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Gas pipeline diagnostics and repair practices

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Post-trenching repair method focuses on stress strain behaviour build-up in gas pipeline water crossing zone

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Designing pipeline water crossing repairs, using a post-trenching (additional burial) method, is governed by respective regulations for underwater pipelines. This additional burial assumes pipe bending in the crossing zone, with associated strain unevenly distributed along segment length. Using respective experimental methods and estimates, we have assessed (for Atkara river crossing, summer 2014) the crossing stress-strain levels under post-trenching-based repair phase. We used to record position of individual pipeline local segments over different repair phases; for pre- and post-repair (by design) pipe positions, we have evaluated implications of above-limit stress specifically considering gas pressure implications. We believe it is feasible to find a pipeline position, at final repair phase, for which the operating stress-strain levels would be the lowest.

Keywords: gas pipeline, water crossing, repair methods, stress-strain behaviour, post-trenching method.

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A gas pipeline diagnostics and repair concept for higher stress-corrosion areas

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This paper highlights the key issues related to optimisation of Gazprom's gas pipeline repair planning, with special focuses on stress-corrosion cracking implications. Building on analysis of pipeline diagnostics and observations, the authors concluded it is likely possible to continue using recoated pipeline segments when SCC depth remains at or under 10 % of wall thickness. This SCC-affected pipe strength assessment methodology assumes two pipeline failure types, under brittle and viscous mechanisms. The authors assess highest stress-corrosion cracking rates for pipes under longer operating periods and document experimental and estimated faulty pipe strength relationships for stress-corrosion geometry. They identify the key priorities and future Gazprom's development areas when addressing sustained gas pipeline reliability and integrity under higher SCC levels.

Keywords: diagnostics, repair, gas pipeline, stress-corrosion, cracking.

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Analytic methodology for repair planning based on pipeline diagnostic inputs

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This analysis of repairs planning uses inputs from gas pipeline diagnostics. The domestic gas sector has an integrated diagnostic management framework covering inspections across the entire 50,000 km long gas transmission system with individual pipelines remaining in service for 30 years or longer. Inspection pigging, coupled with ground-based electrometric methods and observation pits, offers a detailed technical pipeline picture. Although the diagnostic costs appear far lower than for other methods, additional research is believed critical, to be focused on efficiency improvements along with cost, time, scope, and assessment quality optimisation. In addition, the existing diagnostic framework needs further development, in terms of predictions, integrity management decisions, and development of diagnostic systems for future pipelines including those in Far North regions.

Keywords: gas pipelines, repairs, energy system, operating security, intelligence, smart technology, smart controls, complex targets, hierarchy, analysis.

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Justifying concrete weight-coated pipe bench testing

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This paper highlights design aspects of experimental bench test installations designed for concrete-coated pipes. It also indicates a strong need for specifications and methodologies for weight-coated pipes to provide grounds for respective applications, including definitions for related characteristics (frame stiffness, bending capacity, etc.) as well as operations management schemes. In addition, the paper summarises Gazprom StroyTEK Salavat's test benches designed for experimental finding

concrete-coated pipe parameters and addresses the key functional and operating requirements to test bench fabrication.

Keywords: gas pipelines, ballasting, service life, concrete-coated pipe, elastic bending radius, bench test, testing, shock load, shear load, frame stiffness, management scheme, specifications, methodology.

Diagnostic inputs to assess and predict gas pipeline technical status

Tkachenko I.G., Suslikov S.P., Ivashchenko S.V., Geras'kin V.G., Malakhova O.V., Vasil'yev M.I., Kim V.V. (OOO Gazprom Transgaz Krasnodar, RF, Krasnodar)

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This paper addresses one topical issue: how to rank gas pipelines by their technical status. The effort is focused on in-depth analysis of existing methods and comparisons, followed by recommended practices and finding priority gaslines for overhauls or extensive diagnostics. As a result, we expect an end-user software which helps us draw conclusions regarding pipeline segment technical status and future maintenance decisions. Eventually, the entire effort is focused on better operating safety and greater maintenance level for a chosen gas transmission system, along with optimised opera-

tions and saving all material and energy inputs. The authors share their findings to date and indicate calculation procedure issues which typically emerge.

Keywords: gas pipelines, benchmarking, flaws, corrosion, single flaws, ranking, technical status, diagnostics, maintenance, assessment.

Bovanenko – Ukhta gas pipeline: Engineering, geological and cryological diagnostics

Kolotovskiy A.N., Petrov D.V. (OAO Gazprom, RF, Moscow), **Elfimov A.V., Mayants Yu.A.** (OOO Gazprom VNIIGAZ, RF, Moskovskaya Obl.), **Kuz'bozhev A.S., Birillo I.N., Shishkin I.V., Shkulov S.A.** (Branch Gazprom VNIIGAZ in Ukhta, RF, Ukhta), **Noskevich V.V.** (Institute of Geophysics UB RAS, RF, Ekaterinburg)
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Gas pipeline companies are known to mainly focus on how to sustain maintainability of their assets and therefore specifically address pipeline stability in permafrost conditions. This is believed mostly achievable by a desire to timely avoid pipeline positional stability loss. The authors come with their pipeline diagnostics segment assignment methodology built around analysis of engineering and geo-cryological shifts along gasline route, over periods of permafrost thawing, based on a set of soil, terrain, and other characteristics. Experimental research into a ground penetrating radar-based monitoring method, applied to permafrost, was undertaken to assess soil conditions (thawed or frozen), its ballasting and carrying capacity, finding meaningful pipeline design aspects, and seasonal thawing depth.

Keywords: gas pipeline, soil, permafrost, diagnostics, projections, assessment, methodology.

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Pipeline purging: Models and explosive risk analysis

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Initial gasline purging, for remaining air removal by gas, is among the core operations associated with tapping new or repaired gaslines into major gas transmission pipelines. Such process is typically associated with undesirable natural gas/air mixing in their contact area. One-parameter diffusion and cellular flow structure models appeared useful to describe lateral flow mixing. The challenge was associated with a need to make provisions of actual processes observed under gas pipeline tapping. Flow mixing zone was assessed along with a time interval required for this zone to pass over a chosen pipe cross-section. Gas pipeline purging was modelled, with a proposed longitudinal mixing model, for two gas flows, describing the entire batch pipelining. Useful metrics were produced as a result and explosive risks analysed.

Keywords: pipeline, gas flow, longitudinal mixing, model, explosive mixture, purging, pipeline tapping.

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Levelling summary drives stress-strain estimates for gas pipeline segments

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This paper proposes a combined approach to assessment of gas pipeline segment stress-strain behaviour based on levelling summary. The approach is built around a polynomial-trigonometric approximation function applicable to pipeline axis deflection and explicit assessment of internal pressure and heat stress. Beam unsupported crossing of existing gasline was chosen as a suitable example of method implementation. Comparisons between actual measurements and assessed bending stress indicate that the proposed combined approach helps us define, with reasonable engineering accuracy, the bending stress distribution across a pipe segment length found in off-spec position.

Keywords: off-spec position, gas pipeline, pipe segment, levelling, sagging, stress-strain behaviour, curving, bending stress.

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Justifying concrete weight-coated pipe specifications

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Concrete weight coating is widely used to achieve on-spec pipeline position. Most regulations assume direct guidelines to such installations which, coupled with unavailable publications in this area, often precludes from full understanding of underlying reasoning. This paper helps us understand how to quantify the concrete-coated pipe specifications. It considers some issues related to concrete coating integrity under pipe storage, transportation, installation, and operation. The authors indicate that apart from a desire to harmonise domestic and international regulations, we need to make provisions for Russian aspects, in particular – lower pipe storage and shipment temperatures as well as available domestic experience to date with ballast coating applications.

Keywords: pipelines, ballasting, water crossing, subsea pipelines, concrete, reinforcement, coating, integrity, strength, deformations.

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External flaw locator scanners for gas pipeline automated nonintrusive testing

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This paper addresses major gas pipeline automated nonintrusive testing practices using external flaw locator scanners. The programme assumed flaw locator field testing to assess their compliance with Gazprom's specifications. Under such operations, testing equipment documentation was considered and analysed, followed by automated nonintrusive pipe and weld testing covering a target gasline segment using external flaw locator scanners, along with experimental assessment of key operating characteristics and additional pipe and weld nonintrusive testing to confirm the identified flaws. The

acquired testing data helped us to identify both benefits and shortcomings of each flaw locator and to formulate recommendation for future upgrades to maintain the compliance.

Keywords: diagnostics, pipelines, overhauls, scanners, flaw locators, specifications, field tests, test summary, compliance, nonintrusive testing.

Long-range facility monitoring assumes finding methane volume content

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Gas pipeline integrity monitoring in crossing areas (water or infrastructure) poses serious challenges for most transmission gasline operators. PetroLait, a Russian energy company, is coming with an upgraded long-range facility monitoring system, SMPO-M, fitted with methane detectors. It is assumed to meet the key requirement: how to locate a gas leak point in mostly inaccessible areas, thereby ensuring process facility operating safety. The paper describes SMPO-M's underlying principles, summarises its key characteristics, presents its structural diagram and a flow chart highlighting fibre-optic methane detectors running within SMPO-M.

Keywords: pipeline, integrity, methane detector, gasline monitoring, long-range pipelines, methane, leak locators.

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How to find running position of Urengoy – Chelyabinsk gasline long sections: A case for complex hydrogeological conditions

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Building on many-year operation of Gazprom Transgaz Surgut's major gas pipelines, in challenging engineering and hydrogeological environment, the authors introduce in this paper a new notion, pipe running position. An underlying study, for chosen pipeline segments, cover a 2010/14 period. The paper describes these issues and key observation phases, along with long pipe position monitoring data processing and proposed criteria to address relative and absolute pipe positional shifts across chosen cross sections. It summarises their findings which evidence a wavelike effect to accompany gasline transverse shifts in soil with weak binding capacity, as well as importance of this process for pipeline design position deviations.

Keywords: gas pipeline, geology, hydrogeology, conditions, off-spec position, running position, pipeline stability, monitoring, deviation.

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Gas pipeline overhauls: Pre-design justification of replacement pipes

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This paper summarises a methodology approach to finding percentage of pipes to be cut out under pipeline overhauls. The approach is centred on a Gazprom's gas pipeline integrity management standard defining pipes which fail to meet strength requirements as well as piles for replacement, given additional grinding costs and labour inputs. Follow-up adjustments concern future flaw probability, pipes most affected by stress-corrosion cracking, metal loss, etc. For pipelines which fail to pass controllability tests, based on inspection pigging, the paper additionally considers a model

designed to find the share of pipes to be replaced. This model is built around analysis of technical assessment and replacement pipe counts statistics.

Keywords: gas pipeline, repairs, methods, corrosion, status, inspection pigging, stress corrosion cracking, flaws, probability, detection.

Gas pipeline repair tools: plasma mobile package and hand tools

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Gas pipeline rehabilitation and recoating need to be prioritised today. Any type of new coating, when applied on poorly treated surface, tends to generate extensive corrosion growth as soon as 1–2 years of operation. Efficient pipeline repair equipment and technology developments are increasingly focal domestically. Rather than imports, Russia is now set to emerge as exporter of innovative and competitive pipeline equipment. This paper summarises a research into a mobile repair package and hand tools designed for stripping old pipeline coating. The technology is centred on a recent plasma-arc treatment method applicable to old coating and other materials. The study benefited from close long-standing cooperation with Gazprom Transgaz St. Petersburg and Petroplasma.

Keywords: gas pipeline, repairs, coating, removal, plasma-arc technology, hand tools, mobile module.

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Corrosion protection improvements for buried gas pipelines

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This engineering solution focuses on gaining higher efficiency of gas pipeline corrosion protection systems built around electric decoupling various electrochemically protected underground structures, such as pipelines, from grounding and lightning protection systems. The proposed approach helps avoiding irrational cathodic protection current flows and sustaining efficient use of new generation protective coatings. The implementation calls for an official certification of opportunities with such cathodic, grounding, and lightning protection systems along with assessment of related equipment compliance and application permits. In general terms, the proposed solution is expected to help cutting corrosion protection construction and operating costs across most large-diameter gas pipelines.

Keywords: corrosion protection, protective coating, electrochemical protection, grounding, circuits, lightning protection, gas pipeline.

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Operating reliability improvements with piled foundations: Yamburg field case study

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Upstream gas operations in the permafrost environment are typically associated with major geocryological risks, undesirable processes and events. Cryogenic soil heaving is one of such processes – it is mostly associated with frost mounds, frost cracks, and piled foundation deformations. Process control and minimisation are among the key parts of basement and foundation geotechnical monitoring. The authors document here their field studies, data interpretation and site zoning, addressing a chosen gas field in Yamburg area, as well as experimental findings related to piled foundation stability improvements.

Keywords: frost-heavin, over-permafrost, water strata, frost mounds, frost cracks, water-lowering sump, temperature measurements, temperature profile, fluid flow model, zonal model.

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Gas pipeline cathodic protection: Potential temperature stratification

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This paper addresses potential opportunities with temperature stratification when considering gas pipeline electrochemical protection. It proposes a new CP system, its operating aspects, and a unique vortex thermoelectric converter (Russian Patents 2233351, 2233352, 2234160, 2234161). In addition, it summarises related estimates and experiments concerning the proposed vortex thermoelectric converter-based pipeline cathodic protection system. It was found that such generator offers a controlled temperature differential between cold and hot junctions, depending on temperature stratification vortex tube operating conditions. The generated current and voltage levels appear sufficient to sustain normal operation of gas pipeline electrochemical protection systems.

Keywords: natural gas, cathodic protection, coating, ageing, pipeline, temperature stratification, potential, estimates, efficiency.

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Ultrasonic flaw locators: Acoustic contact quality improvements

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Supporting structures of gas industry installations are essentially produced using concrete or reinforced concrete – such as compressor station structural elements, power line foundations and supports, road and rail bridges, tunnel finishing, offices and residential buildings, and the like. When defining their expected service life, concrete structure diagnostics data appear critical, along with porosity, concrete cracking, crack size and distribution. The innovation described in this paper relates to non-destructive testing based on ultrasonic methods. They are believed useful when locating flaws in concrete and reinforced concrete construction structural elements widely used across Gazprom.

Keywords: pipes, concrete, flaws, ultrasonic tools, monitoring, diagnostics.

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Centrifugal compressor parametric diagnostics

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Gas compressor operations are typically associated with some issues related to their monitoring and technical assessment. In particular, centrifugal compressor diagnostics is critical as it additionally covers gas turbine drives, enhances overall diagnostics reliability and depth, to enable assessment of numerous compressor station issues in general. Therefore, parametric centrifugal compressor diagnostics, built around a range of computer tools, is believed topical. Compressor models offer extensive automation of gas compressor diagnostics and help timely identify and rectify issues, thereby sustaining normal compressor station operations.

Keywords: gas compressor station, centrifugal gas compressor, models, technical assessment, diagnostics, polytropic efficiency, stability margin.

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Gas compressor reduction gearbox gear wheel flaw diagnostics

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Gas compressor technical monitoring is a priority when safety and reliability are critical. The key parts include vibration monitoring and vibroacoustic diagnostics tools. The paper presents approaches to shaping flaw diagnostic attributes targeting a gas compressor gearbox, model STD-12500. It can be seen that algorithms for processing high-frequency vibration signal envelope appear useful when relying on automated attribute estimation tools built into ASTD-2 diagnostic system. In addition, the paper summarises statistical processing data benchmarked against actual gearbox status data inputs. Proprietary coefficients are generated by ASTD-2 to identify existing flaws. Finally, the authors assess potential future opportunities and expected constraints for respective technical status coefficients.

Keywords: diagnostic attributes, gear wheel, vibration, signal envelope, analysis, signal spectrum, statistical processing, flaws, gas compressor.

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Bovanenko – Ukhta gas pipeline Baidaratskaya Guba crossing: Designing test chambers

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Yamal Peninsula is a strategic priority for Russia, due to huge gas resources with valuable implications for the global economy. A new gas transmission corridor is under way within Yamal mega-project, in particular Bovanenko – Ukhta large-diameter gas pipeline. Complexity and unique aspects of this system are attributable, apart from challenging Far North environment, to a Baidaratskaya Guba (bay) multiloop crossing. This paper highlights some engineering design and fabrication aspects of chambers for pressure testing the marine segment of this pipeline. It presents some engineering technology data for chamber design and assembly phases as well as key factors which appear critical for respective engineering solutions.

Keywords: gas pipeline, testing chamber, caps, design, testing, pipeline crossing, engineering, technology.

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Metalen PE-21: innovative pipe coating

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This paper highlights the key challenges associated with domestic materials used for factory pipe coating when meeting Gazprom and Transneft requirements. Prior to 2013, mostly imported materials, coming from Borealis A/G, Basel Poliolefine, or Atofine, were used for the purpose. These materials essentially met domestic demand for three-layer PE coating for all grades of large-diameter pipes. Now Metakley company is coming with its own nano-modified PE compounds and adhesives designed for factory-based pipe coating using extrusion technology. They are expected to eventually replace

imports and ensure high pipe protection level. Presently, these products have been commercialised (Metalen PE-1 and Metalen APE-1). Metalen PE-21, an innovative single-layer corrosion protection coating, offers better protection and adhesion levels and is more promising commercially as it avoids an individual adhesion layer.

Keywords: pipe coating, domestic materials, counterparts, single-layer coating, factory pipe coating, adhesion, advantages, commercial products.

Integrated gas pipeline corrosion rate assessment: A fuzzy logic approach

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This proposed system centres on fuzzy logic-based data generation to produce outputs specified as "Opportunity for ultimate corrosion" (OUC), a variable believed useful for gas pipeline repair and rehabilitation schedule planning. Flaw location pigging, pit observations, electrometric records, and magnetic tomography, combined, helped us produce target corrosion drivers. Numerical system implementation and respective procedures are the core mathematical support tools for diagnostic decisions using fuzzy logic elements. Numerous elements are assumed as terms for an intermediate linguistic variable, such as *very low*, *low*, *moderate*, *OUC immune*, *average*, *elevated*, and *high*, while linguistic variable outputs use the following elements: *No*, *rather No than Yes*, *rather Yes than No*, and *mostly Yes*. Procedure application is exemplified by a Kazy – Magomed – Kazakh gas pipeline segment.

Keywords: gas pipeline, ultimate corrosion, linguistic variable, fuzzy logic.

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Innovations target gas facility operating safety: Focuses on underfilm corrosion impacts

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Gas pipeline electrometric observation methods often fail to locate corrosion-related flaws when film-coated pipes are used. For some reasons, inspection pigging appears in many cases unproductive as well. This paper describes magnetic tomography applications for gas pipeline diagnostics. Non-destructive gasline magnetometric observations were performed by Transkor-K Research Centre using tomography tools (according to RD 102-008-2002 regulations). SKIF MBC-04 computer system

was used. The tomography-based technology has tested high capacity and sufficient efficiency with gas pipeline diagnostics, when different pipe coating types are used and a range of target pipe positions are addressed. In particular, underfilm corrosion impacts were addressed by this study.

Keywords: underfilm corrosion, gas pipeline, magnetic tomography, diagnostics, reliability, domestic technology.

Integrated approach to gas compressor repairs: GT-750-6 units

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Advanced gas pipeline compressor station technologies are key for reliable and safe operation of core process equipment and ancillary assets. Given the continuously longer gas compressor service life, Gazprom Transgaz Moscow is now increasingly prioritising a comprehensive approach to its equipment repair and upgrade programmes. In particular, such integrated repair programmes target GT-750-6 gas compressor units and assume advanced technologies. Combined with upgrades, these measures

are expected to minimise efficiency gap with most recent compressor types, additionally enhancing compressor operating reliability, cutting energy inputs and costs, and reducing air emissions.

Keywords: gas transmission, gas compressors, reliability, repairs, upgrades, energy efficiency.

Methodology approach to optimum choice of renewable power sources for gas pipeline route users

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Presently, renewable power sources are seen as one of most attractive options when addressing pipeline route user power supply reliability. However, no suitable methodology exists today to optimise the choice of quantity and composition of such sources, given both irregular supply and demand volatility for renewable power. The proposed optimisation solution centres on fundamentals of system-level analysis, probability theory, statistical theory, electric engineering, and heat engineering – all configured for mathematic programming tools. The solution builds around a Simulink computer simulator designed to optimise the choice of a power supply framework based on a set of underlying energy and economic efficiency criteria.

Keywords: renewable power, power supply, pipeline route, power users, wind power, solar power, diesel power plants, optimisation, simulators.

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Hot tapping practices across Gazprom Transgaz Moscow pipelines

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Gazprom Transgaz Moscow is a long-history enterprise presently running over 21,000 km of major gas pipelines. Since 2006, a company's profile subsidiary, UAVR, is responsible for hot tapping operations based on T.D. Williamson technology. This method helps rationalize energy resource use and benefits the environment. Since that year, the company reports its hot-tapping practices

to save about 180 million m³ of gas. In addition, the T.D. Williamson technology gave growth to a new Bank for New Ideas and Solutions, it is expected to manage such practices which would not affect normal gas transmission system operations.

Keywords: hot tapping, gas pipe, pressure culvert, rehabilitation, lateral gas lines.
