INCREASING GAS PIPELINE LIFE SPAN AND RELIABILITY THROUGH NEW ENGINEERING AND LAYING TECHNOLOGIES

B.V. Budzulyak

Russia
ABSTRACT

The Paper gives an outline of new engineering and laying technologies for the Russia-Turkey gas pipeline, which ensure its reliable operation and long life span. The Russia-Turkey gas pipeline has been built with the use of the most advanced achievements in the gas main design, construction and operation sectors.

The pipeline is laid under the Black Sea, at depths of down to 2,000 m, and is operated under a 250 bar pressure. State-of-the-art technologies and materials used for the construction of the 392.5-km-long offshore section having a 610 mm (24”) diameter and 371-km-long onshore section allowed to achieve a high degree of the pipeline reliability.

A number of sophisticated engineering and technical solutions remain unique in the worldwide practice. The onshore segment was built in a harsh mountainous terrain environment predetermining the use of slant drilling, micro tunneling and unique anti-landslide technologies.

The underwater section was constructed by two sea vessels: Castoro-8, for the S-method laying at a depth of down to 370 m and Saipem-7,000, for the J-method laying.

Both the laying depth and anti-corrosion methods are unique from the technological viewpoint. The use of pipes with inner and outer coating enhances the pipeline operational specifications and makes it invulnerable to the extremely aggressive H2S environment of the Black Sea bottom. 5-m-long pipe insertions with 55 mm beefed-up walls are embedded every 500 m into the pipeline offshore section to prevent collapses.

For the first time in history the Russia-Turkey gas pipeline construction ran in parallel with the implementation of sweeping environmental measures securing both the pipeline integrity and high ecological standards.

The Blue Stream project is another indication of Gazprom’s technical capabilities in promoting advanced ideas and innovative technologies. The experience gained during the Russia-Turkey pipeline construction and operation enables the Company to launch even more prominent projects, such as the North European Gas Pipeline, with similar laying technologies projected to be also applied for the construction of a gas pipeline under the Baltic Sea.
TABLE OF CONTENT

Abstract

1. Increasing gas pipeline life span and reliability through new engineering and laying technologies

2. List of figures
1. INCREASING GAS PIPELINE LIFE SPAN AND RELIABILITY THROUGH NEW ENGINEERING AND LAYING TECHNOLOGIES

Providing high reliability of gas industry infrastructure is a Gazprom crucial technical and economic challenge met by a range of measures encompassing the development of innovative construction & inspection technologies and enhancement of gas main safety & security.

**Fig. 1  Russia's Natural Gas Share in the Global Total**

Gazprom operates the world's largest integrated gas extraction and transportation system piping gas from fields to domestic and foreign consumers.

Pipeline transmission is the most significant element in this complex technological process involving more than 80% of Gazprom’s total key production assets. The transmission pipeline length and has so far exceeded 150,000 km and the rated capacity of compressor stations reached 42 mln kW.
<table>
<thead>
<tr>
<th>Major Parameters of JSC Gazprom Mains</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Trunk pipelines and line spurs (thousand km)</td>
<td>156.3</td>
</tr>
<tr>
<td>Products pipelines (km)</td>
<td>5826.4</td>
</tr>
<tr>
<td>Number of compressor stations</td>
<td>264</td>
</tr>
<tr>
<td>Number of gas distribution stations</td>
<td>3818</td>
</tr>
<tr>
<td>Number of compressor units</td>
<td>4078</td>
</tr>
<tr>
<td>Rated capacity of , MW</td>
<td>42 900</td>
</tr>
<tr>
<td>Number of UGS facilities</td>
<td>24</td>
</tr>
<tr>
<td>Number of cathodic protection units</td>
<td>19 181</td>
</tr>
</tbody>
</table>

Fig. 2 Major Parameters of Gazprom’s Gas Mains
In the nearest future Gazprom is planning to implement even larger projects.

Building the North European Gas Pipeline under the Baltic Sea is one of the short-term targets. The ceremony of welding of the NEGP first joint was conducted on December 1, 2005.

A combination of high pipeline pressure – up to 10 MPa, large pipeline diameters – up to 1420 mm, great extension, powerful multi shop compressor stations and harsh environmental conditions predetermine the need of achieving lower technological costs and higher marketing & transmission efficiency.
The gas transmission system undergoes continuous development. The Yamal-Europe gas pipeline is in its final construction stage.

In the coming 6-7 years Gazprom intends to bring on-stream Yamal fields with a total of more than 6 tcm in gas reserves and reservoirs in the Nadym-Pur-Taz region, which requires substantial financial resources. Additionally the Yamal Peninsula is characterized by highly unfavorable environmental conditions and virtually has no industrial and social facilities. Field development in this region requires considerable investments and state-of-the-art technologies ensuring environmental protection under harsh polar conditions. That is why the Yamal-based Bovanenkovo gas condensate field infrastructure is being developed through a large-block installation method implying the manufacture of super blocks with their subsequent transportation by sea.

Developing the Shtokman gas condensate field infrastructure is another step in the gas transmission system de-bottlenecking. This project includes two ice resistant platforms with drilling installations for 20 wells and treatment facilities for 60 wells, 40 of which have underwater wellhead location. A sea gas pipeline (1074 mm in diameter) crossing the Gulf of Finland and Baltic Sea will have the length of 1,295 $10^3$ m, with a compressor station to be built on a stationary platform in the Baltic Sea.

The present-day global gas market trends point to the need of developing new and expanding existing gas sales markets. A unique gas transmission corridor Blue Stream was put into operation at the end of December 2002.

Russia is a prominent supplier of ‘blue fuel’ to Turkey. Our southern neighbor has become the world’s third top importer (among 20 states) of Russian natural gas, preceded only by Germany and Italy. This fact predetermined a need for the construction of a pipeline via the shortest way across the Black Sea with the view of slashing gas transportation distances and expenses.
Blue Stream Gas Pipeline

Fig. 5 Blue Stream – Russia-Turkey Gas Pipeline
The Blue Stream project implementation provided Russia with:

- A 365 bcm increase of natural gas exports for a 25-year period;
- Additional hard currency earnings;
- Reinforcement of Gazprom’s standing as a prominent gas supplier to the Black Sea region.

The use of modern technologies made it possible to construct a gas pipeline of particular complexity. Blue Stream is justifiably attributed as a unique engineering construction that is unparalleled in the world in terms of separate on- and offshore technologies applied primarily for the purpose of enhancing the pipeline reliability at the engineering, construction and operation stages. Said technologies include:

- Using pipes made of top-quality corrosion-resistant steel with smooth lining and polymer coating produced by Italian, Japanese, German and Ukrainian plants;
- Applying cathodic protection materials for the transmission part of the marine section (anodes are used during the pipeline laying process and are designed for the entire operational cycle);
- Tunnel pipeline laying beneath mountain ridges;
- Re-enforcement with concrete inshore gas pipeline sections;
- Applying advanced Russian gas pumping units equipped with Japanese compressors with dry sealing systems.
Blue Stream project provides for:

- increase in Russian Gas export by 365 bcm for the period of 25 years;
- additional export earnings for the Russian economy;
- retaining of presence and buildup of Gazprom position as the major natural gas supplier in Black Sea region.

Major technical features:

- tubes of a high grade corrosion resistant steel with inner and outer smooth polymer coating produced during manufacturing process (in Italy, Japan, Germany and Ukraine);
- cathodic protection of the linear part of offshore pipeline (anodes being placed during construction and are to be operational thru the service life);
- employment of tunneling under mountain ridges;
- concrete coating of coastal sections;
- state of the art Russian compressor units with dry seal compressors manufactured in Japan.

Fig. 7 Blue Stream Project Features

The onshore transmission section consists of a 1,420x19 mm, 307-km-long, 75 bar plain segment from the Izobilnoye compressor station to the Krasnodarskaya compressor station and a 1,220x17.8mm, 65-km-long, 100 bar mountain segment from the Krasnodarskaya compressor station to the Beregovaya compressor station.

For the first time in Russia a pipeline onshore section has epoxy lining improving hydraulic gas transmission.
Fig. 8  Onshore Transmission Section Route

Horizontal directional drilling was applied during the construction of water crossings. In several cases drilling was complicated by psephitic rocks and layers with a complex geological structure.
The mountain segment including the Big Caucasian Ridge (where the height of several saw-edged mountains reaches 600 m above sea level) was particularly difficult for the pipe laying from the geological viewpoint.

Numerous landslide areas (32) along the pipeline route, tectonic ruptures (9) and seismic activity up to 9 on the Richter scale required cardinal review of conventional technologies.

Innovative technological solutions and materials were applied to provide anti-landslide protection to 17 sections situated in landslide areas, with steel wire mats filled with gravel and steel-meshed gabions mounted to hold landslides and auger concrete piles placed in the landslide body.
To control the pipeline stressed-deformed state, 15 “intellectual insertions” equipped with strain-resistant sensors and transducers were installed by the landslide sides. A sound wave profiling acoustic facility which follows the beginning of the landslide segment base down was installed to control geodynamical processes. Additionally some of the most dangerous landslide areas were equipped with subsurface inclination compasses and ground water level sensors.
Fig. 11 Applying Intellectual Insertions

For the first time in oil and gas practice the technology of pipeline laying through a mountain ridge with further dragging through the tunnel was proposed and implemented to increase the gas pipeline operation reliability in complex areas. Laying 3,260m tunnel crossings allowed to reduce direct environmental impacts during the construction period, diminish construction areas, preserve the woods, avoid anti-landslide protection measures and secure operation of the reinforced concrete-covered pipeline.

Pipes were put into position by heavy hydraulic jacks, which grab the pipe and push it into the tunnel. In addition the original design pipeline rolling cradle was applied, which allows to avoid tube insulation crushing.

To protect the pipeline from rock fragments and from surface waters diversion for the first time in history the gas main was covered with a Geotextile material that has highly resistant characteristics and is resistant to water saturated soil.

Gas pipelines which are laid in tunnels are hydraulically tested under a 15 MPa pressure and the entire mountain segment underwent pneumatic tests for capability under a 110 bar pressure with the help of LMF 67/150 (Austria) compressors.

CRG Evans welding systems were widely used for the land section construction.

In parallel to the construction ran sweeping environmental measures fitting with the aims and intentions of Gazprom emphasizing its high-standard environmental priorities.
The main Russian compressor station Beregovaya

Fig. 12  The main Russian compressor station Beregovaya

The Beregovaya compressor station is situated within 2 km from the Black Sea coastline in the vicinity of the Arkhipo-Osipovka settlement. This station is designed under harsh geological and technical conditions. Most of the technologies used for its construction are unparalleled both in Russia and abroad and encompass the construction of several facilities on fill-up ground with seismic activity of 9 on the Richter scale, application of up to 250 bar compressors, a gas treatment facility for each compressor, unmanned operation of the station and a new contractual system for the station and marine section maintenance.
Two marine sections of the 610x31.8 mm pipeline were laid during the construction process. From the technical point of view the laying depth and the pipeline metal protection from the impact of highly aggressive hydrosulfuric fluid of the Black Sea bottom are unique. The gas pipeline laying depth reached 2150 m.

Welding and underwater laying activities were performed from a total of 24 special sea crafts (main and auxiliary). Depending on the depth various pipeline laying technologies was used. The direct laying was performed by two sea crafts:

- Castoro-8 – S-method laying (up to 370 m);
- Saipem 7000 - J-method laying.
Castoro Otto vessel pipeline laying/ trenching

- Pipeline laying in shallow and medium depth waters
- Sideboard units to execute surface backlashes
- Large diameter pipe laying
- Fully automatic welding process using a single weld method

Fig. 14 Castoro Otto Vessel Pipeline Laying/ Trenching

Semi Submersible Crane Vessel Saipem 7000

Technical characteristics:
- Maximum length - 197.95 m
- Hull height - 43.5 m
- Maximum deck area - 9000 sq m
- Maximum deck load - 15000 t
- Standard towing draft - 10.5 m
- Number of compartments 408 (single & double) for 700 persons
- Maximum derrick carrying load - 14000 t
- Towing speed - 9.5 knots
- Engine and thrusters output:
  4 x 4500 kW
  4 x 3000 kW
  2 x 2500 kW
  2 x 2500 kW
- Diameter of system - 4" to 32"
- Principle tension system - 525 t,
  with tension units of up to 2000 t power output

Fig. 15 Semi Submersible Crane Vessel Saipem 7000
In shallow waters (up to 575 m from the water boundary) pipes were laid into a trench embedded in concrete. With no anchoring devices, pipes lie loose at the seabed, holding ground by its own weight and water column pressure.

To operate at depths of up to 2,500 m Saipem-7000 underwent upgrading.

The record high speed of up to 5,120 m per day was reached during the pipeline laying process.

The pipeline is covered with high-tensile epoxy polymer for its interior protection. The outer side is protected from corrosion by extended zinc anodes and a three-ply polymer coating.

New technologies of ground sampling and well drilling in a muddy environment were applied during engineering survey at the Black Sea bottom. The survey was carried out by the Russian company Yuzhmorgeologia with the use of the Aquanaut and Academician Golitsyn vessels, towed acoustic arrays and submerged installations.

5 meter-long pipe insertions with 55 mm beefed-up walls are embedded every 500 m into the pipeline offshore section to prevent collapses. Given that in deep waters the pipe has negative buoyancy, it didn’t require additional concrete or metal ballasting.

The Blue Stream project is another indication of Gazprom and its partners’ technical capability of implementing advanced ideas and path-breaking technologies in the pipeline construction sector. Most of the applied technologies will be used for the construction of new facilities.
2. LIST OF FIGURES

1. Fig. 1 – Russia’s Natural Gas Share in the Global Total
2. Fig. 2 – Major Parameters of Gazprom’s Gas Mains
3. Fig. 3 – Yamal-Europe Project
4. Fig. 4 – North European Gas Pipeline Project
5. Fig. 5 – Blue Stream – Russia-Turkey Gas Pipeline
6. Fig. 6 – Blue Stream Project
7. Fig. 7 – Blue Stream Project Features
8. Fig. 8 – Onshore Transmission Section Route
9. Fig. 9 – River Crossing Construction through Horizontal Directional Drilling Method
10. Fig. 10 – Blue Stream’s Mountain Segment
11. Fig. 11 – Applying Intellectual Insertions
12. Fig. 12 – The Main Russian Compressor Station Beregovaya
13. Fig. 13 – Underwater Laying of two Lines of Blue Stream’s Offshore Section
14. Fig. 14 – Castoro Otto Vessel for Pipeline Laying/ Trenching
15. Fig. 15 – Semi Submersible Crane Vessel Saipem 7000