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Minimum requirements with respect to interoperability and connection to gas supply networks

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Content

Warning

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Anybody is free to use the DVGW system of rules. Users are responsible for the proper use of the DVGW system of rules in each individual case.

Foreword

The DVGW Code of Practice on hand describes the technical requirements in respect of interoperability and connection to gas supply networks and has been formulated taking into consideration the regulations of the German Energy Industry Act (EnWG).

This Technical Rule has been compiled on behalf of the DVGW's steering committee „Gas supply" with the collaboration of interested groups. It represents an acknowledged rule of technology and is continuously adapted to the technical progress.

The DVGW Code of Practice blends in with the existing structure of laws, ordinances and technical rules for planning, construction, operation and maintenance of gas supply networks. It follows the principle of subsidiarity and, together with the DVGW system of rules and other relevant technical provisions, constitutes the minimum technical requirements. With that, objectivity and freedom from discrimination in respect of the interoperability and connection to gas supply networks is guaranteed.

Amendments

Due to the modification of the legal framework requirements and the further development of the business processes in the deregulated gas market, the following amendments of the DVGW Code of Practice G 2000:2006-10 have been made:

a) Adjustment of the definitions of sections 5.3.3 „Biogas plants" to the specifications of the amended Gas Network Access Ordinance (GasNZV)

b) Transfer of the regulations regarding the metering point operation and the measuring into the new DVGW Codes of Practice G 687 and G 689

c) Complete revision of section 6 „Technical network management" to be adapted to the further developed business processes in the deregulated gas market

d) Revision of section 7 „Data management“ to be adapted to the requirements of the electronic data interchange (EDI)

e) Inclusion of the 1. supplement to Code of Practice G 2000 „Guideline for determining the network buffer”, edition September 2007, as section 8 of this document

f) Abolition of the informative annex A „Work flow model for metered measurands for billing“

g) Editorial revision of the complete document

Former Editions

DVGW G 2000 (A):2006-10

DVGW G 2000 (A) – B1:2007-09

1 Scope

This Technical Rule describes the minimum requirements in respect of interoperability and connection to gas supply networks on the liberalised gas market. It applies to gas supply networks with gases in accordance with DVGW Code of Practice G 260, second gas family. It also applies to the feed-in of biogas according to §§ 41a ff. Gas Network Access Ordinance (GasNZV). Regarding the feed-in of gases from regenerative sources into the networks of public gas supply, the requirements of the DVGW Code of Practice G 262 are to be followed.

The application of this Technical Rule ensures the implementation of the technical requirements of EU-wide and national energy legislation. It guarantees the following in an objective manner and free of discrimination:

- the interoperability of gas supply networks
- the correct connection to gas supply networks and
- the correct handling of transportations between network operators and their shippers as well as between the network operators among each other

The generally recognised codes of practise for planning, construction, operation and maintenance of gas supply networks and systems continue to apply.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this DVGW system of rules. For dated references, subsequent amendments to, or revisions of, any of these publications do no apply. However, parties to agreement based on this DVGW system of rules are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references the latest edition of the normative document referred to applies. Listed DIN standards may be part of the DVGW system of rules.

Laws, directives, ordinances

Law on electricity and gas supply (Energy Industry Act – EnWG)

Act governing units of measurement and calibration (Weights and Measures Act)

Ordinance governing access to gas supply networks (Gas Network Access Ordinance – GasNZV)

High Pressure Gas Pipeline Ordinance (GasHDrLtgV)

Ordinance regarding framework conditions for the metering point operation and the measuring in the area of grid-bound electricity and gas supply (Metering Access Ordinance – MessZV)

Weights and Measures Ordinance (EO 1988)

Ordinance regarding general conditions of the network connection and its use for the gas supply at low pressure (Low Pressure Connection Ordinance – NDAV)

ISO Standards

ISO/IEC 8859-1, *Information technology – 8-bit single-byte coded graphic character sets – Part 1: Latin alphabet No. 1*

DIN Standards

DIN 1871, *Gaseous fuels and other gases – Density and other volumetric quantities*

DIN 4710, *Statistics on German meteorological data for calculating the energy requirements for heating and air conditioning equipment*

DIN EN ISO 3166-1, *Codes for the representation of names of countries and their subdivisions – Part 1: Country codes*

DIN EN ISO 6976, *Natural gas – Calculation of calorific values, density, relative density and Wobbe index from composition*

DIN EN 12831, *Heating systems in buildings – Method for calculation of the design heat load*

DVGW system of rules

A = Code of Practice, H = Technical Information, P = Testing Specification

DVGW G 213 (A), *Plants for the production of combustible gas mixtures*

DVGW G 260 (A), *Use of gases from renewable sources in public gas supply*

DVGW G 262 (A), *Gas properties*

DVGW G 280-1 (A), *Gas odorisation*

DVGW G 462 (A), *Steel gas pipelines for permissible working pressures up to 16 bar; installation*

DVGW G 463 (A), *Steel gas pipelines for operating pressures > 16 bar; construction*

DVGW G 465-1 to -4 (A, H), *Inspection of gas pipeline systems with an operating pressure up to 4 bar*

DVGW G 466-1 (A), *Steel gas pipelines for operating pressures > 5 bar; maintenance*

DVGW G 472 (A), *Polyethylene gas pipelines with an operating pressure up to and including 10 bar (PE 80, PE 100 and PE-Xa) – construction*

DVGW G 486 (A), *Gas law deviation factors and natural gas compressibility figures – calculation and application*

DVGW G 488 (A), *Gas property measurement stations – design, construction, operation*

DVGW G 491 (A), *Gas pressure regulating stations for inlet pressures up to and including 100 bar – design, manufacture, installation, testing, commissioning and operation*

DVGW G 492 (A), *Gas flow metering systems with an operating pressure up to and including 100 bar; design, manufacture, installation, testing, commissioning, operation and maintenance*

DVGW G 495 (A), *Gas plants and systems – maintenance*

DVGW G 497 (A), *Compressor stations*

DVGW G 499 (A), *Preheating of natural gas in gas stations*

DVGW G 600 (A), *Technical rules for gas installations (DVGW TRGI)*

DVGW G 685 (A), *Gas billing*

DVGW G 687 (A), *Technical minimum requirements on gas metering*

DVGW G 689 (A), *Technical minimum requirements on the metering point operation gas*

DVGW G 1000 (A), *Requirements on the qualification and organisation of companies for the operation of facilities which supply network-bound gas to the general public (gas supply facilities)*

DVGW GW 1200 (A), *Principles and organisation of the stand-by service for gas utilities and water distribution companies*

DVGW VP 265-1 (P), *Stations for treatment and feed-in of biogas into gas supply networks – Part 1: Gases produced by fermentation – design, manufacture, installation, testing and commissioning*

Technical directives and specifications published by Physikalisch-Technische Bundesanstalt – PTB (National Metrology Institute)

Technical Directives for Gas G 8, *Gas pressure regulating devices for gas billing*

Technical Directives for Gas G 13, *Installation and operation of turbine meters*

Technical Directives for Gas G 14, *Feed-in of biogas into the gas supply network*

PTB Specifications 50.7, Requirements on electronic and software-controlled measuring instruments and auxiliary equipment for electricity, gas, water and heat

3 Terms, Symbols, Units and Abbreviations

Allocation

Allocation of gas quantities to individual transportations, if the gas for several parties is taken over or transferred unseparatedly and is accordingly measured unseparatedly as well as the allocation of gas quantities at the virtual point.

Offtake buffering capacity N_{LA}

Useable gas volume flow (capacity) when feeding out of the linepack, specified in m^3/h at standard temperature and pressure. In the balancing group management, it is specified in kWh/h.

Exit point

A point where gas can be withdrawn from a network operator's network by a shipper in order to supply final consumers, on market area borders or with the purpose of storage.

Exit zone

Aggregation of several network connection points.

Balancing Group Code

Unambiguous code which is given by the balancing group network operator to a balancing group manager for a balancing group and which provides a basis for the identification of nominations or renominations of gas quantities.

Balancing Group Network Operator

Market area network operator or a third person authorized by one or several market area network operators with whom a balancing group can be set up and a balancing group contract will be concluded.

Balancing Group Manager

The balancing group manager is responsible for the balance of his balancing groups and takes over the economic responsibility for discrepancies between feed-in and offtake regarding his balancing group.

Biogas

A gas from renewable sources purified to natural gas properties. More detailed information may be gathered from DVGW Code of Practice G 262.

Calorific value

The heat released according to DIN EN ISO 6976 at complete combustion in kilowatt-hours per standard cubic meter. More detailed information may be gathered from DVGW Code of Practice G 260.

DVGW Market Partner Code

Alphanumeric code to unambiguously identify a market partner in the German gas market in his particular market role within the electronic data interchange.

Feed-in buffering capacity N_{LE}

Useable gas volume flow (capacity) for feeding into the linepack, specified in m^3/h at standard temperature and pressure. In balancing group management it is specified in kWh/h.

Entry point

A point where gas can be transferred into a network operator's network or subnetwork, including the transfer from reservoirs, gas production systems, hubs or mixing and conversion plants.

Entry zone

Aggregation of several entry points.

Gas properties

Properties of fuel gases. The gas properties and the requirements on fuel gases in the public gas supply are specified in technical rules. DVGW Codes of Practice G 260 and G 262 define different technical terms as well as combustion characteristics (examples: Wobbe index, calorific value and relative density). DVGW Code of Practice G 260 classifies gas families with approved fluctuation margins for gas component and gas companion substance content.

Gas business day

Definition of the day specific to the gas industry. The day begins at 06:00 a.m. (CET/CEST) and ends at 06:00 a.m. (CET/CEST) on the following day.

Gas supply network

Gas supply networks within the meaning of this Code of Practice are long-distance pipeline networks and gas distribution networks according to EnWG, comprising systems consisting of gas pipelines, gas transfer stations, metering, regulating and control stations, gas conditioning facilities, overpressure protection facilities, possibly compressor stations, all relevant remote transmission facilities as well as control and monitoring functions.

Compatibility

Adequate pressure and adequate gas properties permitting its feed-in while taking into account the provisions of the Verification Act and observing the DVGW system of rules.

Final consumers

Consumers purchasing gas for their own consumption.

Supplier

Natural or legal person whose business activity is partly or entirely geared to the sale and distribution of gas for the purpose of supplying final consumers.

Metering, control and regulating stations (MSR-Stations)

Installations in the gas supply network serving to measure the volume flow and where necessary the quality as well, to control the pressure or flow of the gas that is fed in or out and to protect the downstream network and installations against overpressure.

Measuring instrument

Instrument to record one or several physical values (e. g. gas meter, gas volume conversion device etc.).

Metering point

Location where gas is metered. At a metering point all the measuring systems/measuring instruments required to carry out billing-relevant metering of gas quantities are located.

Metering point operator

A network operator or a third party which performs the task of the metering point operation according to the Metering Access Ordinance (MessZV).

Metering service provider

According to the MessZV responsible for the meter reading of the metering facility, the verification of the metering data and the transfer of the data to the beneficiary.

Metering point operation

Installation, operation and maintenance of metering facilities.

Measuring data recording facility

Facility to record the hourly gas usage and other data on a metering point.

Network

See gas supply network.

Network connection point

A network connection point connects the gas supply network with the final consumer's technical facilities.

Network operator

Operator of gas supply networks within the meaning of §§ 3 No. 5, 6 and 7 EnWG (Energy Industry Act).

Network operator number

6-digit number assigned by DVGW to unequivocally identify a network operator during data exchange.

Network interconnection point

Connects two gas supply networks with each other.

Network gas content *NI*

The quantity of gas present in the network at the respective gas pressure.

Linepack *NP*

The linepack describes a gas network's useable volume to compensate forecast deviations and to smooth the load profile at network interconnection points or exit zones within a 24-hour interval or a longer interval.

Network Point

Generic term for exit point, entry point, network connection point and network interconnection point.

Non-useable network gas content NI_{NN}

Is the quantity of gas that has to be available in the network in order to secure the pressures required in the network for transportation.

Nomination

Declaration about the (heat) quantity (in kWh) to be transported within certain periods and for certain network points, entry or exit zones and virtual trading points.

Standard volume

Volume a gas quantity takes up at normal conditions.

Normal conditions

The normal conditions of a gas is the reference state, defined by the standard temperature T_n = 273.15 K (t_n = 0 °C) and the standard pressure p_n = 1.01325 bar [DIN 1871].

Useable content of buffer facilities allocated to the network NI_{Anl}

The useable content NI_{Anl} is determined from the geometric volume and the available pressure difference of the gas contained in this volume (spherical vessel, telescopic vessel, pipe storage).

Online metered value

Metered value that is not relevant for billing and that is transmitted at short intervals (e. g. 3 minutes) for control purposes.

Consumption metering facility (RLM)

Metering facility to measure the gas quantity with a chronological synchronised hourly registration of the metered values.

Renomination

Modification of an already released nomination before or during its validity period including a lead time for implementation.

Raw data

Unmodified data taken over from the measuring instrument or from the measuring data recording facility.

Shipper-Code

Alphanumerical code serving to make the shipper anonymous.

Transport capacity

Physical capacity of one or several hydraulically connected network elements to conduct gas volumes per unit of time.

Shipper

Wholesaler, distributor including the trading department of a vertically integrated company and end consumer. The shipper makes a contract with the network operator regarding the network access.

Virtual trading point

A virtual point where gas may be traded within a market area behind the entry point and before the exit point. A virtual trading point is not allocated to any physical feed-in or offtake/exit point. It allows buyers and sellers of gas to trade gas without any booking of network capacity.

Heat quantity

The energy content of a certain quantity of gas specified in kWh. It corresponds to the mathematical product made up of calorific value and volume at normal conditions.

Counting point designation

33-digit alphanumerical identification to unequivocally identify a counting point.

Counting point number

20-digit alphanumerical identification that is assigned by the network operator. Part of the counting point designation.

4 Description of network types and elements

4.1 Network types

4.1.1 Pressure-controlled networks

Pressure-controlled networks are maintained at the set pressure level by means of technical control devices.

4.1.2 Quantity-controlled networks

In quantity-controlled networks with predominantly higher pressure stages, set flow rates (daily or hourly quantities) are controlled. The networks' pressure as a dependent variable adjusts itself within specified limit ranges.

4.2 Network elements and their transportation capacities

Apart from pipes, a gas supply network comprises further network elements, the technical configuration of which has a considerable influence on the physical parameters of the gas flow in the gas supply network, such as e. g. pressure or volume flow. Transportation capacity describes the ability of one or several hydraulically connected network elements to transport gas volumes per hour. In the case of transportations between entry and exit point, this capacity is essentially determined by the pipe and network topography, the network elements used as well as the corresponding boundary conditions such as e. g. the availability and the level of further feed-in and/or offtakes, the respectively associated feed-in pressures, minimum pipe pressures to be made available as well as the parameters of the gas to be transported.

A gas pipe's or gas supply network's maximum available transportation capacity can therefore vary considerably from pipe to pipe or from network to network and from load condition to load condition. It has to be individually determined by the network operator according to the state-of-the-art, taking into consideration all respectively valid boundary conditions (e. g. minimum pressures, flow directions).

As a rule, the calculation of transportation capacities in gas supply networks can basically not be carried out in a completely analytical manner, but suitably complex numeric methods of calculation (algorithms) that are implemented in network calculation programs shall in fact be used. By means of simulation calculations and by varying the boundary conditions, it is possible to obtain findings in respect of the load flows and thus in respect of the available capacities.

4.2.1 Pipelines and fittings

Based on the principle of conduction and taking into consideration the equation of state for real gases according to the approach by Darcy and Weisbach, it is possible to develop the following functional correlation between capacity and initial and final pressure of a horizontally laid pipeline:

$$Q_n = \frac{\pi}{4} \times \sqrt{\frac{(p_1^2 - p_2^2) \times T_\mathrm{n}}{\rho_\mathrm{n} \times p_\mathrm{n} \times K \times T} \times \frac{d_\mathrm{i}^5}{\lambda \times L}} \tag{1}$$

The drop in pressure caused by fittings can also be formulated as a reduction in capacity by means of equivalent transformation. In principle, equation (1) applies, merely the pipe friction element

$$\lambda \times \frac{L}{d_i}$$

is substituted by the individual resistance coefficient ζ or the sum of all individual resistances $\Sigma\zeta$i. In practical application, fittings are accounted for in the calculation of transportation pipelines by applying an integral pipe friction factor.

If the pipeline overcomes a geodetic difference in height between its start and end point, the pressure change caused by the change in potential energy has to be additionally allowed for:

$$\Delta p_\mathrm{h} = (\rho_\mathrm{Luft} - \rho_\mathrm{Gas}) \times (h_2 - h_1) \times g \tag{2}$$

Considering the influence of the geodetic height, a pipeline's capacity therefore becomes

$$Q_n = \frac{\pi}{4} \times \sqrt{\frac{(p_1^2 - e^{\xi} p_2^2) \times T_\mathrm{n}}{\rho_\mathrm{n} \times p_\mathrm{n} \times K \times T} \times \frac{d_\mathrm{i}^5}{\lambda \times L} \times \frac{\xi}{e^{\xi} - 1}} \tag{3}$$

with

$$\xi = \frac{2 \times \rho_\mathrm{n} \times g \times T_\mathrm{n}}{K \times T \times p_\mathrm{n}} (h_2 - h_1) \tag{4}$$

In the case of horizontal pipelines ($h_1 = h_2$), the last term under the root converges towards one, and with that equation (1) is once more obtained.

4.2.2 Compressor stations

Compressor stations serve to increase the pressure in the gas supply network (see also DVGW Code of Practice G 497). The requirements for compressor stations for the feed-in of biogas into gas supply networks are specified in DVGW Testing Specification VP 265-1.

The power P_{Gas} necessary to compress the flowing gas is a mathematical product made up of the mass flow rate $\dot{m}$ and the enthalpy change Δh_i. Considering of the mechanical efficiency

$$\eta_m = \frac{P_{Gas}}{P_K} \tag{5}$$

and the isentropic efficiency

$$\eta_s = \frac{\Delta h_s}{\Delta h_i} \tag{6}$$

results in the simplified equation for a compressor station

$$Q_n = \frac{P_K}{\rho_n \times \Delta h_s} \times \eta_m \times \eta_s \tag{7}$$

with

$$\Delta h_s = \frac{\chi}{\chi - 1} \times Z_1 \times R_s \times T_1 \times \left[\left(\frac{p_2}{p_1} \right)^{\frac{\chi - 1}{\chi}} - 1 \right] \tag{8}$$

The following guide values can be specified for the efficiency of the two compressor designs „reciprocating compressor“ and „turbo compressor“

Table 1 – Guide values for the efficiency reciprocating compressors and turbo compressors

Compressor type	η_m	η_s
Reciprocating compressor	0,8 … 0,9	0,9
Turbo compressor	0,8 … 0,9	0,6 … 0,85

4.2.3 Pressure regulating stations

Pressure regulating stations serve to reduce or maintain the pressure in the downstream networks and stations and to protect them from overpressure (see DVGW Code of Practice G 491 and G 495). Pressure regulating stations consist of a number of components arranged in series and/or parallel (fittings, filters, regulators, heat exchangers, pulse signal and control lines, valves and shut-off devices). An important system component is the actual restriction (pressure or quantity control device). For this, the flow rate can be described as follows:

$$Q_n = A_D \times p_1 \times \psi \times \sqrt{\frac{1}{\rho_n \times p_n} \times \frac{T_n}{T}} \tag{9}$$

with

$$\psi = \sqrt{\frac{2 \times \chi}{\chi - 1} \times \left[\left(\frac{p_2}{p_1} \right)^{\frac{2}{\chi}} - \left(\frac{p_2}{p_1} \right)^{\frac{\chi + 1}{\chi}} \right]} \tag{10}$$

If the control device manufacturers make available alternative calculation methods to determine the valves' capacity, these may be used. The maximum flow rates of the other plant components (e. g. safety devices, filters) are as a rule recorded empirically for the respective design and may be gathered from the manufacturers' data sheets. The preheating unit's dimensioning may constitute a further limiting factor. (See also DVGW Code of Practice G 499 in this regard). The overall capacity of the pressure regulating station is then determined by its weakest component's maximum capacity.

4.2.4 Metering stations

Metering stations serve to record gas quantities, loads and qualities (see DVGW Code of Practice G 488, G 492, G 495 and G 685 in this regard). In metering stations, different metering configurations with different metering instruments (e. g. turbine meters, lobed-impeller flow meters, vortex flow meters, ultrasonic flow meters) are implemented. The maximum flow rates of these may be gathered from the manufacturers' approval documents and the gauging inspections.

4.2.5 Gas odorisation

The odorisation of the inducted gas has to be effected in accordance with DVGW Code of Practice G 280-1 and according to the specific conditions of the network operator whose network is being used.

4.2.6 Gas conditioning stations

Gas conditioning stations serve to modulate gas properties (see DVGW Code of Practice G 213). They consist of technical components in which gas flows of different composition are mixed in a controlled manner. In individual facilities, air, liquefied petroleum gas or nitrogen are for example added to adjust the Wobbe index and the calorific value. For this purpose, further systems (air compressors, air decomposition facilities) may be required.

The conditioned gas has to comply with the provisions of DVGW Code of Practice G 260 and G 262. With respect to gas billing the requirements stated in DVGW Code of Practice G 685 must be observed.

5 Technical requirements on network operation, network connections and installations

Planning, construction, operation and maintenance of gas supply networks is carried out in accordance with the legal provisions, in particular the High Pressure Gas Pipeline Ordinance (GasHDrLtgV) and the applicable technical rules of the DVGW, in particular the DVGW Codes of Practice G 213, G 260, G 262, G 280-1, G 462, G 463, G 465, G 466, G 472, G 488, G 491, G 492, G 495, G 497 and G 685 and DVGW Testing Specification VP 265-1.

5.1 Network operation

5.1.1 Network operation planning

Planning the network operation serves to operate the gas supply network in accordance with the regulations.

5.1.2 Execution of network operation

The execution of network operation follows the planning specifications and within the scope of continuous network monitoring ensures that malfunctions are avoided with available operational possibilities and resources or are managed or limited in their effects.

5.1.2.1 Normal operation

During normal operation, all significant operating and compatibility parameters are adhered to and the agreed transportation capacity is available.

5.1.2.2 Restricted operation

Predictable measures (e. g. maintenance measures as necessary according to DVGW Code of Practice G 466/I or G 495) on pipelines, compressors, measuring and control systems, may lead to temporary restrictions of the transportation capacity of the respective network operator. Any further network operators and, if agreed, shippers affected by this are informed of the estimated duration and scope of transportation restrictions.

5.1.2.3 Faulty operation

All conditions that deviate from normal operation or restricted operation can be allocated to faulty operation.

If faulty operation occurs, the network operator will take all technically necessary measures to prevent a spreading of the fault and to efficiently re-establish transportation (fault management). These take precedence over the individual interests of shippers.

The network operator ensures fault management on the basis of DVGW Codes of Practice G 1000 and GW 1200.

5.2 Minimum technical requirements for network connection

According to § 19 EnWG, operators of gas supply networks have to establish „Minimum technical requirements for the design and operation of the network connection to their network“ and publish these specifications on the Internet.

These minimum technical requirements follow the statutory provisions and generally recognised codes of practice. Due to special operational and local boundary conditions, additional network-specific requirements may exist which are integrated in the respective network operator’s minimum technical requirements.

A network connection within the meaning of this system of rules may be effected at network interconnection points, entry points and offtakes, including network connection points.

5.2.1 Network interconnection point

A network interconnection point connects two gas supply networks. Delimitation criteria can be among others ownership, network operator, network characteristic or gas qualities. At least one metering and where necessary regulating station is allocated to every network interconnection point in order to meter, record and where necessary control the gas quantities delivered. Network operators may agree to combine suitable network interconnection points (e. g. to an exit zone) for processing purposes.

These stations allocated to a network interconnection point shall be equipped with the necessary equipment for flow metering and where necessary standard volume conversion, measuring data collection and recording, gas properties measuring stations, switching and operating status supervision, remote control, long-distance transmission and long-distance read out systems according to the respectively valid statutory provisions and the generally recognised codes of practice, e. g. the DVGW system of rules and the DIN standards as well as the network operators' specifications.

Changes to the metering station require the prior approval of the network operators adjoining the network interconnection point.

Compliance with compatibility requirements shall be ensured at a network interconnection point.

The unambiguous designation of the network interconnection points is regulated in Section 7.2

5.2.2 Entry point

The operator of the network into which the gas shall be fed has to verify whether the gas supply network is basically able to receive the gas quantity to be fed in (both capacitive and hydraulic). In other respects, the same provisions as for network interconnection points apply.

5.2.3 Exit point

The operator of the network from which the gas is to be withdrawn has to verify whether the gas supply network is basically able to deliver the gas to be fed out (both capacitive and hydraulic). In other respects, the same provisions as for network interconnection points apply, except in the special case of the network connection point.

5.2.4 Network connection point

Technical equipment is allocated to a network connection point to process and bill transportations and deliveries. One or several final consumers are allocated to a network connection point.

For processing and billing of transportations, technical requirements have to be met at the final consumer's so as to measure or establish, to record, to telemonitor and where necessary to control the gas quantities, and where necessary, hourly consumptions delivered by the shipper.

The equipment required in this regard has to be provided with flow metering and where required with measuring data collection and recording systems, long-distance switching status supervision, long-distance read out and long-distance transmission systems, standard volume conversion and gas property measuring stations.

For a metering station with recording consumption metering, the subscriber permanently makes available at no charge a low-voltage connection and where necessary a suitable communication connection in the immediate vicinity of the metering point. The network operator coordinates the details with the subscriber.

In case the communication connection is missing, not available in due time or permanently faulty, the metering point operator specifies an alternative transmission method.

For the network connection point, at least the following topics have to be set out in writing:

- Connection point, property boundary

- Volume rating
- Provisions for the proper operation of the customer installation (e. g. acc. to TRGI)
- Obligations of the network connection customer regarding the protection of technical equipment
- Provisions in respect of access right and property use
- Installation, operation and reading of control and measuring facilities
- Technical requirements for a delivery block
- Decommissioning of the connection

In respect of the relationship between network operator and final consumer, at least the following has to be set out in writing:

- Regulations regarding the proper operation of the customer system (e. g. acc. to TRGI).
- Where necessary, the volume rating
- Obligations of the network connection customer regarding the protection of technical equipment
- Provisions regarding access right and property use
- Installation, operation and reading of control and measuring facilities
- Requirements for a delivery block
- Provisions in case a supplier does not supply the final consumer (partial or complete supplier failure)

5.2.5 Network connection for biogas feed-in

The biogas network connection comprises the connecting pipe which connects the biogas treatment plant with the existing gas supply network, the link with the connecting point of the existing gas supply network, the calibratable metering of the biogas to be fed in as well as, if applicable, the gas pressure regulating station or a facility to increase pressure and remote control systems.

The use of a network connection may technically demand from the network operator to set up and operate technical facilities (e. g. conditioning plant, liquefied petroleum gas tank, odorisation plant, etc.). The network operator and the connection user agree upon the details.

The network connection is designed for a certain gas property area within the DVGW Codes of Practice G 260 and G 262 and contractually agreed upon between the network operator and the connection user (according to § 41b GasNZV).

Regarding biogas network connections the following points have to be fixed in writing:

- Connecting point, property line
- Connecting values (flow range, pressure range and temperature range)

- Regulations regarding the correct construction and acceptance of the biogas treatment and feed-in plant (e. g. according to DVGW Testing Specification VP 265-1)
- Gas property range of biogases after the biogas treatment process
- Provisions in respect of access right and property use
- Installation, operation and meter reading of the controlling and metering systems
- Decommissioning of the connection

5.3 Minimum technical requirements on installations in network connections

5.3.1 General Requirements

The billing relevant parameters of the inducted and off-taken gas are to be registered metrologically.

The odorisation of the inducted gas has to be effected according to the DVGW Code of Practice G 280-1 and in accordance with the specific conditions of the operator of the subsequent network.

The starting-up of feed-in and offtake facilities has to be coordinated with the network operator.

The requirements of the network operator on online-flow-control (OFC) and control equipment (e. g. operational state in the metering system) including the communication facilities have to be considered.

5.3.2 Planning, construction and operation of gas pressure regulating and metering stations

In particular the DVGW Codes of Practice G 488, G 491, G 492, and G 495 are applicable for planning, construction and operation.

The gas pressure regulating and metering stations serve to expand, meter and, where necessary, odorise the purchased gas. Planning and construction as well as operation and maintenance of the gas pressure regulating and metering station (including buildings) is generally carried out by the operator of the downstream network, in the case of network connection points by the network operator or the subscriber.

Prior to the construction of a gas pressure regulating station and metering station by the subscriber, network operator and subscriber agree on the intended system configuration. For this purpose, the subscriber makes available drawings and adequate documentation in good time. This provision also applies to modifications to existing systems.

Essential components of gas pressure regulating stations are listed in DVGW Code of Practice G 491.

The subscriber informs the network operator before the construction work of the station commences. The dates of testing, accepting and commissioning the facility are to be communicated to the network operator in good time and if necessary coordinated with him. The testing of the completely assembled system including electrical engineering is carried out by the persons nominated for this purpose in the DVGW system of rules. The network operator is entitled to send representatives to this test. The work carried out and the periods of attendance shall be recorded in an appropriate manner.

In coordination with the subscriber, the network operator can specify further measures serving the safety and reliability of the system itself as well as the protection of upstream or downstream networks.

All the above-mentioned provisions apply to entry points accordingly.

5.3.3 Special requirements on metering points

According to the German Verification Act, only approved and calibrated measuring and auxiliary devices may be used in commercial dealings. The requirements of the PTB (e. g. TR G 8, G 13 and G 14) and the DVGW Codes of Practice (e. g. G 492, G 685, G 687, G 689, G 486, G 488, and G 600) shall be adhered to. The minimum technical requirements on the operation of metering points have been summarised in DVGW Code of Practice G 689.

The network operator may determine supplemental conditions in addition to the technical minimum requirements regarding the metering point operation.

At metering stations without consumption metering the hourly values are determined by the network operator with the aid of standard load profiles. The network operator defines the process (analytically or synthetically) and delivers the necessary information for the procedure.

5.3.4 Facilities for treatment and feed-in of biogas into gas supply networks

Planning, construction, operation and modifications of these technical facilities have to be effected according to the generally recognized regulations of technology, especially the technical regulations of DVGW, the DIN standards and the guidelines of the network operators. The adherence to the DVGW Testing Specification VP 265-1 is of particular importance.

5.3.5 LNG plants

Basically all regulations and directives applicable in the Federal Republic of Germany for planning, construction and operation of LNG plants have to be observed, even if they are not expressly mentioned in the network operator’s minimum technical requirements.

LNG shall be fed in gaseous phase. The downstream gas supply network operator’s specifications in respect of temperature, pressure and feed-in quantity shall be observed.

6 Technical network management

In addition to securing the network stability and maintaining the security of supply, technical network management aims at making available the gas quantities at the exit point provided by the shipper according to the respectively valid relevant regulations necessary to carry out transportations. The network operator is responsible for performing the agreed transportations within his gas supply network and for coordinating the other network operators involved in the transportation. All valid statutory regulations are to be applied, in particular the German Energy Industry Act (EnWG) as well as the Gas Network Access Ordinance (GasNZV).

6.1 General provisions

In order to duly handle the transports, the network operator has to receive information regarding the quantities to be transported, and has to exchange and align transportation-relevant data in respect of the network interconnection points and network connection points with the network operators of the respective upstream and downstream networks or subscribers.

6.1.1 Nomination procedure

Nominations serve as a basis for the quantities to be allocated and if applicable controlled at an entry point, exit point, virtual trading point, market area border point or cross border point within a certain period, if nominations are required at these points. Data exchange between the network operators is necessary for transportation handling, in particular for nomination balancing, and for network control and allocation. The network operator will set up suitable procedures if no valid nominations are available.

The following types of nomination may be used:

- Long-term nomination (by arrangement)

Long-term nominations are carried out irrespective of the nomination time limits listed below. Long-term nomination can be agreed upon between shipper and network operator.

- Weekly nomination

The shipper declares every week at certain agreed times his transportation requirement for every day of the following week. Weekly nomination can be agreed upon between shipper and network operator.

- Daily nomination

The shipper declares the hourly quantities to be transported on the following day to the network operators every day. This declaration has to arrive by 2:00 p.m. the previous day. If no daily nomination is available, the values from the last weekly or long-term nomination valid for the respective period are adopted, if these are available.

- Renomination

The shipper can only change his already nominated transportation requirement with the network operator by means of a renomination for a future period. A lead time of two hours to the next full hour applies to changes of the current gas business day, before changed values take effect. Shippers have the possibility to renominate for every hour of the gas business day. Deadline for renomination for the first hour of the following day is 4:00 a.m. on the previous day; deadline for renomination for the last hour of the current gas business day is 3.00 a.m.

6.1.2 Nomination replacement procedure

Notwithstanding the methods mentioned under 6.1.1, network operator and shipper may agree upon alternative methods.

One example is the provision of online data. The shipper arranges for the provision of online measurements for the transport-relevant exit point.

With the aid of these online measurements, the network operators are able to offer an online control. A prerequisite for this procedure is that the measurement is transmitted by cyclic online remote data transmission.

6.1.3 Regulatory requirements between shipper and network operator and among network operators

Network operators and shippers have to exchange all necessary information in order to carry out transports. With respect to transports exceeding networks, there are further agreements necessary between network operators. Details on the necessary information result from laws, ordinances and regulations as amended as well as from the industry agreements which are based on them.

6.2 Handling of transportations

6.2.1 Availability and communication test

The network operator and the shipper or his representative (person responsible for balancing group) undertake to be available 24 hours a day on every gas business day. Availability has to be ensured at least by telephone under one telephone number only and if possible via another communication channel.

Before the start of the first transportation, the network operator may demand a communication test with the shipper or his representative. During this communication test, the network operator verifies whether his communication requirements have been met and whether the shipper or his representative are able to send messages and notifications concerning transportation handling to the network operator as well as to receive and process messages and notifications from the network operator. The network operator informs the shipper or his representative about the result of the communication test.

6.2.2 Nomination

The shipper nominates the quantity to be transported to the network operators in accordance with the procedure agreed upon in section 6.1.1 and 6.1.2.

As a rule, the network operator confirms the due receipt of the nomination by means of automated procedures.

The nomination may be rejected if contract parameters are being violated or the required information are lacking.

6.2.3 Nomination balancing (Matching)

Balancing of the nominations made to the network operator is carried out if and as far as this is requested by one of the network operators and if this is necessary and appropriate from a transportation point of view. Balancing is based on hourly values.

Transportations to be handled have to be unambiguously allocated to balancing groups or shippers by balancing group code or shipper codes.

The network operators exchange the information in respect of the quantities nominated for transportation and compare it to the nominations per balancing group code pair and where necessary shipper code pair available to them for the same validity period. In case of differences in the nominations, the balancing rules agreed upon for the network interconnection point are applied. The balancing rules take into account both the quantity as well as its direction of flow.

The network operators inform themselves about the balancing result. This is done

- daily by 4:00 p.m. on the previous day as well as
- after the receipt of renominations up to the full hour after next

The shipper is informed if any differences occur during balancing of his nominations and is requested to make corrections, unless something to the contrary has been agreed upon.

6.2.4 Network control

Based on these nominations and taking into consideration the balancing results and the technical condition of the network, schedules for the following period are compiled for quantity controlled networks. These schedules serve as basis for quantity control at the relevant entry and exit points.

During restricted or faulty operation, (see section 5.1.2), curtailments for one or several shippers at entry and exit points may occur. The following procedure is applied in this connection:

- If the shipper is the problem originator and has been positively identified as such, only this party is curtailed.

- Otherwise, bilateral regulations by the network operators are required.

6.2.5 Quantity allocation

The allocation of feed-in and offtake quantities becomes necessary if the gas from several shippers at one of the network points defined in section 5.2 is transferred or handed over unseparatedly and is accordingly measured unseparatedly. This allocation is carried out on the basis of measurements of the nominations confirmed – if applicable after application of nomination balancing – and on the basis of the allocation procedure specified for the respective network point.

Every network operator informs his shippers, as far as necessary, about the allocation procedure applicable for their transportations. Allocation results relevant for the respective transportation at the network points are determined and made available by the network operator.

6.2.5.1 Allocation according to declaration

In case of allocations according to declaration, all quantities are allocated according to confirmed nominations. The differences between the measured hourly gas quantity and the sum of the nominated gas quantity of the same hour are balanced as agreed upon in a network operator steering account to be arranged for.

The network operators specify the boundary conditions for this procedure's applicability.

6.2.5.2 Allocation according to quantity

In case of allocations according to quantity, the measured quantity is for every hour apportioned to the individual transportations at the ratio of the respectively confirmed nomination to the total confirmed nominations (pro rata).

6.2.5.3 Further allocation procedures

The network operators involved can agree on mixed forms of the allocation procedures described above. In the process, notwithstanding the principle of using confirmed nominations, it is also possible to allocate the quantity measured at the network point on the basis of quantities measured at offtakes for final consumers. Measurement substitute procedures, such as standard load profiles, can be taken into account in this connection.

The network operators specify the boundary conditions for this procedure's applicability.

6.3 Balancing Group Management

Balancing serves the purpose of verifying the due handling of transportations. The Balancing Group Network Operators are responsible for compiling and maintaining consistent balancing models. These are based on balancing groups combining feed-in and offtakes.

After transportation, balancing group network operators maintaining balancing groups compare the feed-in and offtake quantities and provide the balancing group manager with information in respect of the balancing status in accordance with their current level of information.

Details are derived from the applicable requirements and the constitutive industry agreements.

7 Data management

7.1 General

The Energy Industry Act, the Gas Network Access Ordinance and regulations of the Federal Network Agency define the standardisation and automation of business processes which in turn lead to numerous monthly, daily or under daily processes to be automatised and processed in a non-discriminating way. To carry out these processes all participants have to communicate all information which are required for the complete realisation of each process step. Regarding the handling and exchange of data, normally electronical messages with the data format UN/EDIFACT have to be applied. The types of messages required for the corresponding processes are published by the project leading organisation, the BDEW, under the professional participation of the DVGW on the platform EDI@Energy.

The data transfer and the remote control (e. g. process data, transmission route, transmission system, etc.) have to be agreed upon between the market partners involved.

7.2 Unambiguous designation of network interconnection points

A consistent and unambiguous designation is the prerequisite for an unambiguous, permanent identification of network interconnection points. This facilitates consistent, not-direction-bound transportation processing between shipper and network operator as well as between network operators. The network interconnection points are encoded in accordance with the method used by the EASEE-gas workgroup „Message and Workflow Design“ according to the ETSO/EIC diagram for encoding cross-border network interconnection points. For Germany, the unambiguous designation (ETSO/EIC code) is allocated by the DVGW according to the structure quoted below and recorded in a list. The network operators provide the DVGW with complete and up-to-date information in this regard.

The designations of all German network interconnection points are recorded in a list compiled and updated by the DVGW and comprising at least the following contents:

- ETSO/EIC code
- Designation/location of network interconnection point network operator 1 (plain text)
- Name of network operator 1 (plain text and DVGW network operator designation)
- Designation/location of network interconnection point network operator 2 (plain text)
- Name of network operator 2 (plain text and DVGW network operator designation)

Structure of network interconnection points' designation (ETSO/EIC code)

Coordinating authority	*identification network interconnection*	*Spare*	*Designation*	*Check character/ check sum*
Example:				
3 7	*Z*	*0 0 0 0*	*1 2 3 4 5 6 7 A*	*9*

Coordinating authority 37 = DVGW
(coordinating authority for national network interconnection points)

21 = EASEE-Gas Workgroup „Message and Workflow Design"
(coordinating authority for cross-border network interconnection points)

Identification network interconnection **Z**

Spare (Example: 0000)

Designation (Example: 1234567A)

Check character/check sum (Example: 9)

7.2 Counting point designation

The network operator ensures that every metering point in his network receives an unambiguous, permanent, alphanumeric designation according to the structure shown below for the exchange of information.

The unambiguous designation ensures that measurements for an unambiguously allocatable metering point are made available to all authorised partners and that, in view of the provision of information about the data determined at the metering point, misunderstandings and faulty allocations of recorded data are avoided.

The designation shall be known to the respective partners and documented accordingly in the billing-relevant documents.

Structure of counting point designation

Country	Network operator (6 digits)	Postal code (5 digits)	Counting point number (20 digits alpha-numeric)
Example:			
D E	7 0 0 5 6 2	6 6 8 0 2	A O 6 G 5 6 M 1 1 S N 5 1 G 2 1 M 2 4 S

Country: International country identification (acc. to EN ISO 3166-1)
Germany = DE

Network operator: 6 digit number of network operator

Allocation of network operator numbers is carried out by the DVGW. The network operator has to apply for the network operator number at the DVGW.

Note: A counting point designation once assigned will not be changed. This also applies in case, e. g. when in the process of a company fusion, another network operator gets responsible for the operation of the network in which the metering station is located and thus the network operator number for the corresponding network changes.

Postal code: 5 digit postal code of the allocated location

Counting point No: 20 digit alphanumeric identification of the metering point

The network operator ensures that the designation in his network area is unambiguous. Capital letters A-Z and numbers 0-9 from character set ISO/IEC 8859-1 (Western Europe) are used to represent the 20-digit network operator counting point number. In case of comparative metering records, a separate counting point number has to be allocated in each case. Counting point numbers for virtual metering points are also allocated by the network operator who defines this metering point. For a metering point with two flow directions only one counting point number will be assigned.

7.4 Time basis and billing cycles

Standard time shall be applied to data provision, balancing and billing. A billing cycle commences at the full hour. The smallest billing cycle is one hour.

7.5 Recording and transmission of metering data

The metering point operator is responsible for the devices for recording, registration and transmission of metering data as well as for the access to the metering data facilities. The minimum requirements for the operation of metering stations are laid down in the DVGW Code of Practice G 689 „*Technical minimum requirements on the metering point operation gas*“. Regardless of these facts, it has to be considered that in the course of business only those values may be stated for the volume which have been collected with a calibrated meter or those values for the thermal energy or thermal output of gases which have been determined by a calibrated metering tool or according to recognised rules of technology (DVGW Code of Practice G 685 „Gas billing“) (§ 25 Calibration Law, § 10 Calibration Ordinance).

The metering service provider carries out the metering data collection and delivers the results to the persons in charge. The DVGW Code of Practice G 687 „Technical minimum requirements on gas metering" describes the personal, economical and technical minimum requirements on metering service providers according to MessZV § 13.

The relation of network operators amongst each other is also defined by these regulations for the recording and transmission, processing and exchange of energy data.

8 Determining the linepack

The following chapter describes the gas containing network components and the basic rules to determine the linepack capacity of the gas supply network from a technical point of view.

It is the respective network operator who makes the commercial decision on the availability of the linepack. The processes and communication paths required are described elsewhere and are not a subject matter of this DVGW Code of Practice.

In addition to the linepack capacity offered by the actual gas supply network, further buffer volumes of possibly existing pipe storages and/or spherical storage vessels may be available. The description of these elements is also not a subject matter of this DVGW Code of Practice.

8.1 Fundamentals regarding the determination of the linepack

8.1.1 General

8.1.1.1 Prerequisites

The minimum network gas content to ensure the transportations is defined by the minimum feed-in pressure p_{ETV}. A systematic use of the linepack presupposes a useable pressure difference between the actual feed-in pressure p_E and the minimum required feed-in pressure p_{ETV}. Quantity-controlled network entries are necessary for this. Feed-in quantities are as a rule controlled by the network operator's dispatching. The network operator has to guarantee the respective minimum pressure p_{Amin} required at all exit points at all times.

8.1.1.2 Methods of calculation/determination

The linepack results from the difference between the maximum network gas content determined and the non-useable network gas content.

The network gas content can be determined by using different methods. The method to be applied depends on the available metered values and initial data as well as on the network structure.

- Calculation of the network gas content based on pressures measured at relevant entry and exit points (determination of missing pressures by means of interpolation). The network's geometric volume must be known for this method.

- Calculation of the network gas content by means of dynamic network simulation based on measured entry and exit load profiles and on the pressures at the entry points.

The linepack may also be determined by balancing inflows and outflows (quantity measurement of all entry and exit points).

For a pipeline section, the basis of calculation is specified below. In the case of branched networks, pipeline sections must be combined accordingly. In the case of complex intermeshed networks, it is necessary to use network simulation programs.

8.1.2 Designations and calculation formulae for different network gas contents

8.1.2.1 Network gas contents

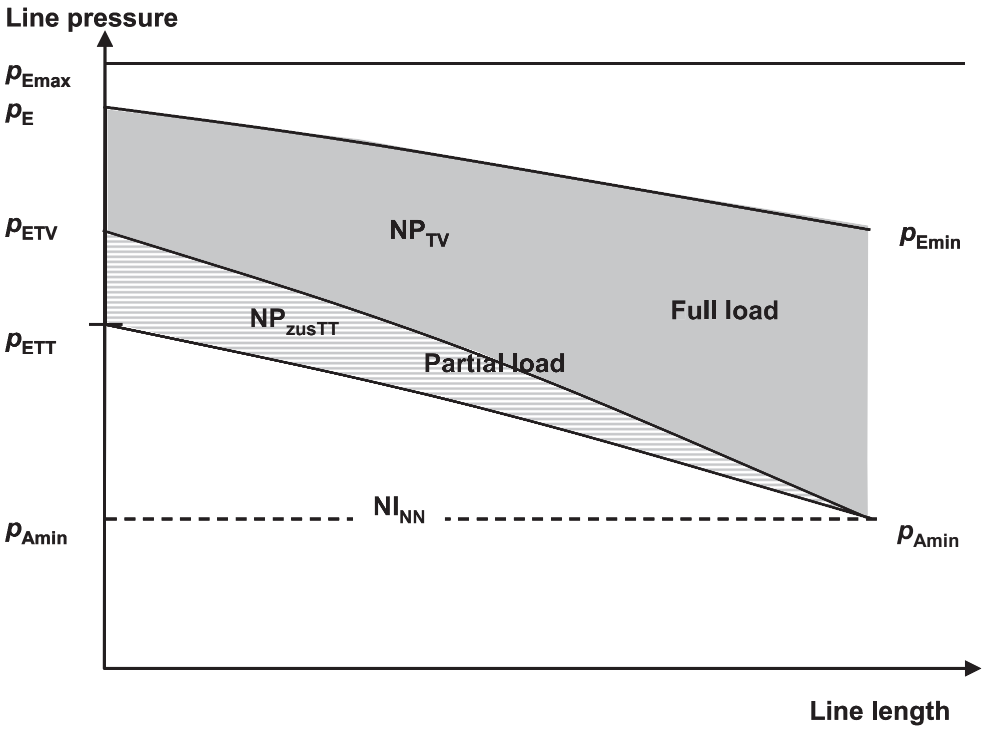

Figure 1 – Illustration of the linepack

p_{Emax} = maximum permissible operating pressure

p_{Amin} = minimum permissible pressure at the exit points

p_{ETV} = minimum required feed-in pressure to secure booked transportations at full load so that the pressure does not fall short of minimal p_{Amin}

p_{ETT} = minimum required feed-in pressure to secure transportations at partial load so that the pressure does not fall short of p_{Amin}

p_E = feed-in pressure, is known in case of historic calculations or is assumed for forecasts

p_{Emin} = pressure at the exit point at feed-in pressure p_E

NP_{TV} = linepack at feed-in pressure p_E and full transportation load (full load)

NP_{zusTT} = additional linepack at feed-in pressure p_E and partial load transportation

The offtake pressure for any exit point in a network can be calculated according to fluid dynamics similarity laws for stationary flow and equal load condition:

$$p_{\mathrm{E\,min}}^2 = p_{\mathrm{E}}^2 - \left(p_{\mathrm{ETT}}^2 - p_{\mathrm{A\,min}}^2\right) \tag{11}$$

for the feed-in pressure p_{E} instead of an feed-in pressure p_{ETT}.

With that, the network gas contents may be determined taking into consideration equation (18):

NI_{NNV} = non-useable network gas content at full load with $p_1 = p_{\mathrm{ETV}}$ and $p_2 = p_{\mathrm{Amin}}$

NI_{NNT} = non-usable network gas content at partial load with $p_1 = p_{\mathrm{ETT}}$ and $p_2 = p_{\mathrm{Amin}}$

NI_{E} = network gas content at feed-in pressure p_{E} with = p_{E} and $p_2 = p_{\mathrm{Emin}}$

8.1.3 Linepack as network gas content difference

The maximum linepack at equal, stationary load condition may be determined as difference between a network gas content with a forecast feed-in pressure p_{E} and a required feed-in pressure p_{ETT} at partial load as:

$$NP_{\mathrm{TT}} = NI_{\mathrm{E}} - NI_{\mathrm{ETT}} =$$
$$V_{\mathrm{geo}} \times \frac{450\,\mathrm{bar}}{p_{\mathrm{n}}} \times \frac{T_{\mathrm{n}}}{T} \times \left(\frac{p_{\mathrm{E}}^2 + p_{\mathrm{E}} \times p_{\mathrm{Emin}} + p_{\mathrm{Emin}}^2}{\frac{3}{2} \times 450\,\mathrm{bar} \times \left(p_{\mathrm{E}} + p_{E\,\mathrm{min}}\right) - \left(p_{\mathrm{E}}^2 + p_{\mathrm{E}} \times p_{\mathrm{E\,min}} + p_{\mathrm{E\,min}}^2\right)} - \frac{p_{\mathrm{ETT}}^2 + p_{\mathrm{ETT}} \times p_{\mathrm{A\,min}} + p_{\mathrm{A\,min}}^2}{\frac{3}{2} \times 450\,\mathrm{bar} \times \left(p_{\mathrm{ETT}} + p_{\mathrm{A\,min}}\right) - \left(p_{\mathrm{ETT}}^2 + p_{\mathrm{ETT}} \times p_{\mathrm{A\,min}} + p_{\mathrm{A\,min}}^2\right)} \right) \tag{12}$$

The linepack at full load transportation at equal, stationary load condition may be determined as difference between a network gas content with a forecast feed-in pressure p_{E} and a required feed-in pressure p_{ETV} at full load as:

$$NP_{\mathrm{TV}} = NI_{\mathrm{E}} - NI_{\mathrm{ETV}} =$$
$$V_{\mathrm{geo}} \times \frac{450\,\mathrm{bar}}{p_{\mathrm{n}}} \times \frac{T_{\mathrm{n}}}{T} \times \left(\frac{p_{\mathrm{E}}^2 + p_{\mathrm{E}} \times p_{\mathrm{E\,min}} + p_{\mathrm{E\,min}}^2}{\frac{3}{2} \times 450\,\mathrm{bar} \times (p_{\mathrm{E}} + p_{\mathrm{E\,min}}) - \left(p_{\mathrm{E}}^2 + p_{\mathrm{E}} \times p_{\mathrm{E\,min}} + p_{\mathrm{E\,min}}^2\right)} - \frac{p_{\mathrm{ETV}}^2 + p_{ETV} \times p_{\mathrm{A\,min}} + p_{\mathrm{A\,min}}^2}{\frac{3}{2} \times 450\,\mathrm{bar} \times (p_{\mathrm{ETV}} + p_{\mathrm{A\,min}}) - \left(p_{\mathrm{ETV}}^2 + p_{\mathrm{ETV}} \times p_{A\,\mathrm{min}} + p_{\mathrm{A\,min}}^2\right)} \right) \tag{13}$$

8.1.4 Fundamentals for the calculation of the gas contents of single pipeline sections

8.1.4.1 Fundamental correlations

The pipeline content results from the **geometric volume** of the quantity-controlled network and the **pressure** prevalent in the pipeline. The pressure over the length of the pipeline is integrated for this.

Considering the compressibility and temperature results, the pipeline content NI of a line section with constant cross section has the following formula:

$$NI = V_{\mathrm{geo}} \times \frac{1}{p_{\mathrm{n}} \times K_{\mathrm{m}}} \times \frac{T_{\mathrm{n}}}{T} \times \frac{1}{l} \times \int_0^l p(x)\,\mathrm{d}\,x \tag{14}$$

The geometric volume is determined by using the length specifications and the internal diameter of a line section of length l.

$$V_{geo} = \frac{d_i^2 \times \pi}{4} \times l \qquad (15)$$

The accuracy of the geometric volume to be determined depends very much on the completeness and accuracy of the pipeline network documentation (plans and drawings). The geometric volume must be calculated using the real internal diameter *d*i. Different pipe materials and wall thicknesses result in non-negligible differences.

For the gas temperature *T*, the temperature of the soil at a depth of 1 meter is adopted. Looked at during the period of one year, this value is not constant. It depends on the season and the geographical location of the network in the Federal Republic of Germany. From DIN 4710 it is apparent that the soil temperature difference between summer and winter may be up to 10 K. It is recommended to specify the gas temperature used for calculation on a monthly basis.

8.1.4.2 Determining the pressure in a pipeline

The further the gas moves away from the entry point, the more diminishes the pressure due to the pressure losses occurring. The transport of gases in pipelines results for laminar flow conditions in a parabolic pressure curve.

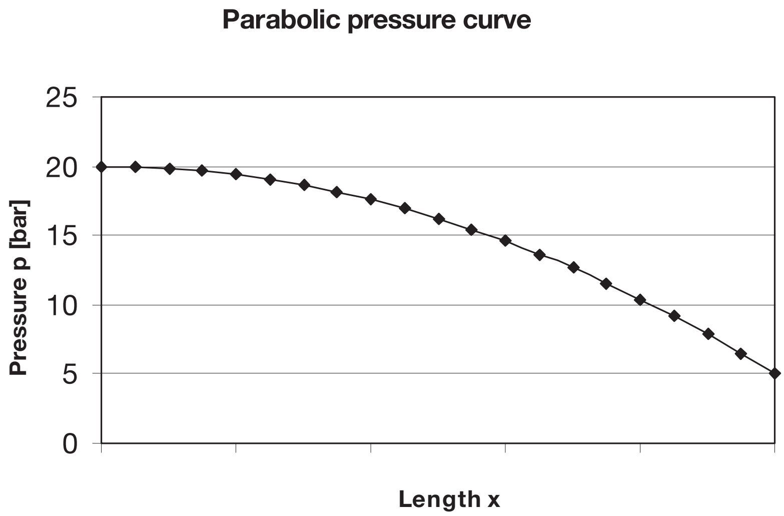

Figure 2 – Parabolic pressure curve in a flow-carrying pipe

The integrated average value of the absolute pressure p_m can be calculated as follows:

$$p_m = \frac{2}{3} \times \frac{\left(p_1^3 - p_2^3\right)}{\left(p_1^2 - p_2^2\right)} \qquad (16)$$

With this integrated average of the absolute pressure p_m, it is possible to perform the calculation of the average compressibility factor K_m according to GERG 88 or by approximation with the formula:

$$K_m \approx 1 - \frac{p_m}{450\,\text{bar}} \qquad (17)$$

The approximate formula in equation (17) applies to gases in underground pipelines at approx. 12 °C and up to approx. 70 bar.

8.1.4.3 Network gas content at stationary flow condition

In general, the following applies to the network gas content at stationary flow condition:

$$NI = V_{\mathrm{geo}} \times \frac{1}{p_{\mathrm{n}}} \times \frac{T_{\mathrm{n}}}{T} \times \frac{p_{\mathrm{m}}}{K_{\mathrm{m}}} \tag{18}$$

Inserting equations (16) and (17) results in:

$$NI = V_{\mathrm{geo}} \times \frac{1}{p_{\mathrm{n}}} \times \frac{T_{\mathrm{n}}}{T} \times \frac{p_{\mathrm{m}}}{1 - \frac{p_{\mathrm{m}}}{450\,\mathrm{bar}}} = V_{\mathrm{geo}} \times \frac{450\,\mathrm{bar}}{p_n} \times \frac{T_{\mathrm{n}}}{T} \times \frac{p_1^2 + p_1 \times p_2 + p_2^2}{\frac{3}{2} \times 450\,\mathrm{bar} \times (p_1 + p_2) - \left(p_1^2 + p_1 \times p_2 + p_2^2\right)} \tag{19}$$

8.1.5 Practical hints

8.1.5.1 Pressure measuring points

The distribution of pressure sensors in the network is crucial in compiling a calculation model. Pressure measuring points should be set up at representative points of the network. Such points are always the starting points (entry points) and end points of breathing networks. In larger networks, the pressure should be additionally measured at important measuring points. When calculating with measured pressures, the network's dynamic behaviour is accounted for.

Missing pressures can also be described by taking into account measured volume flows or by interpolation according to the basis of calculation.

8.1.5.2 Accuracy

The calculation methods and the technical facilities used in this regard should at least satisfy the requirements of in-service measurements. If for operational reasons a greater accuracy is necessary, narrower tolerance limits may be agreed upon between the network operators concerned. Tolerance limits should be kept as small as possible.

The inspection and where necessary re-calibration of the pressure measuring instruments has to be carried out at regular intervals as and when required and has to be documented in a comprehensible way. The time interval must be determined on the basis of empirical values.

The linepack content calculation result considerably depends on the accuracy and suitability of feed-in parameters. Without claiming to be exhaustive, some useful hints are provided below. These should be particularly observed for in the calculation.

- Determination of pressure:
  – Install pressure sensors at suitable, representative points
  – Select an as short as possible measuring line
  – Bear in mind accuracy class
  – Select adapted measuring range
  – Bear in mind the A/D-converters' resolution for metered value transmission
  – Bear in mind the geodetic height (absolute pressure and excess pressure!)

- Determination of volume:
  – Accurate documentation obtained from the GIS or pipe log
  – Internal diameter may not necessarily equal DN specification
  – Select line sections (pay attention to changes in diameter e. g. due to rerouting, etc.)

- Calculation:
  – Selection of calculation method, approximations
  – Influence of gas temperature
  – Pipe roughness
  – Changes in flow/pressure surge
  – Pressure values used (integrated hourly average value, final hourly value ...)

8.2 Analysis of historic results, forecasting and utilisation

In order to examine the capacity of the existing linepack, the following values should be analysed for at least one gas market year:

- Historic hourly feed-in and offtake buffering capacities

- Historic accumulated linepack levels

in each case subject to the feed-in pressures, temperatures and hourly offtakes at the capacity-relevant network interconnection points.

These values are to supply guide values as to the scale of linepack that can presumably be made available in the future.

The objective is to deduce a function (curve, matrix) from which the available linepack values

- maximum feed-in buffering capacity, maximum offtake buffering capacity

- maximum daily quantity – the maximum quantity available for daily compensation

- maximum weekly quantity – the maximum quantity available for weekly compensation

at the respective average daily temperature may be read off.

In the case of a linepack with variable feed-in pressure, the available linepack in each case has to be forecast together with a feed-in pressure forecast.

In the process, the respective transportation task, the respective type of day and the hourly regression have to be taken into account separately at the different daily average temperatures.

8.2.1 Analysis of historic operation mode for long-term estimation

As the exit quantities in most gas networks are not measured at all exit points, it is only possible to calculate them by means of theoretical considerations:

Hourly exit	=	measured hourly quantities at the network interconnection point
	+	calculated hourly change of the linepack

These considerations provide information if and to what extent the linepack would have made it possible to smooth the peak demands that have occurred at the network interconnection points within a gas business day.

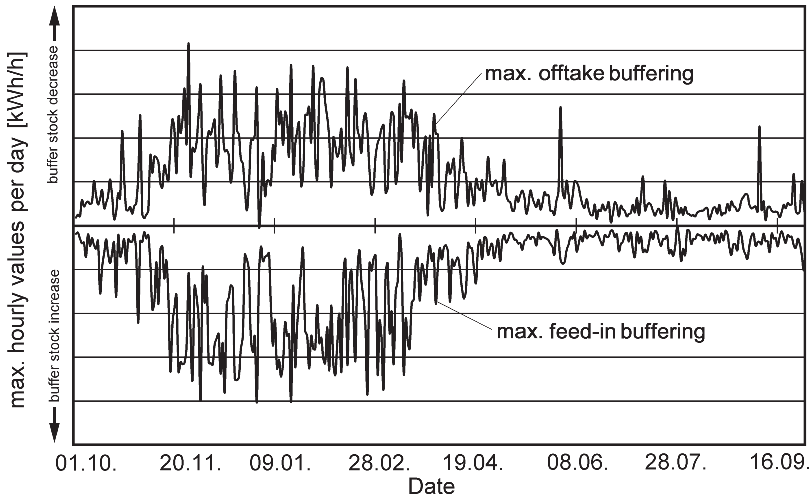

Figure 3 – Example of a historic record of a linepack's daily operating mode – hourly feed-in buffering and offtake buffering values accumulated to the daily value

8.2.2 Linepack's feed-in and offtake buffering capacity

A linepack's maximum feed-in buffering capacity and maximum offtake buffering capacity results from the historic data or they are determined by means of a model calculation. The correlation between the feed-in and offtake buffering capacity is determined at the respective hours of full use. The correlation between the determined feed-in and offtake buffering capacity and the respective hours of full use can be determined by the following equations:

- Feed-in buffering capacity:

$$N_{LE} = \frac{\mathrm{NP}_{ges}}{24} \times B_{hE} \tag{20}$$

- Offtake buffering capacity:

$$N_{LA} = \frac{\mathrm{NP}_{ges}}{24} \times B_{hA} \tag{21}$$

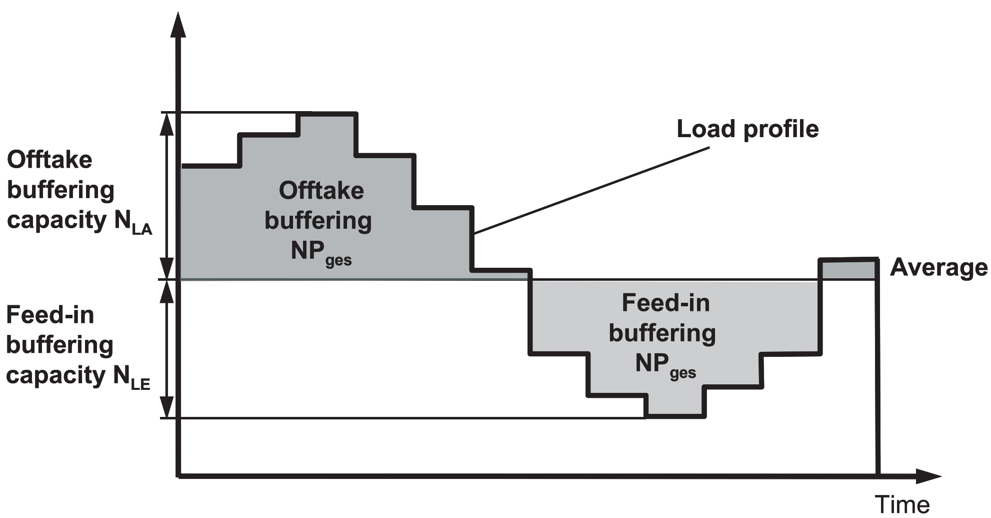

Figure 4 – Feed-in and offtake buffering load profile

The diagram shows the conversion of feed-in and offtake capacity into full hours of use of the storage, i. e. the entire linepack volume is divided by the maximum feed-in and offtake buffering capacity.

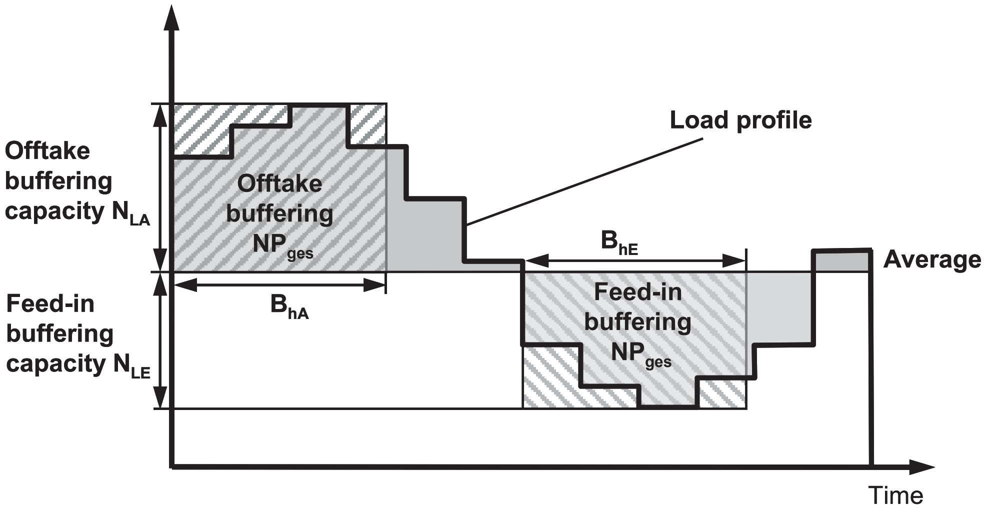

Figure 5 – Correlation between feed-in and offtake buffering capacity and full hours of use

Technical restrictions, such as e. g. maximum number of load changes, maximum flow rate etc. also have to be taken into account in this regard. The specification is optionally made in m^3/h or in full hours of buffer use (B_{hE} for feed-in buffering into the buffer and B_{hA} for offtake buffering out of the buffer).

A linepack, which historically seen did not only smooth across the day, but partly across several days or across a whole week, has to be examined separately. Here, daily smoothing has to be extended to several days.

8.2.3 Determination of forecast values

For the daily linepack forecast, it is necessary to forecast the offtake at the exit points.

As far as necessary, upstream network operators should inform their downstream network operators in particular in the case of network interconnection points with severely fluctuating pressures of the expected pressure ranging above the minimum feed-in pressure p_{ETV}.

Based on his scheduled exit load profile, the network operator calculates an entry load profile that has been as far as possible smoothed. The linepack for the next day is forecast based on this load profile at the network interconnection point and on the expected feed-in pressure.

9 Formula symbols

Latin symbols

A_D	[m²]	cross sectional area of the restriction
B_h	[h]	hours (of operation at) full capacity equivalent
B_{hA}	[h]	hours (of operation at) full exit capacity equivalent
B_{hE}	[h]	hours (of operation at) full entry capacity equivalent
d	[mm]	pipe diameter
d_i	[mm]	pipe internal diameter
g	[m/s²]	acceleration due to gravity
h_1	[m]	geodetic height at the start of the considered pipeline
h_2	[m]	geodetic height at the end of the considered pipeline
K	[-]	compressibility factor
K_m	[-]	average compressibility factor
L	[m]	overall length of a pipeline
l	[m]	partial length
$\dot{m}$	[kg/s]	mass flow
N_{LA}	[kWh/h]	offtake buffering capacity
N_{LE}	[kWh/h]	feed-in buffering capacity
NI	[m³]	network gas content
NI_{NN}	[m³]	non-usable network gas content
NI_{NNT}	[m³]	non-usable network gas content at partial load
NP	[m³]	linepack
NP_{TV}	[m³]	linepack at transportation at full load
NP_{TT}	[m³]	linepack at transportation at partial load
p	[bar]	pressure in pipeline network
p_1	[bar]	pressure at the start of a pipeline section

p_2	[bar]	pressure at the end of a pipeline section
p_A	[bar]	offtake pressure, pressure at the exit point
p_{Amin}	[bar]	minimum pressure at the exit point
p_E	[bar]	feed-in pressure, pressure at the entry point
p_{ETT}	[bar]	minimum required pressure at the entry point to secure transportations at partial load
p_{ETV}	[bar]	minimum required pressure at the entry point to secure transportations
p_m	[bar]	integrated average value of pressure across a pipeline section
p_n	[bar]	standard pressure
P_{Gas}	[kW]	power required to compress the flowing gas
P_K	[kW]	coupling power
Q_n	[m^3/h]	gas volume flow at normal conditions
R_s	[kJ/kg K]	specific gas constant
T	[K]	gas temperature
T_n	[K]	standard gas temperature
V_{geo}	[m^3]	geometric gas network volume
x	[m]	path length of a pipeline section
Z	[-]	real gas factor

Greek Symbols

λ	[-]	pipe friction factor
ρ_{Gas}	[kg/m^3]	density of the gas
ρ_{Luft}	[kg/m^3]	density of air
ρ_n	[kg/m^3]	gas density at normal conditions
χ	[-]	isentropic exponent
η_s	[-]	isentropic efficiency
η_m	[-]	mechanical efficiency

Combined Symbols

Δp_h	[bar]	pressure change caused by buoyancy
Δh_i	[kJ/kg]	enthalpy change with real change of state
Δh_s	[kJ/kg]	enthalpy change at isentropic compression

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