Canadian Gas Association Standing Committee on Operations
Natural Gas Interchangeability Task Force

Natural Gas Interchangeability Guidelines Adopted By the CGA
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1 Introduction

Natural gas production from various conventional reserves in North America has declined over the past several years and it is expected to further decline. New sources and supplies of natural gas will need to keep up with these declines to meet market demand. Sourcing and importing sufficient quantities of gas to meet North American demand is of vital importance. However just as critical is the need to address the quality of the gas streams and their suitability for consumption within the North American market.

The natural gas industry is preparing for a transition; adding more non-traditional supplies of natural gas such as coal bed methane, shale gas, and imported liquefied natural gas (LNG) to name a few. Using these diverse gas supplies safely and reliably requires an assessment of the ability of one gaseous fuel to be substituted for another in a combustion application without materially changing operational safety and reliability. The evolving nature of the gas supply portfolio has raised the interchangeability issue to a national level and presents specific technical and commercial challenges throughout the stakeholder value chain. Ultimately, the desire is to create the maximum flexibility in supply with which end use equipment can operate, in a manner that does not materially change operational safety and reliability.

It is important to recognize that this objective applies equally to imported LNG and domestic supply. Throughout North America many distribution systems experience significant variation in composition from time to time, depending upon the particular source of gas, operational variations at extraction facilities and distribution system flow patterns. In addition, direct receipt of small amounts of unprocessed gas by transmission pipelines has historically contributed to the difference of delivered natural gas in certain areas and continues to be a practice. The definition of acceptable ranges of natural gas characteristics that can be safely and reliably consumed by end consumers is required to permit the Canadian industry to react to changes in supply and adequately prepare their customers.

1.1 History and experience in North America & Europe

Gas Interchangeability in North America

In the United States, Gas Interchangeability became an issue in the early 1930’s with the replacement of manufactured gas (coal and oil derived) with natural gas. During the period from 1927 through 1951 research progressed into the effects on appliance combustion performance when one gas was substituted for another. (AGA Mixed Gas Research, AGA Report 847, Knoy, AGA Bulletin 36, Weaver)[1].

Various single index methods for determining gas interchangeability emerged from this research including; the Wobbe number, Willien Index, Knoy Index, Schuster Index, and the AGA "C” Index.[1]. Single index methods based on the physical properties of the fuel gas such as heating value and specific gravity are generally easy to calculate and apply [2].
Multiple index methods emerged from the Weaver and AGA Bulletin 36 research. The Multiple Index methods incorporate fundamental combustion phenomena of gas burners and the “dynamics” of combustion [2]. From 1970 through 1982 various local distribution companies (LDCs) and research organizations further examined the multiple indices and their application in specific markets. This led to the establishment of specific market index limits based on the results of testing appliances installed within the market area.

From 1980 through to 2003 various LDCs, Interstate Pipelines, and LNG Receiving facilities in the US applied single and multiple index methods to manage the impact of changing gas supplies on existing markets.

In 2003 the Federal Energy Regulatory Commission (FERC), with a number of proceedings where gas interchangeability was raised as an issue, reviewed a report prepared by the National Petroleum Counsel. This report provided a number of findings and recommendations along with identifying the importance of LNG imports to feed US demand for natural gas well into the future.

After a FERC Technical Conference held February 2004 the Natural Gas Council initiated an industry effort (NGC+) to seek consensus addressing the issues regarding gas quality and interchangeability. On February 28, 2005, the Natural Gas Council filed with the FERC the technical paper entitled: Natural Gas Interchangeability and Non-Combustion End Use. This report provided interim recommendations and identified areas of additional research [3].

To this date, US Interstate Pipelines have continued to file changes to their Transportation Tariff in order to address Gas Quality and Gas Interchangeability issues. This is in response to the “Policy Statement on Provisions Governing Natural Gas Quality and Interchangeability in Interstate Natural Gas Pipeline Company Tariffs, (Issued June 15, 2006)”. Some pipeline company filings like North Baja Pipeline, Algonquin Gas Transmission, and Iroquois Gas Transmission had reached consensus through discussions with stakeholders and filed these changes uncontested or after resolution of outstanding issues through a Technical Conference facilitated by the FERC. There are instances of Interstate Pipelines holding Gas Quality Collaborative meetings over many years without reaching consensus and outstanding issues have been litigated before the FERC.

In the instance of Intrastate Pipelines, the California Public Utilities Commission has had hearings into the issue of Gas Interchangeability and has involved many stakeholders including the Southern California Gas Company and the Pacific Gas and Electric Company as pipeline operators.

In Canada, in response to inquiries concerning “gas specifications” from a number of proposed LNG receipt terminals, various stakeholders have participated in industry efforts since 2004 to understand and arrive at approaches to address the issue associated with Gas Interchangeability. This effort has included, Industry Committee Task Group
discussions, a public Gas Interchangeability Workshop (October 2005) hosted by TransCanada, and ongoing participation in CGA and AGA technical committees and participation in research efforts focused on Gas Interchangeability issues.

Gas Interchangeability in Europe
As in North America, the gas industry in Europe began with manufactured gases. As local natural gas fields began production, residential and industrial markets started to receive natural gas. Natural gas distribution systems were developed within individual countries in Europe which then started to become interconnected in the 1960’s. As the distribution and transmission systems expanded, Gas Interchangeability became an increasing concern.

The establishment of gas interchangeability specifications was first focused within individual countries to meet the requirements of the gas appliances built to service their respective market. This resulted in the establishment of varied and inconsistent measures and levels of performance throughout Europe. [6]

Diagrammatic methods or techniques were developed and used for interchangeability determination in certain countries in Europe. These include; the Delbourg method, developed for Gaz de France, and the Gilbert and Prigg methods. These methods involve measures of the flame seed as fundamental characterization parameters, while the method developed by Dutton for British Gas, attempts to classify the behaviour of gases by their chemical composition. [4]

Other countries such as Germany (Code of Practice DVGW G 260:2008) and Italy have identified specific gas characteristics such as the Wobbe Index Range, Relative Density and Gross Calorific Value to specify Gas Interchangeability parameters. [5] Two key initiatives in Europe have lead to the harmonization of Gas Interchangeability specifications in respect to the trade and certification of appliances and the cross boarder movement of natural gas.

Gas Appliance Directive” or Directive 90/396/CEE
The "Gas Appliance Directive” (GAD), published in July 1990, is applicable to all apparatus for heating, cooking, water heating, etc., which burns gas and, if they heat water to stay below 105°C. It is also applicable to burners and to parts of apparatus that can be assembled or included in equipment for professional use. It also excludes those intended for use in industrial applications.

One of the main requirements of the Directive is that, when correctly used, an appliance shall have good flame stability and that the combustion products shall not contain noxious compounds in concentrations deemed unacceptable. This recommendation applies to all appliances regardless of whether they are vented or not.

The member states had to define the type and pressure of gases used on their territory by January 1991 so that normal variations of gas quality can be defined. This led to a
The publication of European Standard EN 437 "Test gases, Test Pressures and Categories of Appliances".

The scope of the European Standard EN 437 is restricted to appliance (as defined in the GAD) test gases and is not a gas quality specification. However, it does establish a number of parameters that characterize gases and defines the composition and Wobbe Index for gases that are to be used for performance testing of gas appliances.[6]

**EASEE-gas CBP 2005-001/01, Harmonization of Gas Qualities**

The need to facilitate the movement of natural gas across different natural gas networks and gas quality specifications throughout Europe was identified at the European Gas Regulatory Forum in February 2002. The Forum invited stakeholders to set out an action plan and a time-schedule for solving issues in relation to technical interoperability and to present them at the Forum’s meeting in October 2002.

Gas Transmission Europe (GTE) prepared a position paper for harmonization of gas quality specifications and units, and was presented at the meeting of the European Gas Regulatory Forum in October 2002. The Forum agreed on the action plan proposed by GTE and therefore invited EASEE-gas in liaison with GTE, OGP (International Organisation of Oil and Gas Producers) IFIEC, Marcogaz and other consumer/trading interests, to take the lead in facilitating the implementation of actions on gas specifications:

The proposal for the Common Business Practice on Harmonisation of Natural Gas Quality was finalised in December 2004, approved by the EASEE-gas Executive Committee on 3 February 2005, and published on 7 February 2005. [7][8]

Currently in Europe, interconnecting pipelines are either: free to implement a number of the gas property specifications, agree to differing values, or maintain current gas property specifications in existing contracts.

### 1.2 – Scope of Canadian Gas Association Study

The scope of this report is to define acceptable ranges of natural gas characteristics that can be consumed by end users in Canada while maintaining safety and reliability. By doing so it is intended to contribute to the understanding of the natural gas interchangeability issue by all Canadian Gas Association (CGA) members. In addition, this report will document the recommended means of assessing the interchangeability of natural gas to be considered by CGA members, ultimately resulting in industry supported guidelines and practices to address the introduction of natural gas of varying specifications into the Canadian marketplace. The utilization of natural gas for combustion purposes is the main application within Canada. This report focuses on interchangeability for combustion purposes only, and is not meant to fully address non-combustion applications.
The sources of information utilized to prepare this report include:

- A review of previously published information on this topic.
- A review of previous research undertaken by non-CGA members.
- A compilation and review of historical empirical data from members of the CGA.
- Independent research completed on behalf of select members of the CGA.

1.3 – The Role of the Canadian Gas Association

Founded in 1907, the Canadian Gas Association (CGA) is the voice of Canada's natural gas delivery industry. The Association is made up of over 125 companies, organizations and individuals who are involved in the delivery of natural gas in Canada and the United States. CGA members are typically local gas distribution companies from coast to coast, transmission companies, related equipment manufacturers, and other service providers. Together, CGA members combine to deliver safe, reliable and environmentally preferred natural gas to more than 5 million customers in Canada and to major markets in the United States. CGA members supply the energy needs to 39% of the commercial sector, 48% of the residential sector and 51% of the manufacturing sector.

CGA acts on behalf of its members to advance policy positions on national issues of relevance to natural gas. CGA is actively working to help shape the future of the North American energy industry by providing support and services that assist its members in achieving:

- efficient energy markets;
- competitive fiscal and regulatory conditions that encourage competitive returns for investment in energy delivery assets;
- a continuous focus on innovation;
- continuous improvement in stewardship and corporate responsibility; and excellence in safe and reliable operations.

To achieve these objectives, CGA develops energy industry policy positions, and makes submissions to organizations such as parliamentary committees and the Council of Energy Ministers. CGA also produces educational and environmental information for consumers and organizes training schools, workshops, seminars and conferences. In addition, the CGA-sponsored Annual Natural Gas Forum fosters dialogue among natural gas stakeholders and policy makers.

The CGA is structured with various committees; the Operations Committee sponsored and developed various 3 year forward looking and proactive initiatives and addressing the issue of Gas Interchangeability is one of them.

Following development and adoption of the Gas Interchangeability Interim Guidelines by the Operations Committee, the CGA, through various committees will be employed to further communicate these guidelines to industry stakeholders. This communication will be for the purpose of:
• Educating transmission and distribution companies about the changes to gas supply and composition as well as a technical understanding of the issue;

• Educating end users to prepare for changing gas composition and the implications of these changes;

• Influencing government agencies and policy makers to accept the CGA’s perspective on the issues related to Gas Interchangeability and mitigate any unnecessary and overly restrictive legislation;

• Work with American industry associations to implement a consistent North American approach to the issues of Gas Interchangeability and to ensure open access to each other’s markets.
2. Technical Basis for Addressing Interchangeability

2.1 Natural Gas Appliances

The appliance standards used for the manufacture of commercial and residential gas fired equipment currently in use were reviewed. Test gases used during the required testing were evaluated to determine how they would fit the proposed Interchangeability Guidelines. There has been an evolution of the standards in Canada to both the revisions of standards and in changes to the issuing body. The Canadian Gas Association was the originator of many appliance standards. However, this has changed to include the National Standards of Canada, Canada Standards Association and, following the Free Trade Agreement, joint American National Standards Institute/Canada Standards Association standards.

The list of standards is comprehensive for residential gas fired appliances and includes the majority of commercial appliances. The required testing identified in the standards varies to some extent to suit the characteristics of individual appliances but generally includes:

1. Combustion quality at normal gas pressure.
2. Flash back and delayed ignition on start up/shut down.
3. Flame roll out.
4. Delayed ignition and flashback of power burners under high and low voltage conditions.
5. Proper pilot operation.
6. Flame travel from burner ports.
7. Flame stability with external air currents.
8. Reliable automatic ignition in a range of variable conditions.

The standards require testing to be performed with the appropriate specific test gas and permit operation of appliances with different gases. The standards explicitly indicate that the appliance is only certified for operation on the gases that the appliance was tested for and that conversion of an appliance for operation from one gas to another shall be made in accordance with the manufacturer’s recommendations. The present testing procedures do not include provisions to establish acceptable upper and lower limits for the gas characteristics.
The test gases listed in current ANSI/CSA standards include:

<table>
<thead>
<tr>
<th>Test Gas</th>
<th>Heating Value</th>
<th>Specific Gravity</th>
<th>Specific Gravity (Air = 1.0)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Btu/scf</td>
<td>MJ/m³</td>
<td></td>
</tr>
<tr>
<td>Gas A (Natural)</td>
<td>1,075</td>
<td>40.1</td>
<td>0.65</td>
</tr>
<tr>
<td>Gas B (Manufactured)</td>
<td>535</td>
<td>19.9</td>
<td>0.38</td>
</tr>
<tr>
<td>Gas C (Mixed)</td>
<td>800</td>
<td>29.8</td>
<td>0.50</td>
</tr>
<tr>
<td>Gas D (n-Butane)</td>
<td>3,200</td>
<td>119.2</td>
<td>2.00</td>
</tr>
<tr>
<td>Gas E (Propane)</td>
<td>2,500</td>
<td>93.1</td>
<td>1.55</td>
</tr>
<tr>
<td>Gas F (Propane - Air)</td>
<td>700</td>
<td>26.1</td>
<td>1.16</td>
</tr>
<tr>
<td>Gas G (Butane - Air)</td>
<td>1,400</td>
<td>52.2</td>
<td>1.42</td>
</tr>
<tr>
<td>Gas H (Propane - Air)</td>
<td>1,400</td>
<td>52.2</td>
<td>1.30</td>
</tr>
</tbody>
</table>

The test gases listed in past CGA standards include:

<table>
<thead>
<tr>
<th>Test Gas</th>
<th>Heating Value</th>
<th>Specific Gravity</th>
<th>Specific Gravity (Air = 1.0)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Btu/scf</td>
<td>MJ/m³</td>
<td></td>
</tr>
<tr>
<td>Gas A (Natural)</td>
<td>1,010</td>
<td>38.3</td>
<td>0.60</td>
</tr>
<tr>
<td>Gas B (Propane)</td>
<td>2,500</td>
<td>93.1</td>
<td>1.55</td>
</tr>
<tr>
<td>Gas C (Butane Air)</td>
<td>1,400</td>
<td>53.0</td>
<td>1.42</td>
</tr>
</tbody>
</table>

The standards do not define an acceptable range of operation from tested conditions.

The Wobbe number for the ANSI/CSA natural gas test gas is 1,333 while the Wobbe number for the CGA natural gas test gas is 1,304. Both of the test gases would be within the limits of the proposed Interchangeability Guidelines.

The Air-Conditioning, Heating and Refrigeration Institute (AHRI), formerly the Gas Appliance Manufacturers Association (GAMA), represents manufacturers of appliance, components and related products used in space heating, water heating and commercial food service and power generation. In the paper “Recommendations on Natural Gas Supply and Demand by GAMA (the Gas Appliance Manufacturers Association) to the Senate Energy and Natural Resources Committee’s Natural Gas Supply and Demand Conference January 7, 2005 supports the proposed National Gas Council’s NGC+ draft natural gas interchangeability guidelines. The AHRI position includes:

- The limits on heat content (35.4 MJ/ m³/950 BTU/scf to 41.4 MJ/ m³/1110 BTU/scf) and Wobbe (+/- 4% from historical mean not beyond 1200 to 1400) are intended to protect 100 million installed gas appliances from natural gas that is not interchangeable with the gas that was likely being delivered to those appliances when they were first designed, installed, adjusted and commissioned.
- The limits are intended to ensure that new appliances do not burn gases that would cause the appliances, if properly adjusted to operate beyond their design conditions.
• As such, the interchangeability limits should be applied so as to ensure that gas
delivered to appliances does not exceed the limits, and that any excursions from
the limits are rare and immediately corrected.
• There are many ways to ensure that the limits are not exceeded, including the
application of equivalent, or even more stringent limits using other
interchangeability indices.
• The need for the limits is independent of whether the gas has crossed national or
state borders on its way to the appliance.
• The range of +/- 4% Wobbe from the historical average is essential, but still is too
broad to ensure that all appliances subject to that full range of gases will
experience no interchangeability-related safety, durability, performance, or
emission related issues. Additional outreach is needed to monitor at-risk
appliances and adjust them as necessary when introducing gas at the extremes of
that +/- 4% Wobbe band.
• From an appliance perspective, the Wobbe number and heating value limits are
sufficient. Restrictions on butane-plus content or other gas characteristics will not
adversely affect appliances.

2.2 Compatibility of Alternate Supplies with Materials in
Existing Systems
The variation between the chemical composition of existing supplies and alternate
supplies that comply with the interchangeability guidelines and existing tariffs is
typically minor. Many older systems have experienced greater changes as they moved
from local manufactured gas to pipeline sources while systems that use propane/air or
LNG peak shaving will also experience some variation. Systems in western Canada near
gas gathering areas have historically operated with gas supplies that have higher heating
content levels and higher levels of higher hydrocarbons. Treatment of an alternate source
may be needed for LNG, bio methane and syngas supplies to meet the requirements of
the interchangeability guidelines.

The NGC+ Interchangeability Work Group 2005 “White Paper on Natural Gas
Interchangeability and Non-Combustion End Use” Appendix B “Impact of Changing
Supply on Natural Gas Infrastructure” evaluated the potential effects of
interchangeability on:

• Steel, cast iron, plastic, and copper piping materials,
• Gaskets and seals (generally butyl rubber and viton)
• Controls and instrumentation
• Metering
• Gas infrastructure equipment including gas line heaters, dehydration facilities,
gas compressors and peak shaving facilities.
The study determined that local peak shaving facilities may be affected depending on the nitrogen and higher hydrocarbons in the supply gas and the original design conditions for the facility. Piping materials would not be affected by changes within the limits noted in the interchangeability guidelines. Elastomeric materials in gaskets, seals, diaphragm meters and others are expected to perform similarly within the interchangeability range discussed. The NGC+ White Paper recommends further work to review “the long term effects of leaner supply compositions on gasket and seal materials that have been traditionally exposed to compositions with hydrocarbon constituents greater than C4”. The associated concern is that the elastomers dry and shrink when the heavy hydrocarbons supplied as part of existing gas are no longer available.

A review of available information on elastomer performance following a change in gas supply identified a case where the Washington Gas Light Company (WGL) had submitted a claim to the FERC in opposition to the expansion of the Dominion Cove Point LNG receiving terminal. The claim being that the introduction of LNG into their distribution system had caused compression fittings to leak. The reason for the leak was alleged to be shrinkage of the rubber gaskets due to a drier gas with reduced levels of higher end hydrocarbons. Following an investigation of the claim, FERC issued approval of the Dominion Cove Point LNG facility on June 16, 2006. In their order they indicated that “the shrinkage due to a change in higher hydrocarbons is well within the margin of safety and should not have caused the leaks experienced by WGL”. Work by NORMAC, the manufacturer of the fittings that were found to be leaking, indicated that a practice by WGL to use hot tar to provide corrosion protection of the fittings resulted in remoulding the rubber gasket to a new shape that was not as effective in sealing. WGL did not accept this ruling and applied for a rehearing on this issue. The rehearing related to the performance of the NORMAC fittings was rejected by FERC in a ruling of January 4, 2007.

Polyethylene is a common material used in distribution systems in Canada. CSA B137.4, Polyethylene Piping Systems for Gas Services “provides requirements for polyethylene pipe, tubing, and fittings for use in gas mains and services, including gathering, transmission and distribution applications that carry fuel gases containing not more than 1% aromatic hydrocarbons”. Fuel gases containing up to 1% aromatic hydrocarbons would contain more high hydrocarbons than the allowable limits noted in the interchangeability guidelines. Therefore, polyethylene materials in the natural gas system are not expected to experience detrimental affects due to increased levels of high hydrocarbons.

2.3 LNG World Markets
Natural gas markets in different areas of the world have developed different gas specifications that suit the individual markets. The heating value specifications for selected countries include:
### Country | Higher Heating Value (MJ/m³)
--- | ---
Japan | 39.7 to 43.3
Korea | 40.0 to 43.6
USA | 35.7 to 40.8
UK | 36.8 to 42.4
France | 36.2 to 43.2
Spain | 35.0 to 44.9

The composition of unprocessed gas varies significantly from location to location. Unprocessed natural gas can contain hydrocarbons ranging from methane to noanes plus, and non hydrocarbons such as nitrogen, oxygen, carbon dioxide, helium, hydrogen sulfide and water vapour. Processing is performed to remove water vapour, hydrogen sulfide and carbon dioxide to control corrosion. Butane, pentane and heavier components are removed to prevent liquid drop out that may occur in pipelines while propane is also typically removed. Removal of ethane and propane may be performed where a local market exists for these materials, or where it is necessary to limit the higher heating value. Different levels of processing are needed to meet this wide range of heating values and not all sources may be suitable to supply all markets. However, it is also possible to provide further processing of the LNG at the receipt terminal to meet specific local requirements. The final heating value and the Wobbe number of the gas will depend on the feed gas and the processing performed.

The design and operation of LNG liquefaction and receiving facilities can be used to adjust the physical characteristics of local feedstocks to meet the specifications of local distribution companies. The higher heating value (HHV) can be adjusted upward or downward if needed. A common means of reducing HHV is to provide injection of inert nitrogen. This will often be limited by the maximum amount of inerts permitted by the purchaser’s gas specifications and will also be limited by the amount of nitrogen in the LNG as received. Typical levels of HHV reduction are 0.9 to 1.2 MJ/m³ (25-35 Btu/scf). LDCs that operate LNG peak shaving facilities have concern about the maximum level of nitrogen in the gas as it can affect the operation of their liquefaction facilities. If nitrogen addition cannot reduce the HHV sufficiently, removal of propane and ethane can be performed. This results in an increased level of plant complexity and disposal of the ethane can be an issue if a local market is not present. Increasing the higher heating value is commonly done by the addition of propane.

The more processing that is needed to permit a LNG supply to be accepted by a LDC will increase both facility investment and operating costs. Flexibility in natural gas specifications can permit processing requirements to be limited while also providing access to more of the global supply sources. Untreated characteristics of potential supply sources and the post treatment characteristics of these sources are shown below:
LNG Supply Utilization

Processed LNG Utilization Curve
The typical LNG composition provided by a number of existing facilities is:

<table>
<thead>
<tr>
<th>Component</th>
<th>Algeria</th>
<th>Abu-Dhabi</th>
<th>Australia</th>
<th>Malaysia</th>
<th>Indonesia</th>
<th>Brunei</th>
<th>Indonesia</th>
<th>Alaska</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>0.278</td>
<td>0.0106</td>
<td>0.014</td>
<td>0.32</td>
<td>0.03</td>
<td>0</td>
<td>0.09</td>
<td>0</td>
</tr>
<tr>
<td>Methane</td>
<td>91.379</td>
<td>87.074</td>
<td>87.822</td>
<td>91.151</td>
<td>89.18</td>
<td>89.40</td>
<td>90.60</td>
<td>99.80</td>
</tr>
<tr>
<td>Ethane</td>
<td>7.874</td>
<td>11.410</td>
<td>8.304</td>
<td>4.284</td>
<td>8.58</td>
<td>6.30</td>
<td>6.00</td>
<td>0.10</td>
</tr>
<tr>
<td>Propane</td>
<td>0.443</td>
<td>1.271</td>
<td>2.982</td>
<td>2.873</td>
<td>1.67</td>
<td>2.80</td>
<td>2.48</td>
<td>0</td>
</tr>
<tr>
<td>i-Butane</td>
<td>0.004</td>
<td>0.062</td>
<td>0.040</td>
<td>0.701</td>
<td>0.24</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>n-Butane</td>
<td>0.004</td>
<td>0.079</td>
<td>0.475</td>
<td>0.661</td>
<td>0.271</td>
<td>1.30</td>
<td>0.82</td>
<td>0</td>
</tr>
<tr>
<td>i-pentane</td>
<td>0</td>
<td>0.001</td>
<td>0</td>
<td>0.010</td>
<td>0.02</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>n-pentane</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.01</td>
<td>0</td>
</tr>
<tr>
<td>HHV(MJ/m³)</td>
<td>40.1</td>
<td>41.8</td>
<td>42.6</td>
<td>44.2</td>
<td>41.6</td>
<td>38.0</td>
<td>41.4</td>
<td>37.6</td>
</tr>
<tr>
<td>(BTU/scf)</td>
<td>41.8</td>
<td>41.4</td>
<td>42.0</td>
<td>42.6</td>
<td>41.6</td>
<td>38.0</td>
<td>41.4</td>
<td>37.6</td>
</tr>
<tr>
<td>Wobbe Index</td>
<td>1393</td>
<td>1419.4</td>
<td>1431</td>
<td>1414</td>
<td>1417</td>
<td>1423</td>
<td>1411</td>
<td>1358</td>
</tr>
</tbody>
</table>

Source: Gas Conditioning for Imported LNG - D. McCartney, 82nd GPA Convention, March 2002

With the CGA Interchangeability Guidelines at a maximum Wobbe number of 1,400 and a maximum higher heating value of 41.4 MJ/ m³ (1110 Btu/scf) it can be seen that 7 of these sources would require receipt point processing to meet the Wobbe and HHV limits while 2 sources would require processing due to high Wobbe numbers.

### 2.4 Existing Gas Quality Requirements Defined in Transportation Tariffs or General Terms and Conditions

The interchangeability guidelines are intended to be applied in addition to any gas quality requirements that may form part of existing transportation tariffs. Typical gas quality requirements listed in existing transportation tariffs may include:

1. Minimum heating value
2. Freedom of objectionable matter such as sand, dust, gums, oils and hydrocarbons that may form liquids in the pipeline.
3. Limits on hydrogen sulphide, total sulphur and mercaptan.
4. Limits on carbon dioxide
5. Limits on water content.
6. Limits on maximum temperature.
7. Limits on oxygen levels.
8. Limits on total inerts.
9. Limits on hydrocarbon dew point.

Most pipeline companies do not currently specify an upper limit on heating value most likely for the reason that high heat value gases would typically be addressed by pre-existing hydrocarbon dew point specifications. High heating value usually results from excess amounts of propane, butane and heavier hydrocarbons which would typically liquefy at normal pipeline operating pressures and temperatures causing violations of the hydrocarbon dew point specification. Some considerations with respect to utilization of Higher Heating Value gases include potential of appliances to exceed over-firing limits and elevated temperature combustion.

### Gas Component Effect on Hydrocarbon Dew Point

<table>
<thead>
<tr>
<th>Gas Component</th>
<th>Effect on Hydrocarbon Dew Point</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td></td>
<td>95.00</td>
<td>86.60</td>
<td>79.85</td>
<td>73.12</td>
</tr>
<tr>
<td>C2</td>
<td></td>
<td>3.00</td>
<td>6.00</td>
<td>8.00</td>
<td>12.00</td>
</tr>
<tr>
<td>C3</td>
<td></td>
<td>2.00</td>
<td>2.00</td>
<td>3.00</td>
<td>6.00</td>
</tr>
<tr>
<td>iC4</td>
<td></td>
<td>0.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.50</td>
</tr>
<tr>
<td>nC4</td>
<td></td>
<td>0.00</td>
<td>1.40</td>
<td>1.40</td>
<td>1.50</td>
</tr>
<tr>
<td>C5</td>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>1.50</td>
</tr>
<tr>
<td>C6+</td>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>3.75</td>
<td>1.38</td>
</tr>
<tr>
<td>C6</td>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>2.00</td>
<td>0.75</td>
</tr>
<tr>
<td>C7</td>
<td></td>
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<td>0.00</td>
<td>1.00</td>
<td>0.36</td>
</tr>
<tr>
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<td>0.50</td>
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<td>0.09</td>
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<tr>
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<td></td>
<td>0.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>N2</td>
<td></td>
<td>0.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>HV</td>
<td></td>
<td>39.75</td>
<td>41.51</td>
<td>48.14</td>
<td>49.72</td>
</tr>
</tbody>
</table>
3 Canadian Studies

The transition from historical gas supply and gas composition to the evolving gas supply and gas composition profile presents specific technical and commercial challenges throughout the stakeholder value chain. The safety, reliability and environmental performance of end use equipment must be maintained.

At issue is the ability to substitute one gaseous fuel for another in a combustion application without materially changing operational safety, efficiency, performance or materially increasing air pollutant emissions.

This task force leveraged existing studies, consulted with industry experts and examined the historical gas composition of various companies across Canada to establish a safe gas composition envelope.

Two CGA member companies employed the Gas Technology Institute (GTI) to provide individual assessments regarding the impact of changing fuel gas from natural gas to substitute gases (primarily LNG) on the operating characteristics of residential and commercial appliances, industrial and commercial burners, on reciprocating engines, microturbines and turbines and other process gas equipment. Information on current and historical natural gas supplies were provided by the Sponsors, and Atlantic Basin LNG data was obtained from a survey conducted by suppliers. End use equipment surveys were conducted to which GTI added industry sourced information. The results are consistent with other studies performed across North America, the findings of which are summarized below:

The scale, complexity, performance needs, operating characteristics, and control methods vary between and within the broad classes of end use equipment covering appliances, commercial and industrial burners, engines, and turbines.

The guidelines are designed to provide the broadest range of acceptable gas supplies with the least needed adjustment of existing and anticipated end use equipment.

At the proposed maximum Wobbe value, no properly adjusted appliances are expected to have performance or emissions concerns. Concerns with appliances exist when burning gas having a higher heating value than the maximum proposed in the interim guidelines due to potential for incomplete combustion and the resulting increase of carbon monoxide production.

Industrial processes with temperature sensitivity and poor controls should be adjusted to operate appropriately with changing gas supply. Small baking operations in particular should be adjusted. Other process heating equipment can be retuned and operators of these systems, particularly high temperature and oxygen-fired equipment, should be informed of need for potential adjustments. Where there is a frequently changing gas supply special consideration may be required. Most process equipment, including
boilers and low NOx boilers, can be adjusted with labor only. Some minor equipment costs may ensue, but no overall system replacements are envisioned.

The guideline on maximum inert gas-free HHV of 41.4 MJ/m$^3$ (1110 Btu/scf) and a C4+ content of 1.5% is proposed to maintain Methane Numbers (MN) above 80. Mobile engines with closed-loop control and older mobile engines with MN ratings above 80 will need no attention. Smaller stationary engines will also need no attention. Only large stationary engines with BMEP above 300 kW and rated MN under 80 would need adjustment when accepting significantly different gas. This population is small, and the adjustments include labor and retrofit kits.

Low emissions of NOx, CO and unburned hydro carbons have become essential for Gas turbine combustion systems and industrial gas turbine combustion design has changed substantially since the 1990s to meet these demands.

Burner technology has migrated from a diffusion flame design to more complex “lean premix combustors” or Dry Low NOx /Emissions (DLN) designs.

DLN combustors balance fuel/air ratios to manage flame temperature and avoid local low or high temperatures inside the combustor that will produce large amounts of NOx or CO respectively. DLN equipped gas turbines also need to manage combustor “noise” that damages and limits the life of the combustor. To operate properly, these DLN gas turbines are tuned to local gas supplies and for these reasons DLN gas turbines are less tolerant to changing gas composition than gas turbines with diffusion flame combustors.

The time rate of change of fuel composition will be problematic for most DLN gas turbines and can result in increased emissions, reduced reliability/availability and decreased parts life. Turbine manufacturers are aware of this issue and are developing active control systems that will allow a wider fuel gas range. Therefore efforts should be made to keep gas supplies to large turbines as stable as possible, turbine operators should be made aware of large changes in gas supply properties to allow turbines to be retuned to the new gas supply or active tuning technology will need to be incorporated in the unit’s operation. Diffusion-flame turbines should need no attention.

In addition to a review of assessments on the impact of changing fuel gases, this Task Force compiled historical gas composition data from members companies over the last 2-5 years. The following observations were made:

- there is little change in gas composition of gas delivered in Ontario and Quebec (gas from the TranCanada system) and that this data falls within the NGC+ guidelines

- there are much larger variations in gas composition heating value and Wobbe number in Saskatchewan, Alberta and British Columbia.

- gas at some delivery and receipt points in Saskatchewan, Alberta and British Columbia exceeds the NGC+ guidelines.
The data presented on the charts following Appendix A are based on gross or higher heating value (HHV) at standard conditions of 101.325 KPa, 15 deg C, dry, ideal basis using interchangeability guidelines are specified based on gross or higher heating value (HHV) at standard conditions of 101.325 KPa, 15 deg C, dry, real basis.

As the Task Force identified situations where the gas composition falls outside of recommended NGC+ Interim Guidelines, a study was completed on this system to provide information on the real life experience by a LDC with gas of varying composition within and outside of the guidelines. The study entailed identifying specific areas within the system that have significant variations in gas composition, heating value and Wobbe number and identify any end user issues.

Initially three areas were investigated and the graphs that follow show the heat value variations over a one year period of time for these three locations. Further investigation revealed that all 3 areas served small rural areas (farms or acreages). A review of the service call history over a 2 year period revealed that there were no calls relating to gas composition or problems relating to the operation of the gas fired equipment. The distribution systems in these areas are in the 20 to 35 year old range and represent a heating load system only.

An additional five areas in a region were also evaluated. The customer base for the areas is included in the following table:

<table>
<thead>
<tr>
<th>Location</th>
<th>Customers:</th>
<th>Age (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Residential</td>
<td>Commercial</td>
</tr>
<tr>
<td>Tap 6</td>
<td>506</td>
<td>57</td>
</tr>
<tr>
<td>Tap 7</td>
<td>13718</td>
<td>189</td>
</tr>
<tr>
<td>Tap 8</td>
<td>cannot be determined since integrated another station</td>
<td></td>
</tr>
<tr>
<td>Tap 4</td>
<td>185</td>
<td>6</td>
</tr>
<tr>
<td>Tap 5</td>
<td>833</td>
<td>7</td>
</tr>
</tbody>
</table>

High Use Customers are defined as greater than 8,000 GJ/year

The heat value variations for these locations over a one year period of time has been plotted on the graphs included in Appendix B. The majority of the heat values for these locations fall within the curve of the guidelines (upper heating value of 41.4 MJ/m3/1,110 BTU/scf). Occasionally the gas is close to the 42 MJ/m3 (1,129 BTU/scf) value. Upon checking with the service staff there is no record of any customers expressing concerns regarding gas interchangeability (e.g. yellow tipping, incomplete combustion/CO issues). The staff also report never having to adjust appliances in these areas. The results support the GTI study that changing gas composition does not
materially affect the performance on residential appliances and further validates the NGC+ guidelines.
4 Interim CGA Interchangeability Guidelines

Scope: Applies to point of receipt on Transmission and Distribution systems. Blending of gases in a transmission system is acceptable if the final gas composition meets the requirements of these guidelines. These guidelines supplement a company’s transportation tariffs and contracts.

1. A range of plus and minus 4% Wobbe Number Variation from local historical average gas or, alternatively, established adjustment or target gas for the service territory:

   Subject to:
   Maximum Wobbe Number Limit: 1,400
   Maximum Heating Value Limit: 41.3 MJ/M3 (1,110 BTU/scf)\(^1\)

2. Additional composition maximum limits:

   Maximum Butanes+: 1.5 mole percent
   Maximum Total Inerts: 4 mole percent

3. AGA Bulletin 36 indices:

   Weaver Incomplete Combustion Index \(\leq 0.05\)
   AGA Yellow Tipping Index \(\geq 0.86\)

4. Bacteria: Free of any microbiological organism, active bacteria or bacterial agents.

5. Exception:

   Service territories with demonstrated experience with supplies exceeding these stated above may continue to use supplies conforming to this experience as long as it does not unduly contribute to safety and utilization problems of equipment.

Notes:
\(^1\) based on gross or higher heating value (HHV) at standard conditions of 101.325 kPa, 15 dec Celcius, dry, real basis.
Other issues that may apply and should be given consideration:

Historical Average: is a calculation of the representative historical component values over at least 5 years, if the data is available.

Demonstrated experience refers to actual end use experience established by end-use testing and monitoring programs.

Total Inerts limit of 4%
- Consideration to be given where peak shaving facilities exist
- Higher amounts are acceptable to the point they impact the lower HV limit or industrial customers.
- Where there are down stream export considerations

Each company must identify issues and concerns with the specific additional guidelines

Minimum Heating Value as stated in current tariff, refer to AGA Report 4A where not specified in a tariff

AGA Heat Rate and lifting index should be considered when exceed -4% Wobbe

Bacteria: Remains under development

Components: e.g. water, sulphur, H2S, objectionable materials and identified equipment warrantee issues, it is assumed these and other component restrictions exist in transportation contracts

Synthetic Gas: Restrictions TBD

4.1 Commentary on Interim CGA Interchangeability Guidelines

The guidelines recommended by this document were developed to assist the industry with specifying the “safe envelope” of gas that can be accepted onto their system. The intent of this commentary is to provide some insight as to why certain criteria have been included in the guidelines and where they are of particular importance so that each company can apply the guidelines appropriately depending on considerations specific to their system. The commentary may provide useful information to companies performing engineering assessments on the implications of gas compositional changes both within and outside of the guidelines.

**Wobbe Number Variation subject to maximum Wobbe and Heating Value Limits:** Several indices have been developed to assess natural gas interchangeability. The Wobbe Number is the most widely used single parameter for assessing interchangeability in
combustion applications. The Wobbe Number alone however does not always adequately predict all combustion phenomena. For this reason, additional indices are often used to more fully characterize a combustion system. The AGA Bulletin 36 and Weaver Indices are commonly used in conjunction with Wobbe number to assess natural gas interchangeability. However, as AGA Bulletin 36 and Weaver Indice calculations are quite complex, it is often more practical to use supplemental criteria such as a limit on heating value to account for behaviors that these more complex limits would more closely predict.

The guidelines specify a range of +/- 4% Wobbe variation from local historical average.

The higher limit on Wobbe is imposed to address combustion phenomenon such as yellow tipping and incomplete combustion while the lower Wobbe limit is imposed to address flashback, lifting and production of excessive CO.

The range of Wobbe variation specified in the guidelines is subject to supplemental criteria including maximum Wobbe and heating value limits.

The absolute maximum Wobbe limit in the guidelines of 1,400 is based on +4% of the 1992 U.S. mean Wobbe of 1,345.

The maximum heating value of 43.1 MJ/m$^3$ (1,110 Btu/scf) is used to address incomplete combustion that would not always be sufficiently addressed by maximum Wobbe limits alone. The literature states “Laboratory testing and combustion theory has shown that simply selecting a maximum Wobbe is not sufficient to address incomplete combustion over a range of gas compositions (especially for natural gas with heating values in excess of about 1,100 Btu/scf. However, the limitation can be overcome by selecting a more conservative maximum Wobbe Number coupled with an additional parameter such as heating value.”

Some additional considerations with respect to utilization of higher Wobbe and heating value gases include potential for appliances to exceed over-firing limits and experience elevated temperature combustion.

Some Canadian LDC’s have demonstrated experience operating outside of these limits. It is important to understand that the acceptable absolute upper limits for Wobbe and heating value change depending on the local historical average or adjustment gas that is chosen to define the safe operating envelope. Literature states that “choice of adjustment gas will change the absolute upper limits for Wobbe and heating value although the +/- 4% will likely define an acceptable range, according to the current calculation methodology.” There is an exception in the guidelines that allows service territories with demonstrated experience operating outside of guidelines to continue to use supplies conforming to this experience as long as it does not unduly contribute to safety and utilization problems with equipment. Where historical experience with Wobbe numbers and/or heating values outside of limits exists, it is recommended that alternate indices

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1 Halchuk-Harrington, Rosmarie, Wilson, Robert D., AGA Bulletin #36 and Weaver Interchangeability Methods: Yesterday’s Research and Today’s Challenges, 2006
such as the AGA Bulletin 36 and Weaver Indices be used to help maintain supply within acceptable limits.

**Compositional limits:**
The guidelines also place limits on inert and heavy hydrocarbon components.

Heavy hydrocarbon content may be limited due to potential impacts on propane-air peak shaving operations. These facilities have specific blending capabilities and limitations depending on the composition of the pipeline gas supply they are designed to supplement. Existing systems may not have enough capacity to maintain interchangeability criteria while blending peak shaving supplies with pipeline supplies containing higher amounts of heavier hydrocarbons. The presence of heavier hydrocarbons also lowers the methane number of a natural gas. Low methane numbers can cause engine knock and operating performance issues in reciprocating engines.

Total inerts, made up primarily of nitrogen and carbon dioxide, are of concern in both combustion and non-combustion end uses. Nitrogen and carbon dioxide have no associated heat value. As the concentration of inert components increases, the total energy per unit volume of natural gas decreases. High inert supplies can decrease the efficiency of a pipeline system because inert compounds occupy space and take up transportation capacity that would otherwise be utilized by methane or another combustible component.
High nitrogen can impact the efficiency and reliability of LNG Peak Shaving facility operations and can also cause issues with LNG storage systems because of increased tank boil-off. Nitrogen, one of the lightest fractions, will be one of the first to boil-off and as such boil-off contains a relatively large percentage of nitrogen as compared to other components.

Nitrogen can also be an issue in non-combustion end use applications where natural gas is used as a feedstock. Feedstock processes that produce hydrogen from natural gas can experience increased maintenance expenses when nitrogen content in the natural gas stream is increased.

Some Canadian LDC’s have demonstrated operating experience with inert levels in excess of those recommended by the guidelines. Depending on the situation, higher amounts of inerts may be acceptable to the point that they impact ability to meet existing quality specifications or interchangeability index limits. Once again, there is an exception in the guidelines that allows service territories with demonstrated experience operating outside of guidelines to continue to use supplies conforming to this experience as long as it does not unduly contribute to safety and utilization problems with equipment.

**AGA Bulletin 36 and Weaver Indices:**
As discussed previously, the Wobbe Number alone does not always adequately predict all combustion phenomena requiring the use of additional indices to assess interchangeability. Weaver Incomplete combustion and AGA Yellow Tippin limits have also been specified in the guidelines to address situations where supplemental max Wobbe and heating value limits may not adequately define the safe operating envelope. These indices address potential appliance concerns related to sooting and production of carbon monoxide. Heat rate and lifting indices should also be considered when lower Wobbe limits are exceeded.

It is important to understand that there is some duplication between the AGA Bulletin #36 and Weaver Indices. In general, AGA Bulletin #36 methods tend to yield more satisfactory results for natural gas whereas Weaver methods tend to be more suited to manufactured or petroleum gases. It is possible that one of the indices may be more accurate for a particular mixture than the other, particularly for a system where there are many different mixtures on the system at any one time. In some situations, it may be beneficial to evaluate all indices for both the AGA Bulletin #36 and Weaver methods.

**Additional Considerations:**
Some compounds outside of existing gas quality specifications such as hydrogen, CO, and microbiological agents are often associated with non-traditional gas supplies including bio methane and synthetic gases. Interchangeability issues associated with these gases are the subject of ongoing research. Concerns and limitations involving the introduction of bio methane into existing natural gas grids need to be fully understood to ensure potential hazards are identified and mitigated appropriately.
Hydrogen gas is usually present in non-traditional gases and can cause a variety of concerns with varying concentrations. A comparison of natural gas and hydrogen properties is key to understanding any associated safety risks. Metallic materials in the pipeline systems may be more susceptible to hydrogen embrittlement with hydrogen present. Compared with natural gas, hydrogen is more likely to permeate through materials (especially PVC and HDPE piping) and leak through small openings. Hydrogen has a wider flammability range and can be ignited with a lower energy source however it is more difficult to achieve flammable concentrations of hydrogen in air (especially at outdoor locations) due to its low specific gravity. Because hydrogen gas leaks are relatively more likely than natural gas leaks, one of the more notable safety risks for existing low pressure distribution pipeline systems containing hydrogen is at poorly ventilated indoor locations that are occupied. Hydrogen’s high burning rate in a fuel gas mixture could facilitate flashback whereby the flame front moves upstream from the burner tip into the burner body and tubing.

Carbon Monoxide can also be present in bio methane and synthetic gases. Carbon Monoxide is a highly poisonous substance that must be monitored and dealt with accordingly. Carbon Monoxide in natural gas reduces the flame size making it more likely to adjust an appliance’s air/fuel ratio outside of its ideal ratio. CO will likely remain in the combustion gas without being oxidized and as such appropriate CO limits should be in place.

Bio methane may also contain many other trace components and objectionable materials such as Heavy metals, Bacteria/microbes, Ammonia, Siloxanes, Pesticides, Pharmaceuticals, PCBs, Semi-volatile and volatile organic compounds, and Halocarbons. Further research is being conducted to study the introduction of renewable bio methane into the natural gas distribution and transportation systems.

Bacteria are also a concern in offshore or marine applications. Bacteria can damage pipeline materials and associated equipment; therefore appropriate limits must be in place to protect the pipeline system.

Most recently, Engler and Botros discuss the development of gas interchangeability evaluation methods, both numerical and diagrammatical that can be used to assess gas interchangeability [9].
### CGA Natural Gas Interchangeability Task Force Members:

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- Chris Pezoulas

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- Charles Teeuwsen
- Ted Whitfield & Rachael Marozzo

Pacific Northern Gas
- TransCanada
- Gaz Metro
- TransCanada
- Union Gas
- Manitoba Hydro
- TransGas
- ATCO
- Enbridge
References:


Appendix A – Historical Gas Composition Across Canada

Company 1 – Tap 1

Operating Window

Company 1 – Tap 2

Operating Window
Company 2

Operating Window

Company 3

Operating Window
Company 4
System Export Points

Company 5
Operating Window

Company 6
Appendix B – Company Gas Study

Tap 1

Tap 2