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REDE NACIONAL DE TRANSPORTE DE GÁS NATURAL - PORTUGAL

GAS PROPERTIES

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1.0 SCOPE

This document contains the natural gas definition and composition according to *International Standard ISO 13686 / 1998-05-01 Natural gas – Quality designation*, as well as the quality specification published in Portuguese legislation regarding natural gas quality (Despacho n.º19 624-A/2006 de 25 de Setembro – Anexo IV – Regulamento da Qualidade de Serviço).

It also presents the annual average compositions and properties of the natural gas in the Portuguese high pressure transport network – the Algerian natural gas from Magreb Europe Pipeline and the Nigerian natural gas from LNG Terminal.

2.0 DEFINITIONS

2.1 Natural Gas

A gaseous fuel obtained from underground sources. It consists of a complex mixture of hydrocarbons, primarily methane, but generally also including ethane, propane and higher hydrocarbons in much smaller amounts. It generally also includes some inert gases, such as nitrogen and carbon dioxide, plus minor amounts of trace constituents.

2.2 Liquefied Natural Gas

Natural gas which, after processing has been liquefied for storage or transportation purposes. Liquefied natural gas (LNG) is vaporized and introduced into pipelines for transmission and distribution as natural gas.

2.3 Reference Conditions

The preferred reference conditions are referred to as normal conditions and denoted by the subscript "n":

p_n = 1,01325 bar(a)
T_n = 273,15 K (0 ºC)

2.4 Superior Calorific value, Hs

The amount of heat which would be released by the complete combustion in air of a specified quantity of gas, in such a way that the pressure at which the reaction takes place remains constant, and all the products of combustion are returned to the same specified temperature as that of the reactants, all of these products being in the gaseous state except for the water formed by the combustion, which is condensed to the liquid state at the above mentioned temperature. The above mentioned pressure and temperature must be specified.

2.5 Inferior Calorific Value, Hi

The amount of heat which would be released by the complete combustion in air of a specified quantity of gas, in such a way that the pressure at which the reaction takes place remains constant, and all the products of combustion are returned to the same specified temperature as that of the reactants, all of these products being in the gaseous state. The above mentioned pressure and temperature must be specified.

Both superior and inferior calorific values, which differ by the heat of condensation of water formed by combustion, can be specified on molar, mass or volumetric basis.

2.6 Density

The mass of gas divided by its volume at specified pressure and temperature.

2.7 Relative Density

Often called specific gravity, it is the mass of natural gas, dry, per unit volume divided by the mass of an equal volume of dry air, both at the same specified pressure and temperature.

2.8 Wobbe Index

The Wobbe Index is the measure of the heat input to gas appliances, derived from the orifice flow equation. It is defined as the specified calorific value, always on volume basis, divided by the square root of the corresponding relative density. The heat input for different natural gas compositions is the same if they have the same Wobbe index and are used under the same gas pressure.

2.9 Water Dew Point

The dew point defines the temperature above which no condensation of water occurs at a specified pressure. For any pressure lower than the specified pressure there is no condensation at this temperature.

2.10 Joule-Thompson coefficient

The relationship between temperature, pressure and volume of a gas is simply described by the gas laws. When volume is increased in an irreversible process, the gas laws do not uniquely determine what happens to the pressure and temperature of the gas. Reversible adiabatic expansion, in which the gas does positive work in the process of expansion, always causes a decrease in temperature. The Joule-Thompson coefficient is the quocient between the temperature decrease and pressure decrease.

2.11 Specific Heat Capacity

Specific heat capacity, also known simply as specific heat is the measure of the heat energy required to raise the temperature of a specific quantity of a substance (thus, the name "specific" heat) by certain amount, usually one kelvin. A kelvin is a unit increment of thermodynamic temperature and is precisely equal to an increment of one degree Celsius. Virtually any substance may have its specific heat capacity measured, including pure chemical elements, compounds, alloys, solutions, and composites.

2.12 Viscosity

Viscosity is a measure of the resistance of a fluid to deform under shear stress. It is commonly perceived as "thickness", or resistance to pouring. Viscosity describes a fluid's internal resistance to flow and may be thought of as a measure of fluid friction.

2.13 Isentropic Expansion Factor

The adiabatic index of a gas, is the ratio of its specific heat capacity at constant pressure (c_P) to its specific heat capacity at constant volume (c_V). It is also known as the *isentropic expansion factor*, γ.

2.14 Enthalpy

In thermodynamics, the quantity enthalpy, symbolized by *H*, also called *heat content*, is the sum of the internal energy of a thermodynamic system plus the energy associated with work done by the system on the atmosphere which is the product of the pressure times the volume.

2.15 Entropy

Entropy, symbolized by *S*, is a state function of a thermodynamic system defined by the differential quantity, where *dQ* is the amount of heat absorbed in a reversible process in which the system goes from the one state to another, and *T* is the absolute temperature. Entropy is one of the factors that determines the free energy in the system and appears in the second law of thermodynamics.

3.0 PARAMETER RANGES AND VALUES

a) Composition [1]

For information only, this is the range of European market natural gas dried components:

Components	Mol %
CH_4 (Methane)	78,2 – 100,0
C_2H_6 (Ethane)	0,2 - 10,7
C_3H_8 (Propane)	< 3,3
C_4H_{10} (Butane)	< 0,6
C_5H_{12} (Pentane)	< 0,1
N_2 (Nitrogen)	< 19,2
CO_2 (Carbon Dioxide)	< 6,1

[1] According to *International Standard ISO 13686 / 1998-05-01, Natural gas – Quality designation.*

b) NG Specification

		Minimum	Maximum
Wobbe Index	$MJ/m^3(n)$	48,17	57,66
d (relative density)	-	0,5549	0,7001
H_2S content	$mg/m^3(n)$		< 5
Total S	$mg/m^3(n)$		< 50
H_2O content	ºC @ 84 bar(g)		< - 5

The parameter units and reference conditions used are in according to the EASEE-gas, CBP 2003-001/01. This implies that the energy unit is MJ with a combustion reference temperature of 25 ºC, and the volume unit is m^3 at reference conditions of 0 ºC and 1,01325 bar(a).

The natural gas delivered shall not contain other constituents and/or impurities to the extent that it cannot be transported, stored and/or marketed without quality adjustment treatment.

4.0 PROJECT GAS [2]

4.1 MAGREB EUROPE PIPELINE

For information only and in case precise values of natural gas are needed for further calculations, the following average properties shall be used.

Components	mol %
Methane	87,885
Ethane	8,056
Propane	1,378
i-Butane	0,108
n-Butane	0,158
i-Pentane	0,022
n-Pentane	0,018
n-Hexane	0,020
Nitrogen	1,088
CO_2	1,266

Molecular Weight (kg/kmol)	18,192
Density (kg/m^3(n))	0,8141
Specific Gravity (relative density)	0,6297

	MJ/m^3 (n)	kWh/m^3 (n)
Superior Caloric Value [25 ºC; (0ºC; 1,01325 bar)]	42,47	11,80
Inferior Caloric Value [25 ºC; (0ºC; 1,01325 bar)]	38,39	10,66
Wobbe Index (on Hs)	53,52	14,87

[2] The presented physical properties were calculated according to *ISO 6976:1995 (E). Second edition 95.12.01. Corrected and reprinted 96.02.01. Natural gas - Calculation of calorific value, density, relativedensity and Wobbe index from composition.*

4.2 LNG TERMINAL

For information only, and in case precise values of the gas are needed for further calculations, the following average properties shall be used.

Components	mol %
Methane	92,215
Ethane	4,841
Propane	2,111
i-Butane	0,360
n-Butane	0,381
i-Pentane	0,018
n-Pentane	0,003
n-Hexane	0,000
Nitrogen	0,071
CO_2	0,000

Molecular Weight (kg/kmol)	17,646
Density (kg/m^3(n))	0,7897
Specific Gravity (relative density)	0,6107

	MJ/m^3 (n)	kWh/m^3 (n)
Superior Caloric Value [25 °C; (0°C; 1,01325 bar)]	43,21	12,00
Inferior Caloric Value [25 °C; (0°C; 1,01325 bar)]	39,05	10,85
Wobbe Index (on Hs)	55,30	15,36

5.0 PROPERTIES [3]

For information only, the following properties were calculated with the two compositions previously presented.

5.1 JOULE-THOMPSON COEFFICIENT, μ

	Magreb Europe	LNG Terminal
Pressure [bar(a)]	(K/bar)	(K/bar)
80	0,650	0,633
70	0,659	0,644
60	0,663	0,648
50	0,661	0,647
40	0,655	0,643
30	0,647	0,635
20	0,636	0,626
15	0,630	0,620
10	0,624	0,615
Normal conditions	0,677	0,667

5.2 SPECIFIC HEAT CAPACITY AT CONSTANT PRESSURE, Cp

	Magreb Europe		LNG Terminal	
Pressure [bar(a)]	(kJ/(kmol.K))	(kJ/(kg.K))	(kJ/(kmol.K))	(kJ/(kg.K))
80	53,82	2,96	53,40	3,03
70	51,22	2,82	50,90	2,88
60	48,69	2,68	48,47	2,75
50	46,31	2,55	46,16	2,62
40	44,10	2,42	44,02	2,49
30	42,10	2,31	42,02	2,38
20	40,30	2,22	40,30	2,28
15	39,47	2,17	39,48	2,24
10	38,68	2,13	38,71	2,19
Normal conditions	36,76	2,02	36,81	2,09

[3] All the presented properties were calculated according to Peng-Robinson equation of state. Calculated considering an average gas process temperature of 15 °C (288,15 K).

5.3 SPECIFIC HEAT CAPACITY AT CONSTANT VOLUME, Cv

	Magreb Europe		LNG Terminal	
Pressure [bar(a)]	(kJ/(kmol.K))	(kJ/(kg.K))	(kJ/(kmol.K))	(kJ/(kg.K))
80	31,53	1,73	31,52	1,79
70	31,17	1,71	31,17	1,77
60	30,82	1,69	30,83	1,75
50	30,48	1,68	30,5	1,73
40	30,15	1,66	30,17	1,71
30	29,83	1,64	29,86	1,69
20	29,52	1,62	29,55	1,67
15	29,37	1,61	29,41	1,67
10	29,22	1,61	29,26	1,66
Normal conditions	28,32	1,56	28,38	1,61

5.4 ISENTROPIC EXPANSION FACTOR, γ

	Magreb Europe	LNG Terminal
Pressure [bar(a)]		
80	1,71	1,69
70	1,64	1,63
60	1,58	1,57
50	1,52	1,51
40	1,46	1,46
30	1,41	1,41
20	1,37	1,36
15	1,34	1,34
10	1,32	1,32
Normal conditions	1,30	1,30

5.5 VISCOSITY, μ

	NG Magreb Europe	LNG Terminal
Pressure [bar(a)]	(10^{-5} Pa.s)	(10^{-5} Pa.s)
80	1,325	1,304
70	1,272	1,254
60	1,227	1,209
50	1,187	1,171
40	1,154	1,138
30	1,125	1,110
20	1,100	1,086
15	1,090	1,075
10	1,080	1,066
Normal conditions	1,016	1,003

5.6 ENTHALPY, H

	Magreb Europe		LNG Terminal	
Pressure [bar(a)]	(kJ/kmol)	(kJ/kg)	(kJ/kmol)	(kJ/kg)
80	7946,0	436,8	8011,4	454,0
70	8189,9	450,2	8249,8	467,5
60	8436,3	463,7	8490,8	481,2
50	8683,0	477,3	8732,5	494,9
40	8928,3	490,8	8973,2	508,5
30	9170,8	504,1	9211,6	522,0
20	9409,7	517,2	9446,7	535,3
15	9527,7	523,7	9562,8	541,9
10	9644,5	530,2	9677,9	548,4
Normal conditions	9291,4	510,7	9321,2	528,2

5.7 ENTROPY, S

	Magreb Europe		LNG Terminal	
Pressure [bar(a)]	(kJ/kmol.K)	(kJ/kg.K)	(kJ/kmol.K)	(kJ/kg.K)
80	79,39	4,36	76,91	4,36
70	80,66	4,43	78,18	4,43
60	82,1	4,51	79,62	4,51
50	83,79	4,61	81,31	4,61
40	85,82	4,72	83,34	4,72
30	88,39	4,86	85,9	4,87
20	91,94	5,05	89,45	5,07
15	94,42	5,19	91,93	5,21
10	97,87	5,38	95,38	5,41
Normal conditions	115,07	6,33	112,57	6,38