QUALITY ANALYSIS IN THE SUPPLY CHAIN OF TRANSPORTED LNG

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Abstract

The natural gas market has changed over the last few years. The approach to commercial relations hitherto was conditioned by the method of supply of this raw material, which was mainly carried out using gas pipelines. Taking into account the fact that natural gas has a six hundred times higher energy density in the form of LNG than in uncompressed form, it is economically justified to transport the resource by more than just traditional gas pipelines. Maritime transport of LNG has become an alternative means of delivering volumes to areas with insufficient gas resources. The article presents general methods of settlement and quality control of LNG in marine loading and receiving terminals. The types of measurements used in LNG settlements carried out on ships and on land are analysed. The aim of the paper was to analyse the way of ensuring and supervising the quality of LNG transported to the ship and to design an assessment form and monitor the stability of the quality level of LNG supplies with the use of a single measurement control card. It is proposed to use a two-track numerical stabilisation control card for single measurements and a mobile range IX – MR (Xi – MR).

Keywords: supply chain, natural gas, liquefied natural gas (LNG), quality control

Introduction

One of the components of the energy transformation is a gradual shift away from the use of traditional energy carriers, i.e. crude oil, in sea and land transport towards alternative fuels, among which a significant potential is connected with popularisation of the use of vehicles powered by LNG (liquefied natural gas). Nevertheless, the energy transformation within the transport sector determines the need for state investment in many areas which are seemingly not related to each other and require a specific policy for each of them. The areas mentioned above should include the following: systemic-market, legal, economic, technological and infrastructural. In addition to the above, the social sphere should be placed, within which transformations are much slower and are a resultant of changes introduced in other areas. In each of these areas, there is a series of barriers and risks that could slow down the processes mentioned, which stem from the specific nature of liquefied cold gas supplies (Brodacki 2017: 4). Therefore, the quality of transported LNG plays an important role.

Product quality is defined as the degree of compliance with specified requirements or benchmarks (Lisiecka 2002: 106; Hamrol 2002: 267-269). The quoted definition finds its application in the area of fuel quality, in the context of controls carried out at individual links on the logistics transport and distribution chain. The objective of the inspection is to ensure an appropriate level of quality of the set of features important from the point of view of functionality and environmental protection, as well as the life and durability of internal combustion engines (Ryczyński 2011: 260; Ryczyński 2012: 262).

The subject of this paper is the analysis of quality management in the supply chain of transported liquefied natural gas (LNG). The analysis of this issue will be based on a multifaceted analysis of the logistics supply chain of LNG and accounting measurements (transferred energy) of LNG. The aim of the article was to analyse the way of ensuring and supervising the quality of transported LNG and to present a draft form of assessment and monitoring the stability of the quality level of LNG supplies with the use of a single measurement control card. The information from the proposed single measurement control card will protect against unloading LNG of low energy value into the storage tanks of the terminals.

Forms of processing and characteristics of natural gas

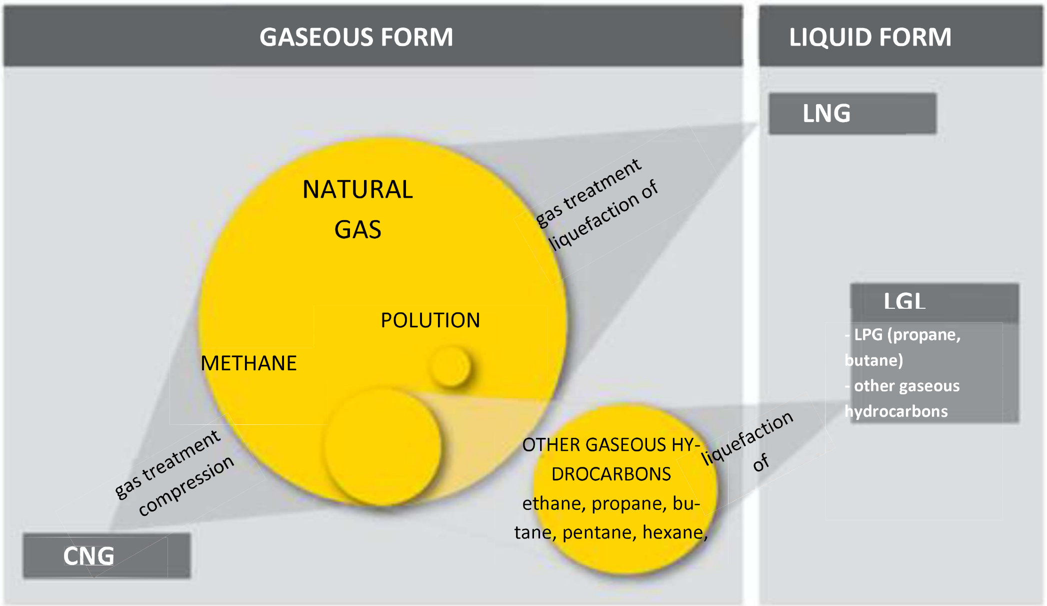
Natural gas produced from conventional and unconventional deposits or extracted from crude oil mainly consists of methane – CH_4 (85-95% depending on the deposit). Natural gas may also contain other hydrocarbons such as: propane – C_3H_{10}, ethane – C_2H_6, butane – C_4H_{10}, isobutane – C_4H_8, pentane – C_5H_{12} and other elements not used in industry – impurities (e.g. oxygen, hydrogen, carbon dioxide, helium, nitrogen, steam). It may also locally contain ingredients such as mercury (Tałach and Rudkowski, 2012: 284-287 and Woroch Klonowski, 2006: 30-31). Cold gas can be transported more cost-effectively through compression or liquefaction. Both methods make it possible to increase the energy density of cold gas by reducing the volume. The process of liquefaction of natural gas requires thorough drying and purification of the gas. Appropriately prepared natural gas is liquefied and in a liquid state at a temperature of approx. -162°C (depending on the composition in the range -166°C - 157°C) is ready for storage and transport. LNG occupies only 1/600 of the volume required for a comparable – primary – natural gas quantity at room temperature under normal pressure (Łaciak and Nagy 2010: 707; Molenda 1993; Zaleska - Bartosz and Klimek 2011: 724). By reducing the volume, LNG reaches a significant energy density per 1 m^3 (expressed in GJ/m^3).

The following products are obtained by changing the state of concentration of natural gas and its components:

- NGL (natural gas liquids) – heavier hydrocarbon molecules (propane and butane) present in the liquid state are evaporated at the pressure prevailing on the earth's surface. The most popular product produced by NGL is LPG (liquefied petroleum gas) composed of propane, butane or their mixture, which at a pressure of a few atmospheres is a liquid.
- CNG (compressed natural gas) – is a compressed natural gas that is the result of more than two hundred times the compression of natural gas (after the removal of pollutants).

A diagram of the transformation of natural gas to LNG, NGL and CNG is shown in Figure 1.

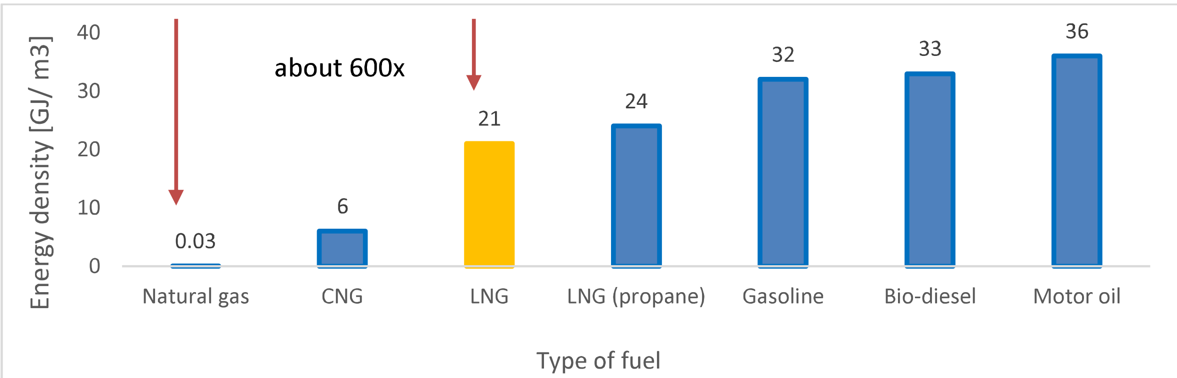
Figure 1. Basic forms of natural gas processing and its components



Source: www.uniongas.com (access: 01.11.2019)

Given the fact that natural gas has a six hundred times higher energy density in the form of LNG (21 GJ/m^3) than in uncompressed form (0.03 GJ/m^3), the transport of natural gas is economically justified not only by traditional (onshore or offshore) pipelines but also by other means. For this reason, the maritime transport of LNG has over time become an alternative means of supplying natural gas volumes to areas with insufficient gas resources. The energy density of LNG per 1 m^3 is also over three times higher than the energy density of CNG (6 GJ/m^3), but it should be remembered that it is about 1/3 lower in relation to traditional fuels – petrol or diesel (with energy densities of 32 and 36 GJ/m^3 respectively). Figure 2 shows the energy densities of individual fuels.

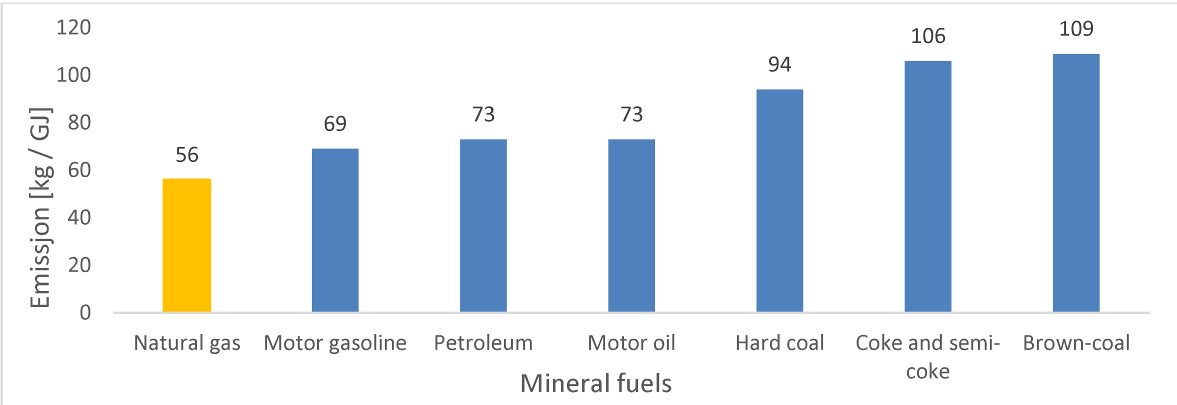
Figure 2. Energy sensity



Source: www.igg.pl (access: 01.11.2019)

LNG is a much more environmentally friendly fuel than other fossil fuels. The carbon dioxide emission factor per unit of energy is equal to 56 kg CO_2/GJ, which means that the combustion of natural gas emits almost 50% less CO_2 than the combustion of fossil fuels (coal and lignite), whose emission factors are 94 and 109 kg CO_2/GJ respectively. Natural gas is also considerably more environmentally friendly as compared to liquid fuels (petrol and diesel), whose benchmarks are 69 and 73 kgCO_2/GJ. These characteristics make the use of LNG for energy purposes more attractive, mainly in countries that are trying to reduce their greenhouse gas emissions. Figure 3 presents emission factors of selected types of fossil fuels.

Figure 3. Energy sensity flues



Source: Own calculations based on the data available: Calorific values (TOC) and CO2 emission factors (EC) in 2016 to be reported under the Emission Allowance Trading Scheme for 2019, Warsaw 2018.

LNG logistical supply chain

A supply chain is defined as a set of a specified number of units working together in an integrated way to deliver the right product to the right place, at the right time, at the right quality and at the lowest cost (Adamczewski 2001: 22). The supply chain includes integration that goes beyond a single company's area, because the supply chain is understood as the cooperating mining, processing, trade, logistics and other service companies that are involved in improving the flow of products, funds and information (Witkowski 2003: 15-20). Thus, the supply chain connects and refers to the participants in the process of bringing the finished product to the market.

The LNG supply chain can be described as a network of cooperating licensed companies engaged in the production of natural gas from onshore and offshore fields, as well as joint ventures using LNG production terminals (liquefying natural gas) and shipowners owning various types of specialised LNG vessels, LNG terminal receiving companies (regasification terminals) and end customers who buy natural gas, i.e. companies from different sectors of the economy and households. The main objective of the chain is to develop an adequate flow of natural gas from the extraction area to the customer while ensuring maximum efficiency from the perspective of the producer and end user.

In order to permit the free supply of natural gas, it has become necessary to supply, by sea, natural gas volumes to areas where there are insufficient natural gas resources. LNG import with the use of specialised ships (gas carriers) is a transport technology used in many countries. Liquefied natural gas trade began in 1965, when the first fixed route for LNG supplies from the Arzew terminal (Algeria) to Canvey Island (Great Britain) (Filin and Zakrzewski 2006: 848; Dobrowolski and Kolodziejczak 2009: 10) was launched.

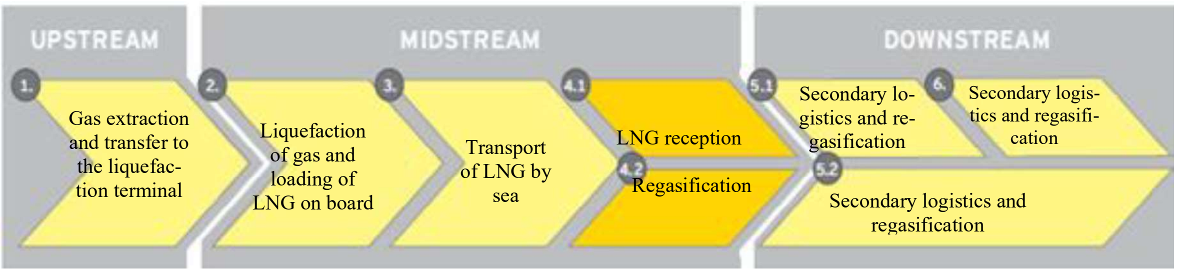
Maritime transport facilitates the import of LNG from various sources located in different parts of the world, which is a kind of guarantee of security of supply, despite the higher costs for land transport by pipeline for closer sources of supply. The condition for this type of supply is to have a maritime fleet with parameters adjusted to the sailing conditions prevailing in various parts of the world and LNG receiving terminals (Ficoń and Sokołowski 2012: 404-405).

The international transport of liquefied natural gas is carried out in accordance with the following steps:

1. Natural gas is usually supplied via pipelines from the field to liquefying installations, i.e. loading terminals also known as export or liquefaction terminals.
2. In export terminals, the process of liquefaction of gas is carried out and it is compressed onto ships or stored in tanks. LNG carrier ships (methane carriers) can accommodate from several tens of thousands to about 250 thousand m^3 of LNG (currently there are methane carriers under construction with a capacity exceeding 250 thousand m^3 of LNG).
3. LNG is delivered by sea in methane carriers to reception facilities – regasification terminals.
4. After the cargo has been delivered by sea to the receiving installation:
   4.1. Pressurising the LNG from the methane carrier ships to the shore and storing usually a small part of it in an unchanged form;
   4.2. the regasification process (change in the state of contentration from liquid to gas by increasing the temperature and volume of the natural gas) to which most of the transported liquid fuel is subject;
5. Liquefied natural gas can be transported further, e.g. by smaller methane carriers (so-called secondary logistics) or tankers. Secondary logistics usually concerns a small amount of volumes received at the terminal.
6. After regasification, liquefied natural gas is injected into the gas pipeline network or distributed to end users.

A simplified diagram of the flow of liquefied natural gas is shown in Figure 4.

Figure 4. Logistics chain of liquefied natural gas supply



Source: Own calculations based on the data available: "Wpływ terminalu LNG na rozwój społeczno-gospodarczy w Polsce i w województwie zachodniopomorskim". Ernst & Young Global Ltd. Warszawa 2013.

Due to the complexity of the LNG supply process, it is important to ensure that the process is carried out correctly in order not to lose the quality of liquid gas at any of the stages presented.

An adequate level of quality in the natural gas supply chain is ensured by the right infrastructure, which guarantees the smooth execution of all logistics processes. The physical flow of natural gas at all stages of the supply chain is most dependent on this (Ficoń and Sokołowski 2012: 403-404; Chłopińska and Nowakowska 2017: 1353; Łaciak 2011: 508; Łaciak, et. al. 2012: 430).

Export (liquefying) and import (regasification) terminals are a strategic element of LNG distribution logistics. The basic task of regasification terminals (such a terminal is located e.g. in Świnoujście) is to receive liquefied natural gas and then regasify it and inject it into the transmission network. Taking into account the functional solutions applied, it is possible to separate several types of LNG terminals (Analysis of costs and benefits of regional liquefied natural gas solution in the East Baltic area, including proposal for location and technical options under the Baltic Energy Market Interconnection Plan, Booz&Co, 2012):

- The onshore terminal – LNG is pumped from methane carriers to tanks located on land in close proximity to the port. Liquid gas is regasified in onshore installations and injected into the gas system.
- Maritime gravity terminal – the terminal together with regasification installations is located on an artificially created island. LNG is delivered to the terminal, regasified and injected into the onshore transmission network using an underwater gas pipeline.
- Regasification methane carrier – methane carriers transporting liquid gas may be equipped with regasification installations. Upon arrival of the methane carrier at the destination port, the LNG is regasified directly on board the vessel and injected into the onshore transmission network using an underwater gas pipeline.
- Maritime storage and regasification terminal – the terminal takes the form of a floating platform or a vessel equipped with LNG tanks and regasification infrastructure. The terminal can be permanently or temporarily immobilised at a specific point in the sea near the shore. Liquefied gas from methane carriers is pumped to the terminal, where it is regasified. The resulting gas is injected into the onshore transmission network via an underwater gas pipeline.

Some of the LNG can also be stored in cryogenic tanks – LNG storage facilities.

Settlement measurements of LNG – transferred energy

The accounting of liquefied natural gas cargoes transported by sea has been carried out for a long time worldwide and expressed in units of energy. The accounting system functioning in unloading terminals is based on measurements of many components of values, on the basis of which the final value of energy "stored" in the unloaded quantity of transported LNG is calculated. The measurement idea is based on a precise assessment of the effective volume of the tested LNG batch and the determination of its calorific value. The product of both cases is the target energy value (Rosłonek 2015: 123).

Some of the measurements are made on the ship and these include (Rosłonek 2016: 91):

- measurement of LNG level in the cargo chamber of the gas carrier, carried out both before and after the start of the unloading process,

- measurement of the pressure of the gas phase located above the liquid in the cargo compartment of the LNG carrier,
- measurement of the temperature of the LNG in the carrier cargo compartment,
- measurement of the temperature of the gas phase above the liquid in the carrier cargo compartment,

Outside the ship, the chemical analysis of the transported LNG within the quality range of C_1-C_{6+}, N_2 and CO_2 is performed. Although in practice, in cargoes of liquid gas transported by sea, hydrocarbon components reaching more than C_4 do not occur, similarly to carbon dioxide. LNG quality control is the only "measurement" performed on land at a part of the terminal (Rosłonek 2016: 91).

On the basis of these measurements it becomes possible to calculate (GIIGNL 2015):

- the quantity of liquid gas in each cargo chamber of a gas carrier as the difference in height of the LNG liquid in the vessel's chamber before and after the unloading. In order to properly classify the height of the LNG column to its volume in the cargo chamber, so-called ship correction tables are used, taking into account its specificity – the list along the main axis of the hull (LIST) and the difference in draught of the bow and stern resulting from the momentary re-ballasting of the ship (TRIM), as well as from all kinds of tables concerning temperature correction coefficients affecting the thermocryogenic expansion/shrinkage of steel elements and the displacement of floating elements in the liquefied gas.
- calculation of the volume of BOG (Boil Off Gas – gas vapour transferred from onshore tanks to the gas tanker chambers when discharging the liquefied LNG) filling the space in the cargo chamber when the liquefied gas is discharged into the onshore terminal tanks – the volume of BOG introduced and the volume of LNG discharged should be equal,
- LNG density calculation is performed according to the algorithm ISO 6578,
- the calculation of the gross calorific value of the gas filling the gas carrier (BOG) chamber is performed according to the ISO 6976 algorithm,
- calculation of the gross calorific value of LNG according to the algorithm in ISO 6578,
- calculation of the final energy value of the unloaded batch.

During the unloading of LNG from the gas carrier to the tanks located at the receiving terminal, the total energy of LNG treated as fuel is calculated according to equation (1). In the case of loading onto a ship at the loading terminal, the formula (2) (GIIGNL 2015) is used to calculate the total energy. A diagram of the determination of the transferred LNG energy is shown in Figure 5.

$$E = V_{LNG} \cdot D_{LNG} \cdot GCV_{LNG} - E_{Gas\ displaced} - E_{Gas\ to\ ER} \quad (1)$$

$$E = V_{LNG} \cdot D_{LNG} \cdot GCV_{LNG} - E_{Gas\ displaced} + E_{Gas\ to\ ER} \quad (2)$$

where:

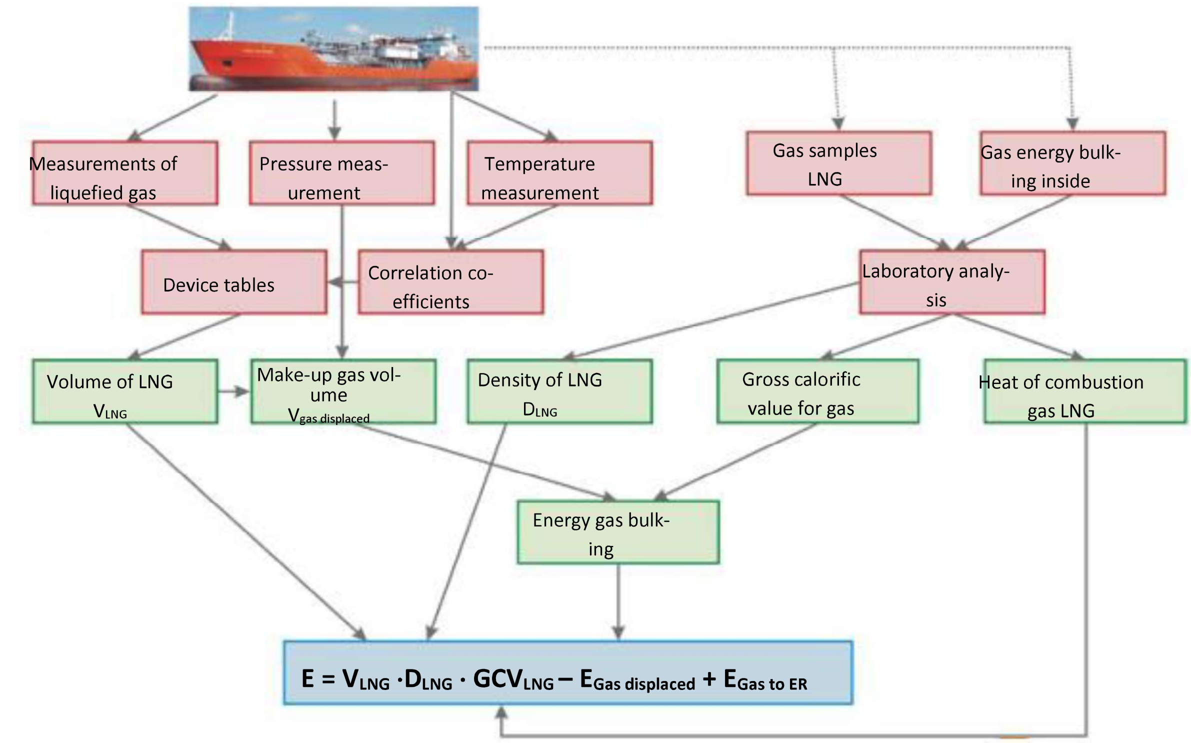
E – total 'net' energy reduced by that part of the energy 'transferred' in the form of BOG (EGas displaced) from the terminal tanks to the cargo chambers of the liquefied natural gas carrier during the unloading of the LNG – or alternatively complementarily reduced by EGas to ER,

V_{LNG} – the volume of liquid gas discharged or transferred [m3],

D_{LNG} – the density of the LNG [kg/m3],
GCV_{LNG} – the gross calorific value of liquefied natural gas in relation to the mass unit of the liquid (often referred to as GCV) [MJ/kg],
$E_{Gas\ displaced}$ – BOG energy [usually MMBTU],
$E_{Gas\ to\ ER}$ – energy consumed for the potential LNG supply of engines or motors on board the vessel for the operation of various systems on board (most often during loading/unloading EGas to ER = 0) [usually MMBTU].

In international trade in liquid gas, the most frequently used unit of account is the British heat unit – MMBTU (million British thermal units, 1 MMBTU = 106 BTU), but it is not an SI unit. The BTU value indicates the amount of energy needed to increase the temperature of one pound of water by one degree Fahrenheit. Due to the imprecise nature of the definition of this unit and due to the change in the specific heat value of water at different temperatures, the energy value oscillates between 1054 J and 1059 J (i.e. from about $2.92 \cdot 10^{-4}$ kWh to about $2.94 \cdot 10^{-4}$ kWh) (Nerć-Pełka 2009: 138-139).

Figure 5. Scheme determination of the LNG energy transferred



Source: Own calculations based on the data available: GIIGNL 2015

The BOG energy value represents a small part of the total "net" energy, so it is often assumed in the calculations that the BOG vapours are pure methane, which is additionally treated as a perfect gas. The compressibility parameter for BOG vapours should not be taken into account in this determination. This is justified because, as mentioned above, the BOG energy is a relatively small element in equation (1) and the vapour pressure of the BOG slightly exceeds the atmospheric pressure. On a large number of unloading terminals, the $E_{Gas\ displaced}$ segment is not calculated, but a constant value, e.g. 0.3% (GIIGNL 2015). The simplifications presented do not contribute to any material error, but merely facilitate the practical use of equation (1).

In practice, all calculations performed during LNG unloading are usually performed twice – on the ship and at the receiving terminal, by CTMS (custody transfer measurement system).

Quality control of transported LNG

In order to determine the value of LNG energy in the settlement process of the load (delivered and unloaded in the receiving terminal), it is necessary to precisely define its composition. Ongoing analyses of the quality of the liquid gas are carried out on the basis of which it is possible to calculate the density of the LNG and any calorific values. As in the case of natural gas quality control in line infrastructure, gas chromatography (Rosłonek et al. 2005: 7-8) is used for quality control in offshore LNG terminals. Considering the need to ensure constant measurement and analytical supervision over gas chromatographs, these devices are located exclusively on land (within the terminals). During the unloading of LNG, liquid samples are taken and directly regasified. A representative evaporated LNG sample is analysed for content. Analyses within the terminals are performed using process gas chromatographs on-line or in stationary laboratories (Rosłonek 2016: 93).

Proposal to use control cards to monitor the transferred LNG energy

The multithreaded nature and complexity of the problems to be solved by the various organisations present in the LNG supply chain make it necessary to select appropriate methods in the decision-making support process, on strategic and operational grounds. The Statistical Process Control (SPC) is a possible proposal for a method to support the quality assurance of transported liquid gas and at the same time to improve the quality of the organisation's operations.

Due to the growing emphasis on quality (TQM) in all types of organisations, it seems obvious that SPC should be applied to non-production processes. SPC has been used, among other places, in supply systems (Zurier 1989), transport systems, service systems (Mundy et al. 1986) and in the fuel and energy industry (Lager 1999; Thomson et al. 2000; Braga et al. 2013). The wide range of SPC applications is due to the fact that in any larger system, whether it is a district heating/cogeneration, electricity or gas system, variability will occur sooner or later, making a statistical approach to prevent process deregulation desirable (Saluga et al. 2017: 27-28). Control cards are an easy to use and relatively effective tool to prevent this problem.

Process control cards are among the oldest tools for statistical quality control (Mazur and Gołaś 2010: 60). With the help of control cards, it is possible to track the status of selected characteristics on the basis of samples (taken at specified intervals), while an excessive level of deviation of the values of controlled characteristics signals the presence of special disturbances, which must be eliminated by corrective actions. In view of the fact that there are deviations in each actual process, it is necessary to define the tolerances for the lower and upper control limits, which are indicated on the control charts as a line. If the values of the characteristics of the subsequent samples taken from the stream of product to be tested are within the specified control lines (GLK and DLK), then the process can be considered stable and running properly (Myszewski 2009: 129-

130). Process deregulation occurs when one of the border (control) or warning lines has been crossed.

In contrast to 100% or even step control, most of the control cards are designed for multi-part samples, which makes them cheaper, faster and very effective with the use of appropriate methodology. Diagnostics of several or even a dozen elementary samples is basically the only solution in the case of destructive testing. However, the control cards are not devoid of imperfections. In addition to the need to use an adequate methodology, special attention should be paid to the skilful selection of the control card and the randomness of sampling. It should also be noted whether there was no correlation between the properties of goods in the tested sample (Szymszal et al. 2006:367; Bartkowiak 2011: 63-64). These shortcomings should be highlighted in particular in processes other than typical production processes. This is the case, for example, with measurements of liquefied natural gas, specifically one of the components of the LNG volume coefficient – temperature, since the temperature of liquid gas in one sample area depends on the temperature in the neighbouring area. A particular application of the SPC could take place in the area of pumping LNG to the tanker. It seems advisable to monitor the flow of gas. This objective is economically justifiable. Pumping poor quality LNG into the tanker and only then performing the current quality control, even repeated at the customer's, will not protect against technical, organisational and economic consequences. Due to the specific nature of the LNG transport process to the terminal, an appropriate control card was selected for the analysis of the stability of the quality of liquid gas supplies for continuous processes and low variability between subsequent samples. It was a two-track numerical control card for stabilisation of single measurements and moving range IX - MR (Xi - MR). On this card, position measurements are monitored by single measurements of a selected feature, and the so-called moving ranges (MR), which are the absolute value of the difference between two consecutive measurements, are used as a measure of variability. On the IX – MR card, the average value of moving spreads is the starting point for determining the control position of the limits in the card. The draft form for assessing the stability of the quality level of LNG supply is presented in Figure 6.
The chart of the card shows five lines::

- Upper control line (GLK),
- Central line (LC),
- Lower control line (DLK) – if its value does not appear in the chart of moving ranges, it is assumed to be equal to 0.

Sometimes, after some time of using the card, the following warning lines are added: upper warning line for track value IX (GLOIX), lower warning line for track value IX (DLO), upper warning line for track value MR (GLOMR). Their values are determined from formulae analogous to control lines but taking into account indicators selected from tables depending on the situation.

The value of the control card line is calculated as follows:
For track values of individual measurements (IX):

- Calculation of average sample values:

$$\bar{x} = \frac{\sum x}{n} \quad (3)$$

- Calculation of the central line value (LC) for the single measurement value track (IX):

$$LC = \bar{x} = \frac{\sum x_i}{n} \quad (4)$$

- Calculation of the moving range mean value from single measurements:

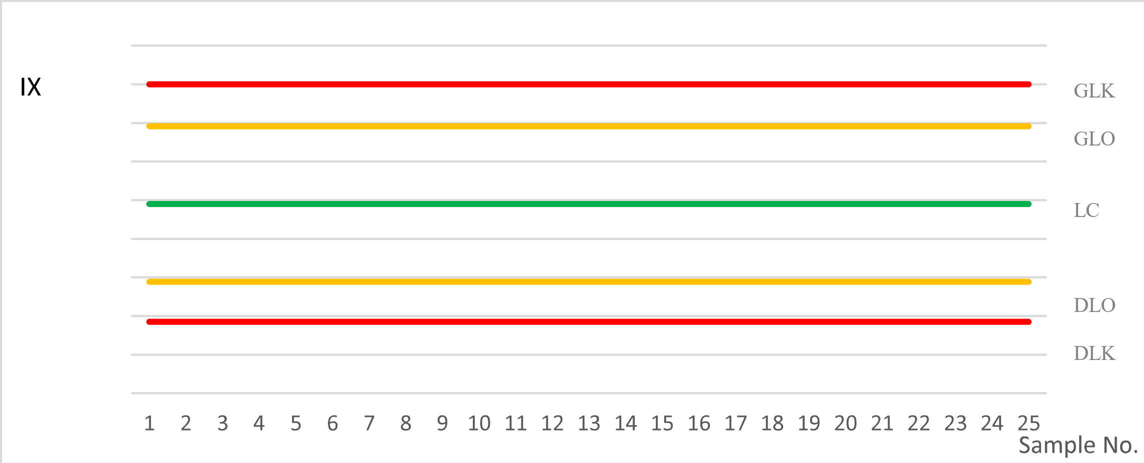
$$C\overline{MR} = \frac{\sum MR}{n-1} \quad (5)$$

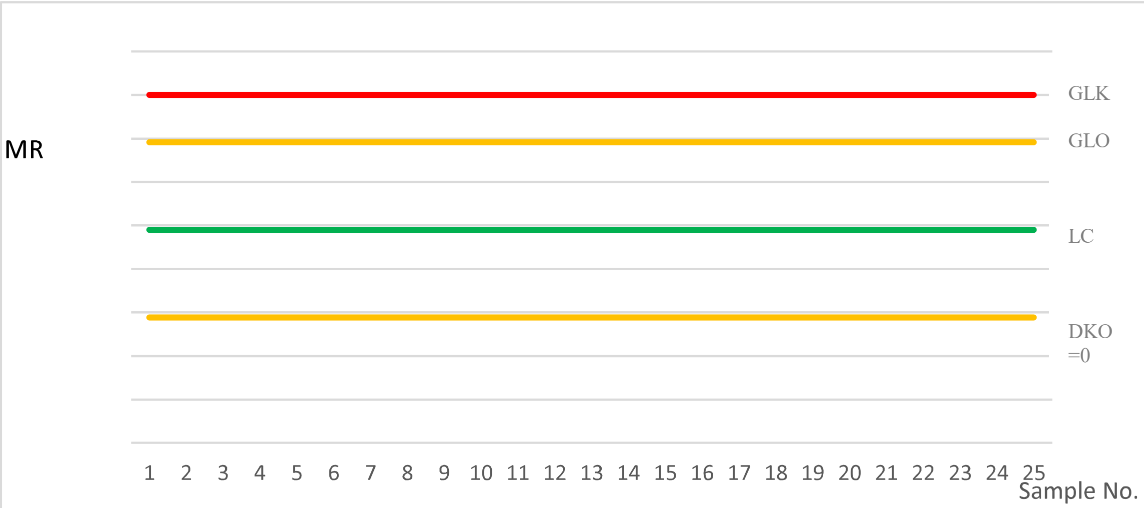
$$DLK = \bar{x} - 2{,}66 \cdot \overline{MR} \quad (7)$$

A_3 for e.g. two-element samples (individual measurements) equals 2.66.

Figure 6. Draft of a charter of control IX – MR

Company logo			CONTROL CARD IX - MR								Date of issue:		
Terminal:			Control card number:					Period between samples:					
Ship:			Gas carrier unloading chamber number:							The number of samples:			
Sample No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1													
2													
3													
4													
Sum													
x̄													
R													
Sample No.	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**
1													
2													
3													
4													
Sum													
x̄													
R													





Source: Own calculations

For the MR movable range tracks:

- The moving range is calculated as the absolute difference between the measurements of the values of adjacent samples.
- Calculation of the centreline value (LC) for the path of moving ranges (already calculated value):

$$LC = \overline{MR} = \frac{\sum MR}{n-1} \quad (8)$$

- Calculation of the upper (GLK) and lower (DLK) control lines for the single measurement value track (IX)

$$GLK = 3{,}27 \cdot \overline{MR} \quad (9)$$

$$DLK = 0 \quad (10)$$

D_4 for two-element samples (individual measurements) equals 3.27.

The formulae for this card use the designations:

x_i- the *i*th value of the feature,

n- number of measurements,
MR- mobile range calculated from the formula:

$$MR = |x_i - x_{i-1}| \tag{11}$$

$\overline{\text{MR}}$- average value of the mobile range.

The analysis of control grids is limited to determining, on the basis of the results obtained (shape of the diagrams drawn up), whether there are grounds for considering the monitored process as maladjusted. If there are no indications to that effect, the process should be considered as correct and no corrective actions should be taken. However, when there are signals, intervention is needed. Possible signals are described in the PN-ISO 8258 standard. The classic signal forcing an intervention is the crossing of a control line. Nevertheless, other signals are also used for analysis, e.g. trends (7 consecutive values of increasing or decreasing character) or runs (7 consecutive values on one side of the central line).

The use of control cards makes it possible to improve the quality level with relatively low costs (much lower than e.g. modernisation of the machine park). The most important benefits of using control cards are (Montgomery 1997: 227; Demski 2009: 48-49):

- Prevention of problems – the use of control cards makes it easier to detect trends and changes in the process, which makes it possible to detect disturbing changes in the process before it starts producing non-compliant products (in our case LNG with inappropriate parameters).
- Avoidance of unnecessary corrections – control cards make it easier to distinguish random changes from changes to which eliminable causes can be attributed,
- Determination of the average value of the quality indicators of the product (LNG) and the range of variability, so that it is possible, for example, to determine the expected fraction of non-compliant product or to choose a better way of securing the cargo.

For the unloading of liquid gas, monitoring of the quality of the unloaded LNG (analysis of the results obtained from the samples within the control chart charts) will make it possible to stop the unloading in case of a diagnosis of inadequate LNG quality to avoid problems and unnecessary costs. The information from the proposed single measurement control card will protect against unloading LNG of low energy value into the storage tanks of the terminals.

An additional advantage of using the proposed control card is that it is easy to use and understand. The proposed form is a tool that enables the analysis and monitoring of the LNG quality level at the unloading point.

Summary

The belief in the good quality of liquid gas determines whether the customer is satisfied and loyal. The most important criterion in this respect is confidence in the level of quality offered. Measures and systems to ensure the safety and security of both LNG installations and transport are constantly being improved. The constant development of technologies (terminals, storage tanks, methane carriers, monitoring devices, etc.) contributes to raising high standards in LNG operation.

Recently, Poland has joined the group of countries and companies that participate in the global trade in liquefied gas supplied by sea transport. The rules of LNG settlement in offshore terminals differ from those used for settlement of gases in linear infrastructure. Therefore, the article presents general methods of accounting and quality control of liquid gas in offshore terminals. In addition, the types of measurements used in LNG settlements carried out both on land and on ships were analysed. The aim of the article was to analyse the way of ensuring and supervising the quality level of transported LNG and to present a draft form of assessment and monitoring of the stability of the quality level of LNG supplies with the use of a single measurement control card.

The proposed solution for monitoring the level of quality of LNG received by terminal storage will allow, in the case of obtaining results exceeding control lines or a series of disturbing results indicating inadequate LNG quality, unloading to be stopped in order to avoid technical problems and often significant costs. The information from the proposed single measurement control card will be able to protect against unloading LNG of low energy value into the storage tanks of the terminals.

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