BRITISH STANDARD

BS EN 12838:2000

Installations and equipment for liquefied natural gas — Suitability testing of LNG sampling systems

The European Standard EN 12838:2000 has the status of a British Standard

ICS 75.200

National foreword

This British Standard is the official English language version of EN 12838:2000.

The UK participation in its preparation was entrusted to Technical Committee GSE/38, Installations and equipment for LNG, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Summary of pages

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Installations and equipment for liquefied natural gas – Suitability testing of LNG sampling systems

Installations et équipements relatifs au gaz naturel liquéfié - Essais d'aptitude à l'emploi des systèmes d'échantillonnage du GNL

Anlagen und Ausrüstung für Flüssigerdgas - Eignungsprüfung von Flüssigerdgas-Probenahmesystemen

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Contents

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of an identical text or by endorsement, at the latest by July 2000, and conflicting national standards shall be withdrawn at the latest by July 2000.

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

1 Scope

This standard specifies the tests to be carried out in order to assess the suitability of LNG sampling systems designed to determine the composition of Liquefied Natural Gas, in combination with an analytical device such as a chromatograph.

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.

EN 1160, *Installations and equipment for liquefied natural gas - General characteristics of liquefied natural gas*.

ISO 2854, *Statistical interpretation of data - Techniques of estimation and tests relating to means and variances*.

ISO 6568, *Natural gas - Simple analysis by gas chromatography.*

ISO 6578, *Refrigerated hydrocarbon liquids - Static measurement - Calculation procedure*.

ISO 6976, *Natural gas - Calculation of calorific values, density, relative density and Wobbe index from composition.*

ISO 8943, *Refrigerated light hydrocarbon fluids - Sampling of liquefied natural gas - Continuous method.*

3 Terms and definitions

For the purposes of this European Standard the following definitions, in addition to those given in EN 1160, apply:

3.1
liquefied natural gas (LNG)
see EN 1160

3.2
transfer line
pipe through which LNG is transferred

3.3
sampling bomb
small capacity container filled with vaporized LNG and used to determine the composition by means of a chromatograph

3.4
continuous sampling
process for continuously collecting Liquefied Natural Gas from the transfer line, which is subsequently vaporized and stored in a gasholder

3.5
discontinuous sampling
process for continuously collecting Liquefied Natural Gas from the transfer line; the liquefied natural gas is subsequently vaporized and either analysed by chromatography at regular intervals, or sampled in sampling bombs at regular intervals

3.6
reference gas
gas against which the gas sampled, by means of the tested sampling system, is compared

3.7
regression equation of the reference gas
relationship of a physical property with time, calculated via a polynomial function of order 5

4 Description of a continuous LNG sampling system

The continuous LNG sampling system to be tested for suitability prior to installation on a transfer line, shall be designed in accordance with the requirements of ISO 8943 standard. It is characterized by the use of a small capacity gasholder within which a sample of vaporized LNG, representative of the stock, is stored throughout the entire transfer operation.

Once the transfer operation is completed, sampling bombs are filled with the gas stored in the gasholder. The LNG composition is then determined by chromatographic analysis of the gas contained in the sampling bombs for subsequent determination of the physical properties of the stock (LNG density, gas density and calorific value).

Annex A presents a diagram of a continuous LNG sampling system.

5 Description of a discontinuous LNG sampling system

A discontinuous sampling system supplies a continuous flow of natural gas derived from LNG vaporization, which is transferred via a sampling line to a chromatograph for analysis, at regular intervals, of the composition of the LNG conveyed in the transfer line. In the absence of a sampling line, sampling bombs may be filled at regular intervals for subsequent chromatographic analysis of the contents.

Once the transfer operation is completed, the physical properties of the LNG are then deduced via the arithmetic mean of the properties derived from the respective analyses.

Annex B presents a diagram of two discontinuous LNG sampling systems.

6 Characteristics of the test rig

6.1 Description of the test rig

The accuracy of an LNG sampling system shall be determined by comparing physical properties such as density and gross calorific value derived from chromatographic analyses with the same properties calculated on the basis of the composition of the gas sampled following supercritical regasification of the LNG. The regasified LNG, hereafter designated as 'reference gas', shall serve as a reference to assess the accuracy of the tested sampling systems.

NOTE The supercritical regasification process eliminates any risk of fractionated vaporization during LNG transformation into natural gas. The composition of the resulting reference gas is thus free from fluctuation during regasification. Annex C describes the thermodynamic conditions for LNG transformation into natural gas for various gas compositions.

The test rig shall be composed of the following:

a) a regasification unit, consisting of one LNG storage tank, one primary pump, one high pressure pump and one vaporizer;

b) a low pressure test loop containing the tested LNG sampling system;

c) a sampling line for transfer of the reference gas from the sampling point located after the vaporizer towards a chromatograph;

d) in the case of a discontinuous sampling system, a sampling line between the sampling system and the chromatograph.

Annex D specifies the test rig to be used.

NOTE All precautions should be taken to prevent any partial condensation of the reference gas prior to analysis.

6.2 Measurement required

6.2.1 Measurement required to evaluate the test rig

In order to evaluate the test rig, the following quantities shall be measured and recorded:

a) LNG pressure and temperature in the vicinity of the tested sampling system;

b) gas pressure at the outlet of the high pressure vaporizer;

c) flow rate of the high pressure vaporizer;

d) natural gas temperature in the vicinity of the sampling point of reference gas;

e) composition of reference gas by chromatographic analysis in compliance with ISO 6568.

Annex E specifies the measuring equipment to be used.

6.2.2 Measurement required to evaluate a continuous LNG sampling system

The following quantities shall be measured and recorded in order to evaluate a continuous LNG sampling system:

a) temperature and flow rate of the gas leaving the sampling vaporizer;

b) pressure and flow rate of the gas during filling of the gasholder;

c) pressure and flow rate of the gas during filling of the sampling bombs;

d) composition of the gas contained in the sampling bombs by means of the same chromatograph as previously used to analyze the composition of the reference gas.

Annex F specifies the measuring equipment to be used.

6.2.3 Means required to evaluate a discontinuous LNG sampling system

The following quantities shall be measured and recorded in order to evaluate a discontinuous LNG sampling system:

a) temperature and pressure of the gas leaving the sampling vaporizer;

b) flow rate of the gas transferred via the sampling line;

c) composition of the gas vaporized in the LNG sampling system by means of the same chromatograph as previously used to analyze the composition of the reference gas.

Annex G specifies the measuring equipment to be used.

7 Suitability tests

7.1 General requirements of test performance

The suitability testing of a LNG sampling system shall be regarded as valid only if the following requirements are met:

a) the number of analyses performed to determine the composition of the reference gas shall be at least 40;

b) when testing a continuous LNG sampling system, the duration of gasholder filling time shall be equal to the time required to determine the composition of the reference gas; in addition, the number of analyses performed to determine the composition of the gas contained in each sampling bomb shall be at least 6;

c) when testing a discontinuous LNG sampling system, the number of analyses on the gas flowing from the system shall be identical to the number of analyses performed on the reference gas; such analyses shall be performed alternatively on collected on LNG samples and reference gas samples collected alternately.

7.2 Operating procedure

The test shall be performed in accordance with the following operating procedure:

a) start up the regasification unit;

b) start up the tested LNG sampling system as soon as the regasification unit reaches a stabilized supercritical state;

c) sample the reference gas and the LNG in accordance with the following procedure:

   1) measurement and recording of the physical properties (pressure, temperature, flow rate) characterizing the flow in the various LNG and natural gas lines;

   2) determination of the reference gas composition;

   3) when testing a discontinuous LNG sampling system, chromatographic analyses of the LNG samples;

   4) when testing a continuous LNG sampling system, filling of the gasholder;

d) shutdown the regasification unit;

e) when testing a continuous LNG sampling system, fill the sampling bombs and subsequently determine the composition of the gas samples.

7.3 Calculation of suitability criteria for the tested sampling system

7.3.1 General principles

The suitability of the LNG sampling system shall be assessed by calculating the accuracy of the values of the physical properties (for example gross calorific value, gas density and LNG density) derived from the chromatographic analyses of the gas performed with the chromatograph associated to the tested sampling system.

The gross calorific value (Hs) and gas density (ρ_{NG}), shall be calculated in accordance with ISO 6976. The LNG density (ρ_{LNG}) shall be calculated in accordance with ISO 6578.

7.3.2 Method of calculation of the accuracy of the test rig

During the LNG sampling system test, the relationship with time of the physical property referenced as X (Hs, ρ_{LNG} or ρ_{NG}) and derived from the chromatographic analyses on the reference gas shall be determined by calculating the constants of the regression equation of the reference gas according to the least squares method.

The accuracy of the test rig shall be determined by calculating the following values:

a) the random error $E_{R,X_{\mathrm{Ref}}}$ affected to each value X_{Ref} derived for one gas analysis;

b) the random error $E_{R,\overline{X_{\mathrm{Ref}}}}$ affected to the mean values $\overline{X_{\mathrm{Ref}}}$ of the reference gas.

Annex H specifies the calculation method required to determine the accuracy of the test rig.

The test rig is judged suitable if it conforms to the following requirements :

$$E_{\mathrm{R},\overline{\mathrm{H}_{\mathrm{SRef}}}} < 2{,}0\ \mathrm{kJ/kg}\ ,\ E_{\mathrm{R},\overline{\rho_{\mathrm{LNG\,Ref}}}} < 12 \times 10^{-3}\ \mathrm{kg/m^3},\ E_{\mathrm{R},\overline{\rho_{\mathrm{NG\,Ref}}}} < 4 \times 10^{-5}\ \mathrm{kg/m^3}.$$

7.3.3 Method of calculation of the accuracy of a continuous LNG sampling system

The accuracy of the tested sampling system shall be determined by calculating the following values for each individual gas analysis performed with the tested system:

a) deviation ΔX_i between the considered physical property, derived from each analysis and referenced as i, for the gas contained in the sampling bombs, and the mean value of the same property derived from analyses of the reference gas;

b) random error $E_{R,X}$ of the physical property X;

c) systematic error $E_{S,X}$ of the physical property, the statistical significance of which shall be checked in accordance with ISO 2854.

Annex J specifies the calculation method required to determine the accuracy for the tested sampling system.

7.3.4 Method of calculation of the accuracy of a discontinuous LNG sampling system

All calculations shall take into account the time corresponding to the instant when the gas sample analyzed passes the sampling point.

The accuracy of the tested sampling system shall be determined by calculating the following values for each individual gas analysis (referenced as i) performed with the tested system:

a) deviation ΔX_i between the value of the considered physical property and the value derived from the regression equation of the reference gas at the instant of collection of the gas sample at the sampling point of the tested system;

b) random error $E_{R,X}$ of the physical property X;

c) systematic error $E_{S,X}$ of the physical property, the statistical significance of which shall be checked in accordance with ISO 2854.

Annex K specifies the calculation method required to determine the accuracy of the tested sampling system.

8 Suitability criteria for the LNG sampling system

The tested sampling system is judged suitable if it conforms to the requirements of either of the accuracy classes defined in Table 1.

Table 1 — Suitability criteria for a tested sampling system

		Sampling system			
		continuous		discontinuous	
Class	**Physical property**	**Maximal random error**	**Maximal systematic error (absolute value)**	**Maximal random error**	**Maximal systematic error (absolute value)**
	*H*s in kJ/kg	9,0		54	
A	ρ_{NG} in kg/m^3	$3,0 \times 10^{-4}$	Not significant	18×10^{-4}	Not significant
	ρ_{LNG} in kg/m^3	0,15		0,90	
	*H*s in kJ/kg	18	11	$1,1 \times 10^{2}$	11
B	ρ_{NG} in kg/m^3	$6,0 \times 10^{-4}$	$5,0 \times 10^{-4}$	36×10^{-4}	$5,0 \times 10^{-4}$
	ρ_{LNG} in kg/m^3	0,30	0,20	1,8	0,20

9 Test report

The results from the tests of the LNG sampling system shall be recorded in a report containing the following data:

a) name of testing body;

b) date of test;

c) name of the manufacturer of the tested sampling system;

d) a detailed description of the tested LNG sampling system by means of a technical data sheet including in particular pressure, temperature and flow rate of the various components at the nominal operating conditions;

e) technical data sheets of all measuring and recording devices as well as the last revision of their calibration sheet, if applicable;

f) the detailed procedure followed during the calibration test in terms of preparation, start-up and utilization of the tested sampling system;

g) measurements taken during the operation of the test rig and during the test of the sampling system (see 6.2);

h) measurements of the reference gas, composition;

i) measurements of the composition of the gas generated by the tested sampling system;

j) values of the accuracy of the test rig;

k) values of the random and systematic errors on the following physical properties:

   1) gross calorific value (H_s);

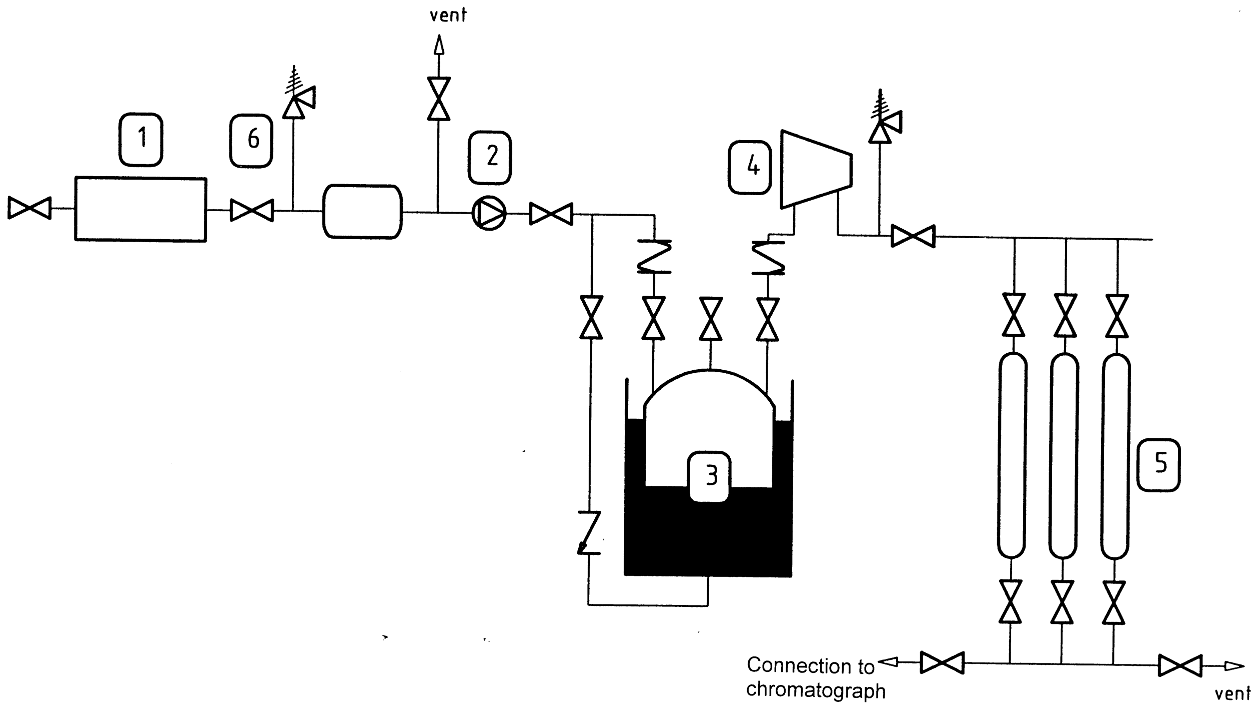
   2) density of gas (ρ_{NG});

   3) density of LNG (ρ_{LNG});

l) the accuracy class of the tested sampling system.

Annex A
(informative)

Continuous LNG sampling system



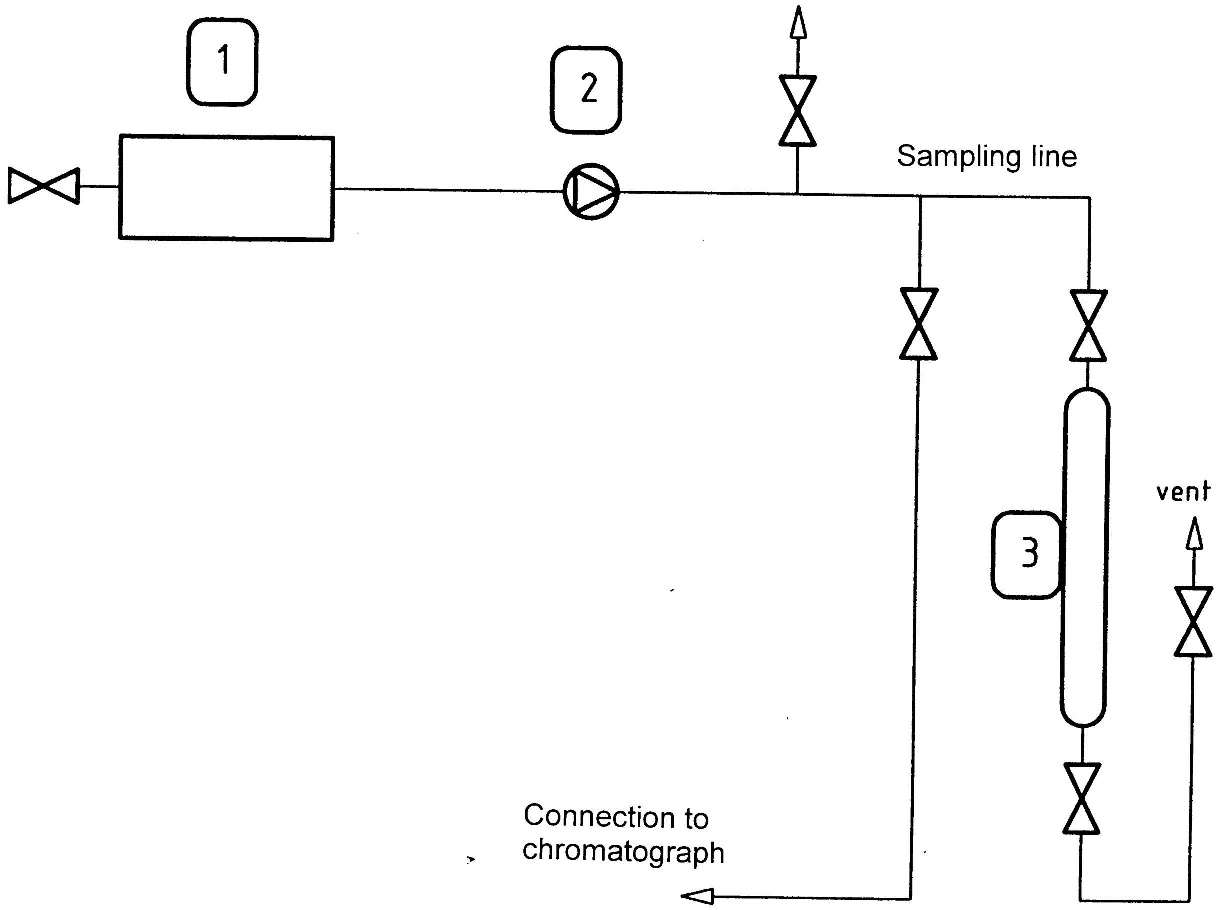
Key

1 Vaporizer
2 Flow control valve
3 Gas holder
4 Compressor
5 Sampling bomb
6 Anti-pulsatory capacity

Figure A.1 — Diagram of a continuous LNG sampling system

Annex B
(informative)

Discontinuous LNG sampling system



Key

1 Vaporizer
2 Flow control valve
3 Sampling bomb
4 Transfer line

Figure B.1 — Diagram of a discontinuous LNG sampling system

Annex C
(informative)

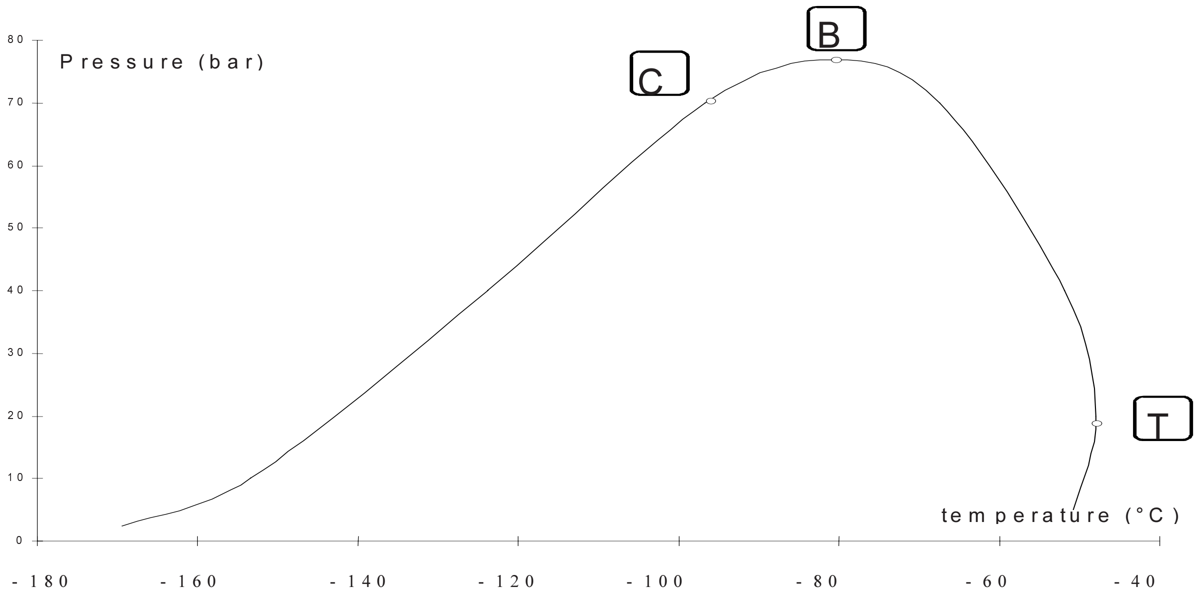
Thermodynamic conditions for the transformation of LNG into natural gas

C.1 General remarks

The supercritical state, also called transformation into dense phase, eliminates any risk of fractionated vaporization which would generate fluctuations in the gas composition during LNG regasification.

Transformation of LNG into natural gas requires a regasification pressure higher than the cricondenbar point.

Figure C.1 presents on a 'pressure vs temperature' diagram the various thermodynamic conditions of GNL quantified as in Table C.1.



Key

B Cricondenbar
T Cricondentherm
C Critical point

Figure C.1 —'Pressure vs Temperature' diagram

C.2 Example of characteristic points

Table C.1 specifies the values of the critical point, cricondenbar and cricondentherm for various LNG compositions.

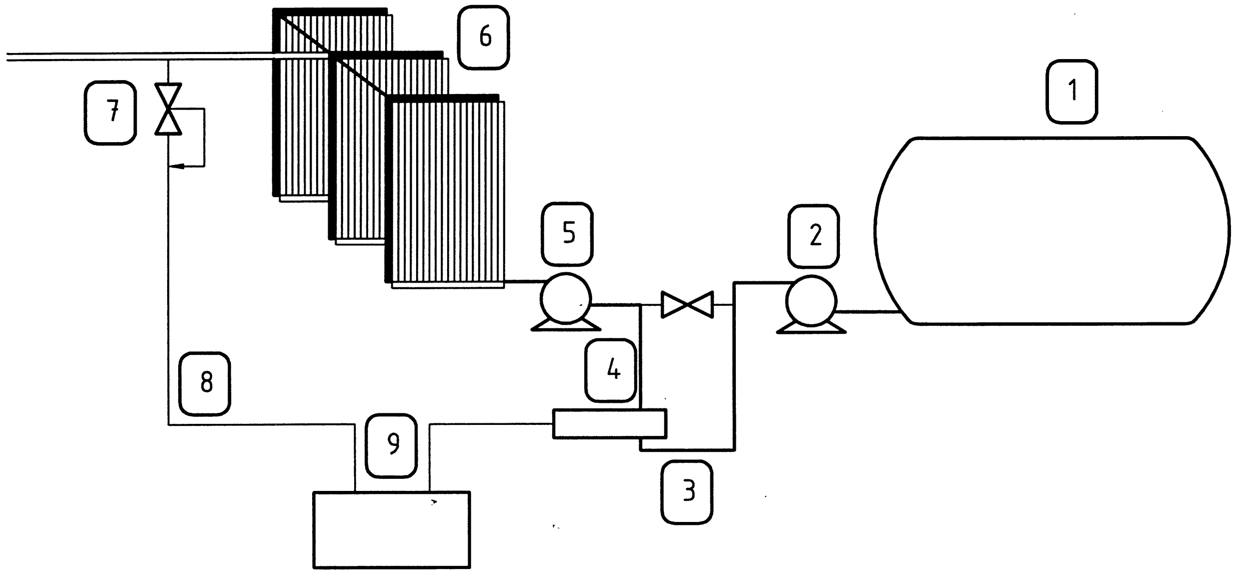
Table C.1 — Values of characteristic points

Composition % mol	**LNG** **Example 1**	**LNG** **Example 2**	**LNG** **Example 3**
N_2	0,5	1,79	0,36
CH_4	97,5	93,9	87,2
C_2H_6	1,8	3,26	8,61
C_3H_8	0,2	0,69	2,74
iC_4H_{10}		0,12	0,42
nC_4H_{10}		0,15	0,65
C_5H_{12}		0,09	0,02
Critical point in bar	49,08	56,49	70,76
Cricondenbar in bar	49,92	60,27	76,77
Cricondentherm in °C	- 77,86	- 49,08	- 24,85

NOTE The critical point, cricondenbar and cricondentherm values are given by way of information and are dependent on the thermodynamic Equation of State used for the calculation.

Annex D
(normative)

Test rig



Key

1 LNG storage tank
2 Primary pump
3 Test loop
4 Tested sampling system
5 High pressure pump
6 LNG vaporized
7 Pressure reducing valve
8 Reference gas sampling line
9 Gas analysing device

Figure D.1 — Diagram of a test rig

Annex E
(normative)

Means required to evaluate the test rig

E.1 General remarks

Since all measurements need to be recorded, it is recommended for the purposes of this test to use a data acquisition system connected to a computer.

E.2 Measuring devices

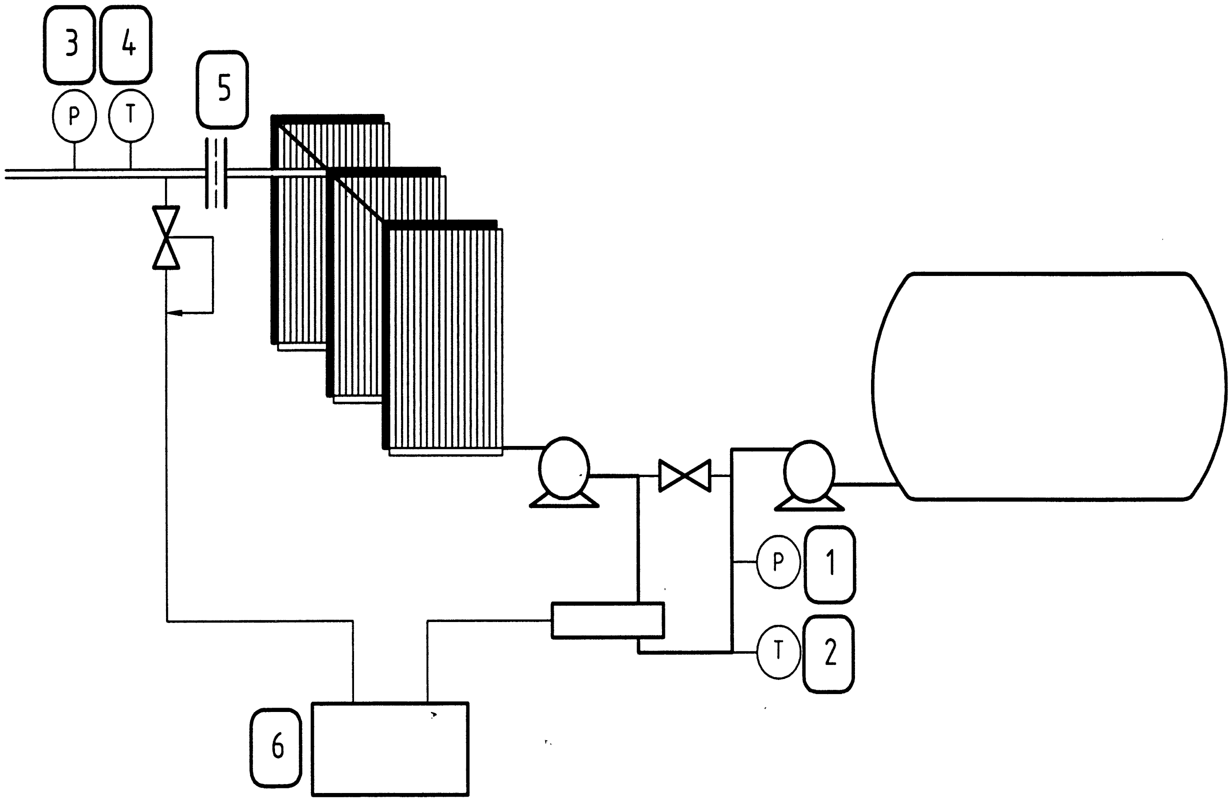
The measuring devices evaluate the test rig shall be as listed in Table E.1:

Table E.1 — List of required measuring devices

Measuring devices	Measurements
Pressure transmitter P_1	LNG pressure at sampling point of tested sampling system
Thermoresistant sensor T_1	LNG temperature at sampling point of tested sampling system
Pressure transmitter P_2	Pressure of gas at high pressure vaporizer outlet
Thermoresistant sensor T_2	NG temperature at high pressure vaporizer outlet
Flowmeter	Flow rate of gas at high pressure vaporizer outlet
Chromatograph	Analysis of reference gas

E.3 Layout of measuring devices in test rig

Measuring devices shall be positioned in accordance with Figure E.1.



Key

1 P_1 pressure transmitter

2 T_1 thermoresistant sensor

3 P_2 pressure transmitter

4 T_2 thermoresistant sensor

5 Flowmeter

6 Chromatograph

Figure E.1 — Layout of measuring devices in test rig

Annex F
(normative)

Means required to evaluate a continuous LNG sampling system

F.1 General remarks

Since all measurements need to be recorded, it is recommended for the purposes of this test to use a data acquisition system connected to a computer.

F.2 Measuring devices

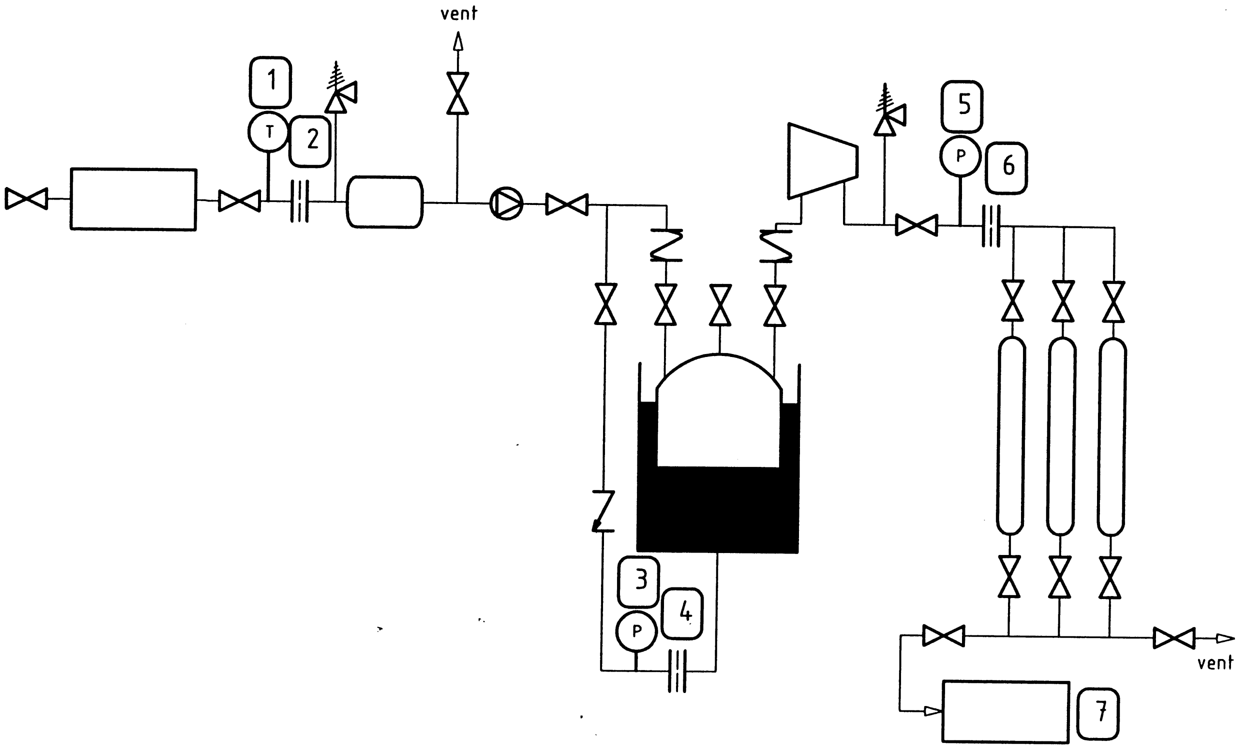
The measuring devices to evaluate the tested sampling system shall be as listed in Table F.1:

Table F.1 — List of required measuring devices

Measuring devices	Measurements
Thermoresistant sensor T_1	Gas temperature at sampling vaporizer outlet
Flowmeter Q_1	Flow rate of gas at sampling vaporizer outlet
Pressure transmitter P_2	Pressure of gas when filling gasholder
Flowmeter Q_2	Flow rate of gasholder filling
Pressure transmitter P_3	Gas pressure when filling sampling bombs
Flowmeter Q_3	Flow rate of gas when filling sampling bombs
Chromatograph	Analysis of gas contained in sampling bombs

F.3 Layout of measuring devices in the tested sampling system

Measuring devices shall be positioned in accordance with Figure F.1.



Key

1 T_1 thermoresistant sensor

2 Q_1 flowmeter

3 P_2 pressure transmitter

4 Q_2 flowmeter

5 P_3 pressure transmitter

6 Q_3 flowmeter

7 Chromatograph

Figure F.1 — Layout of measuring devices in tested sampling system

Annex G
(normative)

Means required to evaluate a discontinuous LNG sampling system

G.1 General remarks

Since all measurements need to be recorded, it is recommended for the purposes of this test to use a data acquisition system connected to a computer.

G.2 Measuring devices

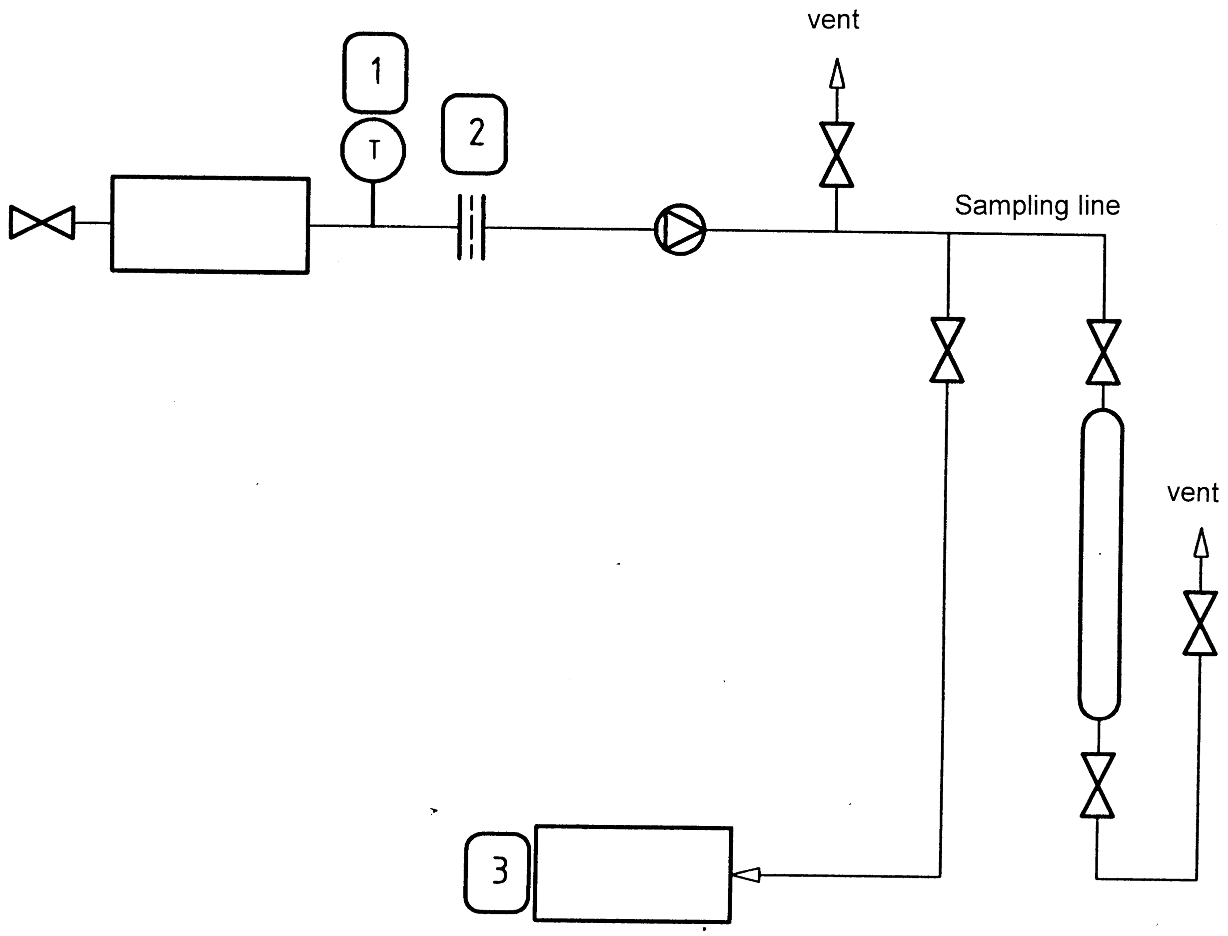
The measuring devices required to evaluate the tested sampling system shall be as listed in Table G.1:

Table G.1 — List of required measuring devices

Measuring devices	Measurements
Thermoresistant sensor T_1	Gas temperature at sampling vaporizer outlet
Flowmeter Q_1	Flow rate of gas leaving sampling vaporizer and flowing through sampling line
Chromatograph	Analysis of gas leaving sampling vaporizer and flowing through sampling line

G.3 Layout of measuring devices in the tested sampling system

Measuring devices shall be positioned in accordance with Figure G.1.



Key

1 T_1 thermoresistant sensor

2 Q_1 flowmeter

3 chromatograph

Figure G.1 — Layout of measuring devices in the tested sampling system

Annex H
(normative)

Method of calculation of the accuracy of the test rig

H.1 Mean values of physical properties derived from the analysis of the reference gas

The following methodology shall be applied for each physical property under study. Given:

$X_{\mathrm{Ref_i}}$ the physical properties calculated from the analysis of the rank i sample obtained with the reference gas at time $T_{\mathrm{Ref_i}}$.

H.2 Calculation of the relationship of the physical property with time of the reference gas

The relationship with time of the physical property *X* derived from the measurements of the reference gas composition, shall then be calculated. This is a polynomial equation of order 5 adjusted to the least squares, such that

$$X_{\mathrm{Ref}} = \sum_{\mathrm{j=0}}^{5} a_{\mathrm{j}} T_{\mathrm{Ref}}^{\mathrm{j}}$$

and

$\sigma_{\mathrm{X_{Ref}/T_{Ref}}}$ the related residual standard deviation.

H.3 Mean value of a physical property of the reference gas

The mean value of the quantity *X* is expressed as follows

$$\overline{X_{\mathrm{Ref}}} = \frac{1}{n} \cdot \sum_{i=1}^{n} X_{\mathrm{Ref_i}}$$

where

n is the number of samples.

H.4 Random error on a value of the reference gas

The random error $E_{\mathrm{R,X_{Ref}}}$ on each value derived from the analysis is equal to

$$E_{\mathrm{R,X_{Ref}}} = t.\sigma_{\mathrm{X_{Ref}/T_{Ref}}}$$

where

t is the STUDENT variable at a 95 % acceptance threshold (*t* = 2,02 for 40 samples).

H.5 Random error on all values of the reference gas

The random error $E_{R,\overline{X_{Ref}}}$ is expressed as follows

$$E_{R,\overline{X_{Ref}}} = t \cdot \frac{\sigma_{X_{Ref}/T_{Ref}}}{\sqrt{n}}$$

H.6 Example of calculation

H.6.1 Example of 40 experimental values

Table H.1 — Experimental results

Sample No	1	2	3	4	5	6	7	8
Sample time T_{Ref_i} in 1/100 h	16,11	41,11	67,78	92,81	119,44	144,44	171,11	196,11
Physical property X_{Ref_i} (ρ_{LNG} in kg/m^3)	454,11	454,13	454,10	454,10	454,12	454,11	454,10	454,10

Sample No	9	10	11	12	13	14	15	16
Sample time T_{Ref_i} in 1/100 h	222,78	247,78	274,44	299,44	326,11	351,11	377,78	402,78
Physical property X_{Ref_i} (ρ_{LNG} in kg/m^3)	454,11	454,09	454,12	454,10	454,11	454,09	454,10	454,10

Sample No	17	18	19	20	21	22	23	24
Sample time T_{Ref_i} in 1/100 h	429,44	456,11	481,11	507,78	532,78	559,44	584,44	611,11
Physical property X_{Ref_i} (ρLNG in kg/m^3)	454,09	454,11	454,10	454,12	454,13	454,13	454,13	454,18

Sample No	25	26	27	28	29	30	31	32
Sample time T_{Ref_i} in 1/100 h	636,11	662,78	687,78	714,44	739,44	766,11	791,11	817,78
Physical property X_{Ref_i} (ρ_{LNG} in kg/m^3)	454,17	454,18	454,20	454,21	454,26	454,27	454,26	454,28

Sample No	33	34	35	36	37	38	39	40
Sample time T_{Ref_i} in 1/100 h	842,78	869,44	894,44	921,11	946,11	972,78	997,78	1024,4
Physical property X_{Ref_i} (ρ_{LNG} in kg/m^3)	454,31	454,31	454,34	454,38	454,38	454,43	454,48	454,53

H.6.2 Relationship with time of the physical properties

The values of the coefficients a_j of the polynomial equation $\left(X_{\mathrm{Ref}} = \sum_{j=0}^{5} a_j T_{\mathrm{Ref}}^{j} \right)$ adjusted to the least squares are :

Table H.2 — Polynomial coefficients

a_0	454,06	a_3	$3{,}01694 \times 10^{-8}$
a_1	$1{,}53661 \times 10^{-3}$	a_4	$- 3{,}3052 \times 10^{-11}$
a_2	$- 1{,}12785 \times 10^{-5}$	a_5	$1{,}3064 \times 10^{-14}$

The value of the related residual standard deviation $\sigma_{X_{\mathrm{Ref}}/T_{\mathrm{Ref}}}$ is : $1{,}80 \times 10^{-2}$.

H.6.3 Mean value of the physical property of the reference gas

$$\overline{X_{\mathrm{Ref}}} = 454{,}192 \ \mathrm{kg/m^3}$$

H.6.4 Random error on a value of the reference gas

$$E_{\mathrm{R},X_{\mathrm{Ref}}} = 3{,}64 \times 10^{-2} \ \mathrm{kg/m^3}$$

H.6.5 Random error on all values of the reference gas

$$E_{\mathrm{R},\overline{X_{\mathrm{Ref}}}} = 5{,}75 \times 10^{-3} \ \mathrm{kg/m^3}$$

Annex J
(normative)

Method of calculation of the accuracy of a continuous LNG sampling system

J.1 Deviation in relation to reference gas, of the physical property *X* derived from gas analyses obtained with the tested sampling system

The following methodology shall be applied for each physical property under study. Given:

$X_{SB_{LNG_i}}$ the physical property calculated from the analysis of the rank i sample SB_{LNG_i} ;

$\overline{X_{Ref}}$ see Annex H.

The deviation ΔX_i shall be calculated as follows for each analysis performed with the tested system

$$\Delta X_i = X_{SB_{LNG_i}} - \overline{X_{Ref}}$$

J.2 Random error of the tested sampling system

The random error $E_{R,X}$ affected to each analysis performed with the tested system is equal to

$$E_{R,X} = t \cdot \sigma_{\Delta X_i}$$

where

t is the STUDENT variable at a 95 % acceptance threshold (for example t = 2,571 for 6 analysis);

$\sigma_{\Delta X_i}$ is the standard deviation associated with the deviations ΔX_i.

J.3 Systematic error of the tested sampling system

The systematic error $E_{S,X}$ of the tested sampling system is expressed as follows:

$$E_{S,X} = \overline{\Delta X}$$

where

$\overline{\Delta X}$ is the mean value of deviations ΔX_i .

J.4 Statistical test on systematic error

In order to determine whether the above systematic error is significant, a statistical test shall be carried out in accordance with the requirements of ISO 2854 on the basis of a comparison of two mean values of known variance.

The variances related to the physical properties are respectively called $\sigma^2_{\Delta X_i}$ and $\sigma^2_{X_{Ref}/T_{Ref}}$.

The assumption of a non-significant systematic error is rejected if

$$\left|\overline{\Delta X}\right| > u_{1-\alpha/2} \cdot \sigma_d$$

with

$$\sigma_d = \sqrt{\frac{\sigma^2_{X_{Ref}/T_{Ref}}}{n_1} + \frac{\sigma^2_{\Delta X_i}}{n_2}}$$

where

$\sigma X_{Ref} / T_{Ref}$ see Annex H;

n_1 and n_2 number of measurements performed respectively with the reference gas and the tested sampling system;

$u_{1-\alpha/2} = 1{,}96$ at a 95 % acceptance level (α = 0,05).

J.5 Example of calculation

J.5.1 Mean value of the physical properties

The mean value of the physical properties of the reference gas is:

$\overline{X_{Ref}} = 454{,}192$ (see H.6.3).

Deviations of the physical properties X derived from gas analyses obtained with the tested sampling system are given in table J.1.

Table J.1 — Deviations

Sample No	1	2	3	4	5	6
Deviation $\Delta X_i = X_{SB_{LNG_i}} - \overline{X_{Ref}}$	- 1,10	- 1,13	- 1,12	- 1,14	- 1,14	- 1,12

J.5.2 Random error of the tested sampling system $E_{R,X}$

$$E_{\mathrm{R,X}} = t \cdot \sigma_{\Delta X_i}$$

$$\sigma_{\Delta X_i} = 0{,}01517 \ \mathrm{kg/m^3}$$

$$E_{\mathrm{R,X}} = 2{,}571 \times 0{,}01517$$

$$E_{\mathrm{R,X}} = 3{,}90 \times 10^{-2} \ \mathrm{kg/m^3}$$

J.5.3 Sytematic error of the tested sampling system $E_{S,X}$

$$E_{\mathrm{s,x}} = \overline{\Delta X}$$

$$E_{\mathrm{s,x}} = -1{,}125 \ \mathrm{kg/m^3}$$

J.5.4 Statistical test on systematic error

$$\sigma_{\mathrm{d}} = \sqrt{\frac{\sigma^2 X_{\mathrm{Ref}} / T_{\mathrm{Ref}}}{n_1} + \frac{\sigma^2 \Delta X_{\mathrm{i}}}{n_2}}$$

$$\sigma_{X_{\mathrm{Ref}} / T_{\mathrm{Ref}}} = 1{,}80 \times 10^{-2} \ \text{(see H.6.2)}$$

$n_1 = 4$

$n_2 = 6$

$$\sigma_{\mathrm{d}} = 6{,}816 \times 10^{-3}$$

$$u_{1-\alpha/2} \cdot \sigma_{\mathrm{d}} = 1{,}336 \times 10^{-2}$$

$$\left|\overline{\Delta X}\right| = 1{,}125 \ \text{(See J.5.3)}$$

$$\left|\overline{\Delta X}\right| > u_{1-\alpha/2} \cdot \sigma_{\mathrm{d}}$$

Consequently, the systematic error of the physical property *X* is statistically significant.

Annex K
(normative)

Method of calculation of the accuracy of a discontinuous LNG sampling system

K.1 Calculation of the regression equation of the reference gas

The equation of the time evolution of the physical property *X* derived from the compositions of the reference gas and the related residual standard deviation shall be calculated in accordance with annex H.

K.2 Deviation of physical property *X* from regression equation

The following methodology shall be applied for each physical property under study. Given:

$X_{SS_{LNG_i}}$ the physical property calculated from the analysis of the rank i sample obtained with the sampling system at time $T_{SS_{LNG_i}}$.

The deviation ΔX_i shall be calculated as follows for each analysis performed with the tested sampling system:

$$X_{SS_{LNG_i}} - \hat{X}_{Ref/\left(T_{SS_{LNG_i}}\right)}$$

where

$$\hat{X}_{Ref/\left(T_{SS_{LNG_i}}\right)} = \sum a_j T^{i}_{SS_{LNG_i}}$$

K.3 Random error of the tested sampling system

The random error $E_{R,X}$ affected to each analysis performed with the tested system is equal to:

$$E_{R,X} = 1{,}96 \cdot \sigma_{\Delta X_i}$$

where

$\sigma_{\Delta X_i}$ is the standard deviation associated with the deviations ΔX_i.

K.4 Systematic error of the tested sampling system

The systematic error $E_{S,X}$ of the tested sampling system is expressed as follows:

$$E_{S,X} = \overline{\Delta X}$$

where

$\overline{\Delta X}$ is the mean value of deviations ΔX_i .

K.5 Statistical test on systematic error

In order to determine whether the above systematic error is significant, a statistical test shall be carried out in accordance with the requirements of ISO 2854 on the basis of a comparison of two mean values of known variance.

The variances related to the physical properties are respectively called $\sigma^2 \Delta X_i$ and $\sigma^2 X_{Ref} / T_{Ref}$.

A significant systematic error is assumed if:

$$\left| \overline{\Delta X} \right| > u_{1-\alpha/2} \cdot \sigma_d$$

with

$$\sigma_d = \sqrt{\frac{\sigma^2 X_{Ref} / T_{Ref}}{n_1} + \frac{\sigma^2 \Delta X_i}{n_2}}$$

where

$\sigma_{X_{Ref}/T_{Ref}}$ see annex H;

n_1 and n_2 are the number of measurements performed respectively with the reference gas and the tested sampling system;

$u_{1-\alpha/2} = 1,96$ at a 95 % acceptance level (α = 0,05).

K.6 Example of calculation

K.6.1 Example of 40 experimental values

Table K.1 — Experimental results

Sample No	1	2	3	4	5	6	7	8
Sample time $T_{SS_{LNG_i}}$ in 1/100 h	0	25	51,67	76,70	103,33	128,33	155,00	180
Physical properties $X_{SS_{LNG_i}}$ (ρLNG in kg/m^3)	456,58	453,93	454,16	454,21	454,22	454,26	454,35	453,96
Sample No	9	10	11	12	13	14	15	16
Sample time $T_{SS_{LNG_i}}$ in 1/100 h	206,67	231,67	258,33	283,33	310,00	335,00	361,67	386,67
Physical properties $X_{SS_{LNG_i}}$ (ρLNG in kg/m^3)	453,88	453,87	454,51	453,86	453,94	454,23	454,21	454,23
Sample No	17	18	19	20	21	22	23	24
Sample time $T_{SS_{LNG_i}}$ in 1/100 h	413,33	440,00	465,00	491,67	516,67	543,33	568,33	595,00
Physical properties $X_{SS_{LNG_i}}$ (ρLNG in kg/m^3)	454,15	454,12	453,95	454,02	453,99	454,01	454,22	454,18
Sample No	25	26	27	28	29	30	31	32
Sample time $T_{SS_{LNG_i}}$ in 1/100 h	620,00	646,67	671,67	698,33	723,33	750,00	775,00	801,67
Physical properties $X_{SS_{LNG_i}}$ (ρLNG in kg/m^3)	454,28	454,36	454,27	454,22	454,4	454,23	454,14	454,17
Sample No	33	34	35	36	37	38	39	40
Sample time $T_{SS_{LNG_i}}$ in 1/100 h	826,67	853,33	878,33	905,00	930,00	956,67	981,67	1008,3
Physical properties $X_{SS_{LNG_i}}$ (ρLNG in kg/m^3)	454,50	454,13	454,30	454,39	454,44	454,52	454,59	454,58

Table K.2 — Deviations

Sample No	1	2	3	4	5	6	7	8	9	10
ΔX_i	2,5	- 0,28	0,04	0,08	0,09	0,14	0,23	- 0,15	- 0,22	- 0,22

Sample No	11	12	13	14	15	16	17	18	19	20
ΔX_i	0,42	- 0,22	-0,14	0,15	0,13	0,14	0,05	0,02	- 0,16	- 0,11

Sample No	21	22	23	24	25	26	27	28	29	30
ΔX_i	- 0,15	- 0,14	0,06	0,00	0,09	0,16	0,06	0,00	0,17	-0,02

Sample No	31	32	33	34	35	36	37	38	39	40
ΔX_i	- 0,12	- 0,10	0,22	- 0,17	- 0,02	0,04	0,05	0,08	0,10	0,01

K.6.2 Random error of the tested sampling system

$$\sigma\Delta X_{\mathrm{i}} = 0{,}4212 \text{ kg/m}^3$$

$$E_{\mathrm{R,X}} = 8{,}256 \times 10^{-1} \text{ kg/m}^3$$

K.6.3 Systematic error of the tested sampling system

$$E_{\mathrm{S,X}} = \overline{\Delta X}$$

$$E_{\mathrm{S,X}} = 7{,}025 \times 10^{-2} \text{ kg/m}^3$$

K.6.4 Statistical test on sytematic error

$$\sigma_{\mathrm{d}} = \sqrt{\frac{\sigma^2 X_{\mathrm{Ref}} / T_{\mathrm{Ref}}}{n_1} + \frac{\sigma^2 \Delta X_{\mathrm{i}}}{n_2}}$$

$\sigma_{X_{\mathrm{Ref}} / T_{\mathrm{Ref}}} = 1{,}80 \times 10^{-2}$ (see H.6.2)

$\sigma_{\Delta X_{\mathrm{i}}} = 0{,}4212$ (see K.6.2)

$n_1 = 40$

$n_2 = 40$

$\sigma_{\mathrm{d}} = 6{,}67 \times 10^{-2}$

$u_{1-\alpha/2} = 1{,}96$

$u_{1-\alpha/2} \cdot \sigma_{\mathrm{d}} = 1{,}307 \times 10^{-1}$

$\left|\overline{\Delta X}\right| = 7{,}025 \times 10^{-2}$ (see K.6.3)

$\left|\overline{\Delta X}\right| < u_{1-\alpha/2} \cdot \sigma_{\mathrm{d}}$

Consequently, the systematic error of the physical property X is not statistically significant.

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