Nord Stream
The new gas supply route for Europe

BACKGROUND INFORMATION

November 2013

Inline Inspection for the Nord Stream Pipeline

Inspection as part of the integrity management strategy

As an operator, Nord Stream AG offers gas transportation capacities via its 1,224-kilometre twin pipeline system, which runs from Vyborg, Russia to Lubmin, Germany. Line 1 began gas deliveries in November 2011. The second string of Nord Stream took up operations as part of the fully-integrated twin pipeline system on October 8, 2012.

Each pipeline is made up of about 100,000 concrete weight-coated pipe segments, each with an average length of about 12.2 metres and a constant inner diameter of 1,153 millimetres. The pipes are made of high-tensile steel, up to 41 mm in thickness that has an internal anti-friction coating and an external anti-corrosion coating. The internal coating consists of a two-component epoxy resin flow coat, which increases flow capacity by reducing friction.

To preserve the pipeline as a valuable asset to the European gas supply security for the coming decades, a number of integrity management measures were designed, which cover the automation systems, landfall installations as well as the 1,224-kilometre offshore section of the twin-pipeline itself.

Part of this maintenance is an external visual and instrumental inspection of the pipeline, conducted via remotely operated vehicles (ROVs) followed by a support vessels. The external inspection serves to confirm that the pipeline itself has not moved on the seabed due to changes in the seabed underneath. It also helps to detect any foreign objects such as trawl nets or debris that may accumulate near the pipeline. Additionally, the inspection data is used to confirm the integrity of the rock berm structures used for stabilizing the pipeline on the seabed. The first external inspection (baseline inspection) for Line 1 was performed in 2012 following the completion of construction and the first period of operation to determine that the pipeline had settled under load. This year, the baseline inspection of Line 2 has been performed and the annual inspection of Line 1 is going on.

The material integrity of pipeline is confirmed by performing an internal inspection of both lines. To that end, inline inspection tools, also referred to as PIGs (Pipeline Inspection Gauges) are sent through the pipeline, propelled by the gas flow. The high-resolution equipment can detect and identify even minor changes in the condition of the pipeline and serves to confirm the absence of corrosion or mechanical defects, in addition to measuring geographical coordinates indicating any pipeline movement compared with as-laid and design conditions.

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Internal inspection process

The internal inspection process was performed for the first time in summer 2013. This baseline inspection confirms the quality of the Nord Stream pipeline building process and provides the very first data set to which all future inspection results will be compared to detect any changes or movements. During this baseline inspection, Nord Stream conducted consecutive internal runs of both lines with pipeline inspection tools.

The different inspection tools are inserted into the pipeline via the PIG launchers at the Landfall Facilities Russia (LFFR). Gas is redirected into the launcher and once the pressure behind the tool exceeds the pressure in front of it, it is pushed through the pipeline. Each line is “pigged” individually. The first tool, the gauge PIG takes three-four days to reach Germany. Once it is received and analysed, a cleaning tool is sent through the pipeline – followed if deemed necessary based on the amount of debris and dust it collects – by a second cleaning tool. After that, the inspection tool is sent through the pipe – which takes about nine days. Once received in Germany, the tools are cleaned, maintained and in the case of the inspection tool, the recorded data is recovered and sent to post processing and a three stage analysis.

All different tools used for the internal inspection come from ROSEN Group. The complex inspection tool sent through each pipeline was designed specifically for the Nord Stream Pipeline by ROSEN. The tools underwent extensive testing, such as a pull-through test in a test line with artificial features in the metal pipe wall, a pull-through test in a line with artificial features in the concrete coating and a pneumatic pump test, in order to confirm functionality and specification. The in-line inspection tool was also tested on a similar but shorter 48”-pipeline in Malaysia prior to its use for Nord Stream.

Three types of inline tools used

During the inspection campaign, three different tools are used: one gauge tool, one cleaning tool and the in-line inspection tool, which maps potential corrosion and metal loss as well as the exact curvature of the lines via an inertial navigation system.

The gauge tool

The gauge tool is used to detect substantial anomalies of the internal diameter along the pipeline which may potentially obstruct the inline inspection tool during its run. Any protruding object would chip away at the gauge plate – the damage of which would later be analyzed to determine the extent of the potential obstruction. The process was previously performed as part of the pre-commissioning phase of the pipelines, when each section of the lines was flooded, cleaned and gauged. To remove the water, dewatering tools, were pushed through the pipeline with pressurized air.

The gauge tool is inserted in the pipeline in the PIG launcher in Portovaya and takes about three-four days to travel with the gas flow downstream to Germany. It weighs roughly 1.5 tonnes and measures 2.2 metres in length.

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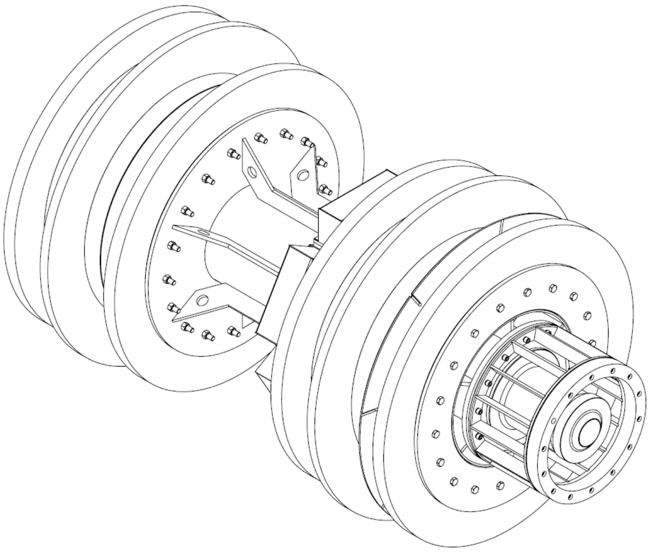

Figure 1. 48 Inch Longrun PIG with Gauge Plates (Gauge Tool)

The cleaning tool

The cleaning tool is sent through the pipe to remove small particles of dust that may have accumulated in the pipeline during the operating time and tiny particles of coating material from the pipeline's inside that may have become loose. The cleaning tool is equipped with brushes to pick up dust particles. In addition, the dust is also pushed ahead in front of the tool by the sealing discs that are sized larger than the pipeline's interior diameter. A bypass that lets parts of gas pushing the tool pass limits the speed and creates a flushing effect in the downstream area as well as supports particle transportation.

The tool measures 2.6 metres and weighs 1.8 tonnes. When received in Germany after about three-four days in the pipe, the tool is cleaned and the material it collected along its run is analysed.

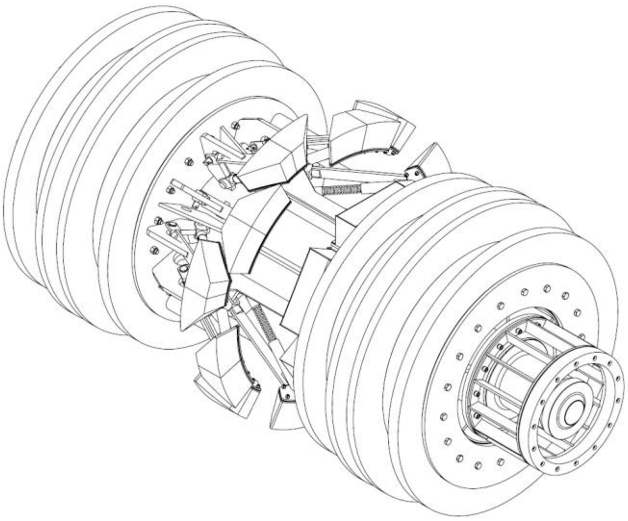

Figure 2. 48 Inch Brush PIG with Magnets (Claning Tool)

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The inline inspection tool

The main inspection tasks are performed by what is commonly referred to as an intelligent combo tool since it combines arrays of sensors to perform different integrity inspection tasks. The tool constantly measures its distance travelled via wheels rolling along the inner pipe walls – which helps map measurement along the length of the pipeline. Since the tool works best at a speed of 1.5 metres per second, an active speed control system measures the speed of the tool and controls a bypass valve to slow the tool to the required speed. The tool weighs over 7.3 tonnes – and measures 6.6 metres in length. The tool is equipped with batteries to power the sensors during the inspection and a high-density memory device to record the data for analysis.

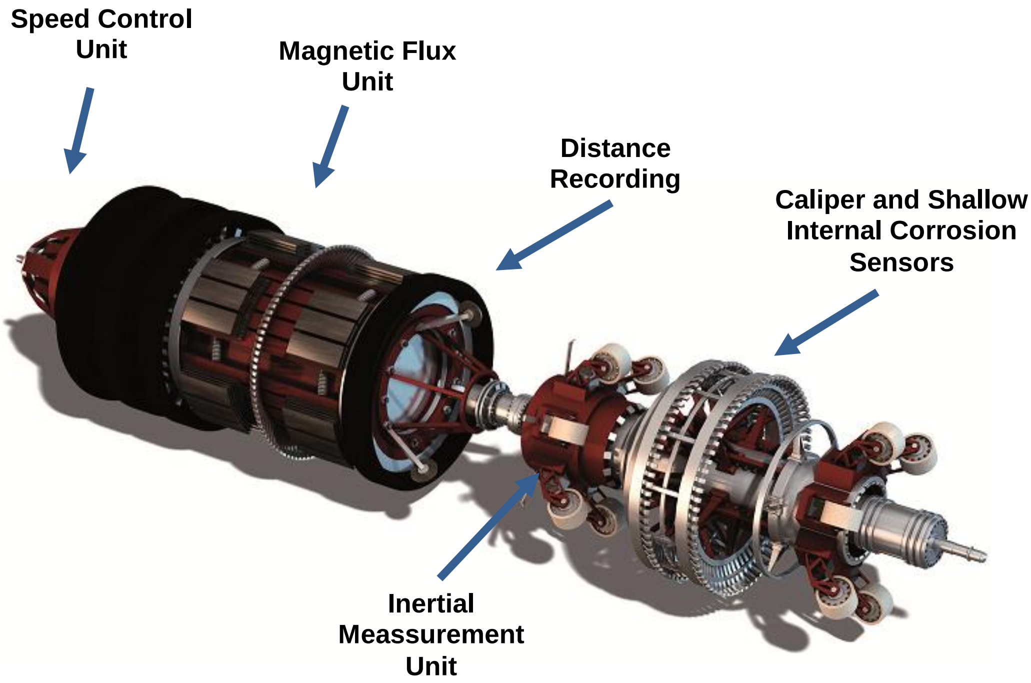

Figure 3. 48 Inch HiRes Metal Loss Mapping Tool (Inspection Tool) and functionality

An **internal diameter (ID) mapping caliper** detects and characterize any deviations from the original pipe shape, some even smaller than one millimetre. Internal diameter changes, ovalities and dents will be detected, localized and identified. The tool is also able to detect and map any misaligned welding joints. The sensors function by measuring incremental changes in how far any of the spring-loaded caliper arms that guide the sensors along the pipe wall are bent when the sensors run through even very small dents or ovalities.

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What the sensor looks like	What a small anomaly would look like in analysed data

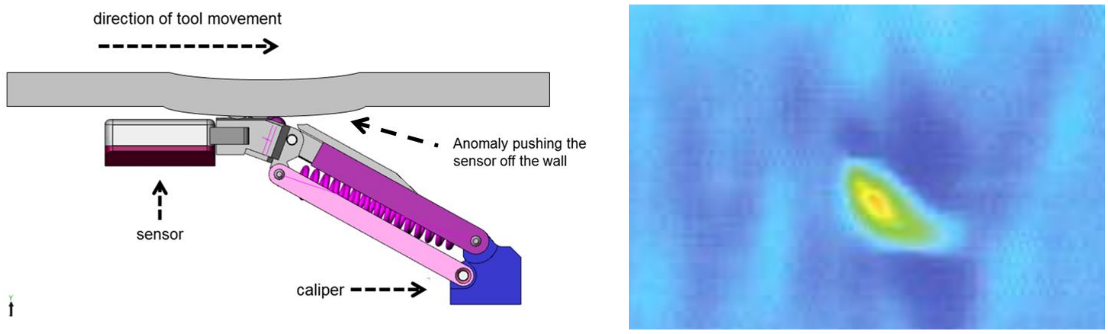

Figure 4. Internal diameter (ID) mapping caliper

Corrosion is not expected during the operation of the Nord Stream Pipeline. The pipeline gas is constantly measured at the inlet to exclude the contamination of the gas with water, a necessary condition for corrosion. Also, the internal walls of the pipe are coated with flow coating, which seals the steel from external influences as well.

The **shallow internal corrosion sensor** is a proximity sensor attached to the caliper arm which can map surface metal loss defects. Small defects on the surface of the inner pipe wall lead to a change of the sensor's proximity to the pipe wall, which the sensor is measuring.

What the sensor looks like	What a small superficial pitting corrosion would look like in analysed data

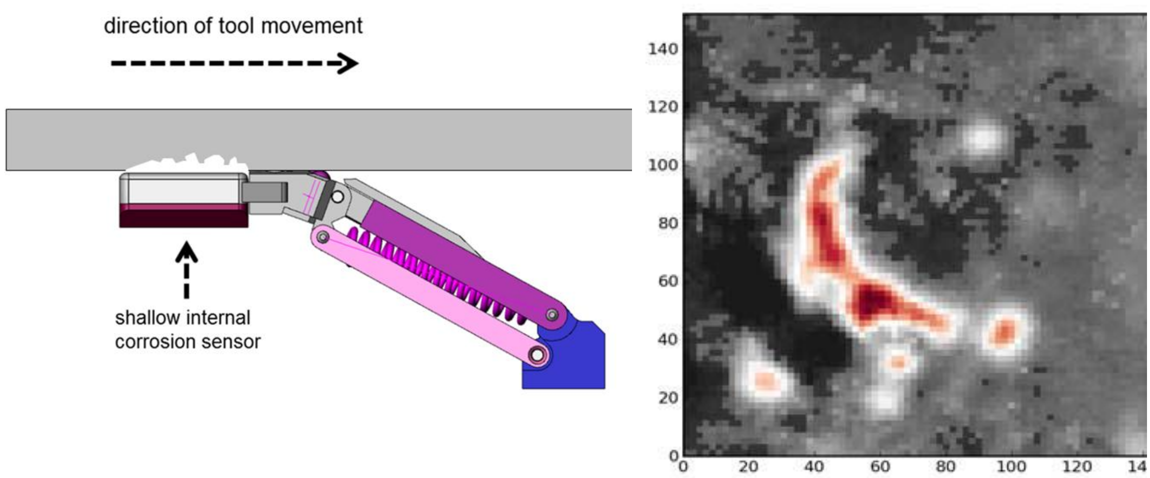

Figure 5. Shallow internal corrosion sensor

Material loss or corrosion that may be enclosed in the steel or occur between the steel and the outside concrete coating would be detectable by a **magnetic flux**

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leakage sensor. A strong magnetic field magnetizes the pipe wall and an electromagnetic sensor is recording any changes in magnetic feedback from the pipe steel. It can detect changes in wall thickness stemming from material loss from corrosion or coating materials coming off.

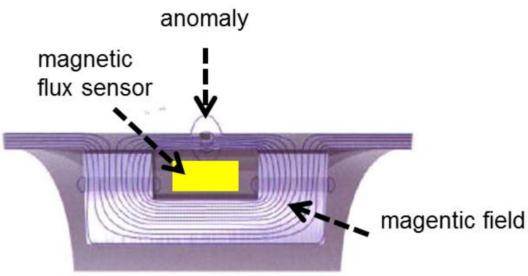
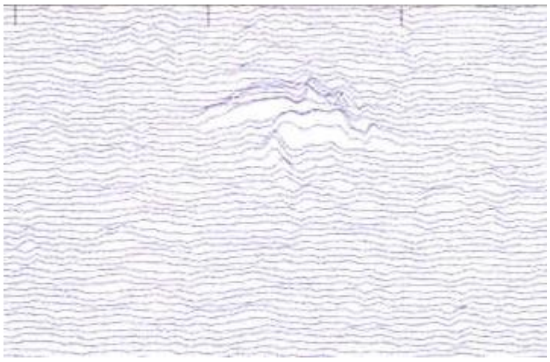
What the sensor looks like	What corrosion would look like in analysed data
	

Figure 6. Magnetic flux leakage sensor

An **inertial navigation system** or XYZ-unit is installed on the inspection tool to accurately map the pipeline's geometry. The baseline data on all curves and bends in three dimensions is later compared with data gathered during subsequent inspections. The aim of the geometry measurement is to detect any incremental movement of the pipeline that could result in bending strains. The tool works by measuring the strain placed on the inertial gyroscope sensor when it traverses a curve in the pipeline. There are of course curves in the pipeline and any changes would register in the comparison. In that case, stabilizing countermeasures such as rock placements could be considered to keep the pipeline from shifting.

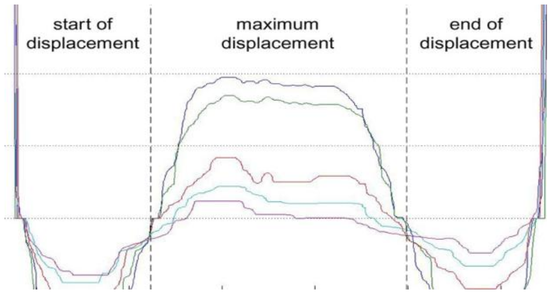
The curvature in a test section of pipeline…	…would register in the analysis as such
	

Figure 7. Inertial navigation system

Facts and figures

- Nord Stream is setting a world record with the internal inspection, in terms of length (2x 1,224km) and in terms of the thickness of pipe-walls (up to 41mm) to be analysed.

- Nord Stream is using an Inspection Tool with the strongest magnet field ever developed.

- The data from the Inspection Tool will be the longest data set from an inline inspection ever recorded.

- With over 2000 measurement channels and one sample recorded every 2.5mm over a pipeline length of 1,224,000,000mm – the tool arrives in Germany with over 1,000,000,000,000 (10^{12}) data samples = over one Trillion.

Following this year's baseline measurement, the inline inspection is scheduled to take place every few years to confirm the absence of corrosion or mechanical defects, in addition to measuring geographical coordinates indicating any pipeline movement compared with as-laid conditions.

All images used are courtesy of ROSEN Group.

More information at www.nord-stream.com

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