

Requirements for personnel qualifications and training for handling the marine part of LNG transport chain

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Key words: transport of liquefied gas, liquefied gas tankers, training

Abstract

The article describes basic problems concerning qualifications required from personnel handling LNG terminal facilities and equipment in view of the new terminal in Świnoujście. Statistical data, separately reported for LNG tankers, indicate a drop of the number of accidents and machinery failures on ships. The legal basis for the organization of common seafarer training and additional training for LNG vessel crews is outlined. Finally, the authors point out the areas of training for shore-based personnel handling LNG vessels, types of equipment of training centers for specialized LNG courses and estimated costs of such training.

Introduction

The construction of Poland's first LNG terminal in Świnoujście has led to many actions taken to assure its safe operation. At the same time discussions are in progress in circles that there is sufficient operational experience with such facilities. The reasons for various arguments are the well known physical properties of natural gas, complexity of storage installation and transport, and common opinions on the threats in connection with a possible LNG installation failure. Lack of national models of safe operation of LNG terminals and vessels necessitates the creation, among other things, a system of LNG personnel training.

The LNG terminal, with its loading and discharge operations, is one of the transport chain links between the production site and end user (Fig. 1).

Growing demand for seaborne LNG leads to an increased size of newly built LNG carriers. Consequently, larger and more efficient LNG terminals for gas loading and discharge are built.

The properties of specific cargo such as LNG require that high standards of safe handling are maintained within each link of the transport chain. LNG loading and unloading are operations that call for particular care. There may exist obstacles to be eliminated on the ships and at the ship-terminal

interface: cultural and language barriers between the crew and terminal personnel, various means of communication, procedures, measurement units used or incompatible equipment. In this connection detailed procedures and personnel training are being prepared for LNG terminal personnel and LNG tanker crews. The training is aimed at mastering the procedures, as well as justifying why such procedures have to be implemented through explanations of physical and chemical processes that take place during LNG loading and unloading. The International Maritime Organization (IMO) and other international organizations dealing with the organization of work at sea, such as the International Labour Organization (ILO), have developed and implemented in its member states regulations and recommendations, and developed obligatory model training courses. Their completion is the first and foremost element of seafarer training. Some of these are basic tanker familiarization courses. Further training of ship crews and shore personnel takes place at courses developed by classification societies, or industry-related bodies such as SIGTTO – Society of International Gas Tankers & Terminal Operators Ltd, specialist training centres and transport companies. Obligatory training is based on:

- international legal instruments;
- national legislation;

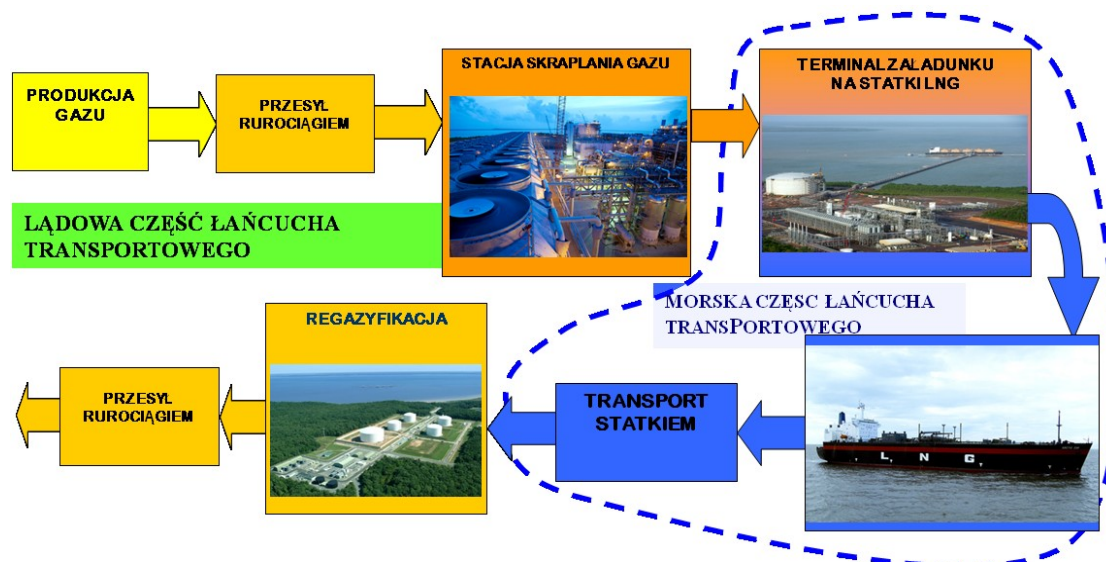


Fig. 1. LNG transport chain with its marine link: gas production, pipeline transport, liquefaction plant, loading terminal, transport by vessel, regasification, pipeline transport

- regulations and programs of classification societies and companies.

LNG tankers carry liquefied gas stored at a temperature of -162°C . For its transport to be safe special materials and constructions of the hull, tanks and installations are required, as well as cargo handling procedures and very strict traffic regulations. Unlike common opinions, ships carrying liquefied natural gas belong to the safest vessels.

Table 1. Number of marine accidents, including LNG tankers in the years 1964–2005 [1]

Type of accident	Years				Total 64–05
	64–75	76–85	86–95	96–05	
Collisions	1	10	4	4	19
Groundings	1	6	0	1	8
Bottom contact	0	4	0	4	8
Fire	2	5	0	3	10
Machinery breakdowns	0	39	7	9	55
Storm damage	0	6	3	0	9
Total ship accidents	4	70	14	21	109
Accidents during un/loading	4	13	3	2	22
Failures of cargo handling systems	7	15	5	0	27
LNG specific accidents/failures	11	28	22	23	49
Accident total	15	98	22	23	158

Despite many safeguards marine accidents continue to happen, involving LNG vessels, but a general downward trend of ship accidents includes a clearly noticeable drop of the number of LNG vessels in these incidents [2], as illustrated by data collected in table 1 and figure 2.

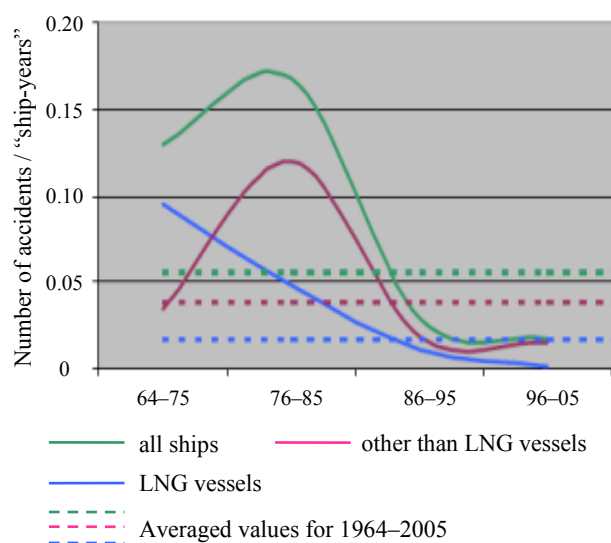


Fig. 2. Frequency of ship accidents in 1964–2005

These data show that over the years the number of accidents has been decreasing, with a clearly dropping trend concerning accidents involving LNG vessels. It is more noticeable on the chart where the number of accidents in relation to “ship-years” is given for each period (Fig. 2).

This positive trend is a result of careful selection of LNG vessel personnel LNG [1] and comprehensive regular training with programs, teaching facilities and evaluation methods specified by a wide scope of regulations. Seafarers employed on LNG tankers are generally those with previous sea service on other types of ships, holding certificates of all courses required on typical sea-going ships. LNG vessel crews have to satisfy additional requirements, international, national and shipowners' regulations and associated training [1].

Training of LNG tanker personnel

Training required by the STCW Convention

Crew members must have competence for ship service supported by certificates and diplomas relevant for the position held. To harmonize these requirements on the global market the IMO at a conference in London adopted in 1978 the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers; (STCW) [3]. Its provisions aim at the safety of personnel and marine environment.

The STCW 1978 Convention with later amendments is a fundamental document defining minimum standards of seafarers training for certificates confirming their competence for each rank. It constitutes a basis for laws and executive regulations in states, parties to the Convention. Compliance with the Convention is a prerequisite for recognition of certificates issued by national maritime administration in the world shipping market. Such recognition means that a seafarer can be employed on a ship of any flag, if no restrictions exist in flag state regulations.

The ship and its crew are subject to inspections carried out by Port State Control inspectors. The inspection focuses on ship and personnel documents. If crew members do not have valid qualification certificates, the ship may be detained until the documents are updated or substitutes with valid and relevant certificates arrive. Every ship carries a certificate of minimum manning, issued by flag state administration. If the minimum requirements are not satisfied, the ship cannot continue its voyage. Due to personnel costs, ship owners generally employ the required minimum of personnel.

The Annex to STCW Convention, its integral part, is divided into chapters:

- I – General provisions;
- II – Master and deck department;
- III – Engine department;
- IV – Radiocommunication and radio personnel;
- V – Special training requirements for personnel on certain types of ships;
- VI – Emergency, occupational safety, medical care and survival functions;
- VII – Alternative certification;
- VIII – Watchkeeping.

Appropriate regulations in the chapters define requirements for specific ship operation areas and refer to details contained in the STCW Code, another integral part of the Convention.

The STCW Code is divided into two parts. Part A contains mandatory provisions, while Part B includes guidance for the implementation of Part A.

The obligatory Part A specifies and supplements general requirements of chapters in the Annex, e.g. on onboard training, but firstly it defines minimum standards for certification in relation to the scope of training. These standards are grouped in four table columns:

1. Competence;
2. Knowledge, understanding and proficiency;
3. Methods of demonstrating competence;
4. Criteria for competence evaluation.

Deck seafarers are subject to provisions of Chapter II, engine personnel to provisions of Chapter III (of the Annex and STCW Code), which include standards of minimum requirements for service at each of three levels (support, operational and management) and in each specific capacity. The achievement of qualifications is confirmed by issued diploma (officers), or certificate (support level). The qualifications apply to a specific vessel size or engine room of specific power.

Chapter V provides additional requirements for crews working on special types of ship (ships distinguished for special threats to people and the marine environment). These include oil tankers, chemical tankers, liquefied gas tankers and passenger / ro-ro vessels. Training is required from all personnel (deck and engine departments) of the mentioned vessel types.

Additional training described in Chapter V is confirmed by separate certificates that can be obtained, fulfilling all provisions of Regulation V, by persons holding general diplomas or certificates of competence as provided for in Chapter II (Deck dpt.), or Chapter III (Engine dpt.). The requirements are identical for the two departments.

The topics to be included in basic and advanced course programs are listed as thematic headings. The form of program contents in the STCW 1995 Convention in Part A, Chapter V, was different from requirements for other types of training which had an ordered structure of criteria.

In June 2010 in Manila, at a conference of parties to the STCW 1978 Convention, revised **appendices** were adopted, mainly to the STCW Code.

Resolution 2 of the Final Act reads:

...Recalling that a large percentage of maritime casualties and pollution incidents are caused by human error,

Appreciating that one effective means of reducing the risks associated with human error in the operation of seagoing ships is to ensure that the highest practicable standards of training, certification and competence are maintained in respect of

the seafarers who are or will be employed on such ships,

Desiring to achieve and maintain the highest practicable standards for the safety of life,

property and security at sea and in port and for the protection of the environment,

Having considered amendments to the STCW Code proposed and circulated to the Members of the Organization and to all Parties to the Convention,

1. ADOPTS amendments to the Seafarers' Training, Certification and Watchkeeping

(STCW) Code, set out in annex to the present resolution; [3]

The revised STCW Code (amended due to rapid technological developments and changes in ship construction and equipment) has a separate section on gas tankers (A-V/1-2), while the other types of tankers are referred to in section (A-V/1-1) [3].

In section A-V/1-2 training requirements for gas tanker personnel were modified to adjust them to the methods of description used in the remaining chapters. Personnel competences were defined (column 1), previous program topics were extended, minimum knowledge, understanding and proficiency standards were specified in greater detail (column 2). Also, methods of demonstrating acquired competences for a certificate were indicated (column 3) along with assessment criteria

(column 4). Model courses, now being updated, may be helpful in the training process.

Due to the type of cargo carried LNG tankers are technologically the most complex ships. Very low temperatures require cryogenic equipment and materials. Most systems and equipment installed on LNG tankers substantially differ in construction, control, maintenance and servicing from typical equipment installed on conventional ships. Here is a brief description of chosen LNG equipment items:

HD Compressor – single-stage turbocompressor compressor of high capacity: 36,000 m³/h, 11,200 rpm. During loading it discharges boil off gas onto shore, it is used for re-gasification, heating and pre-cooling of tanks;

BOG (Boil Off Gas) Compressor – two- or three-stage turbocompressor. The compressor together with interstage coolers works in the gas liquefaction system discharging gas from tanks to a compander;

Compander – Three-stage turbocompressor installed on the joint gear with a single-stage dynamic expander, main machine in the nitrogen circulation for BOG liquefaction, with a power of 6000 kW;

Vacuum pump – pump working in the system of insulation barriers of cargo tanks;

Vaporizer – a heat exchanger used in re-gasification of cargo tanks, inerting tanks with liquid nitrogen and cargo operations;

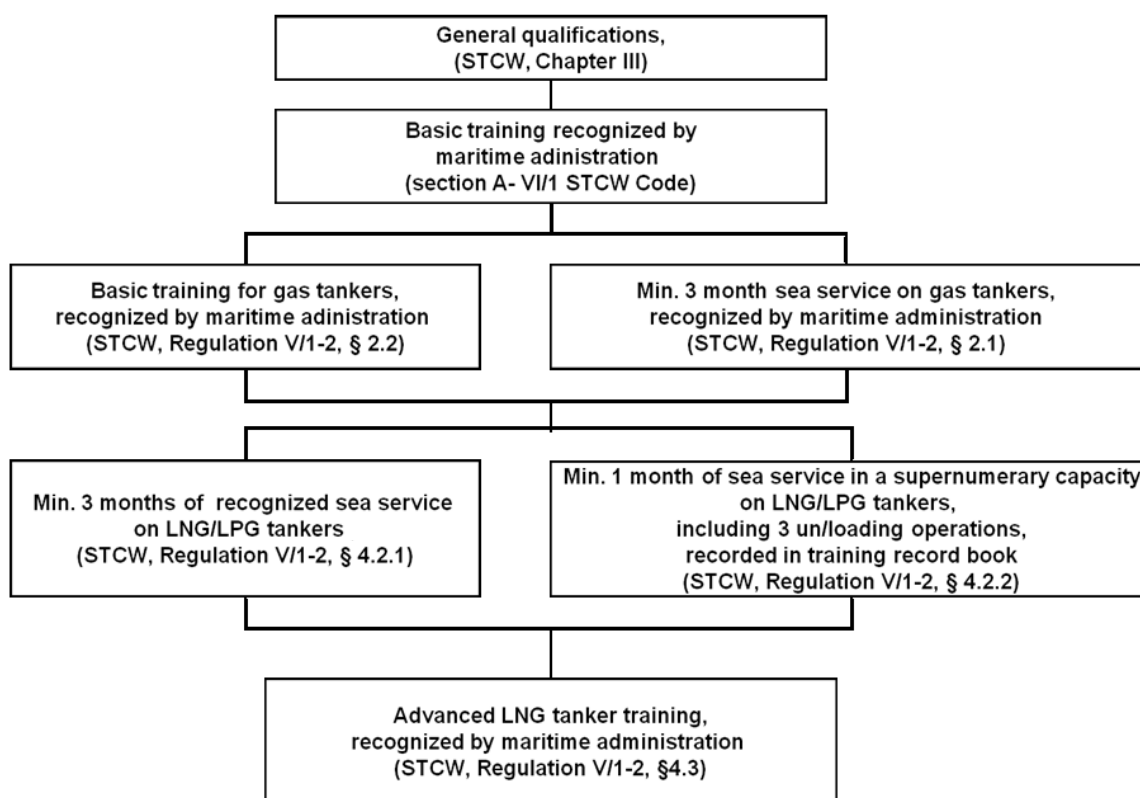


Fig. 3. The structure of additional training for gas tanker personnel as per the STCW'78 Convention revised in 2010

BOG Heater – cryogenic gas heater, a heat exchanger used for heating BOG before inlet to GCU;

HD Heater – cryogenic gas heater, a heat exchanger used for heating BOG before inlet to GCU;

N₂ Generator – produces nitrogen, used in the systems of: pressure control in insulation barriers of cargo tanks and BOG liquefaction;

GCU (Gas Combustion Unit) – BOG is burnt in GCU in case of a failure of gas liquefaction system and in the first phase of cargo loading, when the generated amount of gas in tanks exceeds the capacity of the gas condensation system. GCU is an extra device allowing to stabilize the pressure in cargo tanks, if a failure of primary facilities occurs.

LNG vessel systems:

Re-liquefaction System – responsible for pressure stabilization in cargo tanks, it liquefies boil off gas generated in tanks at a rate of 4000 to 6000 kg/h and transfers liquefied gas to cargo tanks; it uses nitrogen as a coolant;

Nitrogen System – produces nitrogen used in the systems of: BOG liquefaction and insulation barriers of cargo tanks;

Cofferdam Heating System – glycol system for heating cofferdams between cargo tanks; the system has glycol-filled coils heating cofferdam bulkheads between cargo tanks, protecting steel from damage due to thermal stress;

Gas Detection System – with a large number of sensors the system continuously monitors selected areas of the vessel, determines methane concentration in leakage zones and initiates alarms, if explosive levels are reached;

Inert Gas System – generates inert gas used for inerting cargo tanks in operations preparing them for “free gas” and on leaving a shipyard, or after tank inspections in tank re-gasification operations;

Cargo system – responsible for cargo shore-vessel or vessel-shore transfer, for tank spraying, cooling and re-gasification;

Temperature Monitoring System – monitors the temperature of the secondary insulation barrier of cargo tanks and the temperature of cofferdam bulkheads between tanks;

Inter-barrier Space and Insulation Space Pressure Control – controls the pressure and flow of nitrogen in insulation barriers of cargo tanks and protects the tank membranes from dynamic damage, and ensures safe atmosphere in the barriers in case of a gas leak;

Emergency Shutdown System – stops cargo transfer machinery in emergencies, has optic fiberglass,

electric and pneumatic connections between the ship and terminal; in emergency or safety risk the system will shut down machines and valves working during cargo operations;

Water Spray System – sprays manifolds and cryogenic valves of the cargo system; if a gas leakage on deck occurs due to manifold or cargo valve defects, water spray will reduce the impact of low temperature of the liquid on the hull structure, thus preventing steel fractures;

Integrated automatic control computer system – responsible for control all installations and operations on the ship.

Natural gas can be burnt as fuel in steam boilers or self-ignition engines. Most LNG tankers presently in operation have steam power plants with turbines providing main propulsion. The gas fuel comes from cargo tanks as boil-off gas, an amount that vaporizes and increases the pressure in the tanks. For a long time makers of marine piston engines have been offering machines adjusted to alternative combustion of liquid, or gas fuel and such solutions are implemented in LNG tankers. From the operational viewpoint, the main disadvantage of such installations is loss of part of the cargo, as well as higher complexity of installations and, consequently, higher qualifications required from personnel.

Considering recently built vessels and those to be launched in the years to come, one can observe that since 2006, apart from steam power plants, there have been more and more vessels equipped with Diesel engines fed with residual fuel and gas reliquefaction installations, complex systems demanding high standards of operation and maintenance. Although Diesel engines have higher general efficiency than steam turbines, shipowners continue to achieve lower fuel consumption, which directly affects the degree of complexity of power plants and control systems.

One can see that LNG tanker equipment requires from the personnel higher qualifications and more extensive knowledge than those of typical cargo vessels, less technologically complex. The satisfaction of minimum requirements provided for in Chapters III and V of the Convention seems to be insufficient for performance of tasks expected from the LNG tanker engine department.

Additional training of LNG tanker personnel

Taking into consideration the marine link of LNG transport chain, it can determine certain areas of additional training. LNG terminal and tanker personnel (apart from general seafarers' qualifica-

tions) have to acquire additional qualifications related to:

- Specific construction of gas carriers and characteristics of the cargo – training through presentations and computer animations, laboratories, validation through traditional tests;
- Performing cargo operations including those on the ship only – course for relevant training should be based on “full mission” simulators, also used for the validation, as they are equipped with examination scenarios. As a necessary supplement to simulator-based training, practical work on board and at terminals should be incorporated, including planned arrivals and departures, un/loading procedures, methods of cargo measurement, un/loading procedures and plans, ballast operations, tank washing, tank ventilation after unloading;
- Safety Management System procedures – the system for assurance of safe vessel operation is obligatory on all ships, that is why personnel can be trained on land or on a ship through computer presentations and instructions contained in the ship’s SMS book;
- Procedures of the ISPS-Code, obligatory on all types of ship; the basic training for ship and shore personnel is based on film presentations. Advanced training for specific ships is prepared on the basis of an approved ship safety security plan. Lectures should be combined with practical training as supplementary to general training conducted in a real facility. To maintain constant preparedness of ship and port crews to carry out activities stipulated in the ISPS-Code, regular exercise and alarm drill have to be carried out in real facilities.

Training of port personnel handling LNG tankers

Apart from LNG tanker crews and terminal personnel, the other personnel providing services to LNG tankers have to be additionally trained on simulators and in real facilities:

- Port pilots – in most port with LNG terminals pilots take multi-stage LNG tanker handling courses, specific for a given terminal; these include manoeuvring courses on ship-handling simulator, courses based on interactive programs of ship-handling simulator, aimed at the improvement of co-operation with tugs and shore personnel, manoeuvring courses using ship models made to scale. Before a pilot starts independent work, he is required to work under supervision on real vessels.

- Port tug skippers – interactive simulator courses in co-operation with pilots manoeuvring LNG tankers to the port, specific for a given LNG terminal, should be supported by practical supervised work on tugs.
- Fire protection service, crisis management team – courses based on scenarios developed for a specific terminal, on simulators and exercises in real facilities.

The complexity and uniqueness of above activities and operations calls for training with the use of high tech simulators featuring models and scenarios enabling interactive training – simultaneously involving the ship (with a pilot), tug crews and shore personnel. Simulators are the basic item of training costs. Their lifetime generally does not exceed 10 years. Over that period software is regularly updated and upgraded. The cost of a single simulator for advanced training ranges from 3,000,000 to 10,000,000 USD, depending on its purpose and programs. Training centres are needed to offer comprehensive training, equipped with three or more high power simulators, often linked to create an interactive system. Some training centres have simple versions of simulators based on generally available computers equipped with relatively simple software. Their cost is proportionally lower (mid-five figure of USD), but their suitability is limited to general basic courses.

The training of one officer of an LNG tanker, on simulators and real facilities costs a shipowner from 10,000 to 26,000 USD, depending on the training location (and equipment used). If we bear in mind that each vessel has to carry eight qualified officers, the total cost is significant and may amount to 208,000 USD/ship/year. The costly training increases personnel costs of LNG tankers, but research has shown that such expenditure is worth spending for shipowners, calculated as the rolling costs, because it reduces the acceptable risk connected with LNG tanker operation [4].

Regulations on the construction and operation of LNG tankers

Safety of sea carriage, including liquefied gas, is monitored at the stage of designing. Ship structure and ship’s crew have to fulfill a lot of requirements and recommendations, which can be collected in groups as follows:

1. Regulations and conventions concerning all ships [3, 5–11];
2. Additional regulations and conventions concerning LNG tankers [12–14];

3. Guidelines and recommendations for all ships [15–50];
4. Additional guidelines and recommendations for LNG tankers [51–68].

Conclusions

Technical standards in all the links of LNG transport chain have to ensure maximum operational safety. This refers mainly to LNG terminals where ship-shore operations are carried out. The dynamic changes during such operations, particularly those on the ship, require continuous supervision, control and handling of many devices and systems. The requirements for personnel qualifications are very high and can be satisfied through uniform and consistent training, primarily based on ship and terminal simulators supplemented with supervised work in real facilities. The quality of training to a large extent depends on equipment, the quality of simulators in the first place. Dedicated operational simulators cost millions of euro and for single training centres (such as maritime universities) it may be difficult to finance such investment projects on their own. The establishment of simulator-based training centres requires constant expenditure. Simulators have to be upgraded and extended, for such reasons as changing regulations and technological advancements.

In the light of what has been done so far, it seems worth emphasizing that it is the role and duty of state administration to provide proper training conditions, *inter alia*, by financing investment projects relating to training centres owned by the state or business entities, where such centres are components of the system ensuring safe energy supply in the country.

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