BLUE STREAM READY FOR GAS TRANSPORTATION

THE D*REAM BECOMES THE* S*TREAM:* THE WORLD'S MOST CHALLENGING PROJECT AND DEEPEST OFFSHORE PIPELINES ARE NOW COMPLETED

CARUSO Salvatore, Technical Director (Blue Stream Pipeline Company)
DICORRADO Stefano, Offshore Technical Manager (Blue Stream Pipeline Company)
BOROVIK Vladimir, Technical Director (Blue Stream Pipeline Company)

1. INTRODUCTION

In November 1998, OAO Gazprom and ENI S.p.A. entered into a Memorandum of Understanding providing, inter alia, for a joint participation on an equal basis in the Blue Stream Pipeline Company BV (BSPC) for the development and implementation of the offshore segment of a gas transportation system that would allow the transportation of natural gas from Russia to Turkey through the Black Sea (the Blue Stream Project).

BSPC, established under the laws of The Netherlands, has settled and registered branches in Moscow, Krasnodar (Russia) and Samsun (Turkey) for the purpose of managing the activities in the Russian Federation and in Turkey.

In November 1999 BSPC entered into an EPC Contract on a turnkey basis for the design, procurement and construction of the section from the Russian coast to the Turkish one across the Black Sea. The Contract was awarded to a Consortium of companies consisting of Saipem S.p.A., Bouygues Offshore S.A. and a Japanese Consortium (Mitsui & Co. Ltd., Sumitomo Corporation, and Itochu Corporation).

The project consists of three main segments: the onshore section in the Russian territory from Stavropol (Izobylnoe village) to the Black Sea coast controlled by Gazprom, the section of BSPC to cross the Black Sea and the onshore part in the Turkish territory from Samsun to Ankara managed by Botas.

The BSPC part consists respectively of one Compressor Station in Beregovaya close to the Russian coast on the Black Sea (6 turbo-compressors for a total power of 180 MW and 3 turbo-generators (15 MW)) and two 24" offshore pipelines (610 mm OD x 31.8 mm wall thickness) at the world's record depth of 2,150 m.

The Offshore Section was realised laying the pipelines both with standard S-Lay mode in shallow waters and with the innovative J-Lay method for the main part of the routes. J-Lay was executed through the Saipem 7000 (S7000) vessel, custom modified for the purpose. Various technical difficulties had to be solved, such as the geohazard related to seismic activities in the Russian steep slope and on Turkish coast, the presence of H_2S in the seawater and the laying at very deep water.

Furthermore, the Blue Stream Project is very unique in terms also of the maximum pressure and temperature during the operation, of the volume of gas transported and the length of way to go from Beregovaya in Russia to the Turkish coast in Samsun.

All these matters lead to a challenging project from the financial point of view, as the value of the Project is 2.3 – 2.4 x 10^9 USD.

The Offshore Section of the project has been designed, developed and constructed in compliance with the DNV'96 'Rules for Submarine Pipeline System' issued by the Norwegian certifying company Det Norske Veritas AS (DNV). DNV is one of the most accredited independent certifying society for marine project who acted as 'Third Party' during each phase of the Project up to the issue of the final 'Certificate of Compliance'.

The Project is ready for the first gas flow from Russia to Turkish market and the first gas flow through the first offshore line occurred at the beginning of year 2003.

This paper presents the Project (mainly for the section managed by BSPC and particularly the Offshore Section, the most innovative and challenging part) through the various phases, from the very beginning to its conclusion, with deep analyses of main features and characteristics as well as the various challenging matters faced and overcome.

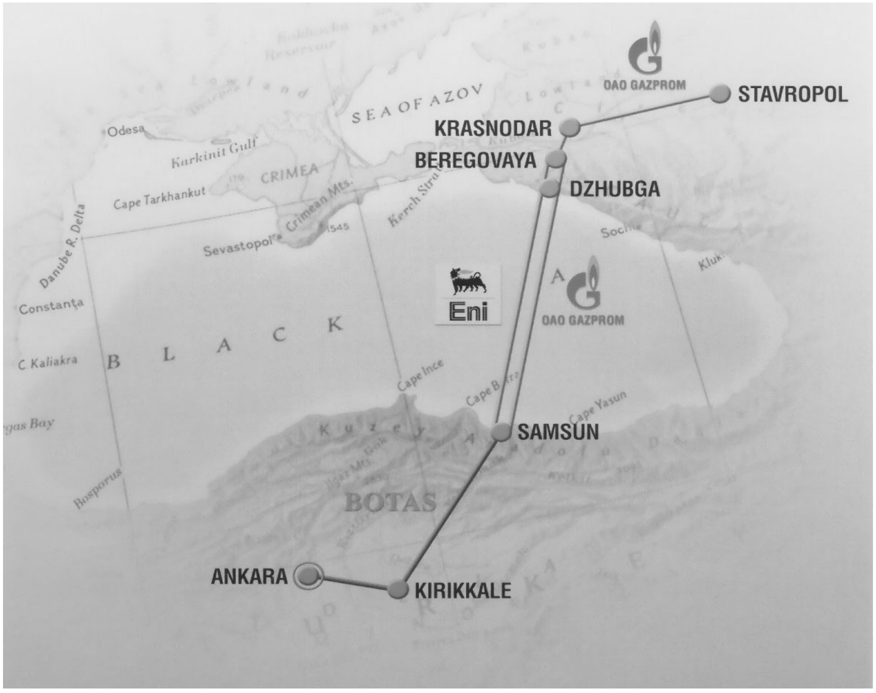
2. BLUE STREAM PROJECT DESCRIPTION

The Blue Stream project is a pipeline transportation system for delivery of processed gas from the network in southern Russia to Turkey across the Black Sea.

Once reached the regime of transportation, the total quantity of natural gas flowing through the two offshore pipelines will be equivalent to 16 x 10^9 standard cubic meters per year.

The project consists of three main segments:

a) the onshore section in the Russian territory from Stavropol (Izobylnoe) to the Black Sea coast, controlled by Gazprom (about 370km with 56" and 48" pipeline);
b) the section of BSPC to cross the Black Sea, which is the main subject of this paper. It is mainly composed by the compressor station located in Dzhubga close to Beregovaya on the Russian coast (the Beregovaya Compressor Station or BCS) and the two offshore pipelines which form the Offshore Section;
c) the onshore part in the Turkish territory from Samsun to Ankara, managed by Botas (about 501 Km with 48"pipeline).



The Blue Stream transportation system – Overall map

Factors	Summary data on the gas pipeline	by sections		
		OAO Gazprom	**BSPC BV**	**BOTAS**
		Russian onshore section (Izobylnoe-Dzhubga)	**Offshore Section + BCS (Dzhubga-Samsun)**	**Turkish onshore section (Samsun-Ankara)**
Length (km)	1253 -1261	370	383+391	501
Diameter (inches)	-	56" (307.8km) 48" (62.2km)	24" (2 lines)	48"
Pressure (bar)	-	75 (307.8 km) 100 (62.2km)	250	75

The Blue Stream transportation system – Overall figures

2.1. Russian onshore section

The Russian onshore section is totally managed and owned by Gazprom and includes 2 compressor station units, 20 valve units, gas measuring stations and 11 cathodic protection stations.

The gas pipeline runs through the territory related to the Azov Sea basin, crossing 7 water obstacles, 2km bogs, 13.5km water encroached territories. The geologic section shows the predominance of the clayey sediments up to 35-45m. The route runs through the Caucasus Mountains on a 308-370Km section. Absolute elevations change from 190 up to 340 m. This region is the area of the development of active geotectonics and the modern geologic processes such as landslides, erosion, screes, etc.

Two compressor stations (Stavropolskaya, 60 MW capacity, and Krasnodarskaya, 60 MW capacity) are to be built on the Russian section.

The compressor station Beregovaya (180 MW capacity) belongs to the offshore section. Its function is gas transmission through the gas pipeline offshore section.

2.2. The section managed by BSPC to cross the Black Sea

The section of the Blue Stream transportation system managed by BSPC consists of:

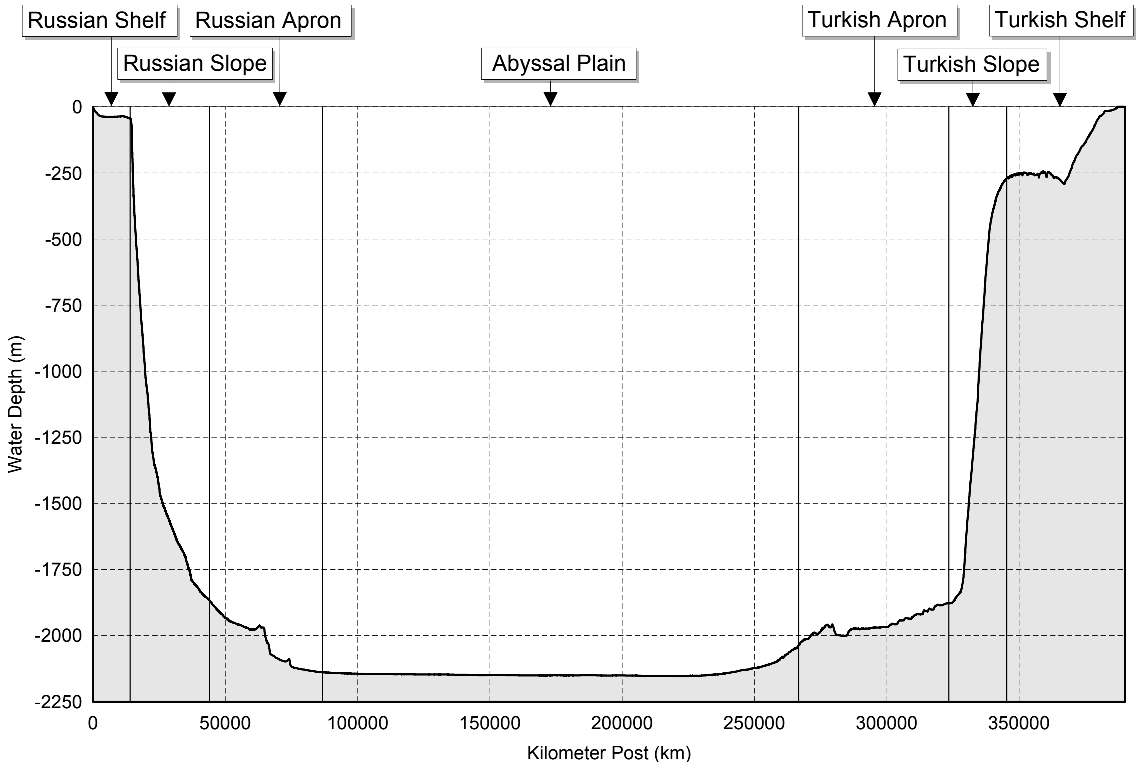
- Onshore Section, composed by:
  1. incoming pipeline section down to the Beregovaya Compressor Station (BCS);
  2. the Beregovaya Compressor Station, including all the ancillary Plant and equipment for the control and management of the system (Dispatching Centre) and relevant interface with the upstream and downstream systems;
  3. two pipeline sections from Beregovaya Compressor Station to the downstream ESD valves, these ESD valves themselves and the relevant insulating joints;
- Offshore Section, composed by:
  two sealines, from Beregovaya Compressor Station downstream ESD valves up to the Samsun area ESD valves.

The Offshore Section of the Blue Stream Project is constituted by two submarine pipelines following two different routes, which for the most of their length are parallel, except where the two routes diverge on the Russian shelf. The two routes, named West Route (W2) and East Route (E1) respectively, have a total length of about 390 and 382 km respectively, reaching a maximum water depth of about 2,150m.

The Offshore Section of the Blue Stream Project consists of the following elements:

- Russian onshore part: 2x24” pipelines between the ESD Valve and Russian LTE (approximately 1,2 Km long);
- Submarine Pipelines: 2x24” pipelines between the Russian and Turkish LTE (approximately 387Km for Line W2 and 380Km for Line E1);
- Turkish onshore part: 2x24” pipelines between Turkish LTE and the ESD Valve (approximately 0,5Km long).

The Offshore Section is designed for a 36 years life; the government rules for the pipeline Offshore Section designed are the Det Norske Veritas ‘Rules for Submarine Pipeline Systems’ (DNV ’96).



2.3. Turkish onshore section

The Turkish section is managed and owned by BOTAS and the relevant construction is composed of 3 main parts:

- Samsun-Ankara Natural Gas Pipeline: total length of 501-km line with a diameter of 48” and 14.3mm-wall thickness. There are 5 take-off valves (Samsun, Amasya, Çorum, Sungurlu, Kırıkkale) and 4 pig stations (Samsun, Çorum, Kırıkkale, Ankara) on the line.
- Samsun Pressure Reducing and Metering Station: Pressure Reducing and Metering Station is built up to reduce the pressure from about 145 bar_g at regime to the maximum operation pressure of 75 bar_g.
- Compressor Station: The requirement of a compressor station will be concluded later.

3.2. BSPC ORGANISATION AND STRUCTURE OF THE PROJECT

Turkey is one of the most perspective and capacious market in the whole European and Asian region from the energy demand point of view. According to the estimations, the natural gas demand in Turkey will considerably increase in the next decades and its average annual rate of growth will be several times higher than its analogue index in the Western Europe.

Russia is the largest gas-producing country in the world with around 1/3 of all total proven reserves and Gazprom is the main Russian Energy Company with particular experience in the onshore pipelines and relevant compressor stations.

ENI is the Italian leading company in the world-wide energy market, from the downstream to the supply-transportation-distribution of oil and natural gas, having competence in all the connected fields, from the engineering to the construction, from the on-shore to the offshore, from pipelines to compressor stations. Particularly, its subsidiaries developed the Transmed project to transport the natural gas from Tunis to Italy across the Mediterranean Sea in 80’s.

When the Russian and Turkish governments decided to go ahead with the Blue Stream project to supply the Turkish market with the Russian natural gas across the deep Black Sea, it was likely that

Gazprom and ENI joint their efforts, resources and competence to make the Blue Stream come into reality.

BSPC, jointly shared by Gazprom and Snam International BV (a subsidiary of ENI), was created together with specific organisation and structure for the purpose of the realisation of the Offshore Section and the Beregovaya Compressor Station. Then, various contracts were activated for the development of the project decided by the shareholders.

In order to manage the activities in the Russian Federation and in Turkey, BSPC established and registered branches in Moscow, Krasnodar (in Russia, close to the Black Sea coast) and in Samsun.

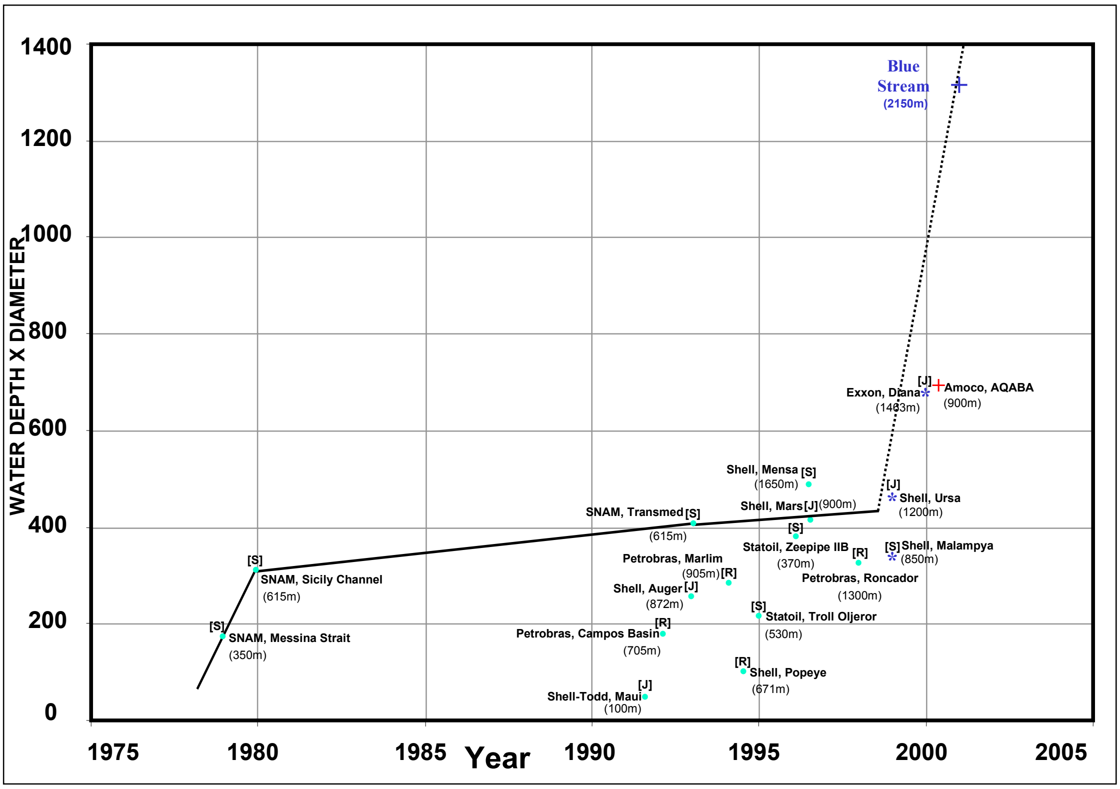
The main contract BSPC entered into was the EPC Agreement for the Engineering, Procurement and Construction of the project with a consortium made by Saipem S.p.A. (a subsidiary of ENI) for the realisation for the Offshore Section, Bouygues Offshore and Katran-K (BOS/KK) French companies for the realisation of the BCS and with a Japanese Consortium for the procurement of materials (pipes, buckle arrestors and relevant coating).

In addition to it, various service agreements were activated for the necessary supports during the development of the project. Particularly, those with the Norwegian Company DNV for the Certification purpose of the Offshore Section according to the international standards and rules DNV'96 and with Gazexport for the transport and supply of natural gas to Botas are the main ones.

Financing the Blue Stream and the international relationships were also a challenge. The total costs of about 2.3 – 2.4 x 10^9 USD, the strategic importance of the Project within the international energy market and the cohesion among the various participants to the Project required particular efforts and resources to be worked out.

4. TECHNICAL ASPECTS OF THE BSPC PART

Hereinafter we present the main characteristics and features of the part of the Blue Stream project managed directly by BSPC to cross the Black Sea. Particular attention and deep presentation of the main challenges faced and overcome will be paid to the Offshore Section, which surely represented the most important and innovative part of the project.



The deep water pipelaying trend

4.1. The Beregovaya Compressor Station (BCS)

The BSPC part of the Russia-Turkey Gas Pipeline named ‘Blue Stream’ is to export the Russian natural gas to the Republic of Turkey. The initial point of the Blue Stream pipeline is assumed to be the point where the projected gas pipeline joins the 1400/1200 mm gas pipeline managed and constructed by Gazprom, which comes from Pochinki, Izobilbnoye and Severo-Stavropolskoye in the Ladovskaya Balka community area.

The terminal point of the Blue Stream pipeline – Russian section – is the stopcock of the marine section of the gas pipeline at the 372nd km of the coastline area, near Dzhubga.

Natural gas is routed through a 1400/1200 mm diameter onshore pipeline to the compressor stations of Stavropolskaya and Krasnodarskaya to reach Beregovaya compressor station, from which it is compressed and sent to Samsun receiving and measuring station located at Turkey coast through two 24” (610mm OD) sub-sea pipelines.

For the purposes of commercial gauging of natural gas flowing through the pipeline, gas metering stations (GMS) are projected at the boundary of the areas supervised by two natural gas providers, Kavkaztransgaz and Kubangazprom, in vicinity of the Stavropol CS and inside Beregovaya compressor station upstream of gas pumping units. Krasnodar compressor station is equipped with a dehydration plant to reduce water content in the gas so that no liquid water is present in BCS as well as a condensate removal plant.

4.1.1 The Technical description of Beregovaya Compressor Station (BCS)

The objective of Beregovaya CS (BCS) construction is the compression of natural gas from the battery limits defined in the upstream 1200 mm incoming pipeline up to the Black Sea shore approach. The scope of Beregovaya CS includes inlet pipeline, filtering units, metering unit, compression plant, cooling system, discharge pipelines, power plant, plant facilities. The BCS is located at 265m above the sea level and about 2Km from the shoreline.

More specifically the Beregovaya CS limit of supply includes the installation of approx. 670 m of 1200 mm onshore pipeline, one (1) receiving scraper trap, one (1) slug catcher, three (3) station filters, one (1) metering skid, six (6) parallel turbo compressors, six (6) gas coolers, six (6) unit scrubbers, two (2) launching scraper traps, three (3) turbo-generators, a methanol injection system and about 750 m of twin 610 mm diameter pipelines at BCS outlet.

Gas intake will originate at the 1200 mm pipeline tie-in point located about 670 m north of Beregovaya CS in correspondence of an Emergency Shut Down valve (ESD valve), that is part of Beregovaya CS scope of work. The pressure at CS inlet will range from 6.8 to 9.8 MPa (abs) with gas temperatures ranging from 22°C to 30°C. The gas will flow to the station by means of a 1200 mm pipeline.

Inlet facilities will include:

- A receiving scraper trap suitable for intelligent pig receiving.
- A slug catcher (vessel type).
- Station filters (No. 2 operating and 1 spare) to clean and condition incoming gas.
- A gas metering station with two ultrasonic metering skids.

Condensates collected in the receiving scrapper trap, slug catcher and inlet filters will be collected in closed drain vessel and incinerated on site.

The compression system will compress gas up to maximum operating pressure of 25.15 MPa (abs) at the outlet ESD valve. The compression plant consists of No. 4 compressors operating and 2 stand by and is designed for a gas volume of 48.17 million Sm3/day.

A cooling system (one air cooler for each turbo compressor) will lower the gas temperature from approx. 136°C to 50°C and unit scrubbers (one for each turbo compressor) are provided to remove any possible condensate downstream of the gas coolers.

The gas is then transmitted to twin 610 mm pipelines provided with pig launchers suitable for intelligent pigging, and delivered up to the pipeline ESD valve.

The BCS will be equipped with a power generating plant consisting in the installation of three (3) turbo generators to comply with the electrical consumption of the station and electrical building to allocate all the relevant electrical installations.

Each turbo generator is designed for the overall BCS electrical consumption. In the normal operation of the BCS two (2) turbo generators will be supplying 50% of BCS electrical consumption and one (1) will be stand-by.

Three (3) gas-cooler electrical sub-stations will be provided to feed the gas-coolers and two (2) diesel generators will be installed to serve as back up for vital and essential electrical loads.

The Beregovaya CS will be controlled at different operation levels:

a) First level – Gas Dispatching Centres (GDC) from where the station can be remotely operated and data exchanged with other sites is input/displayed.

Two identical Gas Dispatching Centres are provided: one in Beregovaya CS operator room, the other in Customer's Krasnodar offices.

b) Second level – Main control room where the main control centre is located. Here the entire plant can be operated through the ACS (Automatic Control System).
c) Third level – Unit Control Panels (UCP) from which the machines can be normally operated. The UCP will be localised close to the relevant machine.

The Beregovaya CS will be provided with the additional facilities:

- Fuel gas conditioning system for turbo-compressors and turbo-generators
- Turbo-Compressors/generators lube oil system
- Oily water treatment system
- Methanol injection system
- Closed drain system
- Firewater/fire-fighting system
- Fire and gas detection system
- Service water system
- Compressed air system
- Plant Blow-down system : cold vents
- Instrument gas system for TC & TG package valve actuators
- Liquid burning facility of the closed type (i.e. no open naked flame)
- Fire building for two fire trucks.

Description	N°	Type/Characteristics
Turbo Compressors	4 +2	Nuovo Pignone PGT25 Plus DLE
Turbo Generators	3	Nuovo Pignone PGT5 DLN
ISO Power installed for gas compression		180 MW
ISO Power installed for electrical generation		15 MW
Design Pressure at inlet ESD valve		9.95 MPa (abs)
Design Temperature for pipeline		50°C
Design Pressure at outlet ESD valves		26.6 MPa (abs)
Max Operating Pressure		25.15 MPa (abs)

Beregovaya Compressor Station: main characteristics

4.2. The Offshore Section across the Black Sea

The offshore part of the Blue Stream project is surely one of the most challenging pipeline project ever realised; its extreme characteristics led the engineers and all the various contractors/sub-contractors to face new problems and situation and to create new solutions never adopted or developed so far.

For the first time also large and thick pipeline (24" OD, 31.8 mm wall thickness) has been laid in ultra deep water with a J-Lay method in an environment with high H_2S concentration, over a very soft sea-bottom and along very steep slopes where geo-hazard required particular efforts, calculation, analyses and solutions to be overcome.

The development of the Offshore Section involved, from the ESD valves in Russia located 1.2 Km ashore to the ESD valves in Turkey at 0.5Km ashore across the Black Sea:

- the Design (basic and detail);
- the Procurement, Fabrication and Manufacturing of all the various materials (in particular pipes, buckle arrestors and anodes);

- the Installation, construction and Pre-commissioning/Hydraulic Testing of the whole section.

The entire development of the Offshore Section was executed according to and in compliance with the international code ‘Rules for submarine Pipeline System’ issued by Det Norske Veritas (DNV’96) who acted as Independent Third Party from the very early beginning up to its definitive conclusion.

Also, specific requirements of BSPC were followed.

4.2.1. The Design

No pipeline was ever laid at so deep water (2,150m), in an aggressive environment with high concentration of H_2S, using the innovative J-Lay method to pose the pipeline on the seabed, all along the very steep slope on the Russian side in very narrow corridors with space for only one pipeline.

All such characteristics implied the development of specific design activity covering a great number of disciplines with involvement of experts in various fields, everything within the respect of the applicable international rules and standards/codes.

The main topics of the Project were the following:

- Risk assessment aspects, both for construction and for operational phases
- Hydraulics and Hydrate aspects
- Pipeline strength design including intervention works
- Geotechnical and geohazard aspects
- Corrosion protection and coating design specification
- Material and component design and specifications
- Environmental description and definition of design criteria
- Intervention works
- S-Lay and J-Lay construction procedures

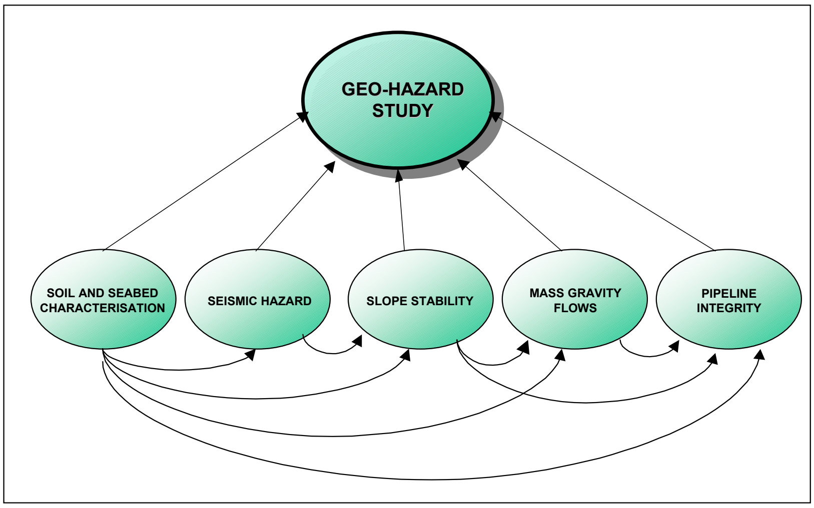
The evaluation of the main critical area have been a major issue since the feasibility phase, particularly because of the novel design conditions of deep-water installation, geohazard, hydrates, possibility to repair and H_2S in the sediments.

Several studies, analyses, laboratory, surveys and in-situ tests have been executed in order to set the exact and final parameters and condition for the design purpose.

<u>Geohazard</u>

The evaluation of geohazard has been a major issue since the feasibility phase, particularly because of the novel conditions and the non-existence of ‘state of the art’ calculation models for the chain of events involved:

- triggering of earthquake, necessitating an earthquake hazard study;
- initiation of soil instability, necessitating slope stability analyses of the complex earthquake loading condition, involving an extensive mapping of critical areas;
- flowing of soil down the slope, necessitating analysis of the flow of the soil remaining as ‘solid intact soil’ and of the part of the soil being dissolved and continuing as ‘turbidity flows’;
- impact scenario and forces on the pipeline involving evaluations of e.g. width, direction and velocity of the impact, and evaluations of impact forces of soil at large velocities being in the transition of domains, where the force is governed by shear strength, by viscosity or by drag;
- pipeline integrity, involving analyses of the pipeline with forces from soil flow



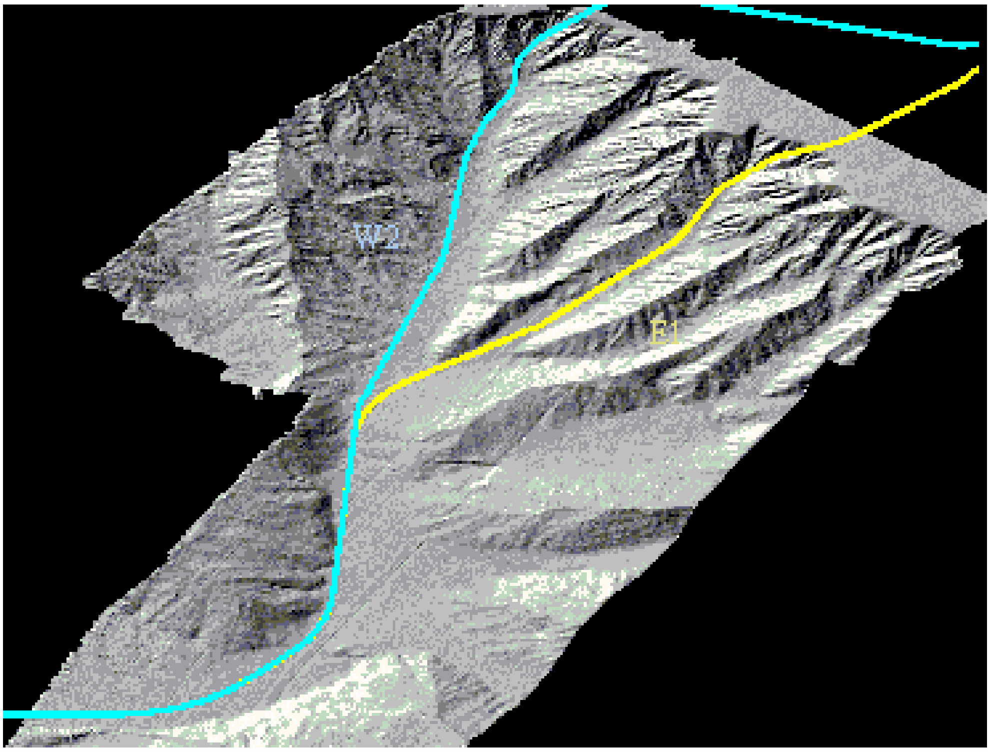
Geo-Hazards assessment studies

impact including relevant boundary conditions from the soil outside the impact area and involving evaluations of the pipeline ultimate capacities.

To document the pipeline integrity along the steep slope on the Russian side due to the possibility of soil flows has also been development work and a big challenge.

The works included pipe-soil interactions and mass flows impact physics on the pipe as well as pipe capacities. Several iterations with even more detailed studies on the above tasks were required combined with the accidental load approach outlined in DNV-OS-F101. This finally documented an acceptable safety level of the pipeline integrity.

Combining the geohazard loads and the pipeline integrity, the geohazard study performed on this project is the most detailed study performed on any project. This leads to the conclusion that risks from geohazard have been estimated in the right order of magnitude and hence in accordance with DNV'96.



Russian slopes: Turbidity Currents trajectories and the two different routes

Corrosion protection and coating design specification

The corrosion protection design is based on corrosion protective coating in combination with cathodic protection. The design complies with DNV'96 and DNV RP B401 (1993). There was much emphasis on the design and qualification of field joint coating systems and linepipe coating repair systems with functional requirements largely identical to that of the linepipe 3-layer coating system based on fusion bonded epoxy, an adhesive of modified polypropylene and an outer layer of polypropylene.

A comprehensive laboratory test program was carried out to examine the suitability of Zn-based and Al-based sacrificial anode materials in the H_2S-containing environment of the Black Sea. A Zn alloy was selected based on the results from the testing and in accordance with DNV'96.

Hydraulic and Hydrates aspects

This aspect also requested efforts during the development of the design, taking into consideration the characteristics of the project such as the length of pipelines, deep water, the possible buried/unburied conditions of the sea-lines during their lifetime and the various pressures and temperatures of the gas flow during transportation.

The critical parameter is the temperature, which shall not be below –5°C during operations (except for very short periods under special conditions). The temperature must never go below –10°C, which is the minimum steel design temperature. The governing parameter for the temperature is the heat exchange coefficient between the gas and the surroundings, which is strongly dependent on the pipeline burial condition (depth of cover). Due to the pipeline profile it is the burial condition on the Turkish slope and landfall that is governing. The worst status is that the pipeline is completely buried and this has been accounted for in the pipeline performance design.

The issue of formation and removal of hydrates, particularly large amounts, has been a concern since the start of the project. If a failure of the pipe occurs in the regions where the pressure outside the pipeline is higher than the gas pressure inside the pipeline, seawater will enter the pipeline and hydrates will likely be formed. Specifications have been developed to be able to implement systems for detection and to plan for actions to reduce the formation of hydrates in case of a leak. Also, methods for location of the hydrate plug and for hydrate removal have been identified.

For instance, location of the leak may be obtained by a combination of appropriate operation of the pipeline after the leak has been detected and the use of systems like ROV (Remotely Operated Vehicle) and/or AOV (Autonomous Operated Vehicle).

No hydrate formation is foreseen at normal operational conditions; furthermore, for the condition of off-spec gas being put into the pipelines a methanol injection system has been provided and installed at the Russian side within the BCS.

W2 route section	Length (m)
Russian onshore pipeline	1215
Russian shallow water pipeline	15540
Submarine pipeline	357894
Turkish shallow water pipeline	13825
Turkish onshore pipeline	476
TOTAL	388950

E1 route section	Length (m)
Onshore Russia	1282
Russian Shallow Water	10676
Deep Water	355763
Turkish Shallow Water	13848
Onshore Turkey	476
TOTAL	382045

Length overview of Line W2 and E1

Bathymetric Province Line W2	From KP	To KP	Water depth range (m)	Max Slope angle (avg. 100 m)
Russian Shelf	0	14.7	0 - 100	1.6°
Russian Continental Slope	14.7	44.0	100 - 1867	25.5°
Russian Apron	44.0	74.5	1867 - 2100	5.3°
Abyssal Plain	74.5	266.7	2154 - 2036	1.9°
Turkish Apron	266.7	328.0	2036 - 1825	3.0°
Turkish Continental Slope	328.0	345.3	1825 - 270	14.4°
Turkish Shelf	345.3	387.26	291 - 0	4.2°

Bathymetric Province Line E1	From KP	To KP	Water depth range (m)	Max Slope angle (avg. 100 m)
Russian Shelf	0	9.8	0 - 105	1.6°
Russian Continental Slope	9.8	36.9	105 - 1867	27.2°
Russian Apron	36.9	67.5	1867 - 2100	5.4°
Abyssal Plain	67.5	259.6	2154 - 2036	2.0°
Turkish Apron	259.6	321.0	2036 - 1825	3.2°
Turkish Continental Slope	321.0	338.5	1825 - 270	14.1°
Turkish Shelf	338.5	380.29	287 - 0	5.0°

Bathymetry overview of Line W2 and E1

4.2.2. The Procurement, Fabrication and Manufacturing

The procurement of the various materials needed for the realisation of the Blue Stream project also required high standard specification, high quality controls, specific test prior of start of the production and in some cases custom tailored production lines and characteristics.

The main materials produced were:

- Pipes
- Buckle Arrestors (B.A.)
- Coating (of pipes and buckle arrestors)
- Anodes
- Bends (cold and hot induction bends)
- Anchor Flanges
- Insulating Joints

The fabrication phase started in June 1999 with the execution of the MPQT (Manufacturer Production Qualification Tests) related to qualification and production of linepipe material, buckle arrestors and coating.

The OffGC was responsible also for the production of materials and BSPC together with DNV verified every single activity covering in particular the following elements, (i) steel making, plate rolling, linepipe production, (ii) manufacture of buckle arrestors, insulating joints, anchor flanges and bends, (iii) external coating, (iv) anode manufacturing. Typically BSPC and DNV involvement covered the following activities:

- Pre-production audits at the steel-, plate- and pipe mills, coating yards and anode manufacturer in order to ensure that all processes and systems were capable of consistently producing linepipe material and anodes according to project specifications;
- Review of the Manufacturing Procedure Specification (MPS), Welding Procedure Specification (WPS), Manufacturing and Inspection Plans (MIPS), manufacturing material traceability system and other documentation systems used as basis for the linepipe, buckle arrestor, insulation joint, bend, anchor flanges, coating yard and anode manufacturers;
- Witnessing of the ‘Manufacturing Procedure Qualification Tests’ (MPQT) for linepipe, B.A., external coating, field joint coating and anodes;
- Issue summary reports for DNV verification during MPQT;
- Monitoring of steel production at the steel mills;
- Monitoring during plate rolling and pipe manufacturing processes;
- Monitoring during fabrication of buckle arrestors;
- Monitoring during mechanical testing;
- Monitoring during fabrication of insulating joints;
- Monitoring during fabrication of anchor flanges;
- Monitoring during fabrication of bends;
- Monitoring during external coating of linepipe and buckle arrestors;
- Monitoring during fabrication of anodes.

The purchase order for the supply of line pipes and Buckle Arrestors (BA) was awarded to the following Companies:

1. Japanese Consortium (JC). The scope of work included the manufacture, internal and external coating, loading and transportation to Samsun (Turkey) of linepipes and buckle arrestors;
2. Corus UK Limited. The scope of works included the manufacture, internal and external coating, concrete coating of a small portion of linepipes, loading and transportation to Samsun (Turkey) of linepipes;
3. Marubeni U.K. The scope of work included the manufacture, internal and external coating, loading and transportation to Samsun (Turkey) of buckle arrestors

DESCRIPTION	JAPANESE CONSORTIUM		CORUS UK		MARUBENI U.K.	
	Metres	Joints	Metres	Joints	Metres	Joints
Linepipes 610 mm OD x 31.8 mm WT Grade SAWL I 448 SF (3Layer PP coated)	689,032	55,747	88,850	7,107	-	-
Linepipes 610 mm OD x 31.8mm WT Grade SAWL I 448 SF (concrete coated)	-	-	5,088	413	-	-
B.A. 651.8/610 mm OD x 31.8/52.7mm WT Grade SAWL I 448 SF (3 Layer PP coated)	16,116	1,298	-	-	1,048	85

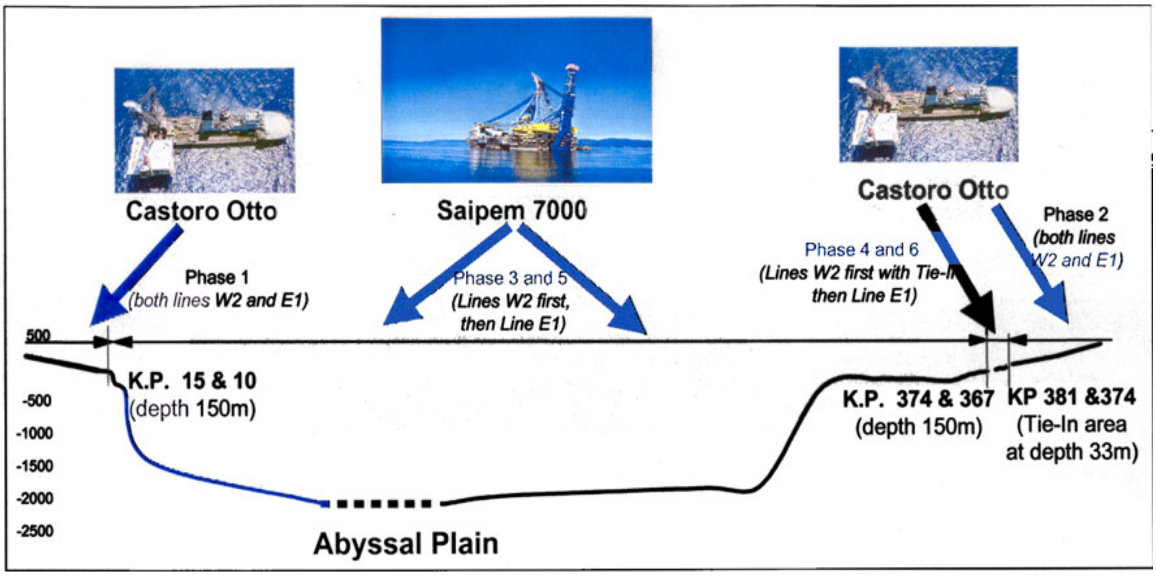
Linepipe and Buckle Arrestors Quantities

4.2.3. The Installation

The activities regarding the construction covered also a very important part within the project under many aspects, from the laying in a very deep water level to the new J-Lay method.

The construction works can be divided into the following main areas:

- On-shore area (the section from the ESD valves to the shore line, both in Russia and in Turkey);
- Shallow Water (S-Laying by the Castoro Otto vessel – named C8) from the shore line down to the section where the S7000 started and concluded the J-Laying both in Russian and Turkish side);
- The Deep Water (J-Laying by S7000 vessel);
- The pre-fabrication of the Quadruple Joints (necessary for the J-Lay) in the Samsun base;
- The intervention works before and after the laying;
- The Pre-commissioning and Hydraulic tests.



The sequence of Laying (S-Lay by C8 and J-Lay by S7000)

<u>The J-Lay in deep water</u>

Naturally, the most challenging work was constituted by the innovative method of J-Laying executed through the Semi-Submergible Crane Vessel Saipem S7000 (SSCV S7000), duly modified for the purpose.

The installation of pipelines in deep water by S-lay method would require longer or more curved stinger along smaller radius. Due to the small radius of the stinger, there may be a certain amount of residual curvature in the pipe once it leaves the stinger. Besides, due to the departure tension, the laid pipeline can be sometimes free spanning and anyway retains a residual axial stress.

The J-lay methodology is the prime technique for laying pipelines in very deep waters. The pipe is laid through a vertical ramp positioned on board a vessel. The deepwater pipeline is maintained in the optimal angular position and pulled under a predetermined high tensile force while being lowered to the bottom. Vertical space configuration on a J-lay vessel allow for only one pipe joining station, hence a fast and reliable pipe-joining technique or multiple pipe sections are prerequisite for practical use of J-lay method.

J-Lay offers the following advantages:

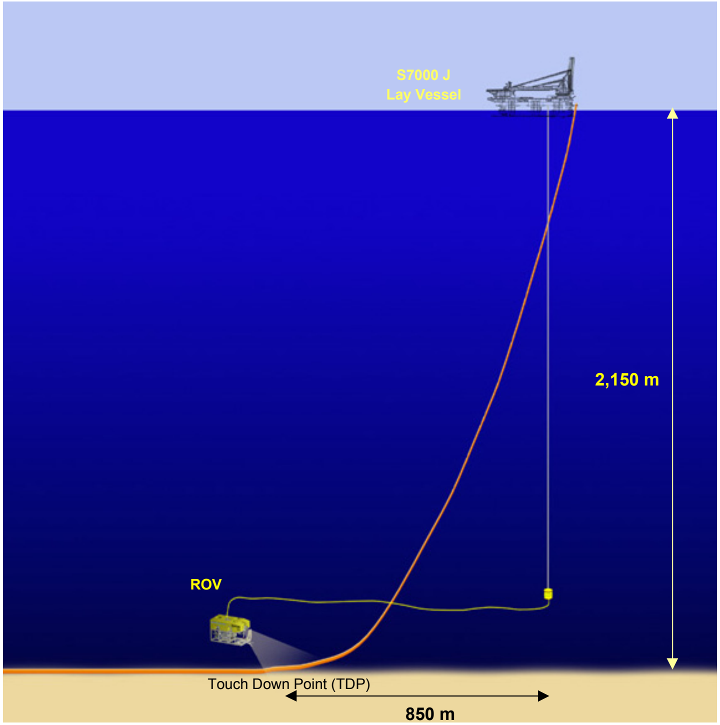
- allows the pipe to be laid in a more ‘natural’ configuration;
- pipe stresses are maintained well within the linear elastic limit;
- lower lay tension required, resulting in reduced on-bottom tension, hence reducing free-span;
- less susceptible to weather condition;
- the vessel is free to choose an optimal heading to minimise environmental forces.

The main limitation of such laying method is that it is primarily designed for deep water and some limitations occur when used in shallow water. For this reason the Blue Stream pipeline was laid with the S-lay method in shallow waters while the extraordinary depth of the abyssal plain compelled to use the J-lay technique in that section.

Several modifications, test and qualification trials were executed both on the vessel and on the ancillary equipment before starting the laying of the first line W2. This involved also the main equipment and construction methodology such as the automatic welding system (n° 3 welding machines with double wires to weld in vertical position) and the field joint coating application as well as the AUT (Automatic Ultrasonic Testing) to check all the welds executed on board.

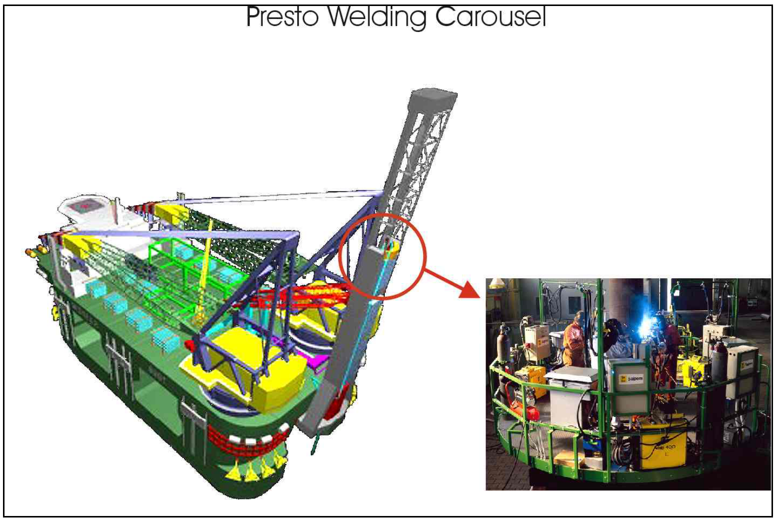
The overall weight of the 135m tower, A-frame, tower angle adjusters, line-up tool and other equipment is 4,500 t.

The J-Lay tower can move up to 20 degrees off the vertical. S-7000 is also a heavy lift vessel with two 7000t cranes mounted on its bow. J-Lay system can be easily installed on the vessel, when it is required to work in J-lay mode or removed to allow Saipem 7000 to act in the heavy lift mode when needed.



The J-Laying by S7000, with Touch Down Point monitoring

The modular tower with its pin connections to the barge is equipped with three tensioners of 175 t capacity each. There are also 2 x 500 t friction clamps for enhanced safety. It also houses two work stations – one for welding and the other for non-destructive testing and coating.



S7000 and its automatic welding station on the J-Lay Tower

The Abandonment & Recovery winch has a capacity of 555 ton.

The J-lay system is designed for rigid pipes with diameters from 4 inches to 32 inches in quadruple joints. (N° 4 x 12.2 metre spools prefabricated onshore). Computers monitor the behaviour of the pipeline for pull, reaction stresses and touch down point position.

The Quadruple Joint fabrication in Samsun

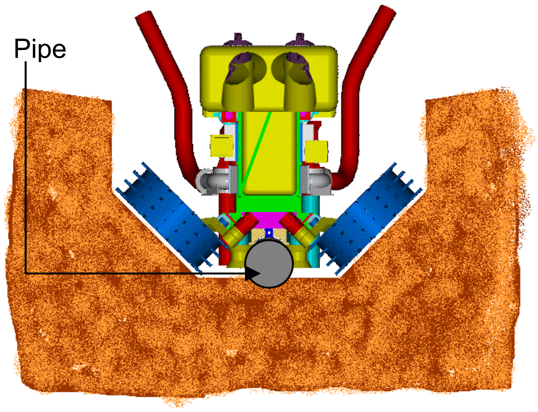
In order to have the necessary Quadruple Joints (QJ) ready for the laying in deep waters; a dedicated pre-fabrication base was installed in Samsun area. Here, the single joints were stacked (coming from the Fabrication/procurement activities) and firstly assembled in a double joint. Then, the two double joints were welded into the final QJ. Each girth weld was subject to the same AUT process used on board the vessels and each weld area was then coated using the same field joint coating method with 3 Polypropylene layer (3 PP) as used on board C8 and S7000.

Once completed the QJ fabrication, the S7000 was regularly supplied with the so pre-fabricated 48,8m long QJ. All such process granted to reach a significant laying rate, with an average of more than 100 welds per day (4880m per day), with a maximum of 116 QJ laid in one day (5,725m per day).

Thanks to the intensive program for the welding and AUT system, together with the deep test and qualification activities executed all along the Project development by Saipem with the supervision of BSPC and DNV, the welding repairing rate on board S7000 was extremely low, equal to 0,15%.

The intervention works

The construction works included also intervention works, such as the trench at the shore approach excavated before laying the pipeline, the installation of mattresses and supports over the telecommunications cables before crossing them with the pipelines and the post-trenching of both Line W2 and Line E1 after their respective laying. The post-trenching was executed in three different areas:



The "Beluga" post trenching machine and the post-trenching phases

- at the Russian and Turkish shallow water, from the end of the pre-trenched area (water depth of 12m) down to a water depth of 30m. This is order to reduce the stress over the pipe in the transition zone and to protect the pipe from the human activities such as fishing;
- at the Russian plateau in order to give the pipelines the necessary stability and protect them against human activities such as fishing;
- in the Russian steep slope, in order to reduce the free-spans length

The post-trenching was executed with a custom tailored machine named Beluga.

The Pre-commissioning/Hydraulic Tests

The Pre-commissioning/Hydraulic Test on each pipeline was executed once all the previous construction works were concluded, in order to test the line at the maximum operating pressure.

The tests included the following steps:

- flooding of the line, with filtered seawaters (specific laboratory tests were executed in order to establish possible corrosion value using seawater for the duration of the water permanence inside the pipeline. The results demonstrated the possibility to use sea water duly filtered);
- cleaning of the inside surface of the pipeline, with the passage of bi-directional pigs;
- gauging of the pipeline, using bi-directional pigs equipped with calibrated flanges;
- hydro-testing of the relevant pipeline, at 1.155 times the pipeline design pressure (for a total value of 31.26 MPa);
- de-watering of the pipeline, using bi-directional and calliper pigs to check any possible deformation of the pipeline;
- drying of the pipeline.
- Packing the pipeline with dry air at a pressure1.5 bar absolute.

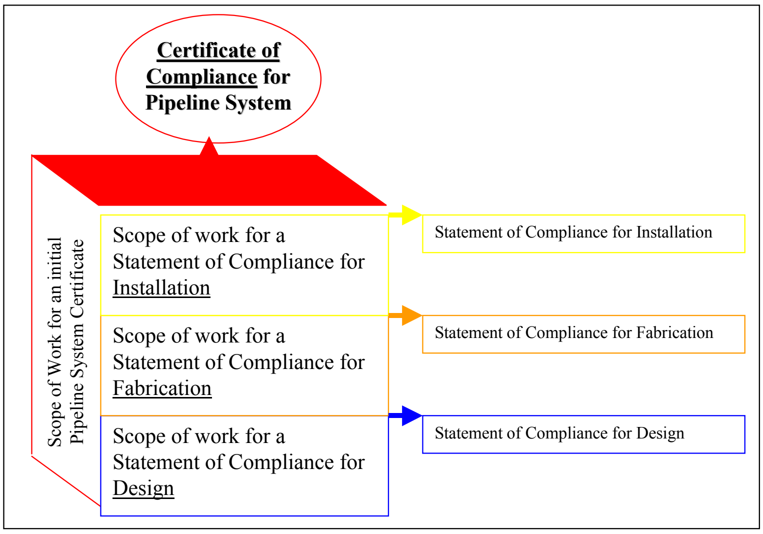
All the operations were executed from the Russian side towards Turkey, using a Temporary Air Compressor Stations (TACS) custom tailored and installed.

Once concluded the Pre-Commissioning activity, each pipeline was ready for the gas transportation and the gas-in operations to insert gas, using the innovative methodology of vacuum system, started. This gas-in activity is described in a separate paper.

5. THE CERTIFICATION OF THE PROJECT BY DET NORSKE VERITAS

Since the very early beginning of the Project, both ENI and Gazprom as well as BSPC decided to have the Offshore Section of the Project certified by the Third Party independent organisation Det Norske Veritas (DNV) according to the DNV'96 rules.

Certification is a defined process of verification leading to the issue of a Certificate. A DNV certificate is as a formal statement expressing that the submarine pipeline system meets specific quality requirements and is, hence, fit for purpose.



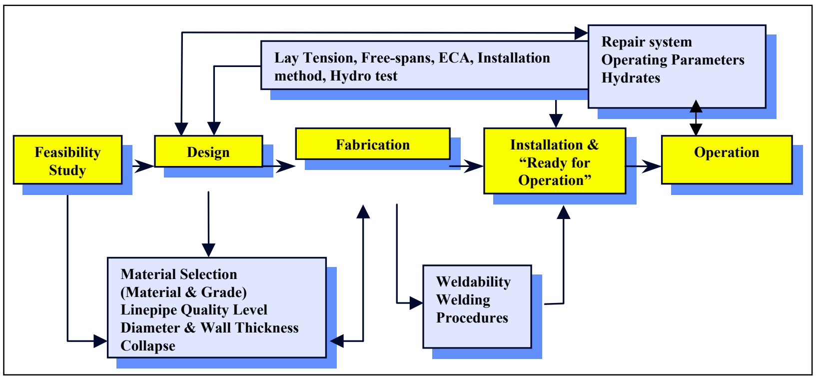
The Certification process in compliance with DNV'96

The initial certification addresses the following stages of a pipeline project:

- detailed design;
- fabrication;
- installation and ready for operation.

To achieve the initial DNV Certificate of Compliance for pipeline system, a verification of the activities described by the scope of work in Section 2 of DNV'96 must first take place. This is illustrated by the figure hereinafter. In order to maintain the certificate, the operational phase must also be verified.

Certification is normally carried out on the basis that a project goes through distinct phases and by passing milestones. This has also been the case for the Blue Stream Certification. The figure below illustrates the phases as well as the complex information flow, typical for today's large international offshore pipeline projects. So also for the Blue Stream, this in addition has been an innovative project with a tight schedule.



The Blue Stream (Offshore Section) Certification Interface between main phases

The verification performed by DNV included all aspects of the project, that is the quality and process control side as well as the technical side, with continuous focus on the totality, having as main guideline the 'philosophy of continuity', which provides a bridge between all phases.

The purpose of the initial pipeline system certificate is to confirm that the pipelines, as installed and ready for use, are in a condition that is compliant with the technical requirements of DNV'96 and of the EPC Contract. The certificate is a confirmation of the status of compliance with DNV’96 of the pipeline systems at the time.

The certification process and the ‘philosophy of continuity’ requires that all the phases are verified and that also the temporary phases are in accordance with DNV'96 and the requirements.

The certification provides a *Statement of Compliance* at the completion of each of the project stages: design, fabrication and installation, and a *Certificate of Compliance* when the pipeline is ready for operation.

6. CONCLUSIONS

The Blue Stream Project is a quite unique project under many points of view: from the financial aspects to the laying in deep waters never reached before, from the international co-operation to the strategic and political issues, from the tight schedule to the high costs involved.

The section crossing the Black Sea certainly represents the most challenging and innovative part. ENI and Gazprom, together with the Dutch company BSPC established for the purpose, decided to join relevant competencies and efforts to realise this unique project and make this dream come into reality.

Now, the project is complete and the gas is flowing from Russia to Turkey across the Black Sea, linking directly two countries with natural gas flowing at the record water depth of 2,150m.

What was called a DREAM is now a real STREAM; what was considered difficult (if not impossible) to be worked out only a couple of years ago is now a reality and new frontiers for the deep water offshore projects are definitively open.

The Authors would like to express all their gratitude and sincere thanks to all who worked, in different ways, to the positive realisation of the Blue Stream Project during the recent years.

Special thanks also to all the persons who gave an effective collaboration for the issuing of this paper, with particular care of the Managing Directors of BSPC.