

**DRAFT TANZANIA STANDARD**

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**Specification for General Purpose Natural Gas**

**TANZANIA BUREAU OF STANDARDS**

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**1<sup>st</sup> edition**

## 0. Foreword

This Tanzania Draft Standard was prepared by the Gases Products Technical Committee CDC 9 under the supervision of Chemicals Standards Divisional Committee, and it is in accordance with the procedures of the Bureau. It serves as a specification for general purpose natural gas, with an emphasis on the safety of the gas for use in natural gas appliances and equipment and for use as fuel in natural gas vehicles.

The quality specification provided by this Standard defines the requirements for providing a natural gas suitable for transportation and for general purpose uses and provides the range of gas properties consistent with safe operation of the natural gas appliance population.

Natural gas conforming to this Standard is suitable for transportation through pipelines; however operational problems have been reported in transmission systems with sulfur concentrations in natural gas below the 50 mg/m<sup>3</sup> specified in this Standard. Research on this issue is continuing. The outcome of the research will be taken into account in subsequent review of the Standard.

Certain limits defined in the specification may be temporarily departed from under some circumstances. The issue of such departures is not within the scope of this Standard and is subject to and provided for under relevant gas sales contracts, legislation and/or government guidelines.

The Standard is not intended to apply to gas supplies where no 'general purpose' users are connected to the supply system, e.g., a dedicated supply to an industrial user.

Gas consumers who have specific needs that are not provided for by the specification would need to nominate in appropriate commercial contracts with gas suppliers or retailers the gas composition suitable for their particular use. The term 'informative' has been used in this Standard and applies to appendices that are for information and guidance only.

**0.1.** In the preparation of this standard assistance has been derived from:

AS 4564:2011 Specification for general purpose natural gas, published by Australian Standard Institute

IGS-M-CH-033(1):2014 Specification for Iranian Natural Gas Quality, published by National Iranian Gas Company

ISO 13686:2005, Natural Gas – Quality Designation published by International Organization for Standardization

NZS 5542:2008, Specification for Reticulated Natural Gas published by New Zealand Standards Body

Natural Gas Composition and Specification based on real and designed data of Gas Processing Plant, GASCO a subsidiary of Tanzania Petroleum Development Corporation, and Songas Gas Processing Plant, 2017

**0.2.** For the purpose of deciding whether a particular requirement of this standard is complied with, the final value observed or calculated expressing the result(s) of a test or analysis shall, be rounded off in accordance with TZS 4 (see clause 2). The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

## 1. Scope

**1.1.** This Draft Tanzania Standard prescribes requirements, methods of sampling and testing, calculation and interchangeability indices of natural gas for general purpose use.

**1.2.** The specification applies to natural gas —

- a) from petroleum, landfill, biogas, coal seam and other sources where these sources provide gas for direct or blended supply on a commercial basis through supply systems serving general purpose customers;
- b) transported and supplied to users for use in natural gas appliances and equipment complying with the relevant Standards. This includes natural gas-powered vehicles, natural gas compressors and refuelling facilities.

**NOTE:** This specification is supported by informative Appendices that provide further information and guidance on the derivation of the requirements, additional issues to be considered in contracts and testing methods to verify compliance, see Appendices.

## 2. Normative references

The following normative references are indispensable for the application of this standard. For dated references, only the edition cited applies. For undated references, the latest edition of the normative references (including amendments) applies

CDC 09 (5663)/ISO 15403 P<sub>3</sub>, *Natural gas — Designation of the quality of natural gas as a compressed fuel for vehicles*

CDC 09 (5675)/ISO 6326-5 P<sub>3</sub>, *Natural gas -- Determination of sulfur compounds -- Part 5: Lingener combustion method*

CDC 09 (5676)/ISO 6327 P<sub>3</sub>, *Gas analysis – Determination of the water dew point of natural gas – Cooled surface condensation hygrometers*

CDC 09 (5677)/ISO 6974-3 P<sub>3</sub>, *Natural gas — Determination of composition with defined uncertainty by gas chromatography – Part 3: Determination of hydrogen, helium, oxygen, nitrogen, carbon dioxide and hydrocarbons up to C8 using two packed columns*

CDC 09 (5678)/ISO 6976 P<sub>3</sub>, *Natural gas — Calculation of calorific values, density, relative density and Wobbe Index from composition*

CDC 09 (5679)/ISO 10101 P<sub>3</sub>, *Natural gas — Determination of water by the Karl Fischer method - Part 2: Titration procedure*

CDC 09 (5680)/ISO 10101 P<sub>3</sub>, *Natural gas — Determination of water by the Karl Fischer method - Part 3: Coulometric procedure*

CDC 09 (5681)/ISO 10715 P<sub>3</sub>, *Natural Gas – Sampling Guidelines*

CDC 09 (5682)/ISO 23874:2006 P<sub>3</sub>, *Natural gas -- Gas chromatographic requirements for hydrocarbon dewpoint calculation*

CDC 09 (5683)/ISO 19739:2004 P<sub>3</sub>, *Natural gas - Determination of sulfur compounds using gas chromatography*

TZS 4, *Rounding off numerical values*

## 3. Terms and definitions

For the purpose of this Standard the following terms and definitions apply:

### 3.1. Heating Values

#### 3.1.1. Higher heating value

amount of energy in MJ/Sm<sup>3</sup> released when one cubic metre of dry gas, at standard conditions, is completely burnt in air with the products of combustion brought to standard conditions, with the water produced by combustion condensed to the liquid state

**Note:** Higher heating value is also known as gross heating value or superior heating value or gross calorific value.

#### 3.1.2. Lower heating value

amount of energy in MJ/Sm<sup>3</sup> 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

**Note:** Lower heating value is also known as 'net heating value' or 'inferior heating value' or 'net calorific value'. The difference between 'higher heating value' and 'lower heating value' is in the latent heat "thermal heat" of condensation of water vapor produced during combustion.

### 3.2. Inert gas

any material that exists predominantly in a gaseous state at standard conditions and which does not contribute to energy release when the gas burns; includes but is not limited to carbon dioxide, nitrogen, oxygen and noble gases

**3.3. Limit**

value beyond which the specified characteristic or concentration of the component shall not be permitted to vary

**3.4. Maximum allowable operating pressure (MAOP)**

maximum pressure at which a pipeline may be operated

**3.5. Natural gas**

gaseous fuel consisting of a mixture of hydrocarbons of the alkane series, primarily methane but, which may also include ethane, propane and higher hydrocarbons in much smaller amount that remains in the gaseous state under the temperature and pressure conditions normally found in service; it may also include some inert gases plus minor amounts of other constituents including odorizing agents

**3.6. Gas quality**

quality of a natural gas is defined by its composition and the physical properties, which are Calorific value, Wobbe Index, Density, Compression factor, Relative density and Dew points

**3.7. Density**

mass of a gas divided by its volume at the specified pressure and temperature

**3.8. Relative density "specific gravity"**

mass of dry natural gas divided by the mass of an equal volume of dry air, both at the same the specified pressure and temperature (see ISO 6976)

**3.9. Standard conditions**

temperature "Ts" of 15 °C and an absolute pressure "Ps" of 101.325 kPa Standard Pressure

**3.10. Normal conditions**

conditions are referred to as normal conditions and denoted by the subscript "n", where Normal Pressure "Pn" is 101.325 kPa and Normal Temperature "Tn" is 0 °C = 273.15 K

**3.11. Total sulfur**

sulfur from all sources including odourization of the gas

**3.12. Wobbe Index**

number expressed in MJ/m<sup>3</sup> produced when the higher heating value of the gas is divided by the square root of the relative density of that same gas

**3.13. Compression Factor "Z-factor"**

quotient of the volume of an arbitrary mass of gas, at a specified pressure and temperature, and that of the same gas under the same conditions as calculated from the ideal gas law the terms compressibility factor and Z-factor are synonymous with compression factor (see ISO 12213-1)

**3.14. Cricondenbar**

highest pressure at which liquid and vapour phased can exist at equilibrium in a multi component system

**3.15. Cricondentherm**

highest temperature at which liquid and vapour phased can exist at equilibrium in a multi component system

**3.16. Critical temperature**

maximum temperature for a pure component at which the component can exist as a liquid above which the fluid is a gas and cannot be liquefied regardless of the pressure applied

### 3.17. Critical pressure

vapour pressure of a substance at its critical temperature

### 3.18. Critical density

density of a substance at its critical temperature and critical pressure

### 3.19. Retrograde region

area inside phase envelope where condensation of liquid occurs by lowering pressure or increasing temperature

### 3.20. Retrograde condensation or vapourization

condensation or vapourization that is the reverse of usual behaviour; condensation caused by a decrease in pressure or increase in temperature while vapourization caused by an increase in pressure or decrease in temperature can only occur in mixtures

### 3.21. Dehydration

act or process of removing water from gases or liquids

### 3.22. Hydrate

solid formed by the physical combination of water molecules and certain of the molecules contained in gas that looks solid like true ice but possess different characteristics

### 3.23. Dew Point

temperature at any given pressure, or pressure at any given temperature, at which liquid initially condenses from a gas or vapour; it is specifically applied to the temperature at which water vapour starts to condense from a gas mixture (water dew point), or at which hydrocarbons start to condense (hydrocarbon dew point)

### 3.24. Water Dew Point

temperature above which no condensation of water occurs at a specified pressure; for any pressure lower than the specified pressure there is no condensation of water vapour at this temperature (see ISO 6327)

### 3.25. Hydrocarbon Dew Point

temperature above which no condensation of hydrocarbons occurs at a specified pressure at a given dew point, there is a pressure range within which condensation occurs except

### 3.26. Total Sulfur

total amount of sulfur found in natural gas

**Note:** The total amount of sulfur, both organic and inorganic i.e. hydrogen sulfide, sulfur oxides, Mercaptan, carbonyl sulfides, ..., may be determined by an analytical method not differentiating between individual sulfur compounds combustion methods.

### 3.27. Molar composition

The molar composition of a gas is the term used when the proportion of each component is expressed as a molar (or mole) fraction, or molar (mole) percentage of the whole thus the mole fraction,  $x_i$ , of component  $i$  is the quotient of the number of moles of component  $i$  and the number of moles of the whole mixture present in the same arbitrary volume. One mole of any chemical species is the amount of substance which has the relative molecular mass in grams. A table of recommended values of relative molecular masses is given in ISO 6976. For an ideal gas, the mole fraction (or percentage) is identical to the volume fraction (percentage), but this relationship cannot in general be assumed to apply to real gas behaviour.

### 3.28. Gas composition

concentrations of the major and minor components and trace constituents in natural gas as analysed

**Note:**

- The major components of a gas are specified as volumetric, molecular or mass proportions in percentage. They also determine the allocation of the fuel gases to the gas families.
- The minor components of a gas can be present as a gas, liquid or solid. The concentration is specified in  $\text{mg/m}^3$ ,  $\text{cm}^3/\text{m}^3$  (also vppm),  $\text{mg/kg}$  (also ppm) for the majority of gas secondary substances, or a specification can be used which relates to the behaviour of the gas during transport.

### 3.29. Interchangeability

measure of the degree to which the combustion characteristics of one gas resemble those of another gas or ability of a distributed natural gas to be substituted by another without the need for adjustment at the customers' equipment, thus the appliances will continue to operate safely and satisfactorily

**Note 1:** two gases are said to be interchangeable when one gas may be substituted for the other without affecting the operation of gas burning appliances or equipment;

**Note 2:** The criteria to be considered for interchangeability are as follows:

**Thermal input:** Flow of gas through an orifice at constant pressure, a function of Wobbe Index.

**Flash back:** The tendency for the flame to contract towards the port and for the combustion to take place inside the burner.

**Lifting:** Burning surface expands to the point where burning ceases at the port and burns above it.

**Yellow Tipping:** Incomplete combustion where excess hydrocarbons could, but does not always, results in unacceptable levels of carbon monoxide. It may result in soot deposition and a continuing deterioration of combustion.

The substituted gas may be deemed to be interchangeable when, without the need for adjustment of the appliances, it provides a thermal input comparable with that provided by the gas previously distributed, without the occurrence of flash back, lifting or yellow tipping. For the examination of the interchangeability there are two routes which can be followed, namely:

Wobbe index or gas composition based prediction methods.

### 3.30. Odourization

addition of an odourant to the natural gas fed into the distribution system for safety reasons, thus permits the detection of the gas by smell at very low concentrations

**Note:** It is a common requirement that natural gas in air be readily detectable by smell at a concentration of 20% of the lower flammability limit (LFL). The LFL of natural gas is normally taken as volume content in air of 4% to 5%. Natural gas is normally odourless thus addition of odorant is necessary for detection purpose.

### 3.31. Water Content

mass concentration of the total amount of water contained in a gas

**Note 1:** Water content is expressed in grams of water per cubic meter of gas

**Note 2:** For raw gas, this means water in the forms of both liquid and vapour, but for pipeline gas this means only water vapour.

## 4. Requirements

### 4.1. General requirements

4.1.1. The gas shall be technical free from:

4.1.1.1. materials, dust, and other solid or liquid matter, waxes, gums, gum forming constituents, and unsaturated or aromatic hydrocarbons to an extent which might cause damage to, or interfere with the proper operation of, pipes, meters, regulators, control systems, equipment or appliances;

**Note:** Technically free means that there are no visible traces of the components mentioned under actual conditions and they are sufficiently removed to ensure the operation of gas appliances and technical gas equipment of standard or normal construction.

4.1.1.2. water and unsaturated or aromatic hydrocarbons to an extent which causes unacceptable sooting;

4.1.1.3. other gases that could adversely affect the transportation or utilization of the gas.

4.1.1.4. other substances such as solid particulate substances to the extent that they cause damage to, or problems in operation of, pipelines or appliances or that cause the products of combustion to be toxic, or hazardous to health, other than substances that are usually found in natural gas combustion products. Solid particle size of natural gas should meet equipment manufacturer recommendations.

4.1.2. Odourizing of natural gas where applicable is provisional, if required by contract terms or regulatory requirements shall not lead to the deviation of the natural gas properties from the limits specified in this standard.

### 4.2. Specific requirements

Natural gas shall also comply with specific requirements in Table 1 when tested according to the methods prescribed in the Table.

**Table 1 – Specific requirements for general purpose natural gas**

S/ No.	Characteristic	Requirement	Test method
(i)	Wobbe Index, MJ/m <sup>3</sup> .	46.05 - 52.34	ISO 6976
(ii)	Heating value, MJ/Sm <sup>3</sup>		
	Higher heating value, max. Lower heating value, min.	43.96 33.95	
(iii)	Relative density	0.55 – 0.70	
(iv)	Oxygen, mol %, max.	0.2	ISO 6974-3
(v)	Hydrogen sulfide, mg/m <sup>3</sup> , max.	5.7	ISO 6326 – 3
(vi)	Mercaptan sulfur <sup>a)</sup> , ppm.	2 – 6	
(vii)	Total sulfur, mg/m <sup>3</sup> , max.	50	ISO 6326 – 5
(viii)	Water content, mg/m <sup>3</sup> , max.	100.0	ISO 10101 ISO 6327 <sup>b)</sup>
(ix)	Hydrocarbon dew point at 7000 kPa gauge, °C, max.	-12	ISO 23874
(x)	Methane Number <sup>c)</sup>	115 - 130	ISO 15403
(xi)	Water dew point at 7000 KPa, °C, max.	-15	ISO 6327
Note: a) The prescribed requirement is intended quality for natural gas conveyed in a distribution pipeline which can be exempted in transmission pipeline b) The method relies on calculation of water content based on the dew point measurement c) Methane Number is the additional property measured only when the gas is intended to be used in vehicle; the figure indicates the anti-knocking capacity of natural gas resulting from its application to vehicles, its limits being subject to a comparison with the octane rating of gasoline. Anti-knocking power is the capacity of the fuel to resist knocking in vehicles at reigning temperature and pressure levels in the engine combustion chamber, caused by compression to which the air/fuel mixture is submitted.			

## 5. Sampling

The sampling shall be carried out in accordance with CDC 09 (5681).

**Annex A**

(Informative)

**Derivation of Specification****A.1 Background**

Any known composition of Tanzanian natural gas so far, can be regarded as ordinary natural gas. In order to retain the greatest flexibility of supply no attempt has been made to detail the composition of the gas beyond those compounds normally regarded as gas contaminants and which have a detrimental effect on the properties of the gas because the chemical composition of natural gas depends on reservoir behavior and controlling processes that are different in gas treating plants. Most of the specification limits in this document are presented in details with studies approach and investigations results. Specification limits in this standard are generally consistent with the global practice since apart of having abundant reserve of natural gas in our country for domestic consumption also there is huge potential for export market which might also trigger importation of the same. Thus, this standard has been prepared taking into consideration the country's natural gas profile while harmonizing with the global practices and demand. In this respect, the specification is intended to cover only those gases that are primarily methane. This specification does not cover other gases such as LPG/air mixtures and synthetic natural gas.

**A.2 Limits**

In any natural gas specification, a balance must be achieved between optimum performance which requires the narrowest possible combustion limits, and cost of supply that, if possible, requires no limits at all so that any available gas can be used. In an endeavor to resolve this issue the limits are set as wide as possible while still maintaining safe combustion performance in gas burning appliances intended for use in Tanzania. If the specification of gas deviates outside the limits, both safety and performance may be compromised. This is dependent on the duration, and extent of the excursion.

Although the rate of change of variables within the limits is not addressed in this specification, it is a matter that may be addressed in gas supply contracts. It is relevant to the performance of combustion control systems particularly in lean burn and low NO<sub>x</sub> applications. In addition, rapid changes in Wobbe Index, for example, may lead to customer complaints, as there may be a noticeable change in performance with some appliances.

**A.3 Characteristics and Components****A.3.1 Wobbe Index**

Wobbe Index is a measure of the heat input to gas appliances that reflects a measure of the energy input rate to a burner at constant supply pressure, and also relates to the combustion characteristics of the burner. A change in the Wobbe Index of the gas will result in a proportional change in the energy output of all gas appliances and equipment supplied, and in the energy carrying capacity of gas pipelines and distribution networks. Fuel gases of various compositions with the same Wobbe Index produce almost the same heat load at the burner under the same pressure (flow pressure), (see ISO 6976).

The permissible range of Wobbe Index is the range over which the present Tanzanian population of gas appliances and equipment can be expected to operate safely. Appliances adjusted on the reference gas, at the normal pressure, and judged to perform satisfactorily with the limit gases at the test pressures, are approved for use within all natural gas resources. In this approach, the Wobbe Index is the primary gas parameter.

The Wobbe Index of a gas is an indicator of its combustion acceptability for a given population of appliances and is the most significant parameter in terms of gas combustion safety; it is derived from the orifice flow equation.



The Wobbe Index is calculated by dividing the higher heating value (or gross calorific value) by the square root of the relative density of the gas as shown in equation below:

$$Wobbe\ No = \frac{Gross\ Calorific\ Value\ in\ BTU/SCF}{\sqrt{Specific\ Gravity\ (relative\ density)}}$$

In all gas appliances the flow of gas is regulated by making it flow through a hole or orifice of given size at a constant pressure. The higher the Wobbe Index of a gas, the greater the heating value of the quantity of gas that will flow through an orifice of a given size in a given amount of time.

The Wobbe Index is therefore an indicator of the rate of heat flow from the burner. Too high a Wobbe Index can result in the over-heating of appliances, or sooting and carbon monoxide (CO) formation due to incomplete combustion and consequently present increased risk of deaths by poisoning. Too low a Wobbe Index may cause flame abnormality that can result in flame lift, becoming unstable or even extinguishing of flames, resulting in the release of unburned flammable gas. With respect to gas-fired power generating plant, Wobbe Index is a critical factor for generator combustion dynamics.

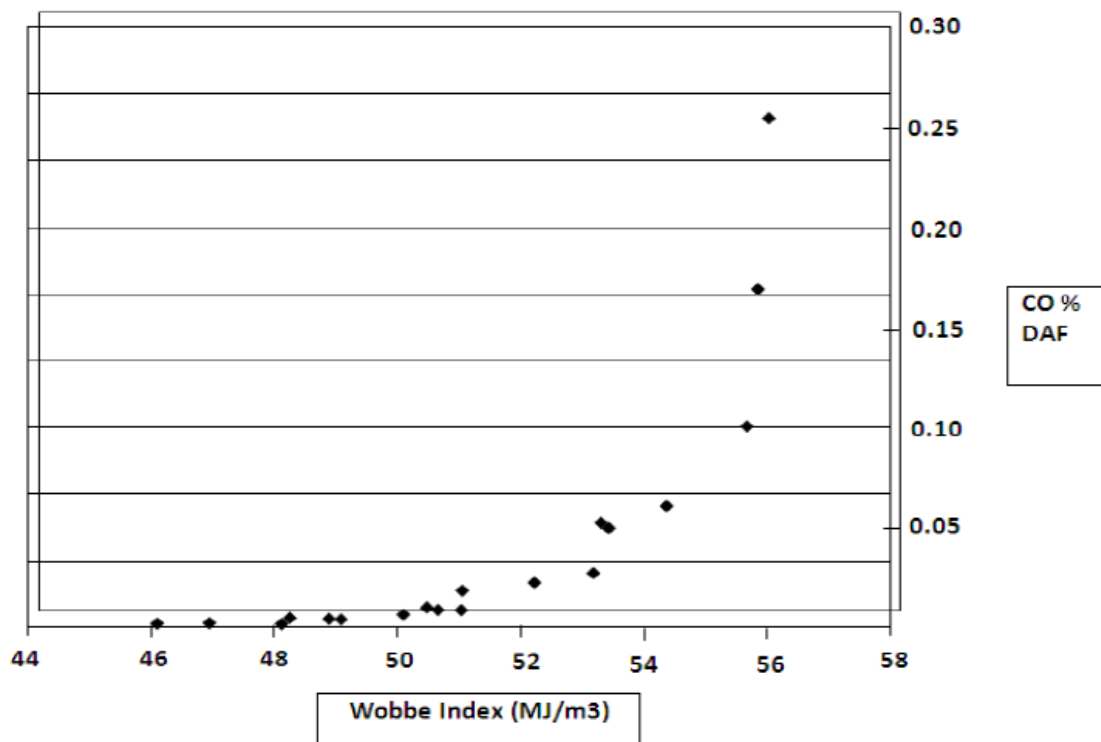
#### **A.3.1.1 A survey on combustion performance on domestic gas appliances**

Under the UK Gas Quality Programme, during 2005 a major test exercise was performed on behalf of the UK Government Department BERR to examine the variation in combustion performance of a range of representative domestic gas appliances working at the extremes of the EASEE-gas Wobbe Index limits and beyond. Some 25 appliances were tested representing about 70% of the UK gas appliance population.

The following data was collected from the appliances operating under different gas qualities:

- CO emissions;
- CO<sub>2</sub> emissions;
- CO/ CO<sub>2</sub> ratio;
- NOx emissions;
- Air Factor from CO<sub>2</sub> and O<sub>2</sub> measurements in flue gas;
- Surface temperature of appliance at three locations (minimum);
- Particulate matter measurements in flue gas;
- Flue gas temperature;
- Derive thermal efficiency of appliance (flue loss method);
- Record any changes in the performance of safety devices;
- Record any changes in ignition characteristics; and
- Fuel leakage measurement from appliance exhaust.

Figure A.1 reveals test results of the study for a wall-hung condensing boiler.



**Figure A.1 Plot of Wobbe Index Versus amount of Carbon monoxide release during combustion of the natural gas in the domestic appliances**

The conclusions from this work were:

- Tests within Wobbe Index 47.2 – 51.4 MJ/m<sup>3</sup> (GS(M)R) resulted in acceptable performance;
- Exponential increase in CO emissions are seen at Wobbe Index beyond 53 MJ/m<sup>3</sup>; and
- There is a potential for badly maintained appliances to produce CO levels that may cause risk to consumer safety.

Generally, the test gases within the range of Wobbe Numbers from 45 to 52 MJ/m<sup>3</sup> resulted in acceptable appliance operability compared with current standards for G20 (pure methane) reference gas. Increasing the Wobbe Number of the gas used will almost certainly increase the emission level of carbon monoxide. Whilst the levels produced from the appliances tested in this program were on the whole modest, except for Wobbe Number gases >53 MJ/m<sup>3</sup>, there is the potential for badly maintained or installed appliances to produce CO levels that may cause an increasing overall health risk.

### A.3.2 Heating Value

A maximum higher heating value of 43.96 MJ/Sm<sup>3</sup> (10500 kcal/Sm<sup>3</sup>) is required by this specification. Gases with higher heating values greater than this limit have an unacceptably higher propensity for incomplete combustion and sooting, which would not necessarily be detected by tests using existing appliance standard limit gases.

Lower heating value refers to quantity of heat released in the form of heat, on complete combustion of a defined quantity of gas with air, at a constant pressure and with all combustion products returning to the original temperature of the reagents. All products, including the water formed during combustion, are in a gaseous state.

The above-mentioned pressure and temperature must be specified for both higher and lower heating values, which differ by the heat of condensation of water formed by combustion, can be specified on a molar, mass or volumetric basis. For the volumetric basis, the pressure and temperature shall be stated at standard reference conditions calorific values can also be stated as dry or wet, depending on the water vapor content of the gas prior to combustion. Normally, the heating value is expressed as the higher heating value, dry value specified on a volumetric basis under standard reference conditions.

### A.3.3 Relative Density

Relative density is limited to a maximum of 0.70 in order to control risk of sooting.

The basis for selection of this value is as follows:

- Sooting is associated with the presence of higher hydrocarbons and relative density correlates well with higher hydrocarbon content.
- Studies carried out by Marcogaz working group to correlate UK parameters with relative density indicate that sooting limit considerations are not significant below a relative density of 0.70.
- Since the comportment of the natural gas depends on reservoir behavior, in case the country will have some wells with having gases with relative density greater than 0.70 though will be out of this specification, it is assumed arrangement will be deployed to ensure will be consumed locally however the guarantee for cross-border trade is not certain due to the global requirements. Moreover, further technical consultation need to be encouraged within the gas industry with the purpose of confirming such recommended.

### A.3.4 Oxygen

Oxygen is generally not present in significant quantities in producing gas fields. Its presence in natural gas is usually attributed either to contamination during transportation, processing, storage and distribution, or to air ballasting as a means of moderating the Wobbe Index. National limits vary widely across the world, reflecting different standards, custom and practice.

Oxygen in the presence of water vapour can cause corrosion within pipelines, and at very high levels has the potential for forming explosive mixtures. The contribution made by the presence of trace levels of oxygen in the gas supply to the combustion process is negligible. Rather, the air-fuel ratio during combustion, that determines most of the associated emissions behaviour, is governed by primary and secondary air entrainment as the gas leaves an appliance injector nozzle. The contribution made by oxygen in the gas supply to the fuel efficiency of gas appliances in the combustion process is also believed to be negligible. Corrosion products from oxidation in steel pipelines have the effect of stripping the injected odorant from gas.

An oxygen concentration of no more than 0.2 mol% has been set in Australia while in New Zealand 0.1 mol% is required as stipulated in the New Zealand Specification (NZS 5542), for the preferred limit, but this is permitted to rise to 1.0% mole in the absolute limit provided the gas is not to be transported through steel pipeline at high and intermediate pressure.

A maximum oxygen concentration of 0.2 mol% is preferred by this specification.

### A.3.5 Hydrogen sulfide

Hydrogen sulfide is a colourless flammable gas which has an offensive odour similar to rotten eggs. It is extremely poisonous. Unfortunately the human system adapts readily to H<sub>2</sub>S odour so that increasing concentrations may not be noticed. High concentrations of H<sub>2</sub>S result in rapid poisoning and death. In many cases it is necessary from a health and safety standpoint.

Hydrogen sulfide is a corrosive gas and its corrosion effect on pipelines and copper components in gas installations tends to be cumulative.  $H_2S$  is also a stress corrosion cracking agent for carbon steel pipeline and the likelihood of creating stress cracks is dependent on the partial pressure of the hydrogen sulfide in as much that at higher gas pressure, thus, it attracts a lower level of  $H_2S$  to be specified.

In the presence of water, hydrogen sulfide can cause hydrogen induced cracking and sulfide stress cracking in high tensile steels at high pressure. This is of particular importance for transportation of gas in steel pipes and for the use of natural gas in vehicles where natural gas is typically stored at pressure up to 26 MPa. By dehydrating, corrosion by  $H_2S$  is effectively eliminated. Similarly the potential for corrosion acid gas can also be controlled by dehydration.

Hydrogen sulfide has also been associated with chemical attack on copper and its alloys leading to the formation of copper sulfide, which can cause malfunctions in appliances, including the blockage of pilot jets.

In general the limitation of hydrogen sulfide in natural gas is important because of the gas quality specifications, the corrosive nature of  $H_2S$  on pipeline materials and the effects of hydrogen sulfide on utilization equipment. Hydrogen sulfide removal is desirable to reduce its detrimental effects.

### **A.3.6 Total sulfur**

Many sources of natural gas contain varying amounts and types of sulfur compounds, which are odorous, corrosive to equipment and can inhibit or destroy catalyst in gas processing. Their accurate amount is essential to gas processing, operation and utilization.

This parameter is the quantity of total sulfur contained in the sulfur containing compounds that are present in natural gas. The limitation is related to air pollution and indoor air quality control. Furthermore the sulfur content of gases adversely affects the life of pipelines and consumer appliances, it is therefore limited for all fuel gases.

The sulfur content of natural gas, used for fuel proposes contributes to  $SO_x$  emissions and can lead to corrosion in appliances, engine and exhaust systems. Sulfur compounds in the gas may also lead to the deposition of elemental sulfur in pipelines, which also have a corrosive effect particularly in the presence of water. The sulfur compounds may have a very strong and unpleasant smell and may lead to nuisance leak reports. Some process catalysts used in petroleum and chemical refining can be poisoned by sulfur bearing materials in the feed stocks. Additionally, certain industrial processes, e.g. glass manufacturers, may be adversely affected by high sulfur content in the gas stream.

A maximum permitted sulfur concentration of  $50 \text{ mg/m}^3$  includes sulfur from all sources including odorization of the gas. Odorants commonly used in worldwide contribute to the sulfur level in the gas. With the widespread use of flueless heating and increasing awareness of air quality it is highly desirable that the sulfur content of natural gas be kept as low as possible. Nevertheless, sulfur deposition as an operating issue in some transmission systems has occurred in some systems even though sulfur concentrations was below  $50 \text{ mg/m}^3$ , thus, in future there might be a need for further research in the domain.

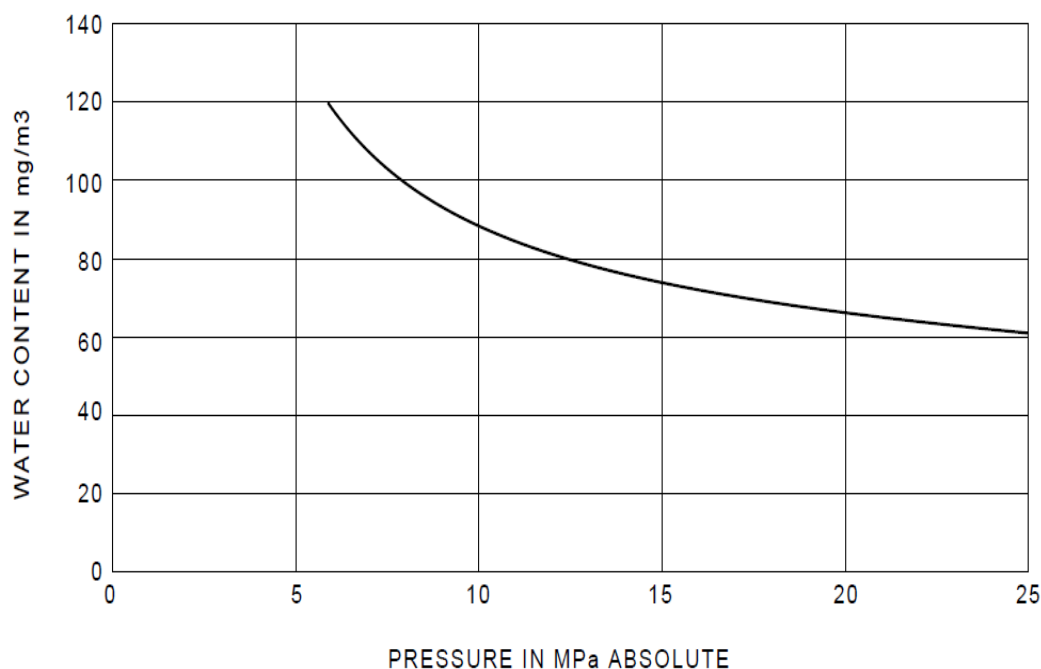
### **A.3.7 Water**

Natural gas and associated condensate are often produced from the reservoir saturated (in equilibrium) with water. Liquid phase water can cause corrosion and the formation of gas hydrates and condensation of free water in transmission systems. In combination with hydrogen sulfide and carbon dioxide, water can also lead to stress corrosion cracking and hydrogen embrittlement.

The stated limits are designed to ensure that hydrate formation and excessive corrosion do not occur in transmission systems.

For applications such as natural gas vehicles requiring compression to higher pressure than the maximum transmission pressure it may be necessary to use a gas dryer to remove moisture from the gas to prevent liquid water or hydrate formation. The temperature of the gas stream must be maintained at a level sufficiently above the water dew point temperature to avoid liquid water formation in pipelines.

This specification covers water content by nominating the dew point at maximum transmission pressures. Additionally, an absolute limit ( $\text{mg}/\text{m}^3$ ) is stated. Figure A.2 defines the water content in  $\text{mg}/\text{m}^3$  producing a dew point of  $0^\circ\text{C}$  for a range of transmission pressures.



**Figure A.2 DEW POINT AT ZERO DEGREES CELSIUS (Derived from ASTM D1142)**

When the water content in gas is determined, the water dew point at any pressure is obtained from Figures A.3 and A.4. Also ISO 18453 specifies a method to provide users with a reliable mathematical relationship between water content and water dew point when one of two is known.

Dew point is the temperature at which the first drop of liquid occurs when gas undergoes cooling or compression. Liquids normally found are water, hydrocarbonates or glycol, which have distinct dew points. The most important safety requirement in respect to natural gas is the temperature of dew point in order to avoid the formation of liquid. Water in a liquid state is the precursor of the formation of corrosive compounds by means of the combination of natural gas components, specifically  $\text{CO}_2$  and  $\text{H}_2\text{S}$ . The combination of corrosive agents and variable pressure during transport of the fuel may result in cracks in the metal and cause obstructions in the gas system.

**Note:** Above mentioned figures are made available and have been extracted from Gas Conditioning and Processing Handbook – Volume 2, Campbell Petroleum Series, 1984.



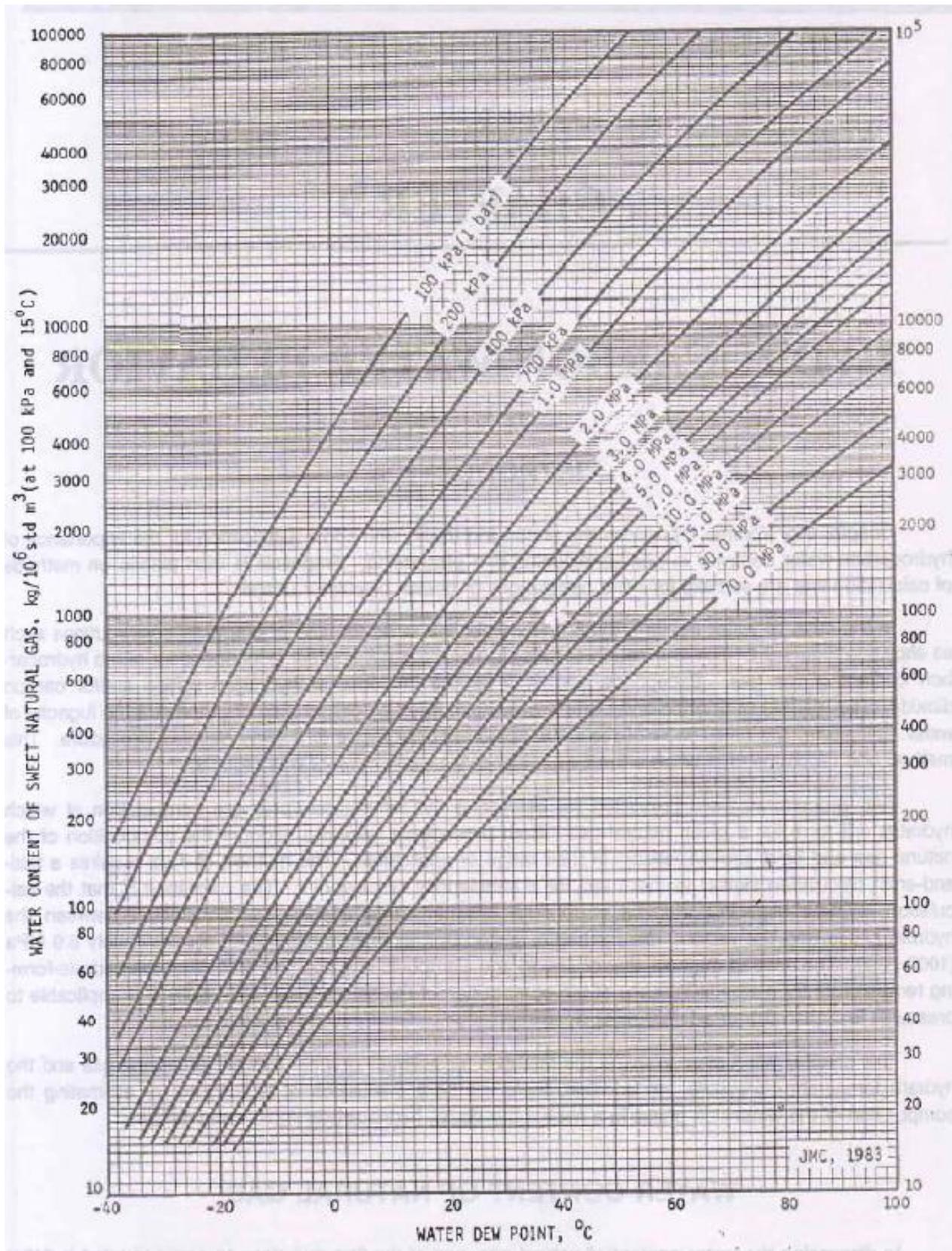


Figure A.3 (a) Hydrocarbon – Water Behavior, Water content of Lean, Sweet Natural Gas



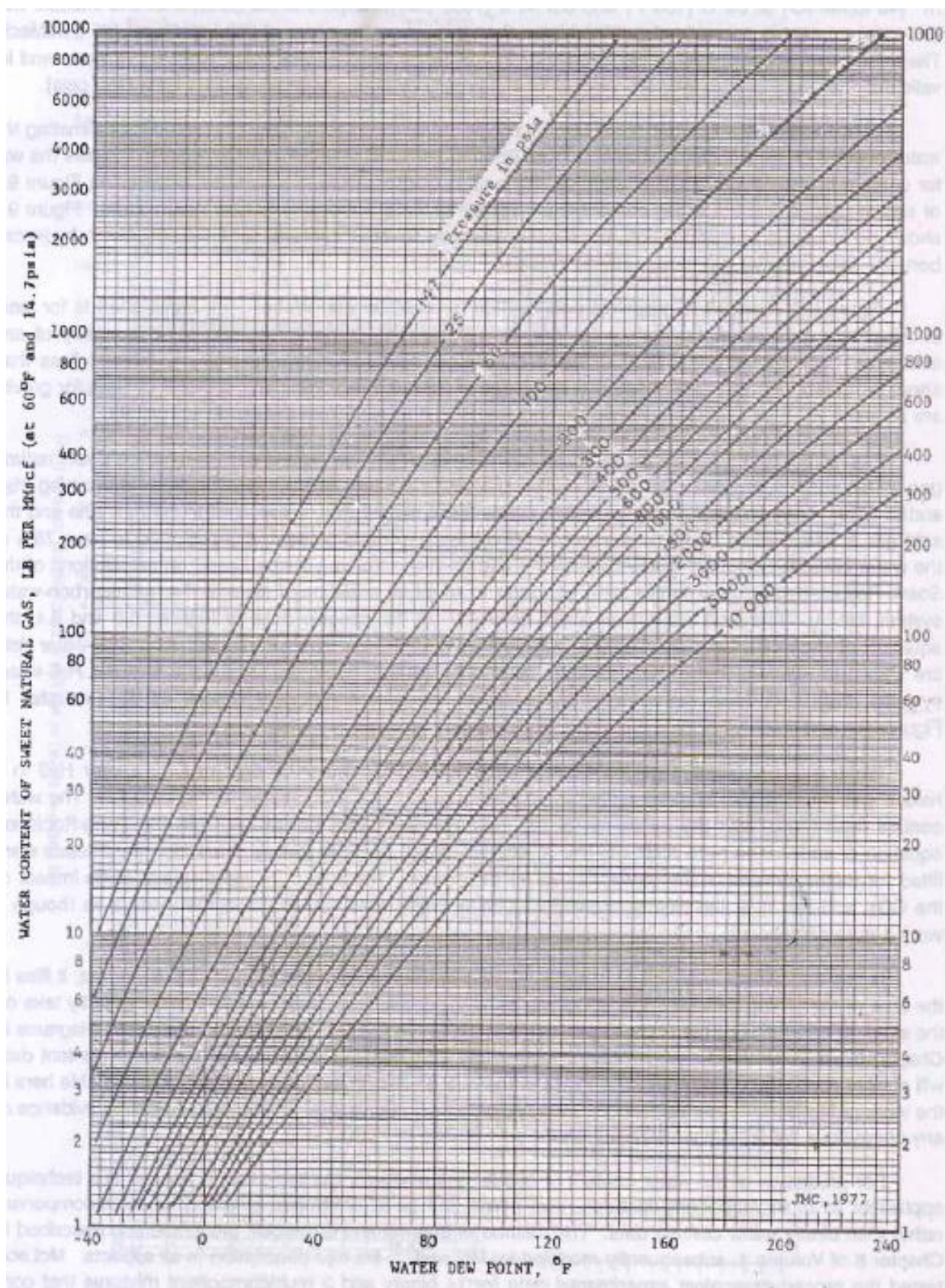


Figure A.3 (b) Hydrocarbon – Water Behavior, Water content of Lean, Sweet Natural Gas

### A.3.8 Hydrocarbon dew point

The hydrocarbon dew point limit controls the level of heavy hydrocarbons (propane and heavier) in the gas. At high pressures, condensation of heavy hydrocarbons may occur at low temperatures. These compounds are of concern because at the high pressure used in both gas transmission and CNG storage condensation of heavy hydrocarbons may occur at low temperatures.

Additionally, retrograde condensation can occur in transmission systems at pressures lower than the MAOP. It is this phenomenon that effectively determines the maximum allowable limits of heavy hydrocarbons in natural gas. The pressure and temperature specified are designed to limit retrograde condensation for typical Tanzanian natural gases (refer to ISO 13686).

The liquid hydrocarbon must be removed from natural gas because of the following reasons:

- The high amount of liquid hydrocarbons can cause pressure drop and decrease the flow capacity of pipeline.
- Liquid hydrocarbons can collect and form slugs which can travel along pipelines and potentially damage gas flow regulating and measurement equipment. Hydrocarbon liquids also cause odorant removal from the gas phase. The presence of both hydrocarbons and odorant in the liquid phase can cause degradation of the rubber components of pressure regulating installations.
- A high hydrocarbon dew point may mean a low Wobbe Index, which may cause flame abnormality. It can also cause increased carbon monoxide formation in surface combustion burners. Too high of a Wobbe Index may give rise to high levels of carbon monoxide in the combustion products of conventional appliances. It can also promote overheating.
- The amount of the higher saturated and unsaturated as well as aromatic hydrocarbons in gases should be limited relative to the gas distribution and the burning behavior of the gases. The concentration permissible for a trouble-free combustion depends not only the type of hydrocarbons but also on the hydrogen and oxygen content of the gas. Carbon dioxide also favors the combustion of unsaturated and aromatic hydrocarbons in comparison to nitrogen, particularly in diffusion burners.

Generally, for a multi component mixture of substances, the phase envelope is similar to Figure A.4. This phase curve is very sensitive to composition, which is the variable that reflects the thickness of diagram. In high pressure pipeline, liquid can be prevented by removing enough of the heavy hydrocarbons and to change the shape and position of the phase curve. Consider line I-J, and the points I and J represents inlet and outlet conditions of pipeline. When line I-J crosses the dew point curve, liquid will begin to condense in the line. From that point on, two-phase flow exists. If the composition is changed enough, then the dashed phase curve would be the outcome, in which case, no liquid will form in the pipeline because the dew point is not reached. Any liquid present would be due to carryover of liquid from separator or having a different composition from the one used to construct the phase curve.

At high pressures, condensation of heavy hydrocarbons may occur at low temperatures. The pressures and temperature specified do not guarantee the total absence of retrograde condensation. Additionally, retrograde condensation can occur in transmission systems at pressure lower than the MAOP. It is this phenomenon that effectively determines the maximum allowable limits of heavy hydrocarbons in natural gas. The pressure specified approximates the cricondenthem pressure which not typical in Iranian natural gases, and is usually within the range of 23 to 51 bar.



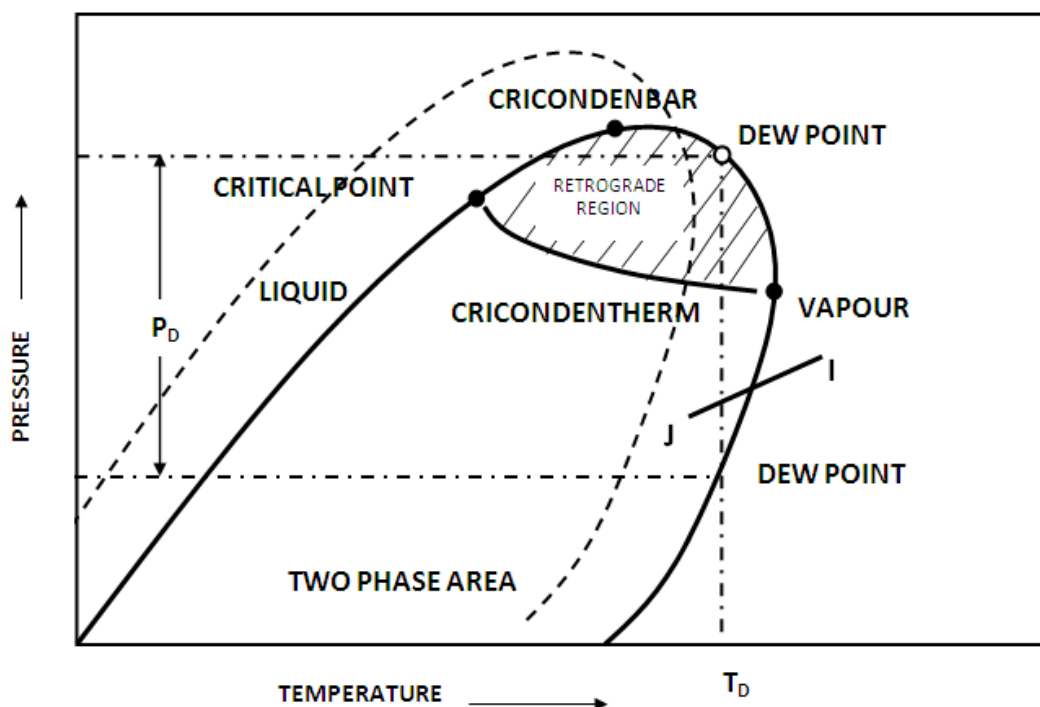


Figure A.4 Phase diagram, a plot of Temperature Versus Pressure

#### A.3.9 Total inert gases

The specification for total inert gases is intended, in conjunction with the Wobbe Index limits, to limit the levels of higher hydrocarbons.

Carbon dioxide ( $\text{CO}_2$ ) is classified as an "inert" along with other inert gases, principally Nitrogen ( $\text{N}_2$ ) and to a lesser extent Helium ( $\text{He}$ ) and Argon ( $\text{Ar}$ ) that may be present in the gas stream. Inert gases by themselves do not create a safety hazard and the specification limit is a method of controlling the levels of non-methane hydrocarbons (ethane, propane, butane, etc.) so as not to exceed the specified Wobbe Index limits. Manufacturing plants that use natural gas as a feedstock may suffer adverse impacts to their processes where there are high carbon dioxide or nitrogen levels. High levels of  $\text{CO}_2$  in particular could have significant implications for some gas consumers that have specific needs, however this is a commercial issue and, where necessary, would be specified in contracts.

#### A.3.10 Other combustion parameters

Other combustion parameters e.g., sooting index, flame speed, lift index were considered but not deemed necessary for inclusion in the specification.

#### A.3.11 Solid particles

Causes contamination, obstruction and erosion of vehicle feed systems and industrial burner injector openings. When natural gas is destined for use as a turbine fuel, the solid particles can cause erosion of the parts that circulate the hot gas.

#### A.3.12 Solid particles

Cause sharp alterations to flame temperature and in the gas turbine load, drawback of flame from pre-mixed flames and can nuclear the condensation of heavier natural gas fractions. When the presence of liquid is identified in the gas to be employed in gas turbines, separators are used and the flow is heated in order to vaporize the liquid phase.

## Annex B

(Informative)

## Specification for Natural Gas Components

**B.1** The chemical composition of natural gas depends on reservoir behavior and generally for some of the below components there is no specific controlling process in gas refineries. Hence, this chemical composition shall be considered as typical and not exact, though is the actual figure obtained in Tanzania from Gas Processing Plant, GASCO a subsidiary of Tanzania Petroleum Development Corporation. Some of the methods which can be used for chemical analysis are:

- a) ASTM D 1945:2003, *Test Method for Analysis of Natural Gas by Gas Chromatography*
- b) GPA 2261:1999, *Analysis for Natural Gas and Similar Gaseous Mixture by Gas Chromatography*
- c) GPA 2286:1995, *Tentative Method of Extended Analysis for Natural Gas and Similar Gaseous Mixture by Temperature Programmed Gas Chromatography*

Table B.1 – Typical Specification for Natural Gas Component

SN	Components	Units	Composition
1.	Methane (CH <sub>4</sub> )	Mole%	99.61922
2.	Ethane (C <sub>2</sub> H <sub>6</sub> )	Mole%	0.00000
3.	Propane (C <sub>3</sub> H <sub>8</sub> )	Mole%	0.13047
4.	nButane(nC <sub>4</sub> )	Mole%	0.02107
5.	iButane(iC <sub>4</sub> )	Mole%	0.01717
6.	nPentane(nC <sub>5</sub> )	Mole%	0.00000
7.	iPentane(iC <sub>5</sub> )	Mole%	0.00217
8.	Hexane(C <sub>6</sub> )	Mole%	0.01384
9.	Hexane and Higher(C <sub>6++</sub> )	Mole%	0.00142
10.	Neopentane	Mole%	0.00000
11.	Nitrogen(N <sub>2</sub> )	Mole%	0.00000
12.	Carbondioxide(CO <sub>2</sub> )	Mole%	0.19607
13.	Density (D)	Kg/m <sup>3</sup>	0.72279
14.	Relative Density(RD)	-	0.55904
15.	Low Heating Value	MJ/m <sup>3</sup>	35.95012
16.	High Heating Value	MJ/m <sup>3</sup>	39.88833
17.	Hydrocarbon Dew Point	Deg. C	-18.99
18.	Water Dew Point	Deg. C at 70 Bar	-15
19.	Water Content		

**Source:** GASCO a subsidiary of Tanzania Petroleum Development Corporation, 2017

## Annex C

(Informative)

## Interchangeability

**C.1** Interchangeability can be defined as the ability of a distributed natural gas to be substituted by another without the need for adjustment at the customer's equipment. The appliances will continue to operate safely and satisfactorily.

The criteria to be considered for interchangeability are as follows:

Thermal input: Flow of gas through an orifice at constant pressure, a function of Wobbe Index.

Flash back: The tendency for the flame to contract towards the port and for the combustion to take place inside the burner.

Lifting: Burning surface expands to the point where burning ceases at the port and burns above it.

Yellow Tipping: Incomplete combustion where excess hydrocarbons could, but does not always, results in unacceptable levels of carbon monoxide. This may result in soot deposition and a continuing deterioration of combustion.

The substituted gas may be deemed to be interchangeable when, without the need for adjustment of the appliances, it provides a thermal input comparable with the provided by the gas previously distributed, without the occurrence of flash back, lifting or yellow tipping.

For the examination of the interchangeability there are two approaches: Wobbe Index or *gas composition* based prediction methods.

The A.G.A. Interchangeability program, catalogue No. XH 8810 uses Index Method based on A.G.A. Research Bulletin 36 "Interchangeability of other fuel gases with natural gas" (1952, 2<sup>nd</sup> edition), the Weaver Index Method, and the Knoy Constant techniques to determine compatibility of gases. All methods involve an adjustment gas and a substitute gas. The A.G.A. and Weaver Index methods require a complete analysis of gas components, but the Knoy constant method uses only the higher heating value and relative density. Only the A.G.A. Index method is covered for this explanation.

**C.2 Equations to Determine Interchangeability Indices**

The possibility of interchangeability, to mix or substitute one type of gas with another gas for any purposes (e.g. peak shaving), is determined by interchangeability indices. The indices and limits for natural gases in this standard specification (high methane) are given below.

$$I_F: \text{Flash - back Index} \quad I_F = \frac{k_s f_s \sqrt{h_s/1000}}{k_a f_a} < 1.20$$

$$I_L: \text{Lifting Index} \quad I_L = \frac{k_a}{\frac{f_a a_s}{f_s a_a} (k_s - \log \frac{f_a}{f_s})} < 1.60$$

$$I_Y: \text{Yellow Index} \quad I_Y = \frac{f_s a_a y_a}{f_a a_s y_s} > 0.8$$

Where:

A = air theoretically required for complete combustion, m<sup>3</sup> per m<sup>3</sup> of gas (cu ft per cu ft of gas) 1

a = 100 A/h – air theoretically required for complete combustion, m<sup>3</sup> per 100 MJ of gas (cu ft per 100 BTU of gas)

d = specific gravity of gas (air = 1.0)

E = total inerts in gas mixture, mole percent

F = lifting constant<sup>1</sup>

f =  $1000 d \cdot 0.5 / h$  = primary air factor

h = higher heating value of gas, MJ per m<sup>3</sup> (BTU per cu ft)

K = F/d = lifting limit constant

O<sub>2</sub> = Oxygen in gas mixture, mole percent

T = yellow tip constant, m<sup>3</sup> of air required to eliminate yellow tips per m<sup>3</sup> of gas (cu ft of air required to eliminate yellow tips per cu ft of gas) – See Table C.1

Y =  $100 T/A + 7E - 26.3$  O<sub>2</sub> = yellow tip limit, percent primary air s and a = substitute gas and adjustment gas, respectively

Use of these equations requires knowledge of the chemical composition, heating value and specific gravity of the gases.

**Table C.1 – Interchangeability Constants<sup>1</sup>**

G		A	F	T
Analysis of Gas Decimal Volume		Air Required for combustion cu ft /cu ft of gas	Lifting Constant	Yellow Tip Constant
H <sub>2</sub>		2.38	0.6	0.0
CO		2.38	1.407	0.0
CH <sub>4</sub>		9.53	0.67	2.18
C <sub>2</sub> H <sub>6</sub>		16.68	1.419	5.8
C <sub>3</sub> H <sub>8</sub>		23.82	1.931	9.8
C <sub>4</sub> H <sub>10</sub>		30.97	2.55	16.85
C <sub>2</sub> H <sub>4</sub>		14.29	1.768	8.7
C <sub>3</sub> H <sub>6</sub>		21.44	2.06	13.0
C <sub>6</sub> H <sub>6</sub>		35.73	2.71	52.0
III*		19.65	2.0	19.53
O <sub>2</sub>		-4.76**	2.9	-4.76**
(Inerts)				
CO <sub>2</sub>			1.08	
N <sub>2</sub>			0.688	
Total	1.00			

\*Representative analysis of 3C<sub>2</sub>H<sub>4</sub>+1C<sub>6</sub>H<sub>6</sub>.

\*\*Always negative. Subtract from total.

**Example:**

GAS DESIGNATION	Composition, vol %				W <sub>ss</sub> MJ/m <sup>3</sup>	H <sub>ss</sub> MJ/m <sup>3</sup>	d <sub>s</sub>	Type of Gas
	CH <sub>4</sub>	H <sub>2</sub>	C <sub>3</sub> H <sub>8</sub>	N <sub>2</sub>				
G20	100	---	---	---	50.72	37.78	0.555	Adjustment gas
G21	87	---	13	---	54.76	45.28	0.684	Substitute gas

<sup>1</sup> Interchangeability of other fuel gases with natural gas, American Gas Association Research Bulletin 36, 1946

Lifting Index  $I_l = 0.941$

Flashback Index  $I_f = 1.034$

Yellow tip Index  $I_y = 0.762$

Interchangeability in the A.G.A program is determined by calculating indices for lifting, flash back, and yellow tipping (complete combustion), and by establishing preferable and objectionable limits for each. The equations used for the individual indices were derived experimentally by the Bulletin 36 work. An exactly interchangeable gas, that is, if the adjustment gas and the substitute gas were of the same composition, would yield values of  $I_l$ ,  $I_f$  and  $I_y$  equal to 1.0. The preferable limits are pegged at this value. The objectionable limits are values which just provide satisfactory performance. Such Values are determined by testing a variety of appliances, by setting them up on the adjustment gas, and by changing gas mixtures until the three interchangeability criteria occur, namely, lifting, flashback and yellow tipping.

The other methods are used for calculating interchangeability Indices that you can refer to ISO 13686.

**Annex D**

(Informative)

**Matters that may be considered in contracts**

The following gas quality matters that are outside the scope of this gas specification may be considered, if relevant, in gas transportation and supply contracts.

- a. The rate of change of critical parameters.
- b. Frequency of agreed tests for verification of compliance.
- c. Exchange of results of all monitoring/testing undertaken.
- d. Retention period for records of the tests carried out to verify compliance.
- e. Excursions and their duration outside the absolute limits set out in Table 3.1.
- f. Response actions to be taken relating to excursions, emergencies, etc.
- g. Commissioning activities, such as hydrostatic testing and drying of pipelines and initial odorant injection activities.

**NOTE:** This is not an exhaustive list.

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