PROCEDURE FOR CONVERSION OF natural gas volume to standardized conditions for metering points without corrector

Ljiljana Hadžibabić
Head of Energy-Technical Department

“Energy 2009”
International Energy Fair
Belgrade, 14-16 October 2009
Contents

- Introduction
- Characteristic natural gas condition
- Calorific value of natural gas
- Charging natural gas
- Analysis of energy entities’ practice before tariff systems implementation
- Agency’s suggestion
- Initiative Decree modification
Introduction

- **Reasons for conversion**
  - Physical properties of gas
  - Energy value of 1 m\(^3\) depends on the pressure, temperature, and calorific value
  - Price specified per 1 m\(^3\) for gas under standard conditions and referent calorific value

- **Goals**
  - Protection of market participants
  - Comparability of data
  - More accurate natural gas balance
  - More precise data on natural gas losses
Gas condition

Equation for condition of real gas

\[ pV = n \, Z \, R \, T \]

- \( p \) – pressure,
- \( V \) – volume (quantity),
- \( n \) – number of mol,
- \( R \) – universal gas constant,
- \( T \) – absolute temperature (K),
- \( Z \) – compressibility factor, \( Z = f(p, T) \)

Volume measured must be converted to the same condition parameters at all system points from entrance into the country to final customers.
Characteristic gas conditions

- **Operating** – real operating pressure and temperature

- **Referent condition**

  1. **Standard condition** – „s“,  
     \[ T = 288,15 \text{ K (15°C)} \text{ and } p = 1,01325 \text{ bar} \]

  2. **Normal condition** – „n“,  
     \[ T = 273,15 \text{ K (0°C)} \text{ and } p = 1,01325 \text{ bar} \]
Conversion of gas volume to standard condition (1)

\[ V_s = V_r \cdot \frac{288,15}{1,01325} \cdot \frac{P_m + P_{atm}}{T_r} \cdot \frac{1}{Z} \]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_s )</td>
<td>Converted gas volume (m³) - STANDARD conditions</td>
</tr>
<tr>
<td>( V_r )</td>
<td>Read gas volume (m³) - OPERATING conditions</td>
</tr>
<tr>
<td>( P_m )</td>
<td>Connection pressure (bar) - OPERATING conditions</td>
</tr>
<tr>
<td>( P_{atm} )</td>
<td>Atmospheric pressure (bar) - OPERATING conditions</td>
</tr>
<tr>
<td>( P_s )</td>
<td>Pressure under STANDARD conditions, 1,01325 (bar)</td>
</tr>
<tr>
<td>( T_s )</td>
<td>Temperature under STANDARD conditions, 288,15 K (15 °C)</td>
</tr>
<tr>
<td>( T_r )</td>
<td>OPERATING temperature (273,15 + T\text{gas in °C}) (K)</td>
</tr>
<tr>
<td>( Z )</td>
<td>Gas compressibility factor</td>
</tr>
</tbody>
</table>
Conversion of gas volume to standard condition (2)

Gas volume corrector by pressure and temperature –
Device for automatic conversion of volumetric gas flow under operating conditions to standard conditions

Conversion formulae are defined by:

No corrector available, conversion by calculation according to the same formulae
Corrector by temperature available – no conversion by calculation

The accuracy of operating condition parameters is the problem
Charging natural gas

- For gas as an energy carrier, quantity and calorific value are important

- **Price 1m³** – in methodologies and tariff systems for:
  - Standard gas condition and
  - Referential lower calorific value of gas of 33.338,35 kJ/m³

- **To invoice natural gas**, the volumetric gas flow must be converted first to
  - Standard condition and
  - Referential lower calorific value of gas
Calorific value of gas (GCV)

- **Real**
  - varies
  - is determined periodically based on chemical content (quality) chromatographic analysis
  - average (weighted) value is calculated for a specific period, taking into account quantities to which the GCV relates

- **Referential – for invoicing**
  To make the data on quantities comparable
Conversion of “standard” to chargeable gas volume

\[ V_o = V_s \cdot \frac{H_{pd}}{H_r} \] (m³)

<table>
<thead>
<tr>
<th>Vo</th>
<th>Chargeable volume; Gas volume converted to referential lower GCV (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vs</td>
<td>Natural gas volume under standard conditions (m³)</td>
</tr>
<tr>
<td>Hpd</td>
<td>Average lower GCV in an observed period (kJ/m³)</td>
</tr>
<tr>
<td>Hr</td>
<td>Referential lower GCV (kJ/m³)</td>
</tr>
</tbody>
</table>

**actual:** 33.338,35 kJ/m³ – agreed on the basis of mean lower calorific value of domestic gas in the seventies

Conversion to referent calorific value is always done by CALCULATION
Average lower calorific value of gas

\[ H_{pd} = \frac{\sum_{i=1}^{n} H_i \cdot V_i}{\sum_{i=1}^{n} V_i} \]  
(kJ/m\(^3\))

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(H_{pd})</td>
<td>Average lower GCV (kJ/m(^3)) for the invoicing period</td>
</tr>
<tr>
<td>(n)</td>
<td>Number of metering during the invoicing period</td>
</tr>
<tr>
<td>(i)</td>
<td>(i) - metering, on the same day for (H_i) and (V_i)</td>
</tr>
<tr>
<td>(H_i)</td>
<td>Measured lower GCV (kJ/m(^3)) – deemed to be the same on all days until next sampling</td>
</tr>
<tr>
<td>(V_i)</td>
<td>Volume of gas flow between two metering (m(^3))</td>
</tr>
</tbody>
</table>

\(H_{pd}\) determined by Srbijagas
1. Conversion to referential condition

a) not implemented

- if the gas delivery via meter without corrector is negligible
- if not negligible, expected effects of conversion are:
  - Integrated into the price (most of the energy entities)
  - Assigned to losses
    Not correct, and with separation of accounts by activities
    not feasible – costs of loss are born by Operator and not supplier

b) Implemented, to varying degrees

- Operating pressure and temperature differently determined
- Conversion by temperature also with temperature compensator installed - periodically
Analysis of energy entities’ practice before tariff systems implementation (2)

2. Conversion to referential lower calorific value

a) not implemented

- expected conversion effect were integrated into the price
- some distributors with high share of domestic gas do not convert by calorific value – the result is unjustified price increase

b) Implemented

- Customers/users have doubts about the lower GCV indicated on the bill (e.g. on the basis a subjective assessment of the flame intensity)
- Insufficiently transparent
Problems identified

- Area insufficiently regulated
- Different practice of energy entities
- Calculations not transparent enough
- Objective difficulties with determining operating condition parameters
- Referential calorific value is low – for more than 80% of gas, the quantity increases by approx. +2% on the basis of GCV
Regulating the area

Responsible stakeholders
- Energy Agency of the Republic of Serbia
- Ministry of Mining and Energy
- Energy entities (EE) within the gas sector

Phases
- Problem analysis – Agency and EE
- Draft conversion procedure - Agency and EE
- Discussions of professionals
- Amendments to documents – Ministry, Agency and EE
Agency’s participation (1)

In line with its legal jurisdictions specified in Article 15 of the Energy Law:

- Collects and processes data on energy entities associated with conducting energy activities
- Monitors compliance with methodologies and tariff systems
- Monitors behavior of energy entities with regard to protection of customers/system users interests
- Processes customers/system users invoice-related complaints in the context of tariff system implementation
- Monitors the behavior of energy entities with regard to separation of accounts by activities
Agency’s participation (2)

Analysis:

- behavior of energy entities with regard to conversion of read to chargeable parameters of gas volume
- experience of other countries
- data availability

Proposal of:

- conversion method - formulae
- method of gathering data
- which referential lower GCV to choose
Goals in choosing the conversion method (1)

- **Equal position of market participants**
  - Mandatory conversion for all metering points without corrector
  - The same method of determining operating parameters for all energy entities

- **Simplicity of application with sufficient accuracy***

* - What does sufficient accuracy mean:
1. The final result of metering and calculation is as accurate as the least accurate element in the procedure
2. When deciding which approximation method to use and when value averaging is done, one should not insist on a precision level that is higher than the requested precision of the metering equipment
Goals in choosing the conversion method(2)

- **Invoicing transparency**
  - Invoice content
  - Publication of relevant data on the energy entities’ and agency’s website

- **Minimization of differences between read and chargeable quantities**
  - Adequate selection of referential values
  - Averaging of effects at the annual level

- **More accurate gas balance in the country and comparable data with international statistics**
Determining parameters of gas operating condition (1)

\[ P_m \] - connection pressure

Simplified for households (and the like)

Germany, Austria, Italy, Croatia: \( P_m = 22 \) mbar

Technical norms for interior gas installations:

nominal connection pressure for home gas appliances - 20 mbar,
allowed total pressure drop within LP area (up to 100 mbar) is 2,6 mbar;

Agency’s suggestion

\[ \text{Calculation } P_m = 22 \text{ mbar} \]

for \( 18 \text{ mbar} \leq P_m \leq 24 \text{ mbar} \)

16 distribution uses already 22 mbar
**Determining parameters of gas operating condition (2)**

\[ P_{atm} \] - *atmospheric pressure* – depends on the sea level

Value used until now:

The most energy entities use \( P_{atm} = 1003.25 \text{ mbar} \) (corresponds to Rimski Šančevi),

Others - up to 1022 mbar

**Analysis of the Serbian Hydrometeorological Office (RHMZ)**

Based on data of the RHMZ on mean values of \( P_{atm} \) in 17 cities – distribution headquarters:

- Monthly for 3 years (2005-2007) and
- Annually for 10 years (1998 – 2007),

The minimum deviation is obtained by using the function:

**Agency’s suggestion**

\[ P_{atm} = 1016 - 0.108 \times h \quad \text{(mbar)} \]
Determining parameters of gas operating condition (3)

\[ P_{atm}(h) \]

\[ h = h_{MMRS} \quad \text{for all delivery points after MMRS} \]

<table>
<thead>
<tr>
<th>Responsibility</th>
<th>To determine and publish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transporter</td>
<td>( h_{GMRS} ) – for all MMRS towards distributions, until the deadline defined in the Decree</td>
</tr>
<tr>
<td>Distributer</td>
<td>( P_{atm} ) – for charging customers until the deadline defined in the Decree</td>
</tr>
</tbody>
</table>
Determining parameters of gas operating condition (4)

Tr - Operating temperature

Energy entities converting according to temperature, apply:

- Ground T at 1m of depth (source RHMZ), maximum - 14 energy entities;
- 6ºC throughout the year (average winter temp.) - 1 en.entity

Study of the Technical Department of Novi Sad University

- Combination of ground temp. and air and T fall due to pressure reduction at the regulator \((0.66 \ T_z + 0.34 \ T_v - 0.4 \ \Delta p)\) - 2 energy entities,
- Combination of ground temp. and air and T fall due to pressure reduction at the regulator \((0.75 \ T_z + 0.254 \ T_v - 0.4 \ \Delta p)\) - 1 en.entity

Some international experience: Austria, Italy, Croatia

One mean temperature throughout the year
Determining parameters of gas operating condition (5)

Mean temperature obtained on the basis of mean daily temperature on those days when heating is expected

\[
K_T = \frac{T_n}{273.15 + \left(22 - \frac{SD}{BD_G}\right)}
\]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(K_T)</td>
<td>Coefficient of conversion according to temperature</td>
</tr>
<tr>
<td>(T_n)</td>
<td>Temp. of gas under <strong>standard</strong> condition, 288.15K</td>
</tr>
<tr>
<td>273.15</td>
<td>273.15 K = 0°C</td>
</tr>
<tr>
<td>(SD)</td>
<td>degree-day number: (\Sigma) (mean temp. inside of the heated premises (20°C) – mean daily temperature^\circ\text{C} \times 1\text{ day})</td>
</tr>
<tr>
<td>(BD_G)</td>
<td>Total heating days (daily and below 12°C for Serbia)</td>
</tr>
<tr>
<td>22- (SD/BD_G)</td>
<td>Operating <strong>temperature</strong> (heating compensates for the difference)</td>
</tr>
</tbody>
</table>
Determining parameters of gas operating condition (6)

Tr - Based on data from RHMZ:

<table>
<thead>
<tr>
<th>Year</th>
<th>Unit</th>
<th>Belgrade</th>
<th>Nis</th>
<th>Novi Sad</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>degree-day</td>
<td>2,715</td>
<td>2,840</td>
<td>3,067</td>
</tr>
<tr>
<td>2005</td>
<td>number of heating days</td>
<td>165</td>
<td>168</td>
<td>177</td>
</tr>
<tr>
<td></td>
<td>mean operating temperature °C</td>
<td>5.54</td>
<td>5.09</td>
<td>4.67</td>
</tr>
<tr>
<td></td>
<td>degree-day</td>
<td>2405</td>
<td>2717</td>
<td>2720</td>
</tr>
<tr>
<td>2006</td>
<td>number of heating days</td>
<td>144</td>
<td>161</td>
<td>163</td>
</tr>
<tr>
<td></td>
<td>mean operating temperature °C</td>
<td>5.30</td>
<td>5.12</td>
<td>5.31</td>
</tr>
<tr>
<td></td>
<td>degree-day</td>
<td>2,227</td>
<td>2,442</td>
<td>2,639</td>
</tr>
<tr>
<td>2007</td>
<td>number of heating days</td>
<td>160</td>
<td>171</td>
<td>184</td>
</tr>
<tr>
<td></td>
<td>mean operating temperature °C</td>
<td>8.08</td>
<td>7.72</td>
<td>7.65</td>
</tr>
<tr>
<td></td>
<td>degree-day</td>
<td>2,449</td>
<td>2,666</td>
<td>2,809</td>
</tr>
<tr>
<td>Averages</td>
<td>number of heating days</td>
<td>156</td>
<td>167</td>
<td>175</td>
</tr>
<tr>
<td></td>
<td>mean operating temperature °C</td>
<td>6.31</td>
<td>5.98</td>
<td>5.88</td>
</tr>
</tbody>
</table>
Determining parameters of gas operating condition (7)

Agency’s suggestion: 6 °C throughout the year

Public consultation results: Tr = 6 °C – Oct - Apr
Tr = 15 °C – May - Sept

Advantages: Simple application for energy entities and ease of control
Determining parameters of gas operating condition (8)

Z - gas compressibility

Energy entities mostly do not apply that for Pm ≤ 1 bar

Suboticagas, 22mbar: \(1/Z = 1,000064\)
Increases volume for 0,0064%

Gauges with correctors:
Requested data are entered and Z is automatically calculated

Gauges without correctors: \(1/Z = 1 + k \cdot Pm\)
for Pm<8bar k<0,0032
Pm ≤ 1 bar: Z=1

Agency’s suggestion For conversion by calculation – disregard
Conversion to standard condition – for households (and similar consumers)

\[ V_s = V_r \cdot \frac{P_m + P_{atm}}{P_s} \cdot \frac{T_s}{T_r} \cdot \frac{1}{Z} \]

\[ V_S = V_r \cdot k_T \cdot k_p \]

\[ k_T = 1,0322 \]

\[ k_p = f(h) \]
**Lower calorific value of ga (GLCV)**

**Agency’s suggestion**

- **Hr**: referential: three-year average LCV of imported gas
- **Hpd**: real: average LCV of gas - weighted

**Public consultation results:**

*The referential value stays the same until transfer to:*  
- Normal condition, and  
- Higher calorific value

**Advantage:** there will be no two changes in a short period of time;  
**Disadvantage:** for more than 80% of gas invoices increase by about 2%
Installation of corrector

Agency’s suggestion

1. Corrector installation criterion
   - for $P_m > 0.5$ bar – a corrector by pressure and temperature is installed, for $P_m \leq 0.5$ bar – a corrector by temperature and temperature compensator is installed

2. Correction by temperature is not done, in case
   - the metering device has a corrector by temperature (compensator), or
   - the metering device without a temperature compensator is installed inside the facility
Measuring of gas calorific value

Agency’s suggestion

The Natural Gas Transmission Grid Code passed by TSO with approval of the Agency shall determine:

- The obligation of the TSO to measure the calorific value of gas at certain system points, with certain frequency and accuracy, using a certain method

- The obligation of TSO to report to the stakeholders on daily/periodic calorific values measured
Decree modification initiative (1)

The Agency prepared:

Elements of the amendments

Decree on General Conditions for Natural Gas Delivery
Decree modification initiative (2)

1. **Method of determining operating parameters:**
   \[ Tr, Patm(h), Pr(Pm); Z(Pm) \]

2. **Application start – as per Decree**

3. **Deadlines for installation of the metering equipment**
Decree modification initiative (3)

Deadlines for installation of the metering equipment:

<table>
<thead>
<tr>
<th>Metering equipment shall have</th>
<th>Condition</th>
<th>Deadline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature compensator</td>
<td>Pm &lt; 0,5 bar</td>
<td>1. Jan. 2020</td>
</tr>
<tr>
<td>Daily protocol recorder and data processing</td>
<td>Pm &gt; 16 bar Transport</td>
<td>1. Jan. 2011</td>
</tr>
<tr>
<td>Daily protocol recorder</td>
<td>Q &gt; 500 m³/h Or Q &gt; 1 Mm³/god Distribution</td>
<td>1. Jan. 2013</td>
</tr>
</tbody>
</table>
Thank you for your attention

Any questions?

Contact:

Ljiljana Hadžibabić
Energy Agency of the Republic of Serbia,
Terazije 5/V, 11000 Belgrade, Serbia
Tel: + 381 11 30 33 829; Fax: + 381 11 32 25 780
e-mail: ljiljana.hadzibabic@aers.rs, URL: www.aers.rs