Proceedings of IPC 2004
5th International Pipeline Conference
October 4 - 8, 2004, Calgary, Alberta, Canada

IPC04-0698

RE-ASSESSMENT SURVEY OF LARGE DIAMETER PIPELINES USING COMPACT MULTI-PURPOSE INLINE INSPECTION TOOLS

Mikhail Viktorovich Bekker
AC Ukrtransgaz of Naftogas of Ukraine NJSC
Klovsky uzviz 9/1
Kyiv 01021 Ukraine
Fax No.: +380 - 44 - 461 23 84

Thomas Beuker
ROSEN Technology and Research Center
Am Seitenkanal 8
49811 Lingen Germany
tbeuker@roseninspection.net

Uwe Thuenemann
ROSEN Europe
Vondellaan 4
7576 AC Oldenzaal The Netherlands
uthuenemann@roseninspection.net

Steffen Paeper
ROSEN Technology and Research Center
Am Seitenkanal 8
49811 Lingen Germany
spaeper@roseninspection.net

ABSTRACT

Large diameter pipelines of 48" and 56" traverse the Ukraine. These pipelines are the life-line for the Russian gas transit to high demand European Union (EU) markets. The high economic impact to several European regions and the complicated legislation of these pipeline systems reduces the operators' ability to change operating conditions to better suit in-line inspection.

Ukrtransgaz requested a reliable and compact inspection tool able to negotiate 1.5D bends. Thirty degree (30º) mitre bends and demanding elevation changes in the range of 1500m (4921ft) also had to be considered. The high economic impact of the pipeline systems did not allow Ukrtransgaz to reduce the high flow speed of the gas, which is more than 10 m/s (22.2 mph), during the inspection. In combination with the beforementioned elevation profile, an inspection tool with active speed control was required. As part of the planned re-assessment survey, an XYZ mapping inspection relying on an inertial navigation system was also required.

The inspection solutions provided by ROSEN were multi-purpose tools providing MFL technology, an XYZ mapping module and active speed control in a single body. It will be discussed in this paper how the miniaturization of electronics and computer technology is not only a key point for small diameter tools, but also essential to meet the demanding targets of inspecting large diameter gas lines. Breaking with the paradigm, that large pipe provides enough internal space, was the basis in accomplishing the demands of the operator.

INTRODUCTION

The Ukraine has a long history of gas transit from the huge Siberian gas fields on the Yamal peninsula and Urengoi fields. Their geographical position emphasizes the importance of more than 37,100 km (23,053 mi) of gas pipelines in the Ukraine. Almost 90% of Russian gas exports are transported through the Ukraine to connect with east and southeast Europe.

Uktransgas, as an affiliated company of Naftogas of Ukraine, has recently undergone vital adjustments. Currently Uktransgas controls not only large diameter transit gas pipelines but also huge gas storage facilities.

Despite the development of new export routes such as “The Yamal-Europe” or “The Blue Stream”, Ukraine still remains as the most important export route for Russia. This is determined by the advantage of Ukraine's geographic position, its huge gas storage facilities and extensive high-capacity gas transportation system connected to all cross-border gas pipelines [1].

Due to the economic importance of the pipeline system, Uktransgas extends and maintains its pipeline system at high levels of quality. This requires in-line inspection technology to be flexible and of a high technical level.

NOMENCLATURE

DGPS	=	Differential Global Position System
ILI	=	In-Line Inspection
IMU	=	Inertial Measurement Unit
GPS	=	Global Position System
GIS	=	Geographical Information System
P.O.F.	=	Pipeline Operator Forum
FEM	=	Finite Element Modelling

INSPECTION DEMAND FOR LARGE DIAMETER PIPELINES

Among other smaller pipe diameter inspection projects, an inspection of 48” and 56” gas pipelines was scheduled for completion in 2003. Most of these lines are part of the east-west transit system from Russia to the Slovak Republic and Hungary. Other sections cover the east-southwest transit from Russia to Romania. This project phase consisted of almost 2000 km (1243mi) of pipeline to be inspected (refer to Figure 1).

A high resolution corrosion survey was requested, based on the P.O.F. pipeline inspection format [2]. In this case a high resolution MFL inspection would match the inspection requirements, however, some other substantial boundary conditions had to be carefully considered.

Figure 1: Map of the Ukraine. The main transit pipelines route from east to west and east to south (copyright INOGATE).

Average flow rates during summer are around 10m/s (22.4mph). During wintertime the flow rates have to be increased to 15-20m/s (33.6 - 44.8mph). The operational boundary conditions did not allow a reduction in flow rate during the ILI tool operation. Flow rate and weather conditions during the winter season required the inspection program to be finalized within the period of autumn 2003. The large diameter of the pipeline and the environmental condition along the right-of-way required an improved anomaly location methodology. A GPS based follow-up procedure was preferred, since this would also allow to document the maintenance progress based on a geographical index, which can be fed into the GIS system operated by the asset management.

The heritage of this pipeline system (parts of it were built 25 to 40 years ago), are numerous tight bends (1.5D) and thirty degree (30º) mitre bends. Therefore the anticipated in-line inspection solution would be required to cope with these kinds of installations.

INSPECTION SOLUTION

Pipeline inspection is a technically driven industry. The specific technical requirements of a pipeline system as described above have to be taken into account during the development of an inspection solution. Experience shows that a common understanding of the customer’s needs or requirements is one of the most important aspects of a successful ILI development project. Today the provision of new developments to the pipeline operator can only be successful if the production cycle of the inspection solution meets the anticipated time frame of the pipeline operator.

Providing technological solutions for the pipeline industry on time requires a strong engineering background and the in-house capability to develop, design and manufacture inspection solutions. For the ILI business, the different disciplines of Physics, Mechanics, Electronics and Software are inter-related and dependent on each other due to the strong requirements dictated by a pipeline’s internal environment. A parallel development and optimization of all disciplines is essential for a successful solution and an on time provision.

Based on this strategy ROSEN was able to develop 48” and 56” high resolution MFL in-line inspection tools. The design and production of the required 56” ILI tool took a record-breaking four (4) months to complete. The tools are single body units, equipped with a speed control system, a XYZ navigation system and the ability to negotiate 1.5D and mitre bends.

OPERATION PERFORMANCE

A compact single body design was anticipated to allow the passage of 1.5D back-to-back bends and to support the operational work during transportation, launching and receiving.

The physical dimensions of the MFL-yoke system is the cornerstone for the compact design of the inspection tool. Finite Element Modelling (FEM) of the magnetic circuits in close cooperation with the mechanical design allows the meeting of operational requirements without compromising inspection performance.

Another cornerstone, permitting a highly efficient speed control mechanism, is the compact data aquisition and storage unit. Due to the size of the inspection tool, more than 900 data-channels had to be managed and stored onto solid state memory. The spin-off from a 4” inspection tool development resulted in a highly integrated and miniaturized design. The required space for the entire electronic is smaller than 13 litres. As displayed in Figure 2, the processing-, power- and storage-unit is positioned at the rear of the tool without obstructing the inlet for the speed control valve.

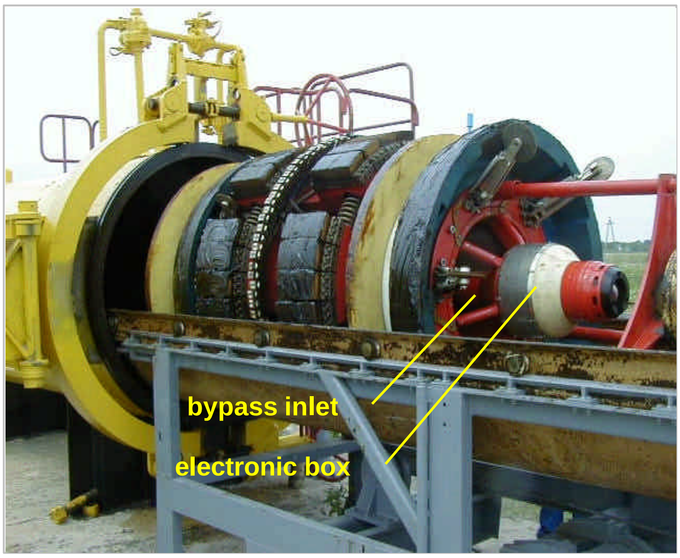

Figure 2: ROSEN 56” 1.5D MFL high-resolution inspection tool at the launcher site. At the rear of the tool the inlet for the bypass flow and the miniaturized electronic box can be seen.

Traditionally, a secondary array of sensors has been used on MFL inspection tools to allow for the important discrimination between internal and non-internal features. The single body concept in combination with the speed control system no longer left room for the secondary sensor array. This functionality was added to the main MFL sensors as an independent measurement channel [3].

MFL HIGH-RESOLUTION INSPECTION

The term “high-resolution” with regards to MFL inspection goes a long way back, when ancient coil sensors were replaced by hall-elements, and analog tape recording by digital data processing. Today the term “high-resolution” not only refers to sufficient spatial resolution of the sensing devices and internal/external feature discrimination but also to more sensitive sensor hardware allowing detection and sizing of corrosion features of 10mm (0.39”) or smaller and a sufficient magnetic excitation of the pipewall of minimum 10 kA/m (126Oe). The result is an improved performance specification of these inspection tools.

In particular, the magnetic saturation of the pipeline is the foundation for more accurate data analysis. The need for an excitation level to saturate the pipeline has been addressed in several publications [4], [5], [6]. An appropriate magnetization level significantly reduces the spurious effects caused by remnant magnetization, pipe stresses and tool velocity effects.

To achieve this level of magnetization a new generation of coupling brushes were used. These so-called “lamella” brushes are a spin-off from recent developments. The mechanical behavior is similar to soft-wire brushes, but with 4x better magnetic conductivity. By using 3D FEM calculations and properties of this new material, the required magnetization level was realized over the requested wall-thickness range.

The operational performance as described in the following section is also beneficial for the inspection performance. The already mentioned mitre bends were not only negotiated succesfully, but high data quality was also achieved. Figure 3 below displays the magnetic field data (the S-shaped verticle lines are the MFL patterns from inclined welds of the mitre bend).

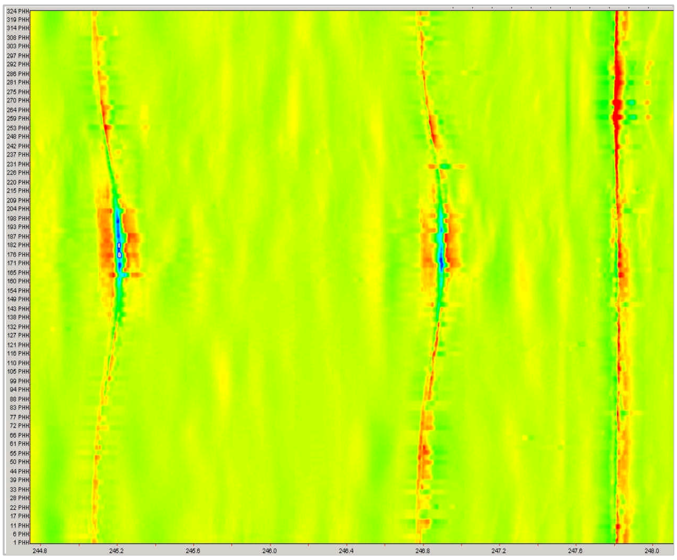

Figure 3: MFL Data sample obtained from a pipe section containing a mitre bend.

SPEED CONTROL SYSTEM

The technical concept for the speed control system to consider the before mentioned operational constraints. The required passage capabilities of 20% OD reduction in straight pipe and of 1.5D bends reduced the available cross-sectional area for a gas bypass flow. Therefore, aerodynamical analysis was performed to reduce the aerodynamical loss factor inherent in such systems.

Another important issue for the design of the speed control valve is the residual bypass of the valve in a “closed” position. A residual bypass can cause problems at the receiver site if the dimension of the kicker line is lower than the tool bypass. The 56” speed control valve assembled for this project achieved a 0.5% residual bypass. This improves the minimum tool speed and reduces the stick-slip behavior at low gas flow rates.

The main application of a speed control valve is to keep the ILI tools' speed within the specified limits for the inspection while operating the pipeline at a significantly higher gas flow (refer to Figure 4).

The regulation of speed-peaks, typically occuring at various pipeline installations, is another important task of the speed control system (refer to Figure 5). This functionality is also needed in areas where mountains have to be crossed (see section XYZ mapping survey below).

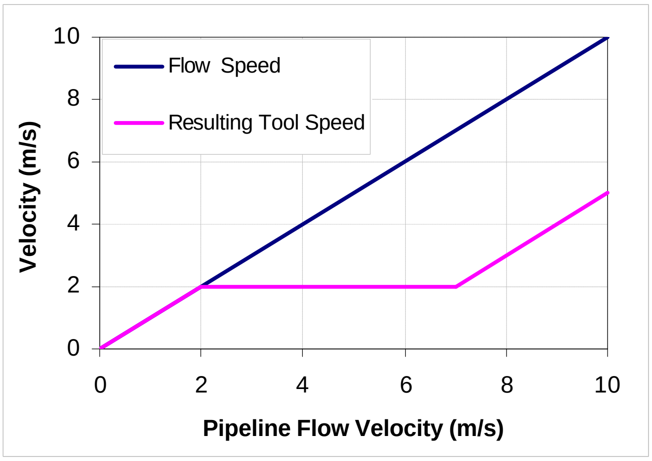

Figure 4: Simplified representation of the speed control functionality. A maximum speed difference of 5 m/s (11.2 mph) can be achieved. Target speed is set to 2m/s (4.48mph)

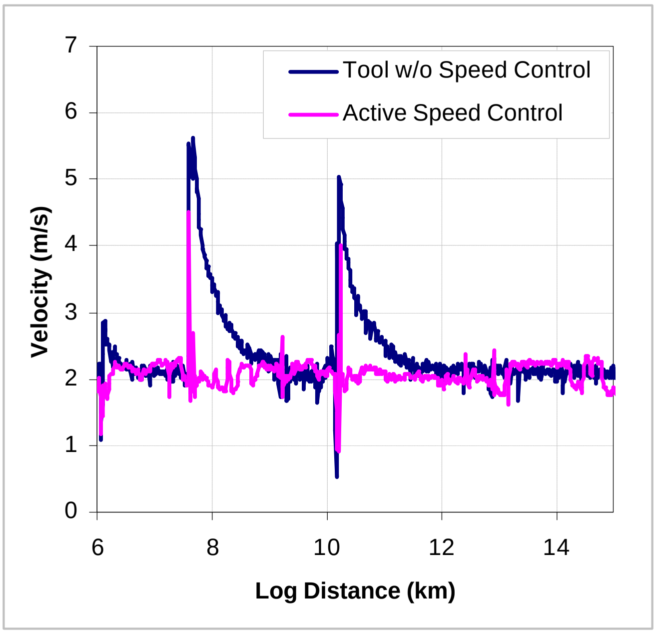

Figure 5: regulation of speed-peaks occurring e.g. at installations. Comparison of two different inspection- tools run in the same pipe section. Exemplary data obtained from a 26" inspection . The target speed for the inspection tool was set to 2 m/s (4.48mph).

Data logs of the tool speed for the 114km long 56" section from Kirovograd to Pivdennobuzka (Figure 6) were compared to the gas flow readings at the launcher and receiver stations (Table 1). Comparing this data validated the available difference between flow and tool speed of 5 m/s (11.2mph).

Although the target speed of 2 m/s (4.48mph) has not been achieved in this case due to the high flow rate, the tool speed of 5m/s (11.2mph) did not compromise the preset distance-based sampling rate of the data aquisition system.

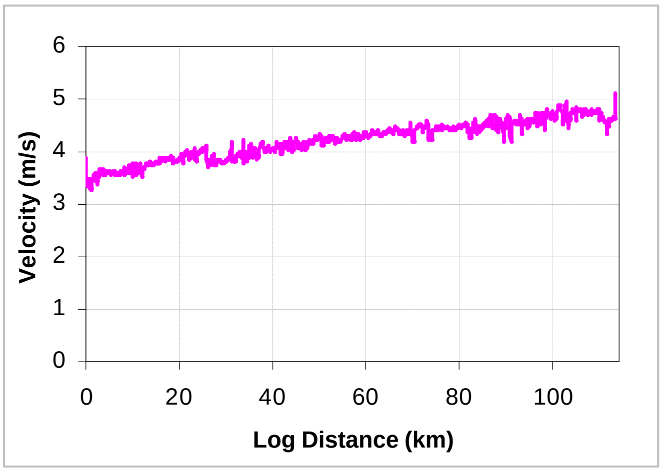

Figure 6: average tool speed for 56" inspection of section Kirovograd to Pivdennobuzka. Achieved flow difference was 5m/s (11.2mph).

	Launcher	Receiver
Gas Velocity	8.8 m/s	10.1 m/s
Gas Flow	3.060.000 sm^3/h	3.060.000 sm^3/h
Pressure	6.68 MPa	5.52 MPa
Temperature	40° C	27° C

Table 1: Operational parameter at launcher and receiver site during inspection of 56" Kirovograd to Pivdennobuzka.

XYZ MAPPING SURVEY

The follow up procedures for the reported anomalies, based on the inspection data required geographical index provided with every reported anomaly or installation, which had to conform with the in-place GIS. It was agreed to equip the inspection tool with an IMU, allowing navigation of the pipeline from the inspection data.

The reported anomalies, including the geographical coordinates and information relevant to the dig site are formatted into ESRI Shape files, which can be transferred to a commercial handheld GPS receiver. The accuracy (3 - 5m or 9.8-16.4ft) of these devices achieved today serves (in most cases) the requirments of the planned field activities. The handheld device allows the maintenance crew to mark out the location in the field and to take notes during the dig activities, which can be directly fed back into the GIS.

Beside the main goal of streamlining the dig-up procedure, the navigational data admits a reassessment of the trajectory of the pipeline and an update of the existing pipeline inventory records.

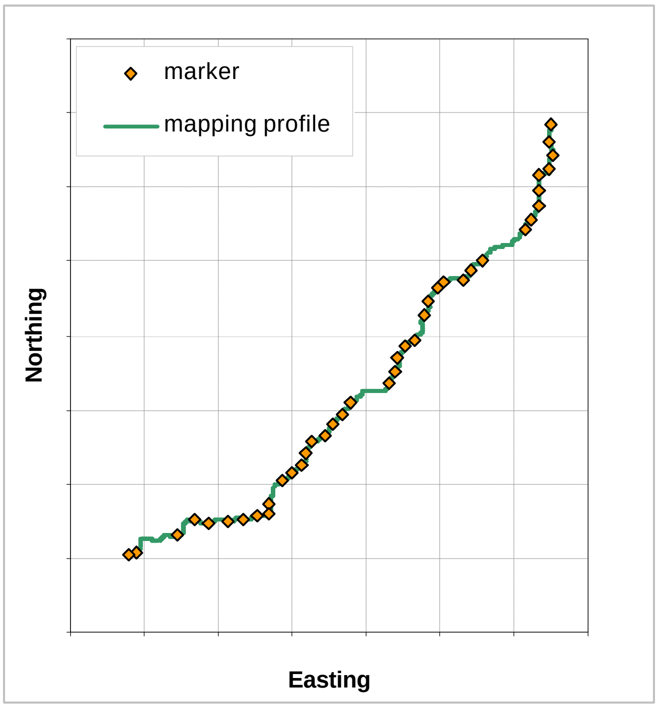

Figure 7: Mapping profile derived from ILI data and corresponding marker measurements.

To enhance the XYZ-results, coordinates of reference tie-in points are required. The density of tie-in points determine the precision of localization of the trajectory. Reference points in this project are 3000m (9842ft) apart. This corresponds to a trajectory precision of 1m (3.3ft). The resolution of the trajectory provided by the inline inspection system is not affected by the reference interval and is typically set to 25mm (1”).

Exemplary XYZ mapping results from the 98 km long 56” pipeline section running from Dolyna to Rossosh are shown. The pipeline crosses the Carpathian Mountain and therefore contains several vertical and horizontal bends. The inspection of this section resulted in a detailed assessment of the number and curvature of vertical bends and horizontal bends (refer to Figure 7and Figure 8). The speed control valve supported smooth run-conditions desired for achieving high data quality from the IMU unit.

PROJECT STATUS

Inspection of the large diameter pipeline system is only a part of a bigger ongoing program in the Ukraine. Where compressor stations, pipelines, gas regulating and metering stations are restructured to secure the competitive strength and atractiveness to gas exporters [7].

During the year 2003, 16 sections between 75km and 185km (a total of 1850 km) were inspected by the 48” and 56” ILI tools. In total, these are 16 sections each between 75km and 185km in length. The inspection of one particular section was postponed to early 2004.

Data evaluation and final reporting were completed early June 2004. Separate reports were requested covering the 16 sections of the pipeline system and the individual needs of the different countries these pipelines traverse. Several dig-up activities were started and are currently being analysed.

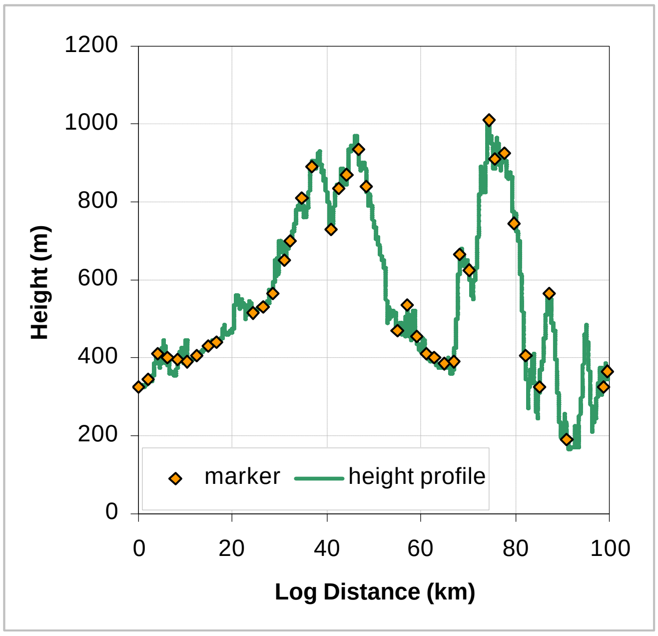

Figure 8: Height profile derived from ILI data and corresponding marker measurements.

CONCLUSIONS

A demanding inspection and maintenance schedule for an almost 2000km long sub part of the 48” and 56” pipeline system was met by addressing the project challenges with a technical solution. 48” and 56” ILI tools were built and operated and were able to negotiate a pipeline route, without compromising the operational constraints, whilst optimizing data quality under testing conditions.

REFERENCES

[1] Andriyovych, R., An Overview: Uktransgas in1999, < http://www.ngbi.com.ua/utg/eng/about.html >, Status 30-Jan-2004

[2] Shell International Exploration and Production b.v., Specification and requirements for intelligent pig inspection of pipelines, Version 2.1, The Hague, The Netherlands, 1998.

[3] Thuenemann, U., Wegjan-Kuipers, J., Control Your Speed, world pipelines, April 2003, pp 31-33.

[4] Beuker, T., Brown, B. et al., Advanced magnetic flux leakage signal analysis for detection and sizing of pipeline corrosion: field evaluation program, GRI report GRI-00/0109, 1999.

[5] Crouch, A.E., Beuker, T., Brown, B.: Flux leakage signals from corrosion defects in pipeline subjected to bending loads, Pipeline Pigging & Integrity Technology 3rd ed., Ed. Tiratsoo, 2003, pp. 267 – 282.

[6] Jansen, H.J.M., et al., Magnetization as a key parameter of magnetic flux leakage pigs for pipeline inspection, Insight, 36, 1994, pp 672 – 677.

[7] INOGATE, Interstate Oil and Gas Transportation to Europe, Umbrella Agreement – Ukraine,
< http://www.inogate.org//html/countries/ukraine.htm >,
Status 08-Mar-2004