Determining factual productive capacity reserve of gas distribution systems

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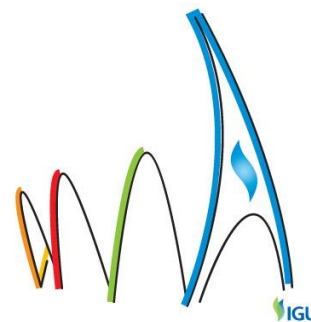M. G. Sukharev
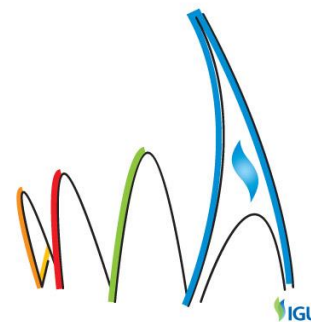(RSU of oil and gas named after I.M. Gubkin)

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Background

The paper treats issues of gas distribution network development and operation in the Russian Federation, including third-party access and determining (in terms of methodology and practice) gas distribution system factual productive capacity reserve allowing for safe and uninterrupted gas supply of the perspective gas consumers.

Gas distribution system in the Russian Federation. Short overview.

Gas supply and distribution in the Russian Federation began to develop in the 1940s. First gas was supplied to Moscow via gas pipeline "Saratov-Moscow" built in 1947. Presently 26 companies among which Gazprom plays a predominate role supply gas to the Unified gas supply system (UGSS) and autonomous regional gas supply systems.

Some 48 gas companies operate in 67 regions of the Russian Federation. These companies basing on the concluded contracts supply gas to the final consumers. Gas is supplied (transported) from gas supply sources (gas distribution stations) via gas distribution networks. These networks' length inclusive of spur gas lines totals some 850 ths. km (of which 202 ths. km is covered by polyethylene (PE) pipes). 270 ths. gas reduction points provide for gas pressure reduction to safe level. Gas distribution networks are operated by more than 100 gas distribution companies (GDO). "Gazprom gazoraspredelenie", the leading gas distributor, has over 150 branches in the Russian Federation constituents.

As of present gas is supplied to more than 40 ths. settlements or to 33,5 mln. apartments and households, 31,7 ths. industrial enterprises, 268 ths. of communal and residential consumers. Total share of apartments and households supplied with natural gas in Russia amounts to 57,1 % (of these urban – 61,2 %, rural – 46,3 %).
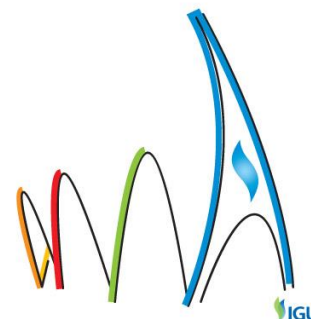
Brief characteristics of gas distribution network status in the Russian Federation as of beginning of 2014 are presented in Table 1.

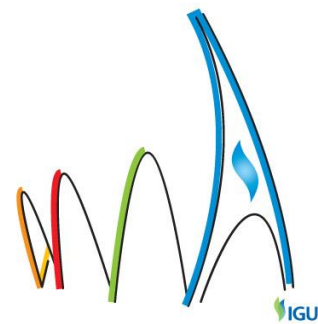Table 1.Russian Federation gas distribution system characteristic.

№№	Index	Total
1	External gas pipeline length, ths. km	849,7
	Including these in the rural districts	539,9
2	Underground gas pipeline length, ths. km	551,5
	Including PE pipes	202,4
3	Quantity of gas distribution points, ths. units	48,9
4	Quantity of gas distribution booths, ths. units	271,4
5	Volume of gas transported to consumers, bln. m3/year	294,9
	Including residential consumers	47,7

Unbundling in the gas industry of the Russian Federation

Unbundling can be characterized from different points of view (see Table 2).

Table 2. Assessment of unbundling in the Russian Federation

Index	Russian gas market
Functional unbundling	Gas companies are distinguished by functionality: production, processing, transportation, storage, distribution and consumer supply
Ownership unbundling	Gas supply is effected by companies without involvement in gas distribution network operation (48 companies act in the Russian federation constituents)
Legal unbundling	Regional gas companies supply gas recovered by different producers (Gazprom and independent producers, 26 of the latter presently have access to UGSS)
Account unbundling	Account of cost of implementing its functions is kept by each company belonging to the gas chain from production to consumer.
Service unbundling	Gas is supplied to consumers by companies without involvement in network operation

Basics of regulating third-party access to gas mains and distribution pipelines in the Russian Federation

Residential consumer gas supply organization falls within responsibility of local self-administration authorities and is effected compliant with the Russian Federation laws and municipal norms.

Third party access to gas supply and distribution systems in the Russian Federation is defined by the below laws and norms:

Federal Law "On natural monopolies" of 17.08.95 N 147-ФЗ setting:

- Natural monopoly responsibility (Article 8);
- Access to information about natural monopolies (Article 13).

Federal law "On gas supply in the Russian Federation" №69-ФЗ of 31.03.1999 defines:

- Gas supply anti-monopoly regulation (Chapter VII);
- Anti-monopoly rules for organizations-owners of gas supply systems (Article 26);
- Organization access to gas transport and gas distribution networks (Article 27).

Russian Federation Government Resolution "Guarantee of gas independent producer access to the JSC "Gazprom" Unified gas supply system" of 14.07.1997 № 858 sets

- Terms and order of ensuring access to available UGSS capacity allowing for JSC "Gazprom" implementation of existing contractual commitments of consumer gas supply.

Russian Federation Government Resolution "Rules of gas supply in the Russian Federation" of 5 February 1998 №162 defines:

- Order of concluding gas supply contracts (Section III);
- Contract party's rights and duties (Section VII).
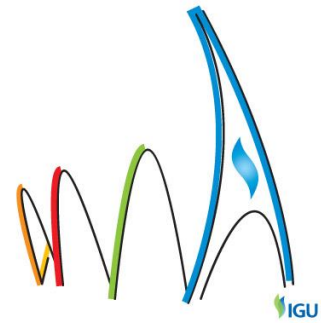
Russian Federation Government Resolution "Provision on ensuring organization access to local gas distribution networks" of 24 November 1998 N 1370) defines

- Terms and order of organization access to local gas distribution networks (Section III);

- Major terms of gas transport via gas distribution networks (Section IV).

Note: Presently Federal Antimonopoly Service (FAS) is finalizing draft Russian Federation Government Resolution "On ensuring non-discriminated access to gas distribution networks" to substitute Russian Federation Government Resolution of 24 November 1998 N 1370 as is in force now

Russian Federation Government Resolution "Rules of using gas and providing gas supply services in the Russian Federation" of 17 May 2002 № 317 defines

- Order of obtaining technical conditions of connecting to gas distribution system.

Order of Federal antimonopoly Service of 23 December 2011 № 893 "On approving forms, time terms and periodicity of data disclosure by natural monopolies providing services of gas pipeline transport" sets requirements to providing

- Data on production capacity reserve availability to provide network access of new consumers.

Russian Federation Government Resolution of 30.12.2013 N 1314 "On approving Rules of connecting (technical connection) of capital facilities to gas distribution networks and on amending and making inoperative several acts of Russian Federation Government" defines

- Order of defining and making available technical conditions (Section II) including:

    – Order of identifying organization issuing technical solutions; (i.6),

    – Grounds for refusal to connect (i.14),
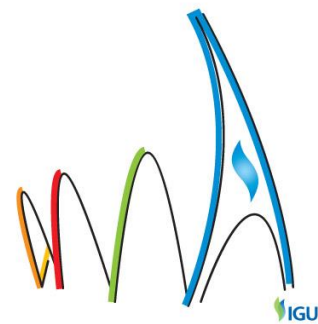
- – Criteria of technical possibility to connect (i. 25),
- Technical conditions validity period (i.29),
- Connection implementation time period (i.85),
- Order of making payments for technological connection (i.91).

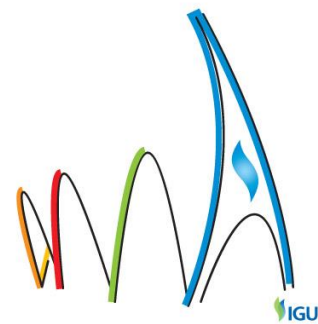## Gas distribution network consumer access ensuring

Consumer access to gas distribution network is as a rule implemented within Gas supply and distribution organization programmes and compliant with General Schemes of gas supply and distribution in the Russian Federation entities.

General Scheme (hereinafter – Scheme) of gas supply and distribution is issued for each Russian Federal entity. Usually this Scheme is amended and upgraded once every 5 years. The Scheme is reviewed by all gas companies of the Federal entity and subject to approval by the Head of Federal entity.

The Scheme is formed basing on regional authorities' data on expected natural gas demand. Expected yearly (mln. m^3 per annum) and peak (ths. m^3 per hour) natural gas demands by each consumer are calculated basing on operating norms.

Scheme development involves assessment of gas distribution network technical capacity transfer gas to new consumer compliant with expected demand. If required they make proposals on constructing new and reconstructing existing gas distribution network facilities (distribution pipelines, gas reduction points). Technical parameters of these facilities are calculated with regard to necessity fully supply all consumers (existing and new) in the region under peak consumption mode.

New consumers included in the Scheme are connected to the network compliant with technical solutions as are documented in the same Scheme. Hence the following options are possible:

- When technical parameters of the gas distribution networks allow for a new connection. Then the connected consumer should obtain technical conditions of connecting to gas distribution networks of the gas distributor, construct gas pipelines from the access point to the gas consuming unit at his land territory compliant with obtained technical conditions and conclude contract for access to gas distribution station with local gas supplier;

- When technical parameters of the gas distribution networks do not at the moment allow for a new consumer access. That requires construction or/and reconstruction of gas distribution facilities and may be even of gas supply ones (spur gas line, gas distribution station).

Gas supply and distribution network construction and reconstruction can be implemented within regional programmes of a Russian Federal entity or within investor programmes. OJS "Gazprom" acts as an important investor and implements its own programme of constructing gas distribution facilities in many regions where local gas distributors make part of its subsidiary JSC "Gazprom gazoraspredelenie".

Construction completion ensures technical possibility of new consumer access.

Special consideration needs the situation when a new consumer requires access after the Scheme (in which this new requirement is not accounted for) has been completed and updated. In this case the gas distributor basing on network capability analysis can issue access technical conditions provided idle capacity availability or it can specify measures necessary to ensure availability of such capacity. These specified measures will be taken into account when updating the General Scheme. Transparency of this process is ensured by FAS Order of 23 December 2011 №893, which binds gas distributors regularly publish data on gas distribution network free capacity availability.
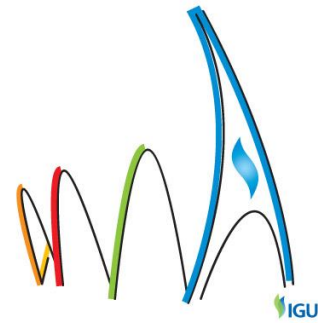
Methodological and practical issues of assessing gas distribution network production capacity availability

Procedure of assessing gas distribution network idle capacity availability for satisfying additional consumer demand is regulated by JSC "Gazprom gazoraspredelenie" (industry standard "Dispatcher control. Dispatcher control processes. Data operation process. Throughput capacity determination, gas pipeline available capacity calculation").

This document standardize major terms related to reserve and production capacity availability in gas distribution lines and gas networks in general. Interdependance of these terms used to define throughput capacity reserve and vailable production capacity at different time intervals is illustrated by Fig. 1.
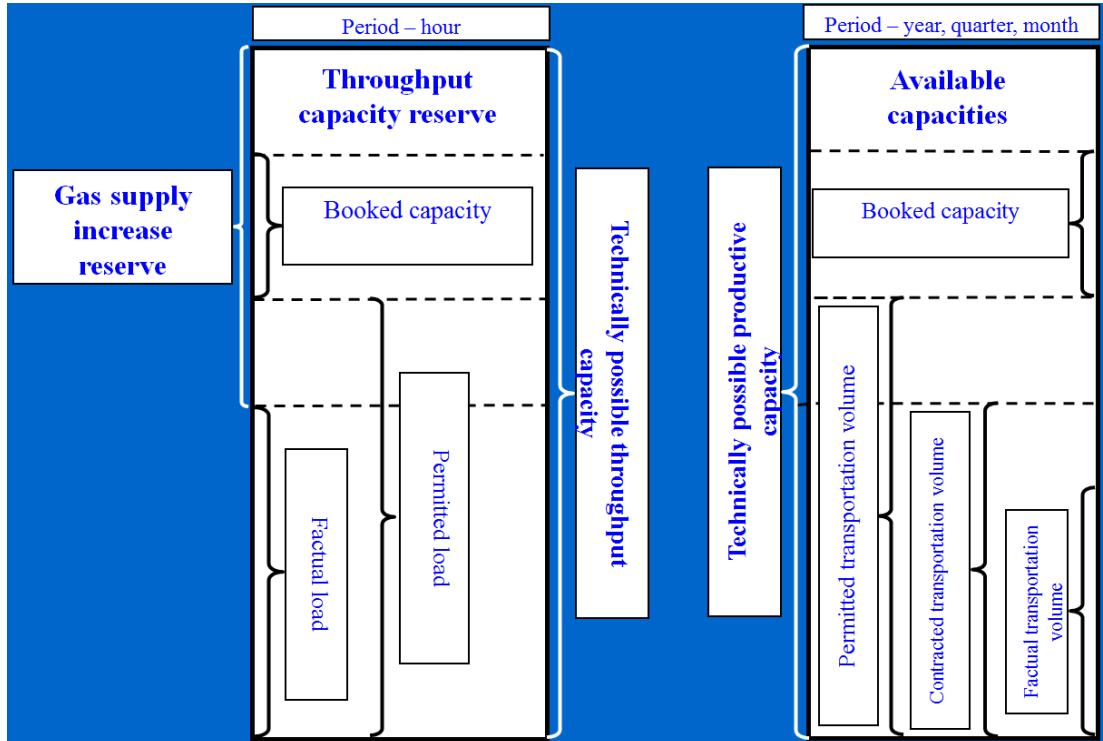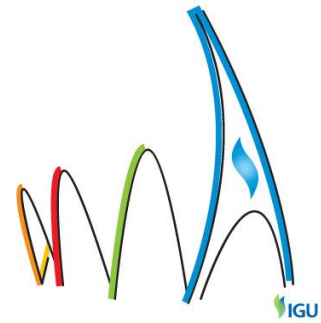

Figure 1. – Illustration of terms used to define throughput capacity reserve and vailable production capacity.

Concepts of throughput capacity and technically allowable capacity (the latter depends on pipeline real operation conditions) are used together with concepts of factual, permitted and booked loads to characterize production capacity (hour indices).

Factual load is determined depending on factual maximum hourly consumer gas consumptions. Permitted load is determined basing on permitted maximum hourly consumer gas consumptions set by the consumer connection technical conditions, or in case of residential consumers set by project of gas supply in cities, towns, settlements or by General Schemes of gas supply and distribution. The booked load depends on gas consumer hourly consumptions set in the prospective consumer connection technical conditions.

Gas pipeline throughput capacity reserve and allowable increase of gas supply of consumer of group of consumers is determined based on such hourly indices.

In terms of year, quarter, month they define gas pipeline technically allowable production capacity or gas volume supplied to the consumer connection point in case of even production capacity load within the set time period (year, quarter, month). Values of permitted, contacted or factual volumes transported up to the consumer connection point are defined basing on issued permissions to use gas as fuel or process materials, operating contracts, actual consumer consumptions. The booked capacities depend on issued consumer permits to use gas and on technical possibility supply gas to consumers not yet connected to gas distribution network.

Division of transport quotas and booked capacities in quarterly and monthly portions is effected with regard to gas consumption seasonal fluctuation. In case of existing consumers contracted and factual supply should be taken into account, and in case of potential consumers indices for similar objects or standardized industrial indices should be referred to.
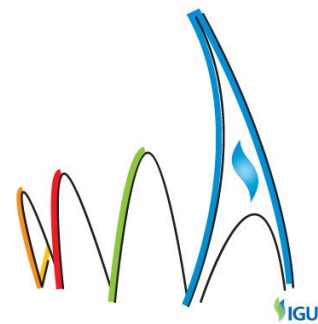
Thus available capacity depends on difference between technically possible productivity and sum of permitted volume and booked capacity.

Difficulties during the standard development lay in determination of similar indices for the gas distribution network on the whole. The network throughput capacity depends on

- The point where delivery of maximum possible gas volume is scheduled, or

- On the order of distributing gas between all the points at once. In the latter case the throughput capacity will characterize system in general and not each gas line or connection point individually.

Thus for gas distribution network concepts of throughput capacity, productivity, throughput capacity reserve and available capacity are defined by means of vector or sum of indices, each of those indices characterize individual connection point, provided fixed indices at all other points.

The standard includes mathematic formulation of finding maximum gas delivery to the new consumer connection point. Flow rule for each element on the calculation net graph, Kirchhoff laws, minimum allowable index value limits and restrictions relating to consumer minimum gas pressure or allowable and booked gas delivery volumes act as limitations in this problem. Figure 2 presents mathematical presentation of the problem of determining gas distribution network throughput capacity.

The optimization problem thus set up is non-linear but can be solved with application of specialized software packages. Technically allowable throughput capacity is determined with application of this same apparatus only provided use of gas pipeline hydraulic efficiency estimated coefficients and values of technically attainable pressure at the gas distributor's junctions.
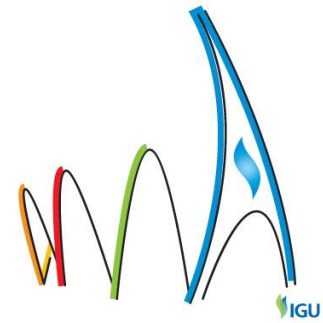
Identify maximum consumer gas supply k

$$Q_k^{\text{пс}} = Q_k \to \max , \qquad (1)$$

Provide 1st Kirchhoff law compliance

$$\mathbf{A}\vec{q} = \vec{Q} , \qquad (2)$$

Law of steady flow via curves of calculation graph

$$\overline{\mathbf{A}}^T \vec{P} = \mathbf{S}\mathbf{X}\vec{q} , \qquad (3)$$

$$P_i = \left(p_i^* \right)^2 , i \in I , \qquad P_j = p_j^2 , j \notin I , \qquad (4)$$

Minimum gas pressure in consumption clusters

$$p_m \geq p_m^{\min} , m \in M \qquad (5)$$

Provision of permitted $\vec{Q}^{\text{разр.п}}$ and booked $\vec{Q}^{\text{бр.п}}$ consumer gas supplies

$$Q_k \geq Q_k^{\text{разр.п}} + Q_k^{\text{бр.п}} , \qquad Q_m = Q_m^{\text{разр.п}} + Q_m^{\text{бр.п}} , m \in M , m \neq k . \qquad (6)$$

Figure 2. – Setting mathematical problem of determining gas distribution network throughput capacity (M – variety of consumers).

Taking the above into account the gas distribution network throughput capacity reserve and available capacities are determined as follows.

a) throughput capacity reserve depends on the sum of values $\vec{R}^{\text{сети}} = \| R_k \| , k \in M$, where each $R_k , k \in M$ is calculated by using the formula below

$R_k = q_k^{\text{твпс}} - q_k^{\text{разр.п}} - q_k^{\text{бр.п}} , k \in M$, where $q_k^{\text{твпс}}$ is constituent k of technically possible gas distribution network throughput capacity as determined with regard to permitted and booked consumer gas consumptions, $q_k^{\text{разр.тп}}$ is permitted gas
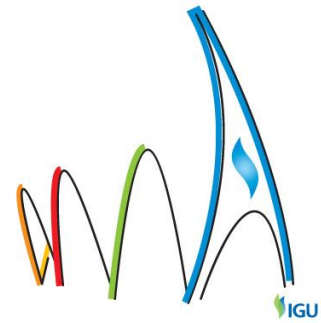
consumption at the connection point k, $q_k^{\text{бр.тп}}$ is booked gas consumption by perspective consumer at connection point k.

    b) available capacity within a month, quarter, year to supply with gas consumer k, $k \in M$ is found using the formula

$$S_k^{\text{п}} = Q_k^{\text{твп}} - Q_k^{\text{разр.п}} - Q_k^{\text{бр.п}}, k \in M ,$$

where $Q_k^{\text{твп}}$ is maximum possible gas amount within the given time period that can be delivered to consumer k provided guarantee of permitted $Q_k^{\text{разр.п}}$ and booked $Q_k^{\text{бр.п}}$ gas deliveries to other consumers.

The suggested mathematical problem setting provides for solution of some relevant gas distribution problems:

- identification of possible points where to connect new consumers and issuance o gas supply technical conditions to potential consumers. Knowledge of the system throughput capacity values and throughput capacity reserve values allow definitely determine whether new consumer connection is possible or not.

- Substantiation of decisions on gas distribution network development and reconstruction. Bottlenecks become evident when the throughput capacities of the system are determined. If reserves are too scarce to connect new consumers, gas distribution network extension by means of laying parallel gas pipelines, interconnection with other supply sources or reconstruction may be required.

- Agreeing operating contracts between gas suppliers and consumers depending on capacity availability within the year period and on availability of reserves to increase gas supply.
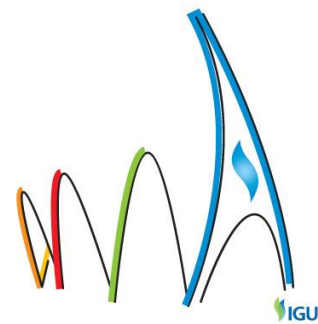
It should be noted that throughput capacity is also instrumental for identification of production capacity load coefficients shown on the current accounts.

Software for production capacity reserve identification

Taken into account gas distribution network complicated structure, and potential connection point great number, production capacity reserves should be identified by using specialized software.

Specialized software complex IRS GRO has been developed to identify production capacity reserves. This complex allow to identify available capacities basing on gas distribution network hydraulic calculations and to present such calculation results as regulated by standards typified throughput capacity reserve reports.

Conclusions

Methodological issues of determining gas distribution system factual productive capacity reserve considered in the paper provide for transparency in taking decision of connecting to gas distribution networks new consumers and issuing relevant connection technical conditions. Developed specialized software complex can be used as instrument of gas distribution development engineering solution substantiation when increasing supply to existing and perspective consumers.