GAS INDUSTRY COMPANY LIMITED

Subject	**Gas (Downstream Reconciliation) Rules 2008**
	Billing factors guideline note
Version	**1.0**
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1. Introduction

1.1. The Reconciliation Rules include obligations on meter owners and retailers with regard to metering accuracy and conversion of measured volume to volume at standard conditions and then to energy. The purpose of this guideline note is to assist retailers and meter owners to meet their obligations under the Reconciliation Rules.

1.2. This note is explanatory in nature and is not legally binding. It needs to be read in conjunction with the Reconciliation Rules and the general approaches set out in this note in no way reduce the requirement upon allocation participants to know and comply with their obligations under the Reconciliation Rules.

2. Background

2.1. The need for billing factors arises because gas meters measure the volume of gas flowing through the meter, while customers are billed according to the amount of energy they have used. There are a number of reasons why the two are not equal. The energy content for a given volume of gas changes according to the conditions present at the time of measurement: temperature, pressure, and altitude all influence the molecular content in a measured volume of a gas. In addition, the energy content of natural gas varies, depending on the gas field it comes from (and therefore its content of hydrocarbon, and other, molecules). Billing factors are the parameters required to convert measured gas volumes into energy quantities.

2.2. This conversion occurs in several stages. First, the volume of gas passing through the meter is measured and recorded at the temperature and pressure conditions prevailing at the meter. The recorded or measured volume is then converted to volume at standard conditions, assuming the gas behaves as an ideal gas. This means that the volume of measured gas is converted to the volume it would be if it were under an absolute pressure of 101.325 kPa at a temperature of 15°C.

2.3. At high meter pressures, the assumption that the gas behaves as an ideal gas no longer holds, and the volume of the real gas will be greater than of an ideal gas, due to compressibility differences. To compensate for this situation, in installations where pressures are greater than 50 kPa, a correction for compressibility is applied to obtain the volume for the real gas.

2.4. Finally, the volume at standard conditions ("standard volume") calculated in the step above is converted to energy by multiplying by the calorific value of the supplied natural gas.

3. Governance arrangements

3.1. A number of documents govern the measurement and reporting of volumes of gas sold to customers.

3.2. The Gas (Safety and Measurement) Regulations 2010 ('Safety and Measurement Regulations') specify that:

- every person who sells gas must conform with the requirements of Part 1 of NZS5259[1] (unless seller and purchaser have agreed otherwise);
- gas is required to be sold by energy content;
- maximum permissible errors for the gas measurement system itself as well as for corrections of volume to standard conditions and for calorific value measurement must not be exceeded; and
- owners of gas measurement systems must manage those to ensure that accuracy meets the requirements of NZS5259.

3.3. The Safety and Measurement Regulations are administered by the Ministry of Economic Development.

3.4. The Reconciliation Rules set out meter owner and retailer obligations relevant to metering equipment and billing factors, and they cite NZS5259:2004 Gas Measurement as the reference standard for compliance. The purpose of the Reconciliation Rules is to "establish a set of uniform processes that will enable the fair, efficient, and reliable downstream allocation and reconciliation of downstream gas quantities". A key prerequisite for achieving that purpose is that gas be measured as consistently and accurately as reasonably possible by all allocation participants.

3.5. The Reconciliation Rules require that:

- retailers ensure metering equipment is installed and interrogated at each customer site;

[1] NZS5259 is the New Zealand Standard for gas measurement. At the time of writing NZS5259:2004 amendment 1 is in effect (the 2004 standard was amended in 2009).

- certain minimum rates of meter reading be undertaken for various allocation groups (or sites within allocation groups);
- conversion of measured volume to standard conditions and then to energy complies with NZS5259;
- meter owners ensure all metering equipment complies with NZS5259.

3.6. The Gas (Switching Arrangements) Rules 2008 ('Switching Rules') set out industry participants' obligations with respect to the gas registry. Of relevance to billing factors is each distributor's responsibility for maintaining current and accurate information in the gas registry for Network Pressure (nominal operating pressure of the network at the point of connection), ICP Altitude and Gas Gate for each ICP for which it is the responsible distributor.

3.7. Gas Industry Co is responsible for overseeing compliance with the Reconciliation Rules and Switching Rules. Under the former, Gas Industry Co commissions performance audits of allocation participants and the allocation agent on a regular basis; event audits may be commissioned from time to time in response to specific situations.

3.8. NZS5259:2004 Gas Measurement is a revision of the previous gas measurement standard NZS5259:1997. Since its release, NZS5259:2004 has been amended by Amendment No. 1, which was approved by the Associate Minister of Energy and Resources on 18 November 2009 and by the Standards Council on 24 November 2009.

3.9. In this paper, 'NZS5259' and 'the Standard' are used interchangeably to mean the most current version of the gas measurement standard.

3.10. NZS5259 comprises two main parts. Part 1 – Performance Requirements – deals with the mandatory performance criteria for gas measurement. It sets out the requirements for each of the elements of a gas measurement system together with maximum permissible errors (MPEs). Part 2 – Means of Compliance – provides a range of information with respect to the design, installation, commissioning, operation and maintenance of gas measurement systems. Of particular relevance to this guideline note is section 2.7 dealing with conversion of measured volume to standard value of energy.

3.11. In relation to the choice between using fixed factors or a conversion device, NZS5259 states that:

> Under normal circumstances, combined errors for pressure, altitude and compressibility in excess of 2% shall be regarded as unacceptable and errors in excess of 1.5% undesirable when considering the use of factors or conversion devices. If however, the individual quantity is very small, larger errors may be acceptable when the cost of avoiding these would be unacceptably high.

4. Conversion formula

4.1. The general equation governing the process of converting register readings to energy is:

$$E = V \times M \times F_T \times F_P \times F_A \times F_Z \times H$$

Where:

E is energy to be billed

V is the volume indicated by the meter (typically the difference between two consecutive register readings)

M is the register (or meter) multiplier (or 1 where no multiplier is required)

F_T, F_P, F_A, and F_Z are the correction factors for temperature, pressure, altitude and compressibility, respectively

H is the calorific value of the gas being measured, i.e. the heat content in megajoules of one cubic meter of that gas (measured at standard conditions). The calorific value of gas is readily available on the Open Access Transmission Information System (OATIS). As this factor does not require the management of specific site information, it is not mentioned further in this guideline note.

5. Billing factors

5.1. Each of the factors in the conversion formula is discussed below with a view to identifying the impact on overall accuracy and providing some guidance on the approach retailers should take to ensure compliance with the relevant governance arrangements.

Register multiplier

5.2. The register (or meter) multiplier is a fixed factor used to scale the register reading to cubic metres (uncorrected). For most meters, the register reading shows the volume, in cubic meters, of gas that has passed through the meter, uncorrected for differences in temperature and pressure from standard conditions. For these meters, no register multiplier is required; i.e. the register already shows cubic metres. In those instances, the value of M in the above equation is one.

5.3. Some meters, however, measure a proportion of the actual gas volumes that flow through them. For such meters, it is essential that the correct register multiplier be used to obtain actual gas volumes. Some meters, for example, have registers that record one-tenth of gas volumes and require a register multiplier of 10; others record ten times actual gas volumes and require a register multiplier of 0.1. Failure to use the correct register multiplier can have a large impact on volumes charged to customers and reported to the Allocation Agent.

5.4. Sources of error include:

- metering information being incorrectly recorded when meters or conversion devices are first installed, or where they are changed;
- conversion devices being incorrectly programmed;
- retailers incorrectly processing data from meter owners regarding meter or conversion device set-up;
- multiplier set-up being miscommunicated or misinterpreted when an ICP switches retailer; and
- inconsistent treatment of a fixed digit (often a trailing 0) on a meter index (either not accounted for or double counted by meter reader and retailer).

5.5. Given the potential impact that an incorrect register multiplier can have, the accuracy of this factor should be confirmed with the meter owner. There are also basic checks that retailers and meter owners can make.

Gas Industry Co expectations regarding register multipliers:

5.6. Retailers and meter owners have systems in place to verify on a regular basis that metering set-up information held by the retailer is consistent with the equivalent information in the meter owner's database (including number of dials to be recorded by the meter reader and the register multiplier). Such verification should take place at least on an annual basis.

5.7. Retailers perform regular checks to ascertain whether the consumption being recorded for a meter is consistent with the volumes for which that meter is intended.

Temperature factor

5.8. When gas becomes warmer, it expands; and when gas cools, it contracts. Thus, for a given pressure, the number of gas molecules per cubic metre changes with changes in temperature. Using a temperature factor makes allowance for this effect in converting a measured gas volume to gas volume at a standard temperature of 15°C.

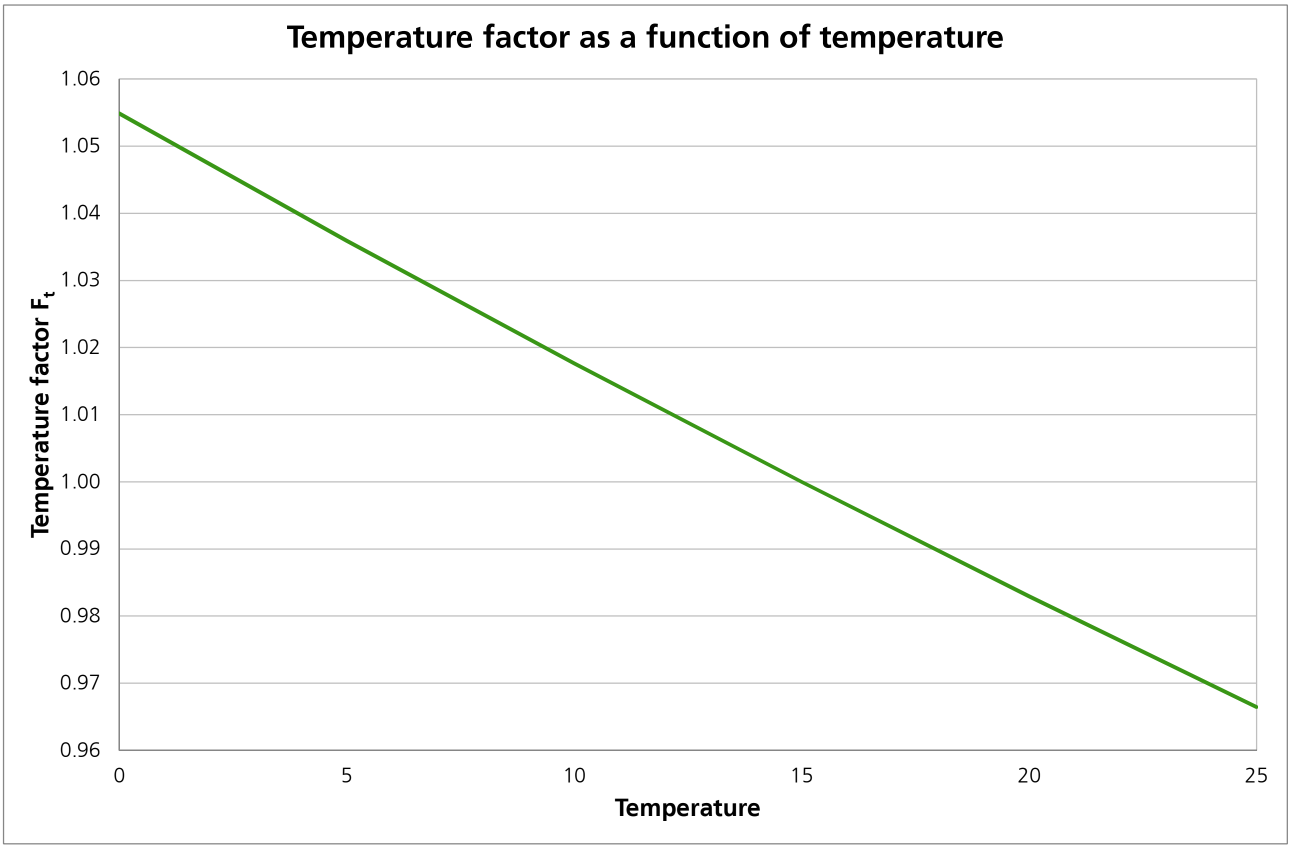
5.9. The temperature factor is calculated as[2]:

$$F_T = \frac{288.15}{273.15 + t}$$

Where *t* is the estimated average temperature of the flowing gas in degrees Celsius (taking into account any other temperature influences such as the Joule-Thomson effect).

5.10. The following chart shows the sensitivity of the temperature factor to changes in temperature. It illustrates that a variance of five degrees from the standard temperature requires a correction to the recorded volume of around two per cent.

[2] The ratio of standard temperature over the gas temperature, both expressed in degrees Kelvin.



5.11. Sites with a conversion device that includes temperature correction have a live feed from a temperature sensor located in the gas stream just upstream of the meter. The conversion device corrects for temperature in real time, so the temperature correction factor in the conversion formula for such sites is 1.0.

5.12. For sites without a conversion device and temperature correction, it is necessary to estimate the temperature of the gas stream. NZS5259 defines four options for doing this.

Options for estimating gas temperature

5.13. In the absence of actual measurements of gas temperature, NZS5259 lists the following options (in decreasing order of preference).

(a) Temperature records of the station under flowing conditions. Historical records can be used if similarity is preserved.

Comment: Would only be appropriate where a corrector with a live temperature feed had been installed at the site for some time but had subsequently been removed, or found to be faulty, and the usage remained reasonably similar to the historic usage.

(b) Records of actual gas temperature in similar installations over similar periods at similar locations may serve to estimate the value of gas temperature in the installation.

Comment: Unlikely to be a practical option for generalised application.

(c) For compact installations directly connected to short risers and well shaded from direct sunlight, where the temperature of the gas is in the vicinity of ground temperature, the temperature may be estimated from the average ground temperature at 300mm depth.

NOTE – Reliable and relevant climatic temperature data may be used as a basis for estimating average 300mm ground temperatures. This may include published data. For installations with seasonal use only, the data for the relevant season or season should be used.

Comment: Reflective of the configuration at the majority of GMS installations as the riser pipe is generally quite short, and a practical option given NIWA has many stations recording such information in areas where gas is supplied.

(d) For installations where the inlet pipes are exposed to ambient air conditions, the temperature may be estimated from the mean temperature obtained at reliable and relevant weather recording stations. For installations with seasonal use only, the data for the relevant season or season should be used. The installation should be shielded from direct sunlight.

Comment: Not reflective of the configuration at the majority of GMS installations as the riser pipe is generally quite short and the gas would be unlikely to achieve ambient temperature.

Gas Industry Co expectations regarding temperature factor:

5.14. Retailers select weather stations relevant to the area supplied by each gas gate at which they are trading. Weather stations should have at least five years of historical ground temperature data at 300 mm depth.

5.15. Retailers obtain daily or monthly average temperature data based on the previous five years of weather records for each chosen weather station.

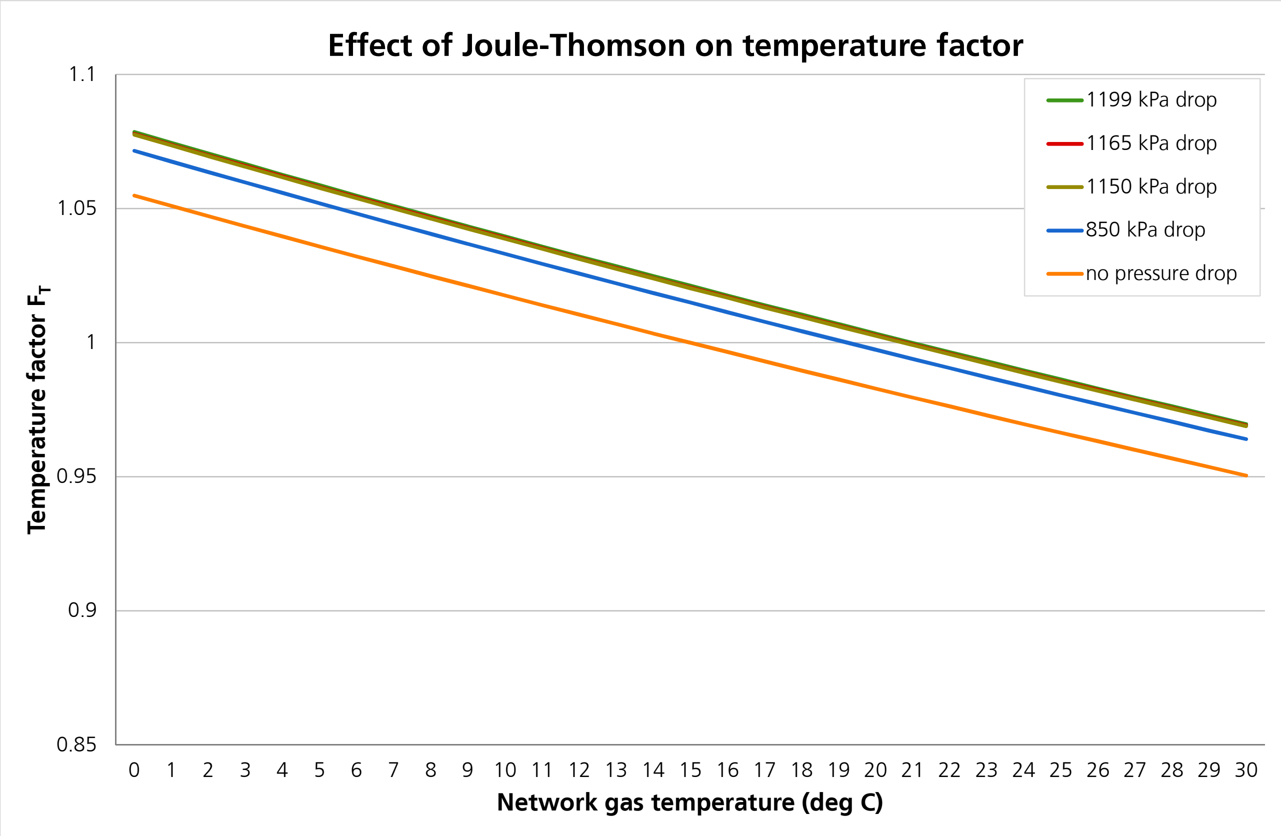
5.16. Retailers use daily or monthly average temperature data to construct average temperatures for billing and reconciliation purposes.

5.17. Retailers refresh temperature data on a regular basis, at least every five years.

Joule-Thomson effect

5.18. A related matter is the Joule-Thomson effect, which explains the decrease in temperature of a (non ideal) gas that results from pressure reduction. In situations where the pressure drop immediately upstream of the meter is of sufficient magnitude, there needs to be a correction for the Joule-Thomson effect. Failing to do so will understate gas consumption and contribute to UFG (albeit to a small level).

5.19. The magnitude of the Joule-Thomson effect can be estimated as 0.5°C for every 100kPa of pressure reduction. The chart below illustrates the effect on temperature of different pressure drops.



5.20. NZS5259 recommends that for large pressure drops or high flow rates, the actual temperature drop should be measured.

5.21. To make it possible to estimate the Joule-Thomson effect, retailers need to know the pressure drop, i.e. the difference between the inlet (i.e. network) pressure for the installation and the pressure at the meter. As noted in "*Event audit to identify sources of UFG in respect of Tawa A gas gate for May 2009 & June 2009*", in a number of instances the network pressure field has not been accurately populated in the gas registry. According to that audit report, only Nova Gas and Auckland Gas Company (both now Nova Energy) were compensating for the Joule-Thomson effect.

Gas Industry Co expectations regarding Joule-Thomson:

5.22. Network owners ensure nominal operating pressures are correctly populated in the registry for all ICPs on their networks.

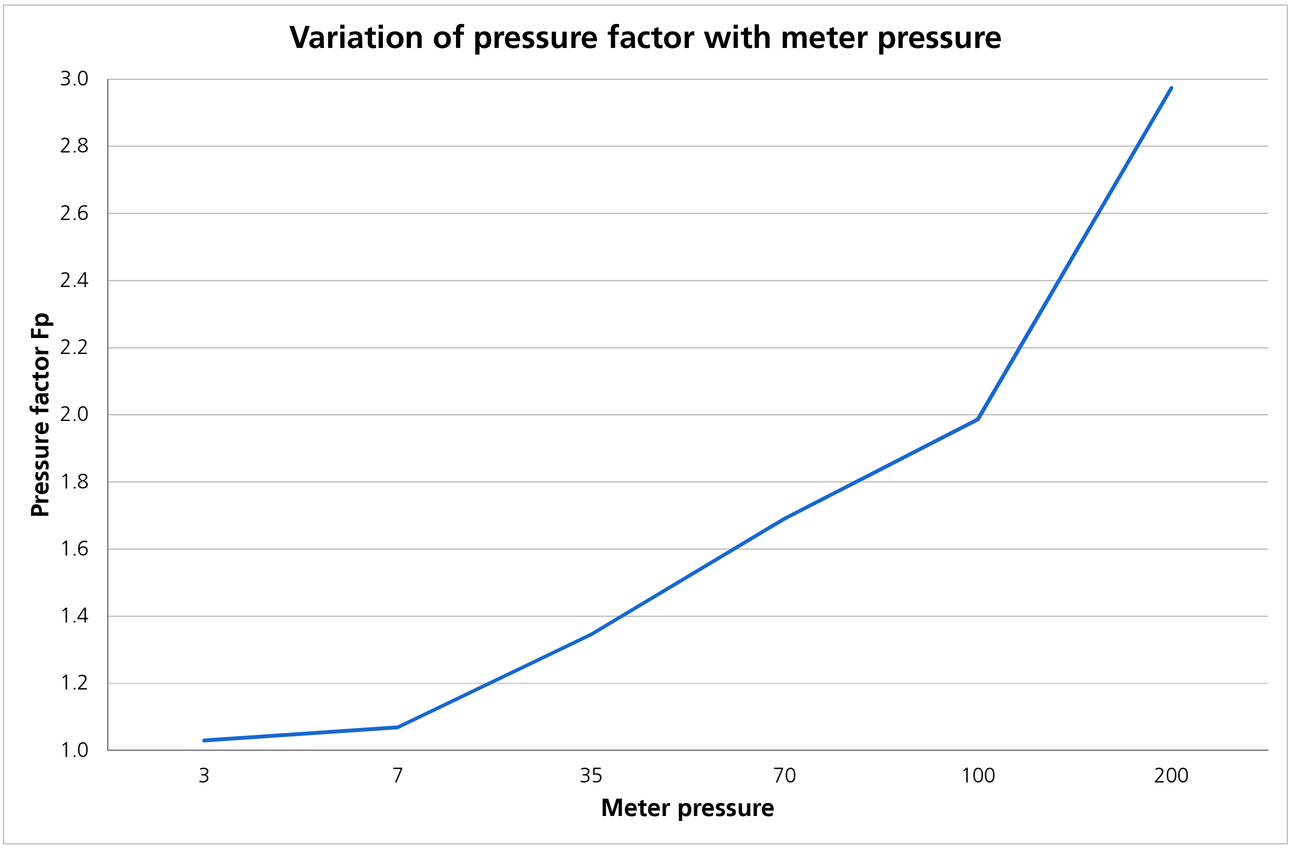
5.23. Once network pressures are correctly populated, retailers ensure that they account for the Joule-Thomson effect by using the network pressure in the registry in their conversions of metered volumes to standard volume, particularly in situations where failure to do so will result in conversion errors greater than those allowed in Table 3 of NZS5259.

Pressure factor

5.24. Increasing the pressure of a gas causes it to contract; lowering the pressure causes it to expand. Thus, for a given temperature, the number of gas molecules per cubic metre changes with changes in pressure. Using a pressure factor makes allowance for this effect in converting a measured gas volume to gas volume at a standard absolute pressure of 101.325 kPa.

The pressure factor is calculated as[3]: $F_P = \frac{P_g + 101.325}{101.325}$

Where P_g is the meter pressure (gauge) measured in kPa. Meter pressure is set by the regulator immediately upstream of the meter and it is essential that this pressure is accurate in converting measured gas volume to volume at standard conditions. The chart below shows how the pressure factor changes with changes in meter pressure.



5.25. The chart illustrates that for sites where the meter pressure is substantially greater than atmospheric pressure, the pressure factor has a dramatic effect on the conversion from volume to energy. Hence it is critical that the correct meter pressure is known and used.

[3] The ratio of the absolute pressure of the gas (the sum of gauge pressure and atmospheric pressure) to standard atmospheric pressure. The calculation assumes that the gauge pressure is measured at mean sea level. The next factor, altitude, corrects for any deviations to this assumption.

5.26. On larger customer sites, a conversion device may be installed with a live pressure feed from the gas stream just upstream of the meter. Such sites automatically compensate for meter pressure, in which case the pressure factor is 1.000.

5.27. For all other sites, it is necessary for the retailer to calculate and apply a meter pressure factor. The retailer requires an accurate figure for the meter pressure in order to be able to calculate this factor correctly. The meter owner must provide the responsible retailer with the correct meter pressure for any new connection and whenever there is any change to an installation that alters the meter pressure. When an ICP is switched, the outgoing retailer is required to provide the incoming retailer with the meter pressure and, for each register, the register multiplier and the number of dials on the register.[4]

5.28. Performance audits have identified varying degrees of inaccuracy with regard to the meter pressure stored in retailers' billing systems. Given that quite small inaccuracies in the meter pressure can result in material errors in the pressure factor, retailers should have systems in place to compare their metering set-up information with that held in the meter owner's database on a regular basis.

Gas Industry Co expectations regarding pressure factor:

5.29. Retailers and meter owners have systems in place to verify on a regular basis that meter pressure information held by the retailer is consistent with the equivalent information in the meter owner's database. Such verification should take place at least annually.

Altitude factor

5.30. The altitude factor corrects for the change of barometric pressure with change in altitude. To calculate the corrected volume, the pressure at the meter must be an "absolute" pressure value. The pressure correction factor outlined above converts gauge pressure to standard pressure presupposing that the gauge pressure is measured at mean sea level. Accordingly, a further correction must be made to account for sites at altitudes above mean sea level.

5.31. For altitudes under 1000 metres, the average barometric pressure can be approximated by:

$$P_m = 101.325 \times \left[1 - \frac{h}{k_2}\right]$$

Where:

h is the altitude in metres

k_2 = 8500 m

P_m is the calculated absolute pressure at the given altitude, expressed in kPa.

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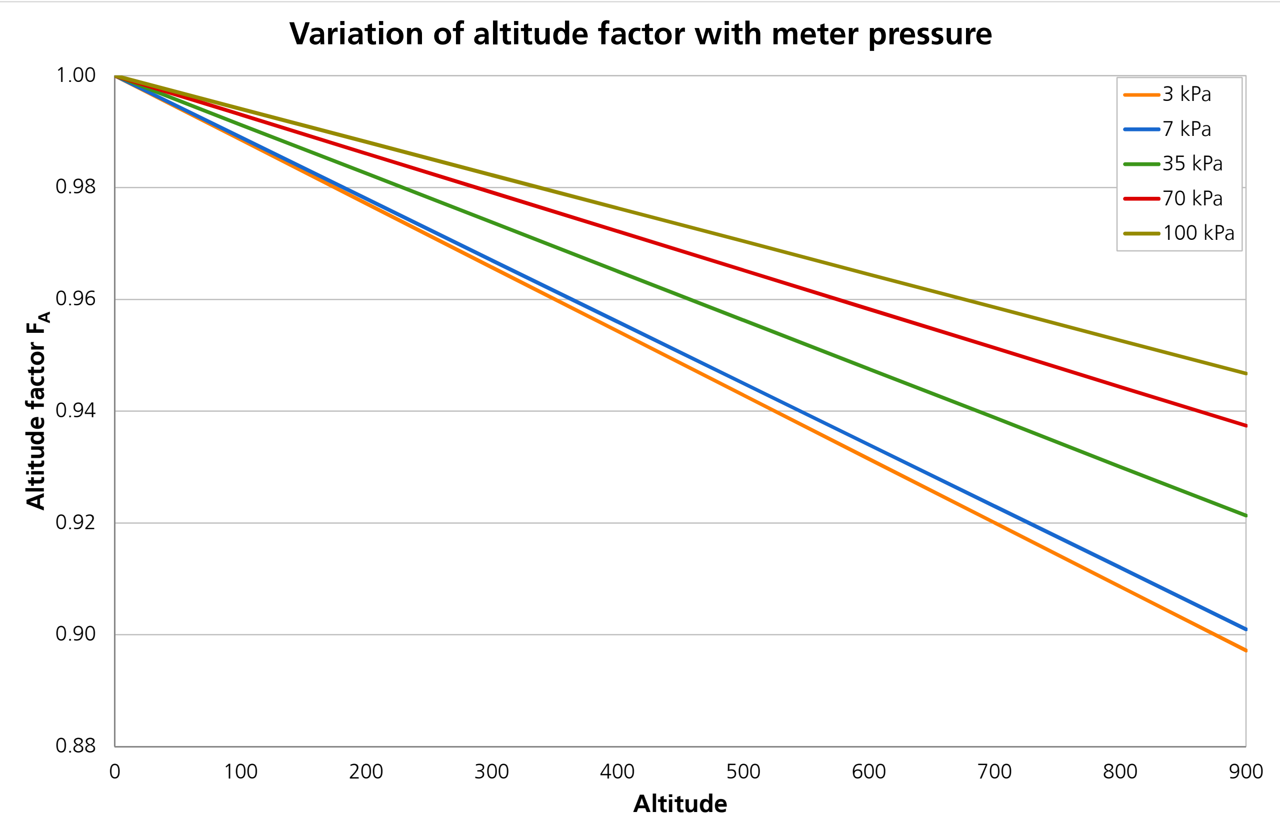
4 See rule 72 of the Gas (Switching Arrangements) Rules 2008.

As a result, the altitude factor (for a fixed factor meter) is defined as:

$$F_A = 1 - \frac{h/k_2}{F_P}$$

5.32. The chart below shows how the altitude factor changes in relation to both meter pressure and altitude.



5.33. The 2009 amendment to NZS5259 included a note that *"To minimise uncertainty due to altitude factor the aim should be to determine the altitude within 10m where practicable."*

5.34. NZS5259 indicates that areas of similar altitude may be defined and the average altitude for that area used for the purpose of calculating the altitude factor. It notes that the difference between the maximum and minimum altitudes in such an area should be such that the maximum permissible errors associated with meter pressure and altitude are not exceeded.

5.35. Table 3 of NZS5259 cites the maximum permissible errors for altitude conversion as ±1% for installations where the metering pressure is less than 100 kPa and ±0.5% otherwise. This could be interpreted as meaning that any installation with an altitude of 90 metres or less (and operating at sub-100 kPa) would not require altitude correction. However, that table also specifies in the notes that when *"factors are used to convert the measured volume to the volume at standard conditions the **combined** MPEs shall not exceed ±1.5%"* (emphasis added).

This suggests that compliance with NZS5259 does require a reasonably accurate assessment of, and correction for, altitude, so that the combined MPE of ±1.5% is not exceeded.

5.36. The programme of baseline performance audits carried out in 2010/11 identified a range of approaches to using altitude factors. The performance audits also identified that the data used to populate the altitude for ICPs on the gas registry were not of uniform quality. A significant number of ICPs on the registry have been given an altitude of zero (sea level) and sampling has indicated that the error rate among this grouping is high. Rule 58.1 of the Switching Rules requires that:

> Each distributor, retailer, and meter owner must use its reasonable endeavours to maintain current and accurate information in the registry in relation to the ICPs and the ICP parameters for which it has responsibility as set out in the Schedule.

Whilst the Reconciliation Rules place the responsibility for accuracy of metering factors on retailers, it would be efficient for retailers to source their altitude data from the gas registry, but they are unlikely to do this if the data is regarded as unreliable.

Gas Industry Co expectations regarding altitude:

5.37. Distributors populate the registry with altitude information to within 10 m for each ICP on its network.

5.38. Retailers to use ICP-specific altitude in the registry its conversions of metered volume to standard volume.

Compressibility factor

5.39. The compressibility factor FZ is used to correct for deviations from ideal gas behaviour.[5]

The compressibility factor is defined as:

$$F_Z = {}^{Z_b}/_{Z}$$

Where:

Z_b is compressibility at standard conditions for the gas being measured, and

Z is compressibility at operating conditions.

[5] Compressibility is a function of gas temperature, pressure and gas composition; and it accounts for differences between the behaviour of the measured gas compared to an ideal gas. In an ideal gas, molecules are assumed not to interact, but in a real gas, they do if the density is high enough.. At low density, gas molecules are far apart and do not interact, so the volume is similar to that of an ideal gas. At somewhat higher densities, the molecules are closer together and the interaction forces between the particles are attractive, so the volume of the gas is less than that of an ideal gas in the same conditions. At still higher densities, the molecules are excessively close together, resulting in repulsive interaction forces. This results in the volume being greater than it would for an ideal gas.

5.40. Calculation of compressibility[6] is beyond the scope of this guideline. However, NZS5259 recommends use of any of the following methods:

a) AGA 8;

b) AGA NX19; or

c) ISO 12213.

5.41. The Standard requires that a compressibility factor be applied whenever the error due to non-application of such a factor would give rise to errors in excess of the limits defined in Table 3 of the Standard (±0.2% for metering pressures below 500 kPa and ±0.25% otherwise). The rule of thumb, as recommended in NZS5259, is to correct for compressibility at pressures above 50 kPa.

5.42. In the most recent amendment to NZS5259, the committee recommended that, at the next review of the Standard, consideration should be given to removing AGA NX19 as a recommended method for calculating compressibility. The reason was that the other methods (AGA 8 and ISO 12213) are applicable over a wider range of operating conditions and gas compositions. As a result of that recommendation, retailers undertaking system changes who are currently using AGA NX19 may want to consider changing to one of the other recommended methods.

[6] Calculation of compressibility requires use of formulae that are complex and iterative.