SLOVENSKI STANDARD
SIST EN 1160:1998

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Napeljave in oprema za utekočinjeni zemeljski plin - Splošne lastnosti utekočinjenega zemeljskega plina

Installations and equipment for liquefied natural gas - General characteristics of liquefied natural gas

Anlagen und Ausrüstung für Flüssigerdgas - Allgemeine Eigenschaften von Flüssigerdgas

Installations et équipements relatifs au gaz naturel liquéfié - Caractéristiques générales du gaz naturel liquéfié

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CEN

European Committee for Standardization
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Content

Foreword

This European Standard has been prepared by Technical Committee CEN/TC 282 "Installation and equipment for LNG", the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by December 1996, and conflicting national standards shall be withdrawn at the latest by December 1996.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard : Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom

1 Scope

This European Standard gives guidance on the characteristics of liquefied natural gas (LNG) and the cryogenic materials used in the LNG industry. It also gives guidance on health and safety matters. It is intended to act as a reference document for the implementation of other standards of CEN/TC 282 "Installations and equipment for liquefied natural gas".

It is intended as a reference for use by persons who design or operate LNG facilities.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

prEN 1473	Installation and equipment for liquefied natural gas - Design of on-shore installation

3 Definition

For the purposes of this standard, the following definition applies :

liquefied natural gas : A colourless fluid in the liquid state composed predominantly of methane and which may contain minor quantities of ethane, propane, nitrogen or other components normally found in natural gas.

4 Abbreviations

For the purposes of this standard, the following abbreviations apply :

LNG : liquefied natural gas ;

RPT : rapid phase transition ;

BLEVE : boiling liquid expanding vapour explosion ;

SEP : surface emissive power.

5 General characteristics of LNG

5.1 Introduction

It is recommended that all personnel concerned with the handling of LNG should be familiar with both the characteristics of the liquid and the gas produced.

The potential hazard in handling LNG stems mainly from three important properties :

a) it is extremely cold. At atmospheric pressure, depending upon composition LNG boils at about - 160 °C. At this temperature the vapour is more dense than ambient air (see examples in table 1) ;

b) very small quantities of liquid are converted into large volumes of gas. One volume of LNG produces approximately 600 volumes of gas (see examples in table 1) ;

c) natural gas, similar to other gaseous hydrocarbons, is flammable. At ambient conditions the flammable mixture range with air is from approximately 5 % to 15 % gas by volume.

5.2 Properties of LNG

5.2.1 Composition

LNG is a mixture of hydrocarbons composed predominantly of methane and which can contain minor quantities of ethane, propane, nitrogen or other components normally found in natural gas.

The physical and thermodynamic properties of methane and other components of natural gas can be found in reference books (see annex A) and thermodynamic calculation codes.

For the purpose of this standard LNG shall have a methane content of more than 75 % and a nitrogen content of less than 5 %.

Although the major constituent of LNG is methane, it should not be assumed that LNG is pure methane for the purpose of estimating its behaviour.

When analysing the composition of LNG special care should be taken to obtain representative samples not causing false analysis results due to distillation effects. The most common method is to analyse a small stream of continuously evaporated product using a specific device that is designed to provide a representative gas sample of liquid without fractionation. Another method is to take a sample from the outlet of the main product vaporisers. This sample can then be analysed by normal gas chromatographic methods, such as those described in ISO 6568 or ISO 6974.

5.2.2 Density

The density of LNG depends on the composition and usually ranges from 430 kg/m^3 to 470 kg/m^3, but in some cases can be high as 520 kg/m^3. Density is also a function of the liquid temperature with a gradient of about -1,35 kg m^{-3} °C^{-1}. Density can be measured directly but is generally calculated from composition determined by gas chromatographic analysis. The method as defined in ISO 6578 is recommended.

NOTE : Method generally known as "Klosek McKinley" method.

5.2.3 Temperature

LNG has a boiling temperature depending on composition and usually ranging from - 166 °C to - 157 °C at atmospheric pressure. The variation of the boiling temperature with the vapour pressure is about 1,25 x 10^{-4} °C/Pa.

The temperature of LNG is commonly measured using copper/copper nickel thermocouples or using platinum resistance thermometers such as those defined in ISO 8310.

5.2.4 Examples of LNG

Three typical examples of LNG are shown in table 1 below which demonstrate the property variations with different compositions.

Table 1 : Examples of LNG

Properties at bubblepoint at normal pressure	LNG Example 1	LNG Example 2	LNG Example 3
Molar content (%)			
N_2	0,5	1,79	0,36
CH_4	97,5	93,9	87,20
C_2H_6	1,8	3,26	8,61
C_3H_8	0,2	0,69	2,74
i C_4H_{10}	-	0,12	0,42
n C_4H_{10}	-	0,15	0,65
C_5H_{12}	-	0,09	0,02
Molecular weight (kg/kmol)	16,41	17,07	18,52
Bubble point temperature (°C)	- 162,6	- 165,3	- 161,3
Density (kg/m^3)	431,6	448,8	468,7
Volume of gas measured at 0 °C and 101 325 Pa/volume of liquid (m^3/m^3)	590	590	568
Volume of gas measured at 0 °C and 101 325 Pa/mass of liquid (m^3/10^3 kg)	1367	1314	1211

5.3 Evaporation of LNG

5.3.1 Physical properties of boil-off gas

LNG is stored in bulk as a boiling liquid in large thermally insulated tanks. Any heat leak into the tank will cause some of the liquid to evaporate as a gas. This gas is known as boil-off gas. The composition of the boil-off gas will depend on the composition of the liquid. As a general example, boil-off gas can contain 20 % nitrogen, 80 % methane and traces of ethane. The nitrogen content of the boil-off gas can be about 20 times that in the LNG.

As LNG evaporates the nitrogen and methane are preferentially lost leaving a liquid with a larger fraction of the higher hydrocarbons.

Boil-off gases below about - 113 °C for pure methane and - 85 °C for methane with 20 % nitrogen are heavier than ambient air. At normal conditions the density of these boil-off gases will be approximately 0,6 of air.

5.3.2 Flash

As with any fluid, if pressurised LNG is lowered in pressure to below its boiling pressure, for example by passing through a valve, then some of the liquid will evaporate and the liquid temperature will drop to its new boiling point at that pressure. This is known as flash. Since LNG is a multicomponent mixture the composition of the flash gas and the remaining liquid will differ for similar reasons to that discussed in 5.3.1 above.

As a guide, a 10^3 Pa flash of 1 m^3 liquid at its boiling point corresponding to a pressure ranging from 1 x 10^5 Pa to 2 x 10^5 Pa produces approximately 0,4 kg of gas.

More accurate calculation of both the quantity and composition of the liquid and gas products of flashing multicomponent fluids such as LNG are complex. Validated thermodynamic or plant simulation packages for use on computers incorporating an appropriate data base should be used for such flash calculations.

5.4 Spillage of LNG

5.4.1 Characteristics of LNG spills

When LNG is poured on the ground (as an accidental spillage), there is an initial period of intense boiling, after which the rate of evaporation decays rapidly to a constant value that is determined by the thermal characteristics of the ground and heat gained from surrounding air.

This rate can be significantly reduced by the use of thermally insulated surfaces where spillages are likely to occur, as shown in table 2. These figures have been determined from experimental data.

Table 2 : Rate of evaporation

Material	Rate per unit area after 60 s kg / (m^2h)
Aggregate	480
Wet sand	240
Dry sand	195
Water	190
Standard concrete	130
Light colloidal concrete	65

Small quantities of liquid can be converted into large volumes of gas when spillage occurs. One volume of liquid will produce approximately 600 volumes of gas at ambient conditions (see table 1).

When spillage occurs on water the convection in the water is so intense that the rate of evaporation related to the area remains constant. The size of the LNG spillage will extend until the evaporating amount of gas equals the amount of liquid gas produced by the leak.

5.4.2 Expansion and dispersion of gas clouds

Initially, the gas produced by evaporation is at nearly the same temperature as the LNG and is more dense than ambient air. Such gas will at first flow in a layer along the ground until it warms by absorbing heat from the atmosphere. When the temperature has risen to about - 113 °C for pure methane or about - 80 °C for LNG (depending on its composition), it is less dense than ambient air. However the gas air mixture will only rise when its temperature has increased so that the whole mixture is less dense than ambient air.

Spillage, expansion and dispersion of vapour clouds are complex subjects and are usually predicted by computer models. Such predictions should only be undertaken by a body competent in the subject.

Following a spillage, "fog" clouds are formed by condensation of water vapour in the atmosphere. When the fog can be seen (by day and without natural fog), the visible fog is a useful indicator of the travel of the vaporised gas and the cloud will give a conservative indication of the extent of flammability of the mixture of gas and air.

In the case of a leak in pressure vessels or in piping, LNG will spray as a jet stream into the atmosphere under simultaneous throtting (expansion) and vaporisation. This process coincides with intense mixing with air. A large part of the LNG will be contained in the gas cloud initially as an aerosol. This will eventually vaporise by further mixing with air.

5.5 Ignition

A natural gas/air cloud can be ignited where the natural gas concentration is in the range from 5 % to 15 % by volume.

5.5.1 Pool fires

The surface emissive power (SEP) of a flame from an ignited pool of LNG of diameter greater than 10 m can be very high and shall be calculated from the measured values of the incident radiative flux and a defined flame area. The SEP depends on pool size, smoke emission and methods of measurement. With increased sooting the SEP decreases. Annex A contains a list of references which may be used to ascertain the SEP for a given circumstance.

5.5.2 Development and consequences of pressures waves

In a free cloud natural gas burns at low velocities resulting in low overpressures of less than 5×10^3 Pa within the cloud. Higher pressures can occur in areas of high congestion or confinement such as densely installed equipment or buildings.

5.6 Containment

Natural gas cannot be liquefied by applying pressure at ambient temperature. In fact it has to be reduced in temperature below about - 80 °C before it liquefies at any pressure. This means that any quantity of LNG that is contained, for example between two valves or in a vessel with no vent, and is then allowed to warm up will increase in pressure until failure of the containment system occurs. Plant and equipment shall therefore be designed with adequately sized vents and/or relief valves.

5.7 Other physical phenomena

5.7.1 Rollover

The term rollover refers to a process whereby large quantities of gas can be emitted from an LNG tank over a short period. This could cause overpressurisation of the tank unless prevented or designed for.

It is possible in LNG storage tanks for two stably stratified layers or cells to be established, usually as a result of inadequate mixing of fresh LNG with a heel of different density. Within cells the liquid density is uniform but the bottom cell is composed of liquid that is more dense than the liquid in the cell above.

Subsequently, due to the heat leak into the tank, heat and mass transfer between cells and evaporation at the liquid surface, the cells equilibrate in density and eventually mix. This spontaneous mixing is called rollover and if, as is often the case, the liquid at the bottom cell has become superheated with respect to the pressure in the tank vapour space, the rollover is accompanied by an increase in vapour evolution. Sometimes, the increase is rapid and large. In a few instances the pressure rise in the tank has been sufficient to cause pressure relief valves to lift.

An early hypothesis was that when the density of the top layer exceeded that of the lower layer an inversion would occur, hence the name rollover. More recent research shows that this is not the case and that, as described above, it is rapid mixing that occurs.

Potential rollover incidents are usually preceded by a period during which the boil-off gas production rate is significantly lower than normal. Boil-off rates should therefore be closely monitored to ensure that the liquid is not storing heat. If this is suspected, attempts should be made to circulate liquid to promote mixing.

Rollover can be prevented by good stock management. LNG from different sources and having different compositions should preferably be stored in separate tanks. If this is not practical good mixing should be ensured during tank filling.

A high nitrogen content in peak shaving LNG can also cause a rollover soon after the cessation of tank filling.

Experience shows that this type of rollover can best be prevented by keeping the nitrogen content of LNG below 1 % and by closely monitoring the boil-off rate.

5.7.2 RPT

When two liquids at two different temperatures come into contact, explosive forces can occur, given certain circumstances. This phenomenon, called rapid phase transition (RPT), can occur when LNG and water come into contact. Although no combustion occurs, this phenomenon has all the other characteristics of an explosion.

RPTs resulting from an LNG spill on water have been both rare and with limited consequences.