of LNG vessels. To complement this, STASCO's specialised technical team – Shell Shipping Technology – is able to offer consultancy and advice on a wide range of marine technical and commercial requirements. This combination ensures the safe and efficient acquisition, building and operation of LNG carriers using some of the most experienced LNG professionals in the field:

■ Port and terminal expertise

- o Advice on the acceptability of new vessels and/or new marine operations within project terminals
- o Provision of experienced LNG marine personnel to participate in the management of port and terminal operations

■ Advice on shipping configurations

- o Analysis of the optimum project fleet requirements at the lowest cost
- o Advice on corporate shipping structures, organisational arrangements and charter party contracts
- o Advice on implications of existing contracts, post-contractual and supervision of the commercial/financial aspect of LNG shipping projects

Shell Shipping Technology team working on design assessments

■ Vessel procurement

- o Advice on the tendering and negotiation process for newbuilds and overall shipping cost
- o Analysis of the current availability of existing vessels and their likely cost according to project specifications
- o Inspection of vessels to assess suitability for charter or purchase
- o Determining shipping costs and freighting analysis
- o Plan approval and construction supervision
- o Assistance in securing vessel employment and advice on possible future opportunities for available vessels in interim trade
- o Analysis of LNG shipping technology and innovative engineering concepts

■ Fleet operations

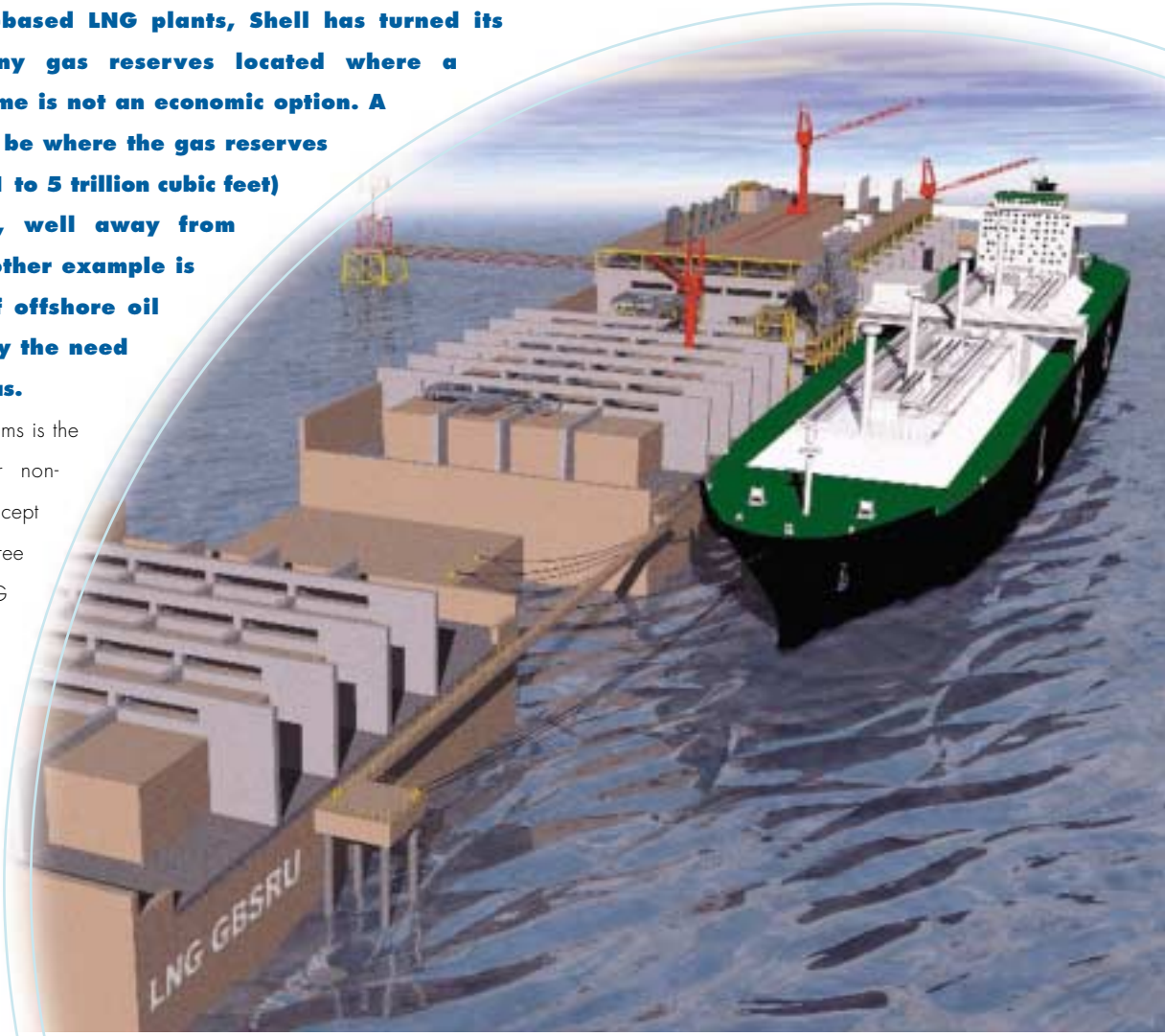
- o Advice on the tendering process for fleet operations and port services
- o Facilitation in training of pilots
- o Vessel management advice
- o Construction of project schedules either using newbuild or existing vessels
- o Preparation, co-ordination and approval of refits, and other refurbishment that may be required to meet latest standards
- o 24 hour Emergency Response facility.

The fleet operations team are formed from a wide range of expertise in both LNG and Oil Shipping

FLOATING LNG

Building on more than three decades of design and operating experience with land-based LNG plants, Shell has turned its attention to the many gas reserves located where a conventional LNG scheme is not an economic option. A typical example would be where the gas reserves are relatively modest (1 to 5 trillion cubic feet) and located offshore, well away from potential markets. Another example is where development of offshore oil reserves is inhibited by the need to handle associated gas.

The answer to these problems is the Floating LNG Concept. For non-associated offshore gas this concept incorporates the replacement of three elements of a conventional LNG scheme, namely the production platform, the pipeline to bring gas ashore and all the onshore facilities for liquefaction and loading. Instead, using sub-sea production, the offshore gas is produced directly to a barge moored above the gas field, with the barge supporting a compact liquefaction plant and storage facility. LNG is then loaded directly onto LNG tankers moored alongside the barge. The whole facility is known as an LNG Floating Production, Storage and Off-loading unit (FPSO). Associated gas can also be treated in this way, though depending upon the amount of gas to be processed, the FPSO may be either a stand-alone plant for LNG or an integrated facility for both oil and gas handling.



Economic competitiveness of a Floating LNG facility depends upon achieving a high energy efficiency and economies of scale. These two requirements are met by Shell's newly developed Double Mixed Refrigerant process. By eliminating both platform and onshore plant and by optimising the layout of the barge mounted equipment, the LNG FPSO maintains the same high level of safety and reliability as conventional LNG schemes.

EXPLANATORY NOTE

This brochure reviews the scope of the natural gas and power related businesses of the Royal Dutch/Shell Group of Companies (Shell). It describes the energy solutions that Shell offers to our customers, co-venturers and the communities with whom we work. Shell has five core business sectors, encompassing:

Exploration and Production searches for, finds and produces oil and gas. Builds the infrastructure needed to deliver hydrocarbons to market.

Gas & Power commercialises natural gas, supplies liquefied natural gas, develops markets and infrastructures, markets and trades natural gas and electricity, develops power plants and converts Gas to Liquids.

Oil Products sells and markets transportation fuels, lubricants and speciality products. Refines, supplies, trades and ships crude oil and petroleum products. Provides consultancy services to third parties based on Shell technology and experience gained in Shell operations.

Chemicals produces and sells base chemicals, petrochemical building blocks and polyolefins globally.

Renewables generates 'green' electricity and provides renewable energy solutions. Develops and operates wind farms, manufactures and markets solar systems and grows sustainably managed forests.

Other activities other business activities include: Shell Hydrogen, Shell Trading and Shell Consumer.

These business sections operate globally and are supported by Shell service companies in London and The Hague, and Shell's research laboratories. Shell's global presence, local knowledge and worldwide pool of expertise and skilled people are available to meet our customers' needs in gas and power.

Offshore LNG Terminal on a gravity base structure

SHELL'S BUSINESS PRINCIPLES

Shell Companies operate under a code of conduct called the Statement of General Business Principles. These principles govern the way we operate and provide, for our employees and for the outside world, an ethical framework which is both mandatory and transparent. This statement has been a public document for the last 20 years.

The Group publishes 'The Shell Report' which provides information on its economic, environmental and social performances set out against the Group's Business Principles.

This publication is one of a range published by Shell Gas & Power External Affairs, which include:

Taking Gas and Power Further (Overview)

Gas Pipelines

Liquefied Natural Gas (LNG)

LNG Receiving Terminals

Power Generation

Shell Middle Distillate Synthesis (SMDS), Process and Products

For copies of the above and details of other titles available, please contact:

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Information about Royal Dutch/Shell Group of companies can be accessed at: www.shell.com

Each Shell company is a separate entity but in this publication, the words 'Shell' 'we' 'us' and 'our' are used for convenience to refer to Shell companies in general or where no useful purpose is served by identifying any particular Shell company or companies.

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