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Introduction

The use of natural gas as an independent branch of the global energy supply sector began in the early 1960s. Prior to that, natural gas had only been regarded as a by-product of crude oil production; there was no use for it and so it was either pumped back into the ground or flared. But all that has changed in the meantime – natural gas currently accounts for 22% of global energy supplies. Huge deposits in Australia are now being exploited and deposits in the USA will soon be coming online, which will increase that global share (Fig. 1.1). There are many reasons for this development – economic, political and ecological: Australia is close to the growing Asian economies, the USA is aiming to reduce its dependence on foreign oil and energy supplies by developing its own resources, and global efforts to replace fossil fuels by gas apply throughout the world.

The International Maritime Organisation (IMO), a specialised agency of the United Nations, has drawn up new rules that have been valid from 2015 and are particularly strict for the North Sea and Baltic Sea. Complying with emissions requirements is difficult when using diesel and heavy oil as marine fuel. But using liquefied natural gas (LNG) as a marine fuel results in – compared with diesel – about 90% less nitrogen oxide, up to 20% less carbon dioxide and the complete avoidance of sulphur dioxide and fine particles [1]. Det Norske Veritas (DNV), the Norwegian vessel classification body, therefore expects that there will be about 1000 new LNG-powered ships by 2020, which amounts to almost 15% of predicted new vessel orders. This change is heavily influenced by the huge drop in the price of natural gas, which has been brought about by the global production of shale gas (Fig. 1.2, Fig. 1.3).

The use of natural gas involves transport and storage difficulties. Transport via pipelines is economic up to a distance of 4000–5000 km, depending on the boundary conditions. In the case of difficult geographic circumstances, such as supplies to islands, e.g. Japan and Taiwan, or where it is necessary to cross mountain ranges, supplying gas via a pipeline is much more difficult and costly. Therefore, the method of liquefying natural gas and then transporting it over great distances in ships had already become established by the mid-20th century.

LNG technology takes advantage of the physical material behaviour of natural gas, the main constituent of which is methane. At the transition from the gaseous to the liquid state, the volume is reduced to 1/600. However, this requires the temperature of the gas to be lowered to -162°C. Only this extreme reduction

Design and Construction of LNG Storage Tanks, First Edition. Josef Rötzer.

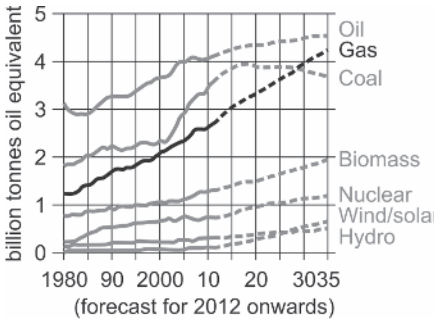

Fig. 1.1 Development of energy demand [1].

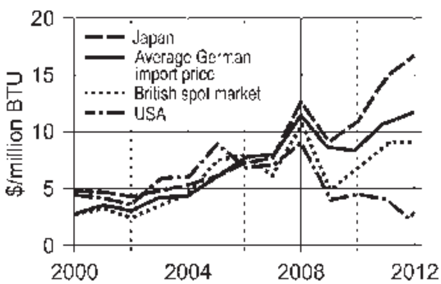

Fig. 1.2 Gas price developments since 2000 [1].

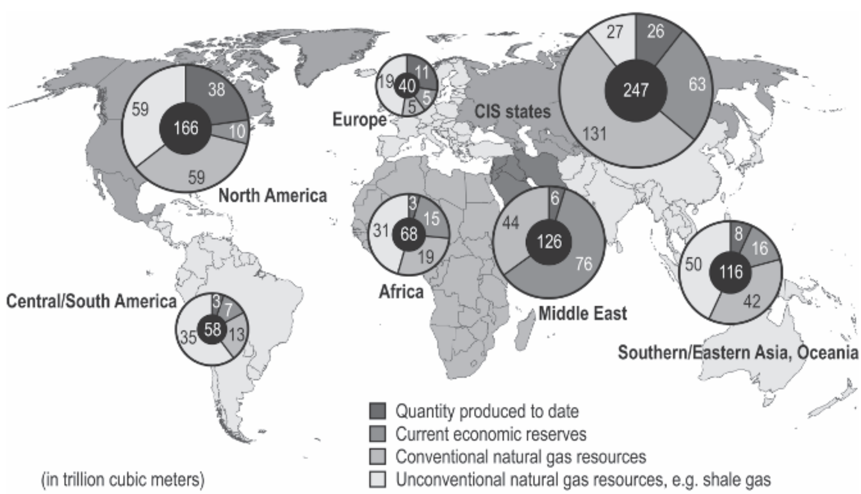

Fig. 1.3 Regional distribution of natural gas potential [1].

in volume makes transport in ships economically viable. The entirety of the elements required for transporting LNG in ships is known as the "LNG chain", which consists of the liquefaction plant in the country supplying the gas, LNG tanks for intermediate storage of the liquefied gas, jetties as berths for the special LNG transport vessels, tanks for the intermediate storage at the receiving (i.e. import) terminal and a regasification plant in the country importing the gas.

It is common practice these days to build full containment tanks, which consist of an outer concrete secondary container surrounding an inner steel primary container. The prestressed concrete outer container serves to protect the thin-wall steel inner container against external actions and also functions as a backup container in the event of the failure of the primary container. The outer container must prevent uncontrolled leakage of vapours into the environment and must also be able to contain the liquefied gas and withstand any overpressure.

The great hazard potential of LNG is the risk of fire. If LNG changes to its gaseous state and mixes with air, the result is a combustible gas that can explode, and certainly burns very fiercely. Safe transport and storage are the technical challenges of LNG. At these low temperatures, the materials normally used in the construction industry exhibit a distinctly brittle behaviour and fail abruptly. During normal operation, the steel inner container takes on the temperature of the liquefied gas and cools to -165°C. In order to guarantee sufficient ductility at this temperature, the inner container must be made from 9% nickel steel or stainless steel. Thermal insulation about 1 m thick is placed between the steel inner and concrete outer containers.

Between the underside of the steel inner tank and the base slab of the concrete outer tank, the thermal insulation consists of loadbearing cellular glass (often called foam glass). The annular space between the inner and outer containers is filled with perlite, and a layer of elastic material (resilient blanket) is installed to compensate for the horizontal thermal deformation of the inner container. The insulation on the aluminium roof of the inner container is made from glass fibre or perlite. What at first sight seem to be very generous dimensions are necessary in order to keep the boil-off rate below 0.05% by vol. per day. Should the inner container fail, the inside face of the concrete outer container cools to -165°C, and that calls for the use of special reinforcement that can resist such low temperatures. The dynamic design for the seismic load case must take into account the action of the sloshing of the liquid and the interaction with the concrete outer container. The tank must be designed to withstand a so-called operating basis earthquake (OBE), i.e. is not damaged and remains operable, and also for a so-called safe shutdown earthquake (SSE).

Reference

1 Flüchtige Zukunft. Wirtschaftswoche, No. 32, 2012, pp. 58–65.