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Technologies of cleaning and in-line inspection of gas mains

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Abstract

In-line inspection of pipe metal is an extremely important component of technical diagnostics of gas mains. The main objective of inspection is determining the actual technical condition of gas pipeline and its equipment with subsequent repair of detected defects to ensure reliable operation of the facility. Untimely diagnostics and repair operations lead to higher failure rate and emergencies. Regular diagnostics makes it possible to determine effectively the technical condition and allows establishing the expediency of further operation and recommendations for the elimination of detected defects.

Keywords: *in-line inspection; technical diagnostics of gas mains; technical monitoring and nondestructive testing of gas mains.*

Most of the gas pipelines (GPs) in Ukraine function for more than their estimated operation life, and substantiation of the possibility of their further safe operation is of great strategic and economic importance [1].

According to the requirements of the "Rules for the Safe Operation of Trunk Gas Pipelines" [2] and the Law of Ukraine "On Pipeline Transport" [3], the operator of the gas transmission system (GTS) of Ukraine has to monitor the actual technical condition of gas pipelines using instruments and technical means, followed by the repair of defective areas of the pipe body identified during inspections.

To ensure reliable operation of GTS in Ukraine, in-line inspection (ILI) of GMs is used as the most informative and perfect method for diagnosing the linear part of GTS.

For the first time the idea of ILI emerged on the territory of the former USSR in the 70s of the last century [4]. In fact ILIs of GMs in Ukraine started in 1996. Based on the competition results of such world-famous companies as Rosen Engineering (then named as Rosen Europe B.V.) (Netherlands), Payptroniks (Germany) and British Gas (Great Britain), there was chosen Rosen Engineering company. As a result of Rosen Europe B.V. operation at the gas mains of Ukraine for the period 2006–2011, there was carried out the diagnostics of 9 201.4 km of gas mains, equipped with cameras for receiving – starting cleaning and diagnostic devices [5], using the ILI method or about 21 thousand km of gas mains in a single-line measurement, including a repeated one, which is shown in Fig. 1.

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In this article, we will consider the means by which such a huge amount of operations was performed at the linear part of GMs.

Rosen Europe B.V. designs, manufactures and applies in-line pistons for cleaning, diagnostics (inspection pistons), inspection of the inner surface of the pipe walls, pipe welds:

SBD, MBD, ACT, HDCP cleaning pistons, depending on the type of operation (standard size, equipment and purpose);

EGP, XGP, CDP, AFD, GYP, CDG, AFG, UWD, UCD, CDW, CDC, ECD diagnostic (inspection) pistons depending on the type of operation (standard size, equipment and purpose).

Raw materials in the pipeline	Gas or liquid
Temperature	0 – 65 °C
Maximum pressure	15 MPa
Working range of movement speed	0.3 – 5.0 m/s
Minimum bending radius of the pipeline	1.5D
Diameters of pipelines	6-56" (325–1400 mm)

All piston electronics are explosion-proof, housings of electronic units are filled with inert gas. Housings with electronic equipment are subjected to hydraulic tests under a pressure of 15 MPa, both after assembly and after repair or before new pipeline inspections.

The qualities of Rosen pistons comply with the requirements of the EN 13980: “Potentially explosive atmospheres – Application of quality systems”, which apply to the production, assembly of equipment with a sealed enclosure and intrinsically safe electrical circuits that comply with ATEX Directive 94/9/EC of the EU, which sets requirements for equipment that is used in an explosive atmosphere, and Directive 1999/92/EC (ATEX 137), which establishes requirements for the health and safety of operating personnel.

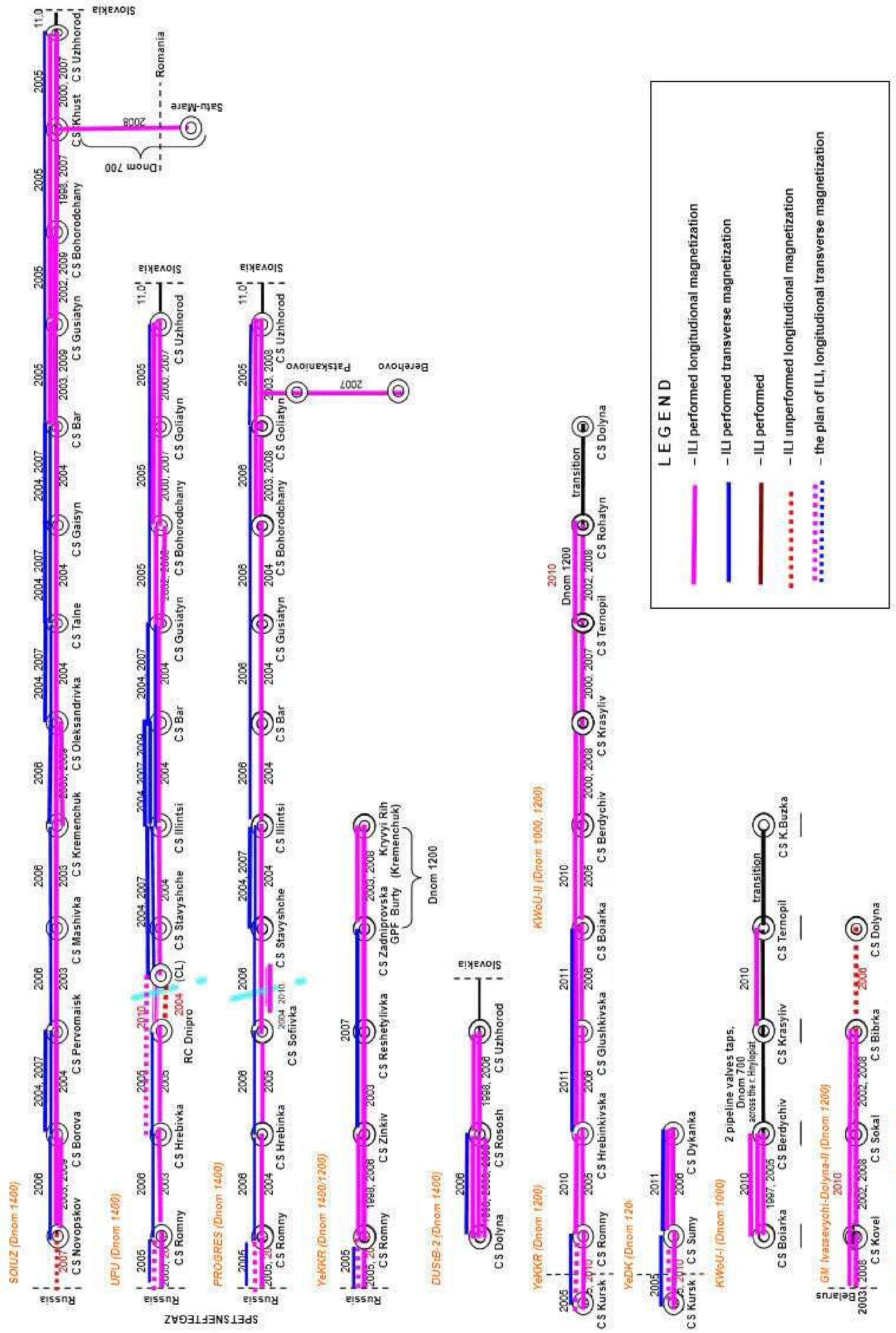
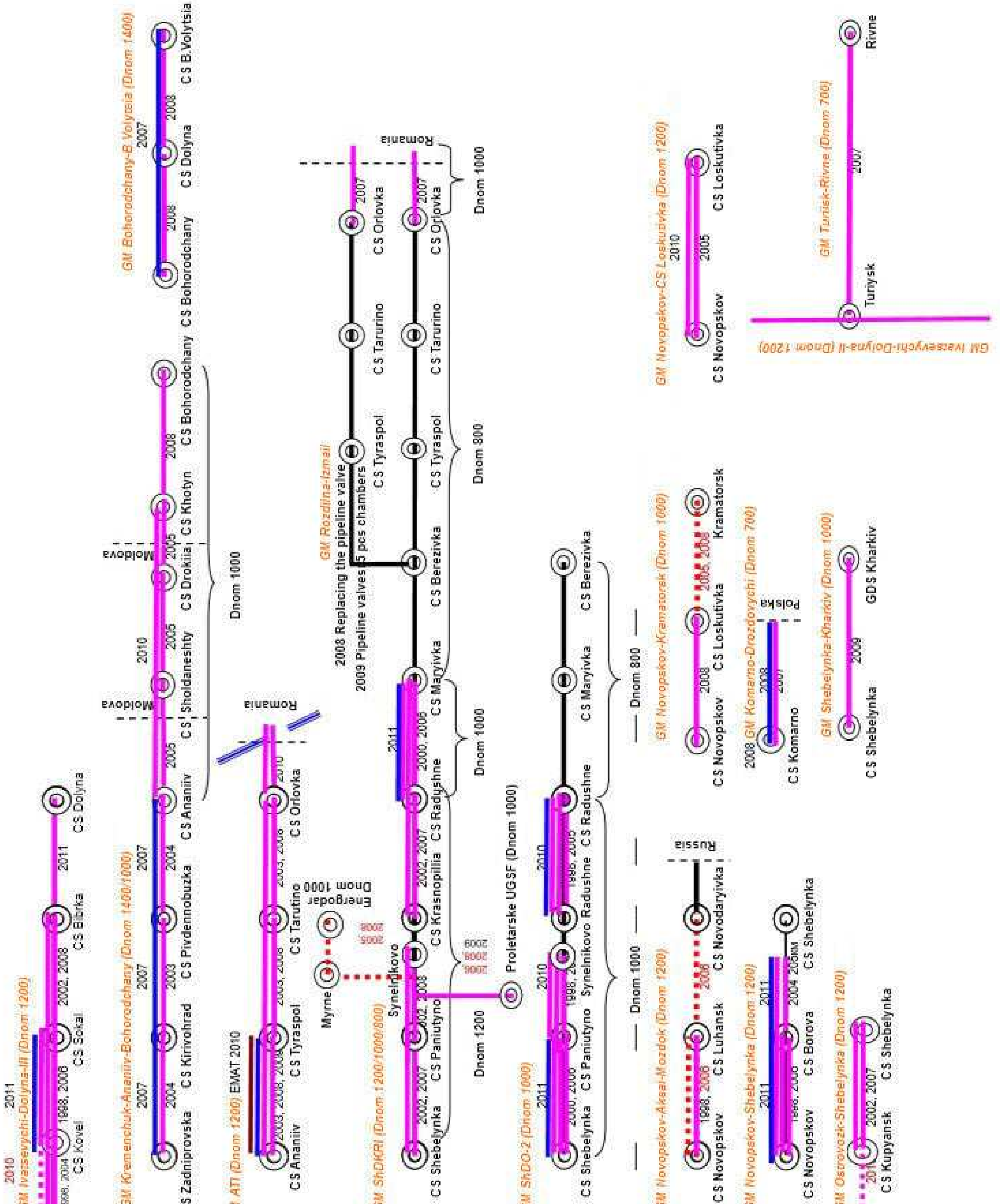


Figure 1 – In-line inspection of Ukrainian GMs of the GTS in 1996 – 2011 (a single-line diagram)



Continuous Figure 1

Figure 2 – Cleaning pistons, polyurethane seals, cleaning brushes

Figure 3 – Results of gas mains cleaning

Let us now consider the purpose, scope, technical characteristics, design and principle of operation of the equipment used.

SBD, MBD, ACT and HDCP cleaning pistons

Since 1983 Rosen Europe B.V. has developed and produced cleaning pistons, which have been used for pre-start operations, as well as for regular cleaning of GMs. The same cleaning pistons are used on all pipeline inspection projects to pre-check the necessary conditions for the degree of cleaning the internal cavity of pipelines.

The basis of Rosen Europe B.V. cleaning pistons is a combination of the so-called “guide and seal” discs instead of using conventional piston seals. There are two different types of cleaning pistons, depending on the length of the pipeline section and the expected amount of contamination: the standard model and the long run model for each type of piston.

Cleaning pistons can be equipped with transmitters, with the help of which the passage of pistons through the pipeline is monitored.

The results of GMs cleaning with cleaning pistons are shown in Figure 3.

Electronic geometric EGP, XGP pistons for inspection of pipelines geometric parameters

Since 1985 Rosen Europe B.V. has developed and produced electronic geometric pistons (Fig. 4).

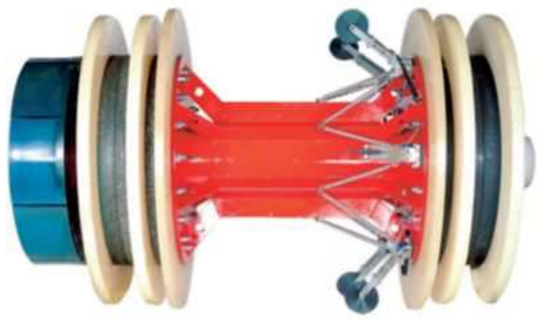


Figure 4 – Geometric EGP piston

The EGP piston is equipped with a contactless 8-channel sensor system developed by Rosen. This system is based on the eddy current method of measuring the distance between the sensor and the pipe wall. It operates in a gas, liquid, two- and three-phase environment and does not require a liquid slug for measurements.

Figure 5 – Results of gas mains inspection with geometric pistons

Figure 6 – MFL inspection piston

XGP pistons are equipped with a multichannel electromechanical sensor system developed by Rosen. This system is based on a combination of eddy current measurement methods and a caliper system. It also operates in a gaseous, liquid, two and three phase media and does not require a liquid slug for measurements.

The results of gas mains inspection with geometric pistons are shown in Figure 5.

CDP inspection pistons (MFL Technology) for high resolution inspection of pipe wall metal loss and longitudinal pipeline defects

Since 1993 Rosen Europe B.V. has designed and produced high resolution inspection pistons.

Rosen Europe B.V. inspection pistons for the determination of metal loss are based on the principle of magnetic flux leakage (MFL technology). This principle allows inspection in a liquid, gaseous and mixed media.

Smart inspection pistons are so called high resolution pistons and represent the third generation of inspection equipment. The new high density digital Hall effect sensors (DHD) enable to meet inspection parameters corresponding to pipeline inspection specifications, that meet the requirements for pipeline inspection by smart pistons developed by the Pipeline Operators Forum.

There are available pistons of standard and individual diameters from 3 to 56", with the ability to determine the spatial position of the pipeline and the option of active speed control. All pistons over 16" are single-section, which is one of the advantages of Rosen Europe B.V. inspection pistons. Inspection pistons can pass segment bends with bevel joints with a 30° angle of rotation and steep bends with a radius of 1.5D.

Since 1998 Rosen Europe B.V. has developed and produced pistons with active speed control.

Many gas pipelines operate at high gas flow rates. The active speed control unit, developed by Rosen Europe B.V., allows operators to maintain a high flow rate during inspection. The speed control unit, created

Figure 7 – AFD inspection piston for detecting longitudinal defects

Figure 8 – Defects of a pipe body revealed with AFD pistons

by the company and integrated into pistons to determine the metal loss, provides a controlled by-pass to reduce the speed of the pistons. This bypass is monitored online (in real time) by the piston to maintain a programmed range of piston speeds (to fully meet specifications, the piston speed range is from 0.5 to 5.0 m/s).

The main advantages of such pistons are as follows:

the ability to maintain a high gas flow rate during inspection;

the bandwidth does not decrease due to speed reduction;

the possibility of a more flexible modes schedule for the operator;

improved data quality due to a high piston speed;

improved data quality due to a more stable piston speed.

AFD inspection piston for detecting longitudinal defects (MFL-CDA technology).

Since 2001 Rosen Europe B.V. has developed and produced pistons for detecting longitudinal defects (Fig. 7).

Pistons with transverse magnetization of the wall (AFD technology) use magnetic flux leakage technology. However, instead of magnetizing the pipe wall in the longitudinal direction, two blocks of magnets are installed in the center of the housing so that the wall is magnetized in a circular manner. The magnetic field is rotated 90° and covers the entire circumference of the pipe. Longitudinal pipe wall anomalies, such as cracks, present their largest dimensions in a given flow, amplifying the leak and creating a strong signal that makes the previously invisible leak clearly visible.

Defects (Fig. 8) that can be clearly identified by inspection using transverse magnetization are as follows:

cracks caused by stress corrosion;

factory defects in welded seams;

thin longitudinal defects and cracks;

longitudinally oriented corrosion;

dents;

fatigue cracks;

large colonies of stress-corrosion cracks.

Rosen Europe B.V. has developed ultra-high resolution pistons with an axial measurement frequency of 2.5 mm and a sensor circle distance of 2.9 mm.

A CDP inspection piston for detecting metal loss of the pipeline wall.

Figure 9 – CDP inspection piston

Figure 10 – Pipe body defects

CDP pistons (Figure 9) of longitudinal magnetization, designed to detect metal loss of the pipeline wall, have been manufactured by Rosen Europe B.V. since its creation in 1980 and their design is being improved every year.

Defects in the pipe body, detected during an examination by CDP inspection pistons at gas pipelines, are shown in Figure 10.

Metal Loss Pistons (CDP):

the presence of pistons from 4 to 56";

passing the turning radii R = 1.5D;

extreme section lengths up to 1000 km;

long pass time up to 2 weeks;

patency of constrictions (up to 15 %);

automatic speed control (on all diameters from 20").

GYP, CDG, AFG pistons for determining the spatial position of a pipeline

Since 2000 Rosen Europe B.V. has designed and produced pistons for determining the spatial position of a pipeline.

Measurements during the inspection of the spatial position of a pipeline (GYRO technology) and three-dimensional maps of a pipeline show clearly its route and profile. The onboard hygroscopic inertial measuring unit (IMU) measures angular and linear changes in velocity along the X, Y and Z axes when the piston moves in the pipeline. GYP, CDG and AFG pistons can determine the spatial position of the pipeline with a very high degree of coordinate determination using landmarks with known geographic coordinates. GYRO inspection allows us to calculate and fix the coordinates of ring seams and defects, as well as determine the

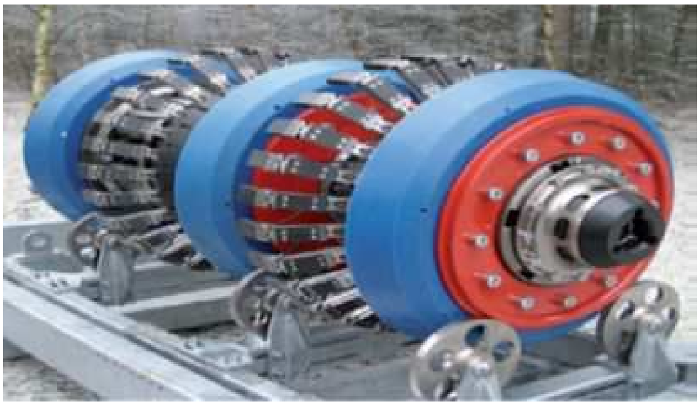


Figure 11 – Piston for determining the spatial position of a pipeline

Figure 12 – HiRes MFL-UT Combo inspection piston

radius of bends and identify deviations from the original structure.

A unique feature of the gyroscope that simplifies its installation and ensures high data quality is the ability of the IMU to determine its own position from the beginning of the inspection pass.

The inspection results include information about the position of the pipeline in a three-dimensional XYZ coordinate system, with visualization of its planned and profile position, as well as its length. Piping position, direction, horizontal and vertical orientation of bends in relation to the angle, radius, direction and location are accurately measured and stored in a computer. In addition, there are stored deformations such as dents, ovality, corrugations. This inspection technology also makes it possible to calculate the deformation of bends.

Combined high-resolution magnetic-ultrasonic CDW, CDC pistons (MFL/UT technology).

To achieve a more efficient detection and measurement of defects in a combined HiRes MFL-UT Combo piston by ROSEN, there is used a combination of two inspection technologies.

The combination of magnetic and ultrasound inspection technologies offers significant advantages over the use of magnetic (MFL) or ultrasonic (UT) methods alone. Ultrasonic technology allows us to detect and measure defects in areas where magnetic inspection is limited, such as large areas of uniform corrosion and delamination. In turn, magnetic inspection allows us to identify and measure defects in areas where the capabilities of ultrasonic flaw detection are limited, for example, pitting corrosion and internal defects hidden by paraffin and other deposits, as well as cracks in the pipe body and welded joints. Inspection technologies complement each other at combined MFL-UT inspection pistons. Knowing the exact size of the pipe wall thickness at the defect location helps to obtain the best results when inspecting with a magnetic method.

Ultrasonic technology can be used in combination with traditional MFL magnetic technology, where the magnetic field propagates in the direction of the pipeline axis, or with MFL transverse magnetic field technology, where the magnetic field propagates perpendicular to the pipe axis in HiRes MFL-UT Combo inspection pistons. The transverse magnetization increases the piston's ability to identify and measure narrow longitudinally oriented defects.

All pistons can be equipped with transmitters, which control the passage of pistons through the pipeline.

Electromagnetic ultrasonic ECD pistons for detecting cracks in the metal of pipeline walls and damage to the insulation coating of pipelines (EMAT technology).

Figure 13 – Ultrasonic flaw detector based on integrated EMAT technology

Since 1987 Rosen Europe B.V. has developed and produced inspection pistons to control the insulating coating; since 2005 there has been applied an EMAT technology (Fig. 8).

The RoCD² ultrasonic flaw detector is a high-resolution inspection piston based on integrated EMAT (Electromagnetic Acoustic Transducers) technology for detecting stress corrosion cracking of pipe walls and peeling of the anti-corrosion insulation coating.

The flaw detector implements an improved technology for converting electromagnetic waves and calculating the acoustics of directed waves.

General characteristics of the piston:

a combined technology that does not require a couplant;

inspection of gas and liquid pipelines;

high-resolution EMAT sensors (located in a circle at a distance of 25 mm);

high sensitivity to stress corrosion cracking;

a technology of versatile directional wave displacement.

The structural design of Rosen Europe B.V. inspection pistons, as well as auxiliary (transport) equipment regulated by the company documentation, operations with equipment ensure the compliance of the equipment with the requirements of the current labor protection legislation, norms and standards of the labor safety system in force in Ukraine.

The constructive and functional solutions applied to the equipment comply with the requirements of regulatory legal acts and standards for electrical safety, explosion and fire safety, loading and unloading operations.

The use (operation) of the equipment, when it is in the in-line pipeline, is carried out in an automatically controlled state, at other stages of the ILI – adjustment by personnel, the main production hazards (moving parts, increased surface temperature, falling loads, poisonous gases, etc.) are absent.

All electronic components of pistons are of an explosion-proof design, the housings of the electronic units are filled with an inert gas (nitrogen at a pressure of 0.5 bar).

All equipment is intended for use in an explosive environment, including in accordance with the "Electrical Installation Rules" and Section 4 of the Index of Regulatory Legal Acts on Occupational Safety 40.1-1.32-01 "Electrical Installation Rules. Electrical equipment of special installations."

Housings with electronic units are subjected to hydraulic tests under a pressure of 15 MPa, both after assembly and after repair or examination before new pipeline inspections.

The pistons are transported and prepared for use with special transport pallets (frame, container) with reliable fastening of pistons, special places for rigging, special means for protection against static electricity and potential equalization with the pipeline.

The elements of the pistons that are in contact with the pipe are made of polyurethane (seals, rings).

For all pistons, it is possible to install special equipment (transmitter) to identify the location (and passage), the signals of which are recorded at a depth of up to 8 meters, at a distance – within a radius of 8 meters.

To ensure the safe use of pistons in high-risk environments, the piston chambers are sealed and filled with nitrogen (through special fittings), and there has been developed and used a special procedure. The vacuum pump is manually operated (preventing the use of an electric drive).

The large piston chambers are additionally equipped with pressure relief valves.

Rosen Europe B.V. policy provides for the use of pistons under the supervision of its own qualified specialists (trained and certified by the company, including on labor protection issues), who carry out transportation, preparation of equipment for use and maintenance after its use.

The equipment is fully provided with operational, technological documentation and instructions for labor protection and industrial safety.

Industrial safety of pistons is confirmed by the experience of trouble-free work of gas pipelines in-line inspection by the PJSC Ukrtransgaz, NJSC Naftogaz of Ukraine (about 21 thousand km of gas mains in a single-line measurement of km as of September 2011).

References

[1] Kryzhanivskyi, YeI & Nykyforchyn, GM 2011, 'Bulk Damage of Long-Term Operated Main Gas Pipelines: The Role of Corrosive-Flood Environment', *Scientific notes*, no 31, pp. 177–181. (in Ukrainian)

[2] Rules for safe operation of main gas pipelines. NPAOP 60.3-1.01-10: State Normative Acts on Labor Protection: approved ... 27.01.2010 no 11. The State Committee of Ukraine for Industrial Safety, Labor Protection and Mountain Supervision. Kharkiv, Industry. 2010. p. 126.

[3] On pipeline transport: Law of Ukraine of 15.05.1996 No 192/96-VR. *Bulletin of the Verkhovna Rada of Ukraine*. 1996. no. 29, p. 139. (in Ukrainian)

[4] Kovalko, MP 2001, *Methods and means of improving the efficiency of gas pipeline transport systems*, Ukrainian encyclopedic knowledge, Kyiv, p. 288. (in Urainian)

[5] Banakhevych, YuV & Banakhevych, RYu 2019, 'Defects Identification of Main Gas Pipelines', *Journal of Hydrocarbon Power Engineering*, vol. 6, iss. 1. pp. 22–29.

[6] Rozgonyuk, VV 2001, *Handbook of a gas transportation enterprise specialist*, Naftogaz of Ukraine, Ukrtransgaz JSC, Rostock, Kyiv, 1091 p. (in Ukrainian)

[7] Grudz, VYa, Grudz, YaV, Kostiv, VV [et al.] 2012, *Technical Diagnostics Of Pipeline Systems*: monograph, Lileya-NV, Ivano-Frankivsk, 512 p. (in Ukrainian)

[8] Reiter, PM, Karpash, OM [et al.] 2014, *Natural Gas: Innovative Solutions for Sustainable Development*: monograph, IFNTUOG, Ivano-Frankivsk, 398 p. (in Urainian)

[9] Banakhevych, YuV & Banakhevych, RYu 2013, 'Experience of identification of detected defects by in-line diagnostics in SC Ukrtransgaz', *Technical diagnostics and non-destructive testing*, no 2, pp. 40–46. (in Ukrainian)

[10] SSU 49.5-30019801-135:2016. *Gas Mains. In-line diagnostics*. PJSC Ukrtransgaz, 2016, 130 p. (in Ukrainian)

[11] SNiP 2.05.06-85. *Trunk pipelines*, Gosstroy of the USSR, Moscow, 1985, 52 p. (in Russian)

[12] Kychma, AO 2001, 'Assessment of defects in pipe metal based on the results of in-line inspection of pipelines', *Bulletin of Lviv Polytechnic National University*, no. 434: Dynamics, Strength and Design of Machines and Instruments. pp. 58–61. (in Ukrainian)

[13] Building Standards of Ukraine B.3.1-00013741-07:2007. *Trunk oil pipelines. Repair method for defective areas*, Ministry of Fuel and Energy of Ukraine, Kyiv, 2007, 114 p. (in Ukrainian)

[14] STO GAZPROM 2-2.3-112-2007. *Methodological guidelines for assessing the performance of sections of gas mains with corrosion defects*, VNIIGAZ, Moscow, 72 p. (in Russian)

[15] STO GAZPROM 2-2.3-173-2007. *Instructions for the comprehensive examination and diagnostics of gas mains subject to stress corrosion cracking*, IRTs Gazprom, Moscow, 56 p. (in Russian)

[16] Kharchenko, EV, Klysz, S, Palyukh, VM, Kunta, OE & Lenkovs'kyi, TM 2017, 'Influence of the Long-Term Operation of Gas Pipelines on the Cyclic Crack-Growth Resistance of 17G1S Steel', *Materials Science*, vol. 52, no 6. pp. 827–833.

[17] Banakhevych, YuV, Banakhevych, RYu, Dragilev, AV & Kychma, AO 2014, 'Static Strength Evaluation of Pipelines Sections with Crack-Like Defects in the Weld Zone', *Journal of Hydrocarbon Power Engineering*, vol. 1, iss. 2. pp. 96–102.

[18] Osadchuk, VA, Banakhevych, YuV & Ivanchuk, AA 2006, 'Determination of the stress state of main pipelines in the zone of circular welded seams', *Physical and chemical mechanics of materials*, 42, no. 2, pp. 99–104.

[19] Banakhevych, YuV, Dragilev, VA & Banakhevych, RYu 2017, 'The system of integrity management of the objects of gas mains of PJSC "Ukrtransgaz"', *Oil and Gas Power Engineering 2017*: int. scientific and technical. conf., Ivano-Frankivsk, 15–19th of May 2017, pp. 208–211. (in Ukrainian)

[20] Grudz, VYa, Tymkiv, DF, Mykhalkiv, VB & Kostiv, VV 2009, *Maintenance and repair of gas pipelines*: monograph, Lileya-NV, Ivano-Frankivsk, 711 p. (in Ukrainian)

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Технології очистки та внутрішньотрубної діагностики магістральних газопроводів

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Важливою складовою технічної діагностики магістральних газопроводів є внутрішньотрубне обстеження металу труби. Основне завдання діагностики полягає в оцінці технічного стану газопроводу та обладнання, яке встановлене на ньому, з наступним ремонтом виявлених дефектів для забезпечення надійної роботи об'єкту. Несвоєчасне виконання діагностичних та ремонтних робіт призводить до збільшення появи відмов та виникнення аварійних ситуацій. Регулярна діагностика дає можливість встановити доцільність подальшої експлуатації газопроводу і рекомендації з усунення виявлених дефектів.

Ключові слова: *внутрішньотрубна діагностика; технічна діагностика магістральних газопроводів; технічний моніторинг та неруйнівний контроль.*