IMPLEMENTATION OF MODERN APPROACHES TO RECONSTRUCTION AND RECOVERY OF GAS DISTRIBUTION SYSTEMS: RUSSIAN EXPERIENCE

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Mass development of gas distribution systems in Russian cities and towns started in 1946 when Saratov-Moscow gas pipeline was commissioned. Presently in Russia the number of flats supplied with natural gas has reached 30 million in approximately 38000 residential areas.

Ensuring safety and security of gas distribution systems and improving their economic, environmental and municipal efficiency is one of the foreground tasks in designing, constructing and operation of these systems. The major part of them is controlled by OAO «Gazprom».

To implement integrated technical policy and to plan activities aimed at reconstruction and re-equipment of gas distribution systems jointly with implementation of the programme of expanding natural gas grids of Russian regions in 2004 OAO «Promgaz» developed «Integrated programme of OAO «Gazprom» gas facilities reconstruction and technical re-equipment for 2004-2008».

The greatest attention should be paid to the residential areas, where low-pressure gas pipelines prevail. The selection of urban gas pipelines reconstruction methods largely depends on peculiarities of urban development.

Trenchless technologies of gas pipelines permitted in Russia have demonstrated their efficiency, but at the same time there is a necessity of developing new technologies of gas pipelines reconstruction enabling to restore their operation capability without considerable change of working pressure value.

OAO «Promgaz» being responsible for implementation of the integrated technical policy on reconstruction and recovery of gas distribution systems is open for cooperation with other firms to adapt these technologies in Russia.
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1. THE HISTORY OF GAS DISTRIBUTION SYSTEMS DEVELOPMENT IN RUSSIA

Ensuring gas distribution systems safety and security with simultaneous improvement of their efficiency is one of the foreground tasks during the system project designing, construction and operation.

Natural gas was used in Russian public utilities for the first time in Saint Petersburg in 1834, then in Moscow in 1865. In 1946 after the Saratov-Moscow gas pipeline with length of 840 km, which transmitted $0.5 \times 10^9 \text{m}^3$ annually, was commissioned, the gas grid construction to residential houses, industrial, commercial and domestic enterprises started. By 1955 over 15 cities and towns of Russia started to receive natural gas. The quantity of flats with gas supply in Moscow, Leningrad, Samara and Saratov run up to 830,000.

Currently the number of flats with gas supply in Russia equates 30 million in approximately 38000 residential areas. The percentage of flats provided with gas supply in urban areas is 61%, in rural areas – 36% (taking into consideration LNG consumption the level of gas supply accounts for 73,76%, including in urban areas - 72,73%, in rural –76,53%) . The total length of gas distribution lines in operation is estimated by 581,000 km. Figure 1 below illustrates the distribution of gas lines categorized by different gas pressure level:

![Figure 1: The share of external gas distribution lines categorized by gas pressure level](image)

Length of external urban gas distribution pipelines is more than 235 000 km (40% of total length of distribution pipelines), their share categorized by gas pressure level is shown on Figure 2:

![Figure 2: The share of external urban gas distribution lines categorized by gas pressure level](image)
It is necessary to mention, that in Russia main pipelines with pressure from 0.3 to 1.2 MPa (MPa = $10^6$Pa) belong to the high-pressure type, with pressure from 0.005 to 0.3 MPa belong to the medium-pressure type and up to 0.005 MPa – to the low-pressure type.

Mass house building in 1960 - 1980 led to construction of new and development of already existing gas distribution systems. As a result, the main part of gas pipelines is more than 20-30 years in operation, but in Moscow, Saint Petersburg and a number of some other cities is more than 40 years in operation. Presently, the low-pressure steel gas pipelines prevail in the urban municipal gas distribution systems. One tenth of these pipelines had used their lifetime resource that inevitably causes the maintenance cost increase. If the re-construction and operational capability restoration activities are not activated, the quantity of such pipelines will increase up to 25000 km by the year 2015.

Age structure of all steel underground gas distribution pipelines is shown on Figure 3, and of the urban steel gas distribution pipelines – on Figure 4:

Figure 3: Age structure of underground gas distribution pipelines

Figure 4: Age structure of urban underground gas distribution pipelines

Thus, every year grows the wear factor of gas distribution system main elements: gas pipelines, gas control points, and electrochemical protection stations. The urban systems require the special attention.
Now gas distribution systems in Russia go through the second stage of their development, related to the further natural gas distribution grids development in the regions of Russia.

The principles and methods of their development have changed considerably. The recent policy of the distributed gas volumes increase was replaced by the trend to improve gas consumption efficiency, considering structural and regime gas consumption changes of existing consumers.

Today, implementing gas distribution grids development, the gas supply and distribution system are considered as an inseparable part of the Russian regions’ fuel and energy balances; the part, which interacts and interferes with the other energy systems, first of all with the systems of heat and power energy supply.

2. THE STRUCTURE OF GAS CONSUMPTION IN RUSSIA

The main share of natural gas consumption traditionally goes to energy power and industrial sector, but lately we observe the decrease of industrial gas consumption and increase of its share in residential and commercial sector. Decrease of industrial gas consumption is connected not only with elimination of non-paying facilities, but also and mainly with implementation of energy saving measures and improvement of industrial technologies. Increase of gas consumption in residential and commercial sector in most cases is connected with conversion of existing boiler houses from solid and liquid fuels to natural gas, as well as with development of small business sector. The structure of natural gas consumption is shown on figure 5.

![Figure 5: The structure of natural gas consumption as of 01.01.2005](image)

The necessity of reconstruction of existing gas distribution systems is closely connected with further development of gas distribution grids in the regions of Russia and with conversion of settlements gas supply from liquefied (propane - butane) to natural gas (methane). In Russia more than 75000 settlements with 10 million flats are used liquefied gas. When gas main comes to these settlements, they conversed to natural gas consumption. Therefore implementing regional gas distribution development we have to decide questions, related to reconstruction of existing gas distribution systems, even in case when these systems is not completely depreciated.

Advanced gas distribution system should comprise the possibility of supplied gas volumes increase in the limits of existing grids, reduction of underground gas pipelines length, secure their durability. It could be achieved through pressure increase in distribution grids, application of polymer pipes, materials and trenchless technologies of construction, reconstruction and recovery.
Government control of industrial safety at hazardous industrial facilities requires form the property owners and operators accepting of preventive measures aimed to elimination of accidents and decreasing of their hard consequences, securing of reliable and safe gas supply.

Now Gazprom and affiliated companies control 206 gas distribution enterprises of Russia, operate 80% of all gas distribution pipelines (460000 km) of the country. Their technical state mainly determines safety and reliability of gas supply to end consumers, including 75% of Russian settlements with gas distribution grids. Gasprom provides gas supply to 56% of flats using gas and to 72% of industrial facilities. The volume of supplied gas is about $158 \times 10^9$ m$^3$ (58%).

3. THE PROGRAMME OF RECONSTRUCTION AND TECHNICAL RE-EQUIPMENT OF OAO «GAZPROM» GAS FACILITIES

Considering existing situation in gas distribution systems Promgaz scientific and technical center by order of Gasprom formulated principles of reconstruction and technical re-equipment of gas distribution systems.

Traditional reconstruction, i.e. construction of a new steel pipeline near the depreciated one, requires not only substantial capital investments, but sometimes is impossible to implement thanks to changed infrastructure of cities and towns.

Application of polymer technologies and materials gives the best results at recovery or reconstruction of depreciated underground pipelines. They allow implementation of work at the shortest possible period with minimal volumes of digging and road works, which means minimal damages to environment. But the main advantage – they are cheaper than traditional “steel-to-steel” method of reconstruction and secure 50 years of operation capability.

Considerable experience of trenchless polymer technologies of gas pipelines reconstruction now exists only in Moscow and Saint Petersburg. In other cities and towns these technologies is used occasionally, but the amount is growing thanks to accepted in 2002-2003 new normative documents. These norms for the first time regulate requirements to implementation of gas pipelines reconstruction using the methods of broaching of round or profiled at plant conditions polyethylene pipes, as well as recovery of steel gas pipelines by means of synthetic fabric hose by “Phoenix” technology. At the same time, lack of investments, deficit of objective information concerning reliability of domestic and foreign equipment, consumer aversion to use polymer materials at the pressure 0,6 MPa and over restrains application of these technologies.

Using stated above principles Promgaz in 2004 developed “Complex programme of reconstruction and technical re-equipment of OAO “Gasprom” gas facilities for a 2004-2008 period”. The main goals of this programme are:

1. Determination of current technical state of Gasprom and affiliated companies gas distribution systems;

2. Planning of works, development and organization of complex scientific, technical and finance measures, taking management decisions aimed at achieving Programme goals;

3. Planning of works on reconstruction and technical re-equipment along with implementation of gas distribution grids development programmes in the regions of Russia;

4. Implementation of uniform technical policy in gas distribution, including studying of future trends of application in Russia new trenchless technologies of gas pipelines reconstruction and their experimental testing on individual sites.

The Programme is supposed in 2004-2008 to reconstruct 3200 km of gas pipelines, 4850 gas control points, 6900 units of electrochemical protection, 500 gas-filling stations and to re-equip gas distribution enterprises.
Complex program of reconstruction is approved by Gasprom as a management directive and recommended for introduction in all gas transportation and gas distribution enterprises of Gasprom group. For database and analytical provision was developed and introduced “The system of monitoring, diagnostics and management of OAO “Gasprom” gas facilities”. This Program is embraced the questions of gas distribution, operation, optimization and rational gas consumption, as well as normative provision.

Economical efficiency of the Programme introduction is formed of:
- rational and timely implemented reconstruction works;
- reduction of operation costs;
- reduction of gas losses;
- reduction of electricity consumption and simultaneous increase of cathodic electrochemical stations efficiency (or their complete elimination if during reconstruction polyethylene pipes is applied);
- prevention of damage to gas supply system caused by reduction of gas supply volumes to consumers.

4. PECULIARITIES OF URBAN GAS DISTRIBUTION SYSTEMS RECONSTRUCTION

As mentioned above, main attention was paid to the questions of urban gas distribution systems reconstruction and recovery of depreciated gas pipelines in restricted conditions.

Every city and town could be conditionally divided at least to three typical zones:
- historic architectural zone;
- zone of low-rise dwellings and buildings, constructed in a period of 1960-70;
- zone of modern buildings construction.

In historic architectural zone at first it is required to carry out an inventory of gas consumers and of gas consumption volumes. These districts are characterized by the changes in the structure of housing recourses, namely:
- implements reconstruction of houses with shared apartments to the comfortable dwellings;
- dwellings reconstructed into offices, etc.;
- at the redeveloped sites new buildings are made.

This city zone has the most restricted conditions for depreciated gas pipelines replacement works. Therefore it is more appropriate to apply the method of broaching of standard polyethylene pipes inside depreciated steel gas pipelines. In this case the system of cathodic electrochemical protection is removed. Small sections of steel pipelines serving as a casing are protected by means of protector units. Depending upon the real gas consumption in the area of gas pipelines reconstruction their pressure category could be kept the same (despite decreasing of flow area after broaching of polyethylene pipes) and it is required to carry out recovery of gas control points with partial replacement of equipment to modern one. If gas consumption volume is the same or slightly growing, pressure should grow and pipeline categorization changing is inevitable. It will lead to partial removing of big gas control units and installation of gas control cabinets for every consumer (consumer groups).

In the zone of low-rise dwellings and buildings, constructed in a period of 1960-70 gas consumption volume could change due to dwellings concentration. Typical reconstruction method in this
area is broaching of polyethylene pipes and increasing of pipeline categorization by pressure (from low to medium pressure) accompanied by installation of gas control cabinets for every consumer (consumer groups), or broaching of profiled polyethylene pipes (U-liner technology) and keeping existing in pipelines pressure category.

In all cases it is advisable to define the expediency of consumers conversion to autonomous (distribute or individual heat supply to each apartment) instead of centralized heating. Autonomous heating efficiency is higher, than centralized heating because heat losses in heating lines are excluded.

Zone of modern buildings construction could include old dwellings with gas distribution system. In this case reconstruction of gas distribution system mainly connected with changing of gas pipeline capacity for provision of new construction requirements, and it is expedient to carry out comparative analysis of trenchless method application efficiency and new construction of polyethylene gas pipeline with bigger diameter.

Gas supply and gas distribution schemes were mostly developed in the Soviet period, therefore lately we observe rather random development of gas grids. It comprises relaying of separate pipeline sections with increasing of pipes diameter or transition from underground to overground position, construction of loops, etc. All these works upset the balance of gas distribution systems.

Joint Moscow, Saint Petersburg and “Gas de France” 15-years experience of depreciated gas pipelines reconstruction applying polyethylene pipes broaching method shows, that in some cases at gas pipelines reconstruction in the area accompanied by removal of big gas control points lateral gas line sections are forming. Finally it leads to decreasing of reliability of the entire grid. As a rule, in gas distribution system gas control points of high capacity are connected, and when outmode facilities at one of these points are out of action, the others are able to support existing mode of gas consumption. In cases when such gas control point is removed the system of loops is interrupted and appeared lateral gas line sections in case of emergency don’t provide required gas consumption mode.

In the coming period it is necessary to correct existing gas supply and gas distribution schemes of cities and towns, implementing qualitative analysis of gas supply and distribution systems unreliability reasons, considering negative influence to gas pressure level due to unstable functioning of gas control equipment not meeting up-to-date requirements.

5. TRENCHLESS METHODS OF GAS PIPELINES RECONSTRUCTION PERMITTED IN RUSSIA

From various applied abroad trenchless methods of gas pipelines reconstruction using polymer materials in Russia only three are permitted by standards and norms:

1, 2 – broaching of standard of profiled polyethylene pipes through depreciated steel pipelines;


In Moscow operability of underwater pipelines across Moscow River was completely recovered by “Phoenix” technology (including underwater pipeline commissioned in 1938 of 600 mm diameter, which was out of order due to numerous corrosion damages), OAO “Promgaz” has successful joint experience of electrochemical system recovery in Ribnoe town, Ryazan region (with Gas de France), of inspection and development of gas distribution system in Zhigulevskoye town, Ulyanovsk region and in Kalyazin town, Tver region (with Ruhrgas). Presently Promgaz, E.ON Ruhrgas and «Rädlinger primus line GmbH» company study the possibility of 2 km underwater pipeline across Ob River reconstruction by means of “Primus line” technology.

Traditionally in Russia cast-iron gas pipelines is not used, and standard sizes of domestic steel pipes sufficiently differ from the foreign pipes. Therefore the technologies allowing keep gas pipeline pressure category and use polyethylene pipes with practically equal to depreciated steel pipe
external diameter are especially attractive here. Application of such technologies for reconstruction of steel gas pipelines with 200, 250, 350, 400 mm passage diameter is enabled to apply standard polyethylene pipes, what makes works implementation considerably cheaper.

There are no special obstacles now for implementation of new foreign technologies of pipelines reconstruction allowing to keep gas pipeline pressure category after reconstruction. But it is necessary to considere the difference in acceptable pressure for various pressure categories of gas pipelines. In contrast to Europe maximum medium pressure in gas pipelines in Russia is 0.3 MPa (1 MPa = $10^6$ Pa), and high pressure is subdivided into two categories: from 0.3 to 0.6 MPa (permitted for polyethylene pipes use) and from 0.6 to 1.2 MPa (application of polyethylene pipes is forbidden by active standards and norms yet, but every year the length of experimental polyethylene gas pipelines with 1.2 MPa pressure is growing in Vladimir, Orenburg, Kaliningrad and other regions). Now it is planned to develop normative document concerning application of polyethylene pipes for construction and reconstruction of up to 1.2 MPa pressure gas pipelines. Production of such pipes in Russia is already arranged and met international standards.

Promgaz is responsible for implementation of unified technical policy in reconstruction and recovery of gas distribution systems and ready to cooperate with other companies introducing similar technologies in Russia, realizing joint pilot projects, creating experimental testing gas pipelines sections, spreading positive results of gas distribution grid reconstruction and recovery in the frameworks of programmes and projects aimed at gas distribution systems development in the regions of Russia.
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