Development and Application of High Strength Pipes for Gazprom's Trunk Gas Pipelines

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The implementation of strategic gas transmission projects is a compulsory condition for stable economic development and energy safety of Russia.

The decisive role in the development of gas industry in Russia in 21st century undoubtedly belongs to the development of Yamal hydrocarbon fields. Therefore, the construction of trunk gas pipelines running from the Yamal Peninsula to central regions of Russia is currently the main Gazprom's project. The project is of high strategic and economic importance; it will ensure planned gas consumption in Russia and fulfillment of long-term export commitments of Russia. The project largely determines the role of Russian gas in the European gas market on the whole.

A new 1100 km pipeline is being built in the Yamal-Ukhta direction to provide Yamal gas transmission. For the period to 2030, with a view to transport 300 BCM of the Yamal gas per year, it is planned to make a progressive capacity growth of the system by building 5-6 strings between Yamal and Ukhta.

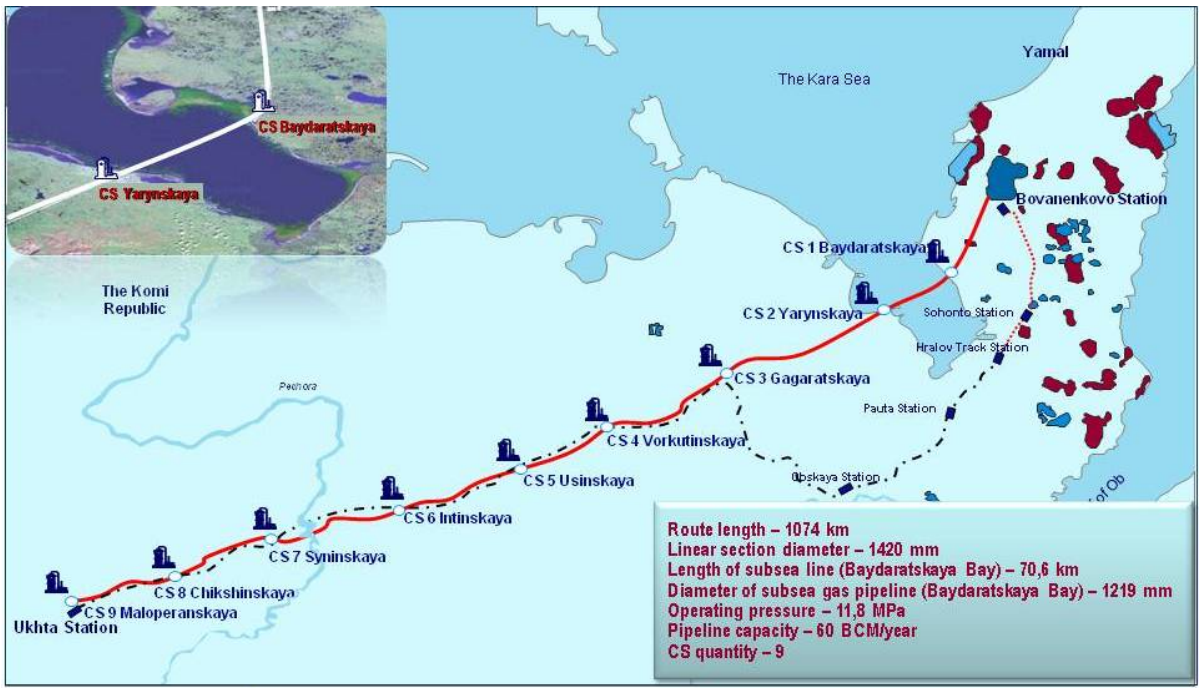


Fig.1 - Bovanenkovo – Ukhta Gas Trunkline Project

The gas transmission system will include 27 modern compressor stations of total capacity of 8600–11600 MW. The total length of the pipeline will amount to about 6 thou. km.

The Bovanenkovo-Ukhta trunk gas pipeline has the following parameters: operating pressure 11,8 MPa, K65 (X80 API 5L) steel grade pipes, diameter 1420 mm, wall thickness to 33,4 mm, operating wall temperature minus 20 C.

The construction of the first gas pipeline of 1100 km length will be completed in July 2012 and 2013 will see the launch of construction of the second gas pipeline.

One of the main difficulties related to the construction of this trunk gas pipeline system is that the construction territory, especially in northern regions, has very complicated engineering and geological conditions, including: permafrost, frost seasonal and long-term heaving, subsidences, high salt content, landslides, thermokarst, roughness and bogginess of the territory.

Fig.2 - Natural and Climatic Conditions Along Bovanenkovo-Ukhta Trunkline Route

Another important feature of the Yamal gas pipeline system is that it goes via the offshore area of the Baydaratskaya Bay of the Kara Sea. The length of the subsea section is about 70 km.

It is evident that the economic efficiency of a long gas pipeline from the region with such severe natural and climatic conditions and lack of infrastructure can be achieved only by using high strength pipes of high operational reliability and long service life.

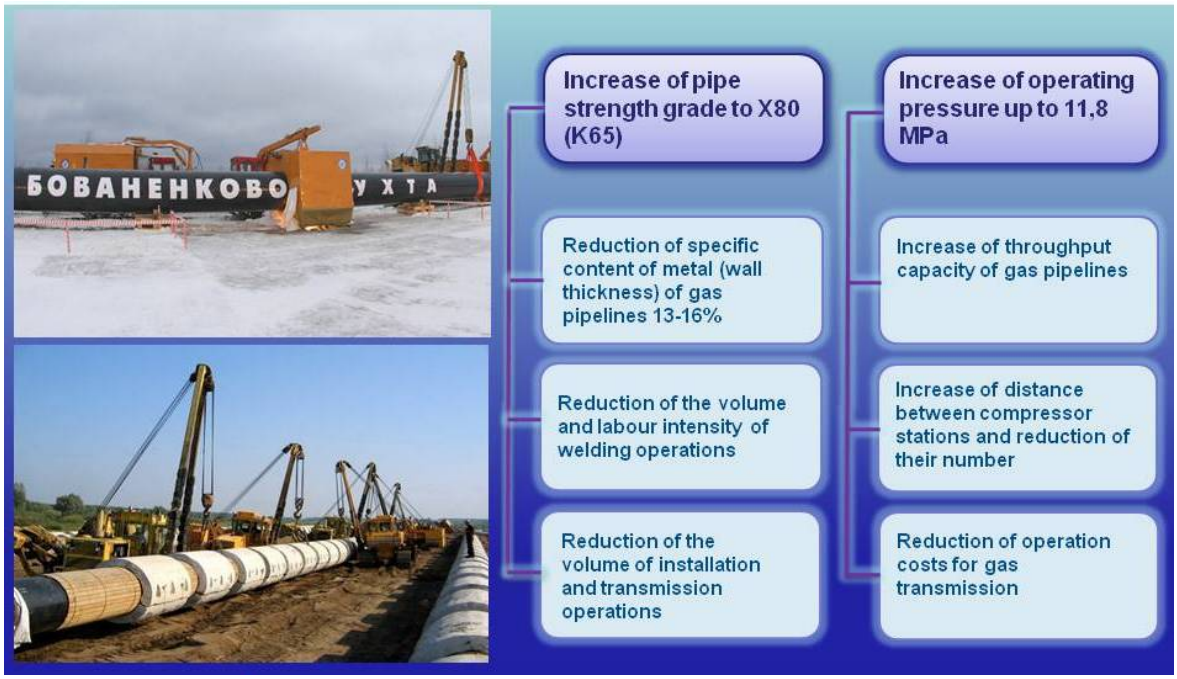


Fig.3 - Natural and Climatic Conditions Along Bovanenkovo-Ukhta Trunkline Route

The calculations showed that application of X80 API 5L (K65 – Russian classification) steel grade pipes provides the following main advantages:

- reduction of specific quantity of metal consumption for gas pipeline;
- reduction of the scope of welding works;
- reduction of construction, assembly and transmission operations;
- increase of gas pipeline throughput capacity;
- increase of the distance between compressor stations;
- reduction of transmission OPEX and energy consumption.

On the whole process solutions and gas transmission system parameters adopted for designing the Bovanenkovo-Ukhta gas pipeline reduce CAPEX to 26% and OPEX to 14% compared to traditional technologies for construction of 7,4 MPa gas pipelines.

Concurrent increment of two key parameters of a 1420 mm gas pipeline: operating pressure and steel grade, used for its construction had no direct analogues in the world and required special attention in providing pipes properties that could guarantee the exception of the risk of long-distance failures. Also it required special attention in choosing welding technology.

It is possible to minimize risks by using pipes with principally new qualitative parameters, development of adequate welding, construction and operation technologies. The lack of experience in production and application of 1420 mm X80 pipes required a great scope of research and experimental works that resulted into the development of a set of regulatory documents stipulating specifications for pipes, technical guidance for welding, construction, repair, defect detection and diagnostics. This work used advanced scientific and technical achievements and global experience in running comprehensive pipeline projects.

The preliminary analysis showed that unique technical and engineering parameters of the Bovanenkovo-Ukhta trunk gas pipeline laid under extreme permafrost and climatic conditions should be ensured by unprecedently high level of technical requirements for pipes that are at the edge of technical capacities of the most advanced metallurgical plants.

The target of creating high strength highly reliable pipes required innovative scientific approaches, development and application of cutting-edge technologies at all stages of metallurgical and pipe treatment: from making especially pure low carbon steel without non-

metal inclusions with highly dispersed ferritic-bainitic structure and stripes of required dimensions and quality to molding, welding and expanding of the pipe blank.

Flat steel made by controlled rolling with accelerated cooling was used for pipe manufacture. Increased requirements for strength, ductility, toughness and fracture resistance of the parent metal and metal of fabricated welded joint, close tolerances for geometric parameter deviations were imposed on pipes.

Strength and plastic properties

Pipe grade	Standardized document	Minimum yield stress s_T, MPa	Minimum tensile stress s_B, MPa	Maximum s_T / s_B	Minimum Relative elongation, %
K60	GOST 52079	440	590	0,90	20,0
L485	ISO 3183	485	570	0,93	15,35
K65	Technical requirements	555	640	0,92	18,0
K65	TU 100-98	539	638	0,85	18,0
L555	ISO 3183	555	625	0,93	14,1

Impact strength at the operating temperature

Pipe diameter, mm (pipe grade)	Impact strength				
	Technical requirements J/sm^2	GOST 52079, J/sm^2	ISO 3183:2007, J (J/sm^2)		
			k=0,625	k=0,72	k=0,80
530 (K60)	100	24,5	41 (51)	50 (62,5)	60 (75)
720 (K60)	110	29,4	48 (60)	58 (72,5)	68 (85)
1020 (K60)	110	58,8	56 (70)	68 (85)	81 (101)
1220 (K60)	130	78,4	63 (79)	77 (96)	91 (114)
1420 (K60)	170	107,8	63 (79)	77 (96)	91 (114)
1420 (K65)	250	117,6	96 (120)	120 (150)	148 (185)

Impact strength requirement for Bovanenkovo-Ukchta pipes exceed substantially norms specified in main standards

Fig.4 - Energy Performance Indicators of the New Gas Transmission Technology

To ensure, inspect and confirm parameters of new generation high strength pipes, Gazprom organized and carried out the testing of pilot 1420 mm X80 pipe lots that incorporated the analysis of the engineering manufacturing process and assessment of plants' readiness for commercial production of high strength pipes and included:

- laboratory tests of metal and welded joints of pipes;
- bench hydraulic tests of pilot pipes to assess full-scale fracture resistance of pipes;
- field pneumatic extended rupture strength tests of pipe stalk.

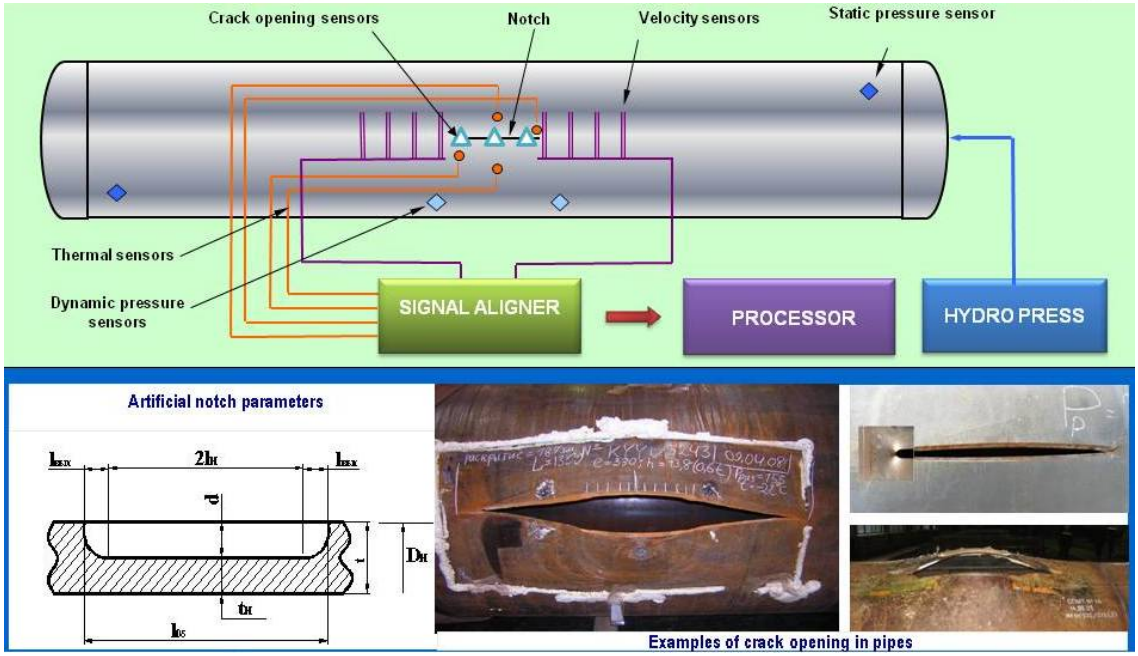


Fig.5 - Technical Requirements for Pipe Grade X80 and Pipe Grade K60 specified in main standards

In this chain of qualification of technologies of the stated steel grade pipe manufacture special attention was paid to field tests of pilot pipe stalk since their results influenced the final decision on the possibility of commercial supplies of high strength pipes for construction of the Bovanenkovo-Ukhta gas pipeline. Scientists of leading research centres formulated methodological grounds for testing, developed technical requirements for pilot pipe lots, processed experimental data and obtained answers for a number of principal questions related to ensuring safety and reliability of pipes.

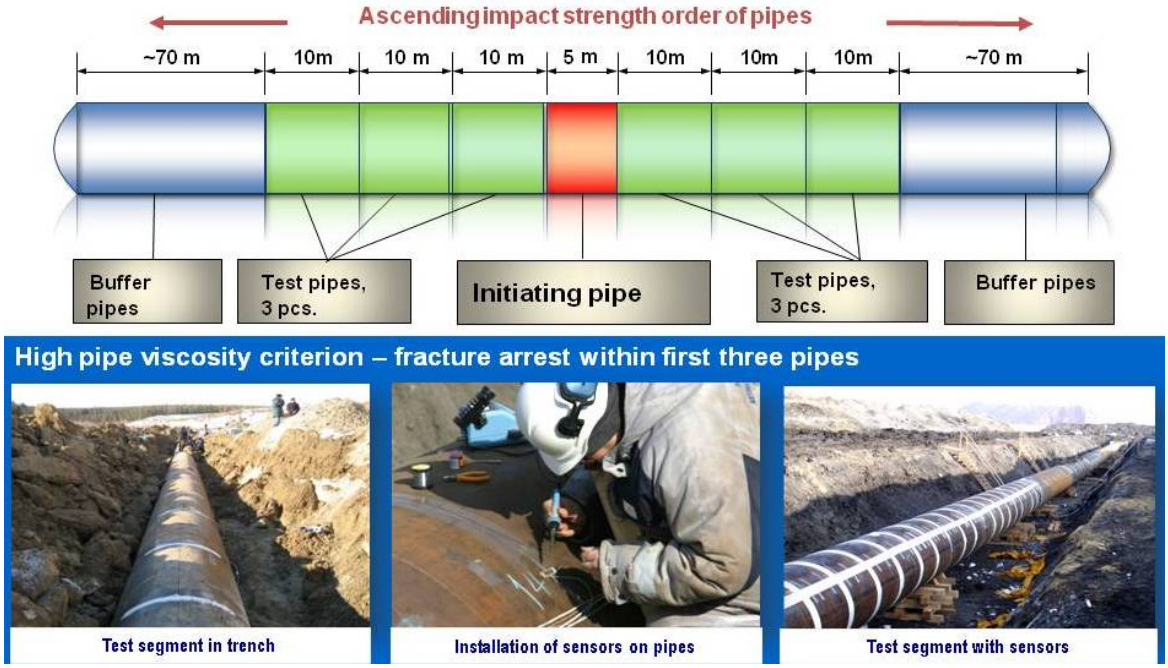


Fig.6 - Field pneumatic tests of X80 pipes

In short term Gazprom created a temporary test site in Kopeysk (the Chelyabinsk region) where 17 full-scale pneumatic tests of X80 steel grade pipes were carried out from March 2008 to December 2011.

Fig.7 - Pneumatic field tests of X80 pipes, town of Kopeysk

The results of field tests were not only a major achievement in development of experimental methods of testing the reliability of new generation pipes, but also promoted the short-term establishment of an essential data base for further development of scientific understanding of mechanisms of simultaneous failures of gas pipelines, development of adequate criteria for assessment of the compliance and confirmation of operational properties of new generation pipes.

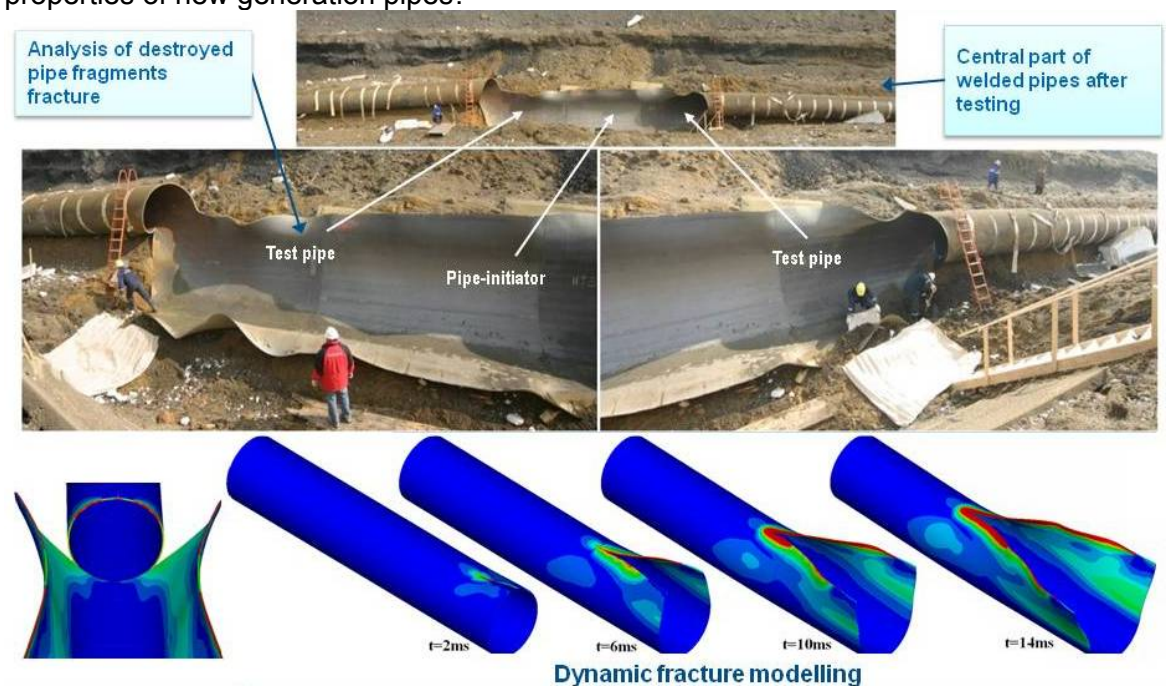


Fig.8 - Pneumatic Field Test Results Analysis

The detailed analysis of results of comprehensive tests of pilot lots of pipes of different manufacturers became the basis for development of final specifications for X80 steel grade pipes, confirmed the reliability of developed technologies for production and control of commercial pipe lots with guaranteed unique parameters: ultimate strength – not less than 640 MPa, yield strength – not less than 555 MPa, ratio of ultimate strength and yield strength – not more than 0,92, relative elongation – not less than 18%, impact strength of the parent metal under minus 40 °C – not less than 250 J/cm^2.

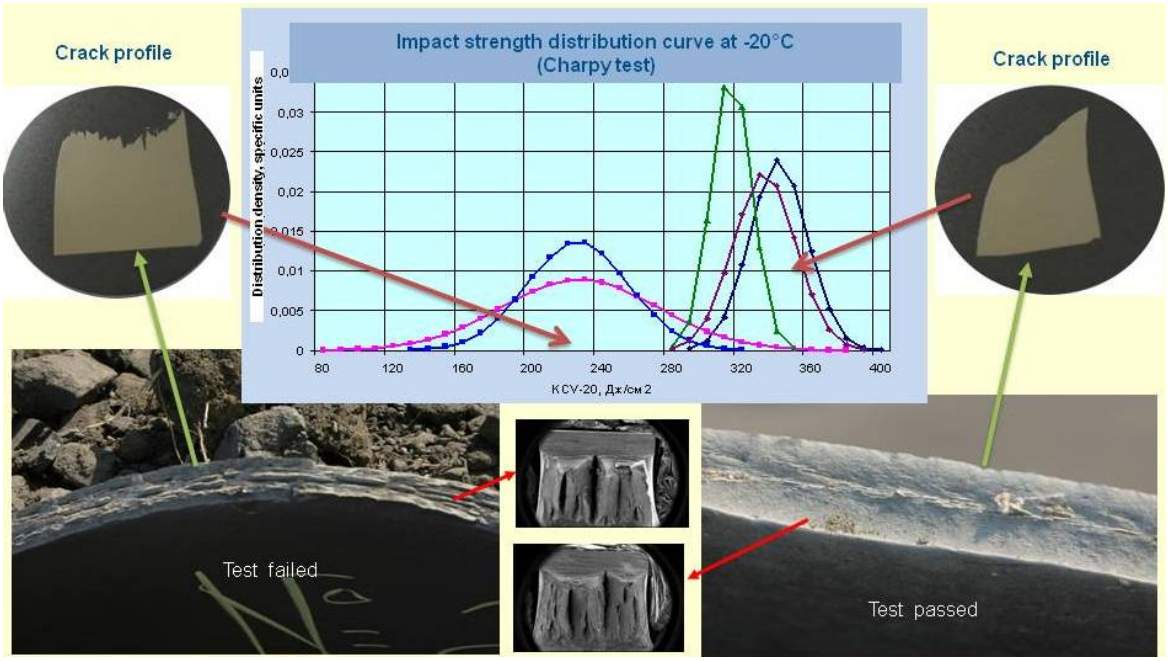


Fig.9 - Matching laboratory, hydraulic pneumatic results

Manufacturing plant	Sheet manufacturer	Wall thick., mm
Vyksa Steel Works (RU)	POSCO (Korea), Nippon Steel Co (JP) Dillinger Hütte, Salzgitter (DE)	23,0 27,7
Izhora Pipe Plant (RU)	Severstal (RU)	23,0; 27,7; 33,4
Volga Pipe Plant (RF)	Severstal (RU), Nippon Steel Co (JP) Severstal (RU), Salzgitter (DE)	23,0 27,7
Chelyabinsk Pipe Rolling Plant (RF)	MMK (RU) MMK, Severstal (RU) GTS Ind., Salzgitter (DE)	23,0 27,7
Nippon Steel Co (JP)	Nippon Steel Co (JP)	27,7
Sumitomo Metal (JP)	Sumitomo Metal Industries Ltd. (JP)	23,0; 27,7
Europipe GmbH (DE)	Dillinger Hütte, Salzgitter (DE)	27,7
JFE Steel Corporation (JP)	JFE Steel Corporation (JP)	27,7

Fig.10 - Pipe grade X80 Suppliers

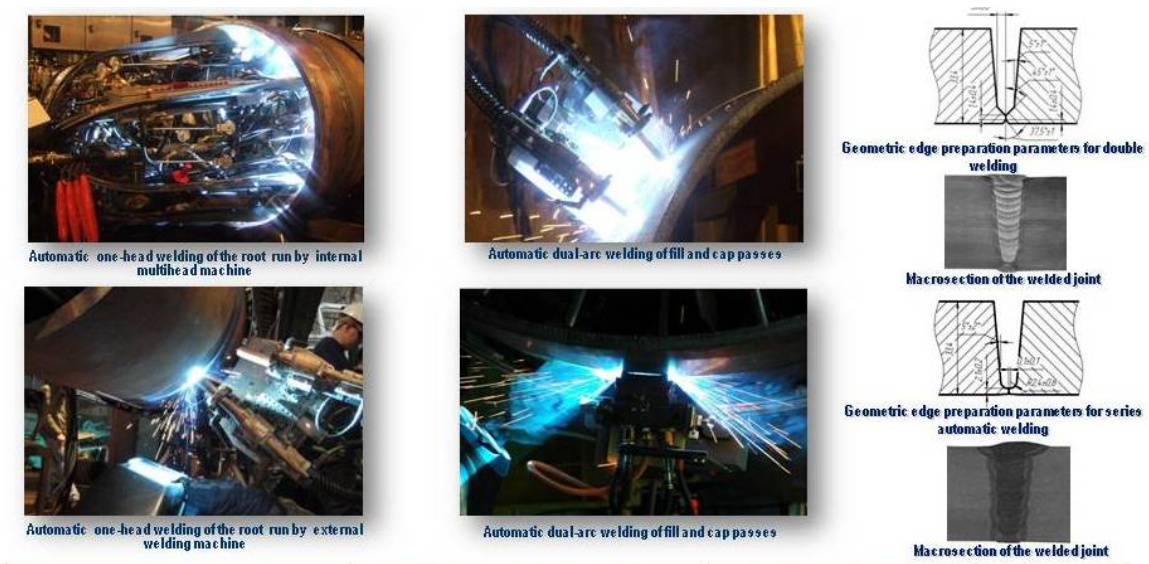
According to the results of the conducted tests and production process audit four Russian plants and four foreign companies confirmed availability to produce 1420 mm X80 pipes, 23,0, 27,7 and 33,4 мм wall thickness. Gazprom have approved specifications of Izhora Pipe Mill, Vyksa Steel Works, Volga Pipe Plant, ChelPipe and Europipe (Germany), Nippon Steel, Sumitomo Metal Industries and JFE (Japan).

Specifications for pipes took into account requirements not only of Russian standards, but also current foreign standards and specifications:

- ISO 3183-2007 Petroleum and natural gas industries- Steel pipe for pipeline – Technical delivery conditions;
- API Spec. 5L Specifications for line pipe, USA, 2004;
- EN 10208-2 European standard. Steel line pipes for combustible materials. Specifications.

Specifications also took into account the experience of current gas pipeline system operation; results of analysis of failures and accidents on the linear section of trunk gas pipelines; Russian and international experience in field extended rupture strength tests.

Another issue that was addressed for construction of the Bovanenkovo-Ukhta gas pipeline was the need for ensuring reliability of field welded joints by the combination of strength, toughness, cold resistance of metal and pipe weldability. To eliminate risks related to poor reliability of field welded joints, a set of studies and qualification tests were carried out to develop new and adjust certain traditional welding technologies and materials for X80 steel grade thick-wall pipe welding under temperature conditions of the construction site on Yamal.



Regulatory requirements	Ultimate tensile strength, MPa	Impact strength, J/cm²	Hardness, HV10
	Not less 640	Not less 50 under t = minus 40°C	Not more 300
Double automatic welding	690-720	120-250	230-280
Series automatic welding	660-700	90-230	210-250

Fig.11 - Qualification of welding technologies for ring butt-welded joints of X80 pipes

When studying weldability of new pipes, different welding technologies for different project sections (onshore and subsea) were tested and welding and testing methods and consumables were certified. The obtained results provided technologies and regulatory documents for welding that ensures reliability and long service life of joints.

In the process of design and construction of Bovanenkovo-Ukhta trunk gas pipeline another important target was achieved as well – the technology of manufacturing fabricated and field cold bents using best bending conditions was developed. Essential parameters and indicators were achieved in this area, and namely: the manufacture of field bends with total

bending angle to 9º inclusive from 1420 mm electrically welded longitudinal steel pipes with wall thickness from 23,0 to 27,7 mm inclusive, length from 11,0 to 12,0 m and from 17,0 to 18,2 m including with protective coating was proved possible. Laboratory and hydraulic tests confirmed the possibility of manufacturing cold bends ensuring preservation of pipe parameters together with minimal deformations.

Resume

Thus, for the first time in global practice Gazprom has scientifically substantiated and experimentally confirmed specifications for 1420 mm diameter X80 steel grade pipes with operating pressure 11,8 MPa, approved specifications for manufacturing commercial lots of such pipes, developed construction technologies for building a maximum diameter gas pipeline from high strength pipes. The construction of the first Bovanenkovo-Ukhta gas pipeline proved the practical feasibility of the project and the possibility of the cost-efficient gas transmission from the Yamal Peninsuls fields via gas pipeline made of X80 steel grade pipes.