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Paper Title: "APPLICATION OF ADVANCED TECHNOLOGIES FOR EVALUATION OF UNDERGROUND NATURAL GAS STORAGE WELLS` INTEGRITY AND OPERATIONAL SAFETY AT "LATVIJAS GAZE" AS FACILITIES"

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"APPLICATION OF ADVANCED TECHNOLOGIES FOR EVALUATION OF UNDERGROUND NATURAL GAS STORAGE WELLS` INTEGRITY AND OPERATIONAL SAFETY AT "LATVIJAS GAZE" AS FACILITIES" - Paper Nº 175.00 selected for Oral Presentation in CS2.3: WOC2 Competencies & Innovative Technologies for UGS

Preamble

Currently there is an intensive search for new ways of improving Underground Gas Storage (UGS) industrial safety, reliability and ecological friendliness. This problem is of high importance for steady and secure energy and gas supply all over the world. The search is closely connected with the development of innovative technologies contributing to the quality improvement of UGS safety and ecological suitability. That is why "LATVIJAS GAZE" AS FACILITIES" and "GAZPROMENERGODIAGNOSTIKA" LLC keep collaborating in research and practical work related to the improvement of functional safety and operational reliability of "LATVIJAS GAZE" AS INCHUKALNSKOE UGS (IUGS) main technological components and engineering systems. This work primarily refers to the improvement of IUGS wells functional safety and to the development of engineering security systems which should provide reliable monitoring of IUGS technical facilities' current engineering status and should allow the prediction and controlling of various risks threatening gas consumers, personnel and environment. The same systems shall automatically inform users about the initiating events, reasons and possible threats of failures or accidental breakdown of IUGS technological equipment and gas pipeline hookups, systems and structures. The development of such engineering security systems has resulted in innovative technologies

which provide the opportunity to verify, test and implement these technologies in the course of their development. At the same time high functional security has increased the commercial benefit of the IUGS operation and has provided a reliable gas supply and energy security.

This paper describes the "LATVIJAS GAZE" FACILITIES" and "GAZPROMENERGODIAGNOSTIKA" LLC best practice in the field of development and implementation of innovative technology for integrity evaluation of IUGS wells and their further operational safety assurance.

Background information about IUGS and its current functional safety status

INCHUKALNSKOE GAS STORAGE (IUGS) — is the third largest gas storage in Europe and the most important structural subdivision of "LATVIJAS GAZE" which deals with natural gas importing, transportation, storage and utilization in the territory of Latvia.
IUGS construction started on May 26, 1966, was finished on August 9, 1968 and a year later 92 million cubic meters of natural gas was injected into it. The main function of IUGS is the periodic injection and topping of natural gas from the layer of porous sandstone located in the vicinity of Inchukalns at a depth of 700 m and forming a closed space confined with gas-proof layer of deposits.

IUGS has the following technical parameters:

- Reservoir – Sandstone at the depth of 680 – 760 m;
  the Reservoir thickness (capacity) is 50 m.
- Storage capacity: total volume - 4,5 bln m^3, active gas - 2,30 bln m^3,buffer gas - 2,2 bln m^3.
- Design capacity: gas injection - 16 mln. m^3/day, gas topping - 24 mln. m^3/day.
- Working pressure: minimum –24 kgf/cm^2, maximum - 105 kgf/cm^2.
- Compressor station output– 33, 8 megawatt (45 500 horse power).
- Number of wells – 183 (93 development wells)
- Number of gas-gathering stations– 3.
- Gas deposit zone– 25 кm^2.

Natural gas is injected into IUGS only in summer when Latvia receives the gas from Russia. It travels over 300 km by the main gas pipeline, which is 700 millimeters in diameter. Over 3 bln m^3 annually can be delivered by this main pipeline. Before entering the storage, the gas goes through special treatment – it is cleared of solid inclusions and oil - and has its volume estimated. After that the natural gas goes into the compressor station process equipment where its pressure increases from 35 to 105 bars, the value required for injecting gas to a depth of 700 meters. Six motor-compressor units, each having 34 MW (Mega Watt) power, are used for compressing the gas. The pressure is increased in three stages as the natural gas is heated during the process. Between the stages the natural gas is cooled to the ambient temperature. When the required pressure is achieved, the gas goes to three gas-gathering stations, where it is separated into several streams – one for every well. After that, the gas is transmitted through clay deposits to porous sandstone by the production wells' pipelines. In autumn and winter, when it is necessary to top the gas from underground storage facilities, the wells' stop cocks are opened and the stored gas goes up through production wells due to its high pressure. The natural gas is gathered in ground gas-gathering stations, has its pressure decreased and is transmitted to dehydration and filtration facilities. Finally, the volume of the topped gas is estimated and the gas goes into the main

pipeline to be supplied to commercial customers. The design capacity of IUGS is about 5 bln m^3 and it is going to be increased.

IUGS specialists monitor the functional safety and the ecological suitability of the production facilities, with a particular focus on wells. That is why today a lot of experts from various countries working in the field of gas and ecological safety have recognized that IUGS maintains a very high standard, from both a technological and ecological standpoint. IGUS pays great attention to monitoring its conformity with the current norms of industrial, ecological and occupational safety. IUGS specialists perform regular assessment of the ecological status of the storage and its environs, focusing on the possible interaction between natural gas and fresh water in the storage's local area. The analysis showed the absence of methane outside the porous sandstone. As the aquifer is located much higher than gas-bearing formation, the fresh water in the territory of the IUGS is within the norm. No other negative effects on the environment have been registered in the territory of IUGS. Independent health care institutions have found no specific health or habitability problems either with IUGS personnel or local residents. The air has been found to be clean and meets all the sanitary norms. Nevertheless, to provide a long-term friendly environment for people and nature "LATVIJAS GAZE» has implemented a system of measures to improve safety and the occupational environment at the IUGS. IUGS complies with OHSAS 18001:2004 and ISO :14001.

Today the main threat for IUGS safety lies in the natural ageing of the UGS facilities and in some undiscovered harmful impacts, which could affect the IUGS's industrial safety.

Aims and factors determining priority monitoring of IUGS wells' functional safety without mandatory killing the wells and removing the tubing.

The systematized evaluation of efficiency factors and risks of UGS monitoring technologies application shall always be relevant for the development of UGS safe operational culture. In our case the importance of such an evaluation is stipulated by:

- The inevitable ageing and degradation of the UGS wells equipment operating in an aggressive environment, in conditions of mechanical impacts and cyclic loads;
- The existing and tendentious stiffening of safety norms and requirements for gas storage facilities, including those located in the vicinity of human settlements and infrastructure facilities.
- The increased requirements for UGS personnel competence, environmental protection, overall system reliability and fail-safety of gas-transport systems, etc.
- The qualitative development of complex technical systems' safety monitoring.
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At the same time, the steady growth of the scope of engineering-diagnostic examination of UGS wells requires constant verification of existing technologies and approbation of innovative ones, which could provide the improvement of IUGS functional safety, system reliability and ecological suitability. In this case our aim is to implement the advanced complex technology of IUGS wells' diagnostics without their decommissioning.

The methods determining the prospects of IUGS efficiency and operational safety improvement on the basis of monitoring and evaluating running wells' integrity without killing the wells. The methodology of innovative monitoring technology and wells' integrity evaluation in view of IUGS wells' further safe operation assurance.

To resist the negative impacts of technogenic and natural character degrading the IUGS efficiency and functional safety, and to improve the personnel competence in the field of IUGS safe operation, it was proposed to implement the innovative technology of monitoring IUGS wells' integrity and assuring their further operational safety. This technology provides for a system of fundamental principles of diagnostic measurement and forecasting integrity, safety and reliability of IUGS wells further operation. These principles are formulated in Table 2, among them:

- The metrological unity of evaluation concepts and algorithms for determining the quantative indicators of UGS wells' integrity current status and assuring their further operational safety;
- The metrological unity of IUGS wells' integrity evaluation concepts and assuring further operational safety of wells for various conditions of natural gas utilization and various scenarios of providing IUGS efficiency;
- The creation of additional conditions for cutting down IUGS operational expenses, keeping the same high level of safety for natural gas consumers.
- The optimization of IUGS wells' nominal reserve capacity for compensating gas supply shortage and providing customers' energy supply security.

The innovative monitoring technology is intended for the timely detection of deviations from the design norms of operation and detection of the following defects of production wells:

- Leakage of couplings and metal of casing strings and tubing;
- Inadequate inter-string pressure;
- Gas flow along the cement stone from the reservoir or from string leakage areas;
- Gas flow in the annulus;
- Critical thinning of casing string and tubing walls as the result of corrosive or mechanical wear;
- Casing string and tubing defects (like cracks, cuts, etc.);
- Casing strings blowout;
- Gas accumulation in the annulus;
- Cavities in wellhead area;
- Cement stone defects.

The innovative technology of monitoring IUGS wells' integrity and assuring their further operational safety applies the following diagnostic methods:

A. For geophysical survey of strings and annulus:

- gas-dynamic logging (highly-sensitive thermometry, barometry, noise-level metering, etc.)
- Magnetic-pulse flaw detection;
- Scanning magnetic-pulse flaw detection;
- Gamma & neutron gamma-ray logging
- Spectrometric methods of gamma, neutron, neutron- gamma-ray logging;

- Pulse methods of neutron, neutron- gamma -ray logging

B. For gas-dynamic logging of annular space:
- methods of registration and measurement by means of wellhead sensors of pressure, temperature, humidity and solids transport

C. For diagnostic examination of the wellhead area and equipment:
- NDT methods and tools (thickness gauge, hardness testers, etc.)

Nuclear methods are also applied, along with the above-mentioned ones for the inspection of complicated technical systems. A number of high-priority problems related to "LATVIAS GAZE" UGS functional safety can be solved by applying nuclear methods. Among other things they allow the users:

- To evaluate the quality of cementing behind the production string, intermediate casing string and conductor;
- To detect voids and holes in cement stone;
- To determine the type of fillings detected in voids and holes in cement stone;
- To detect technogenic gas accumulation in the annulus;
- To detect cavities in the wellhead area;
- To estimate the cavities' radii (from 5 to 50 cm);
- Supplementary geological information – Lithologic log, data on oil-and-gas saturation, porosity, etc.

The development of innovative technology for monitoring the integrity of IUGS wells and assuring their further operational safety included a number of stages.

During the first stage the technology concept was formulated, which required a thorough study of the facility and design specifications of UGS wells, their functional safety and reliability, the analysis of inspection data, applied methods of diagnostics, calculation methods, etc. After that the requirements for the innovative technology quality, completeness and reliability were developed and the conditions of its application at IUGS were specified. It required the development of an entity-relationship model and the classification of IUGS wells' systems and equipment technological status. The results which were obtained allowed the specialists to develop the innovative technology for monitoring the integrity of IUGS wells and assuring their further operational safety and later – to develop tools and algorithms for the technology end-users and implementers.

During the following stages the technology went through verification and approbation at Inchukalnskoe UGS, which included the practical diagnostic activities and collection of technical and volumetric data, their processing and classification in accordance with IUGS structure and operational processes.

The final stage included its practical implementation at Inchukalnskoe UGS and the development of a classifier of technical and volumetric data on IUGS facilities' safety indicators, which are nominally divided into several groups; for example, safety indicators of structural stability, corrosion resistance, and so on.

The results of the innovative monitoring technology application, verification, testing and implementation. The results of risk evaluation in the field of IUGS personnel incompetence in monitoring and providing UGS safe operation assurance for different regions of Russia.

The traditional survey of specialists and consumers was conducted to analyze the efficiency of the innovative technology for monitoring the integrity of IUGS wells and assuring their further operational safety in Russia and other countries. The results of the survey showed that both the specialists and consumers assessed the following advantages of the innovative technology:

- Inspection does not require decommissioning, i.e. killing the well;
- There is no need to prepare the strings for inspection;
- It is possible to perform simultaneous non-destructive examination and thickness measuring of two strings;
- It is possible to perform digital non-destructive examination and thickness measuring of tubing;
- It is possible to perform volumetric examination of lithologic log and caliper log measurements in a cased well;
- It is possible to find the cause of the inter-string flows;
- There is no negative impact of gravity solutions on productive formation which occurs in the process of killing the well;
- It allows cutting the time spend on the wells' technical condition evaluation;
- It allows cutting the cost of the wells' technical condition evaluation and industrial safety expert appraisal.

The results of practical application of the innovative technology for monitoring the integrity of IUGS wells and assuring their further operational safety revealed that there is a steady tendency towards the reduction of the equipment failure in case of conducting preventive maintenance recommended in the result of engineering - diagnostic inspection of the UGS wells.

Conclusions.

The innovative technology for monitoring the integrity of IUGS wells and assuring their further operational safety without killing the wells and removing the tubing has gone through approbation and verification and has proved its efficiency though it still has the space for further improvement in part of processing the obtained results. It has the right to be recommended as best practice and shall definitely help in acquiring new competence for improving UGS efficiency and system reliability.