Identification of Leakage in Couplings of Tubing, Casing and Intermediate Casing for Wells of Underground Gas Storage in Salt Caverns by means of Spectral Noise Logging

A.M. Aslanyan[1], M.V. Volkov[1], S.V. Soroka[1], A.A. Arbuzov[1], D.K. Nurgaliev[2], D.V. Grishin[3], R.S. Nikitin[3], A.N. Malev[4], R.N. Minakhmetova[1]

[1]TGT Service LLC, Kazan, Russia
[2]Kazan Federal University, Kazan, Russia
[3]Gazprom UGS, Moscow, Russia
[4]Gazprom Georesource, Moscow, Russia

Abstract. This paper describes a survey conducted in an underground gas storage well that had excess annulus pressure. The integrated well survey including Spectral Noise Logging (SNL), High Precision Temperature (HPT) Logging and pulse electromagnetic defectoscopy determined the flow geometry in the cemented annuli of the well and identified leaking tubing and casing collars. The paper provides a detailed analysis of well logging data and workover recommendations. Analysis of information on flow and leaks obtained by the survey suggested that the well did not have to be suspended.

Keywords: Underground gas storage (UGS), excess pressure, Spectral Noise Logging (SNL), collar leak, High Precision Temperature (HPT) Logging, pulse electromagnetic defectoscopy, salt cavern

DOI: 10.18599/grs.18.3.7

For citation: Aslanyan A.M., Volkov M.V., Soroka S.V., Arbuzov A.A., Nurgaliev D.K., Grishin D.V., Nikitin R.S., Malev A.N., Minakhmetova R.N. Identification of Leakage in Couplings of Tubing, Casing and Intermediate Casing for Wells of Underground Gas Storage in Salt Caverns by means of Spectral Noise Logging. *Georesursy = Georesources*. 2016. V. 18. No. 3. Part 1. Pp. 186-190. DOI: 10.18599/grs.18.3.7

Introduction

Underground gas storages are modern facilities that ensure uninterrupted gas supply safety even during peak periods. Salt caverns are the most commonly used types of UGS in impermeable rocks.

This paper presents the results of employing High Precision Temperature (HPT) Logging, High Definition Spectral Noise Logging (SNL-HD) and EmPulse pulse electromagnetic defectoscopy as an integrated technology to detect leaks and determine the gas flow pattern in a multi-string salt cavern UGS well. Well integrity analysis based on these advanced technologies can reveal defects in downhole pipe strings, identify sources of excess annulus pressure (EAP) and trace gas flows behind several metal pipes. The obtained information can then be used not only to perform workovers in a particular well but also to produce recommendations for future casing of other wells and, thus, maximise their operating life and minimise workover time and cost.

Technologies

High Definition Spectral Noise Logging (SNL-HD)

The passive SNL technology is based on recording acoustic signals generated by the following processes:

- Fluid flow in the reservoir;
- Cross-flows in cement behind casing;
- Fluid leaks through completion components;
- Wellbore fluid and gas flows.

Subsequent analysis of SNL data in the time and frequency domains ensures an integrated approach to identifying casing and tubing leaks and fluid flow intervals.

The studies described in this paper were conducted with the SNL-HD-9 tool recording acoustic signals in a wide frequency range of 9 Hz to 58.6 kHz. The frequency resolution was 9 Hz below 5 kHz and 114 Hz between 0.1 kHz and 58.6 kHz, and the dynamic noise range was 90 dB. The noise spectrum contained 512 frequency channels, which ensured its high-definition rendering. The wide dynamic range of the recorded signals and the large number of channels make it possible not only to locate zones of elevated noise levels but also to differentiate their spectral compositions and identify their noise sources. For example, wellbore fluid flow generates mainly low-frequency noise, and fluid flow through the reservoir normally generates high-frequency noise.

Detailed descriptions of the wide-band High-Definition Spectral Noise Logging technology have been previously published in Detailed description of the technology of highly sensitive broadband spectral noise logging have been published previously in (Maslennikova et al, 2012; Suarez et al, 2013; Aslanyan et al, 2015;. Marzouqi et al, 2012; Ahmed et al, 2015.).

High Precision Temperature (HPT) Logging

HPT logging is one of the most informative well-surveying techniques to analyse well integrity. Its high accuracy is achieved by conducting measurements using a high-precision temperature measuring tool during downward passes.

If a well is shut in for a long time, a thermodynamic equilibrium sets in between the well and the surrounding rocks. For this reason, the downhole components of a well, including cement behind casing, do not have any substantial effect on the wellbore temperature measured at least several days after shut in, which is a static temperature profile.

The difference between the flowing and static temperatures is caused by fluid or gas flow through the reservoir, casing leaks or cross-flows between reservoirs. Temperature logging detects thermal anomalies caused by thermodynamic processes, such as fluid flow through the reservoir or wellbore, and their shapes are analysed to identify flow sources and patterns.

EmPulse pulse electromagnetic defectoscopy

Multiple casing strings and corrosive brine in tubing created a challenging environment to determine the wall thicknesses of the uncemented casing (177.8 mm), production casing (244.5 mm) and intermediate casing (324 mm). Well integrity control implemented in this survey, including the detection of corroded downhole components and collar location, was based on pulse electromagnetic defectoscopy using the EmPulse-3 logging tool, which can scan casing pipes as large as 355 mm in diameter. The EmPulse-3 tool emits strong magnetic pulses and analyses magnetisation decays in the time domain at each survey depth. The shape of a decay curve contains information on the diameter, electrical conductivity, magnetic permeability and wall thickness for all surveyed pipes. This information is obtained for each pipe by comparing the modelled and measured magnetisation decays at each sensor coil of the tool (Ansari, 2015).

Brief well history and survey rationale

The well was drilled in April 2012 and put into operation in the same year to wash out salt caverns in several stages and subsequently operate an underground gas storage. In December 2013, an excess pressure of 64 kgf/cm^2 was observed in the 244.5/324-mm cement annulus (Fig. 1). In August 2015, pressure testing and bleeding from the 244.5/324-mm and 324/426-mm annuli confirmed their communication. The most recent wellhead annulus pressure measurements indicated excess pressures of 114 kgf/cm^2 in the 244.5-mm string, 58 kgf/cm^2 in the 324-mm string and 16 kgf/cm^2 in the 426-mm string.

HPT-SNL-HD-EmPulse survey results

The integrated well survey showed that the excess pressure was caused by gas from the 177.8/244.5-mm annulus that entered the 244.5/324-mm annulus through a leaking collar in the 244.5-mm string at 203-m depth and the 324/426-mm annulus through a leaking collar in the 324-mm intermediate casing string at 133-m depth (Fig. 1). Another leaking collar was found in the 177.8-mm tubing at 157.3-m depth.

The noise amplitude change observed during pressure bleeding, a temperature anomaly and defectoscopy results confirmed the collar leaks in the 244.5-mm string at 203.0-m depth and in the 177.8-mm string at 157.3-m depth.

The collar leak in the 324-mm intermediate casing string at 132.4-m depth was associated with increased noise intensity during pressure bleeding. Noteworthily, high precision temperature sensors could not detect it because the flow rate was too high for the formation of a temperature anomaly. At the same time, the generated acoustic noise was high enough to be detected by the SNL-HD memory tool.

Alongside this, the EmPulse-3 survey demonstrated the ability of pulse electromagnetic defectoscopy to determine the wall thicknesses of the 177.8-mm, 244.5-mm and 324-mm strings.

Conclusions

The HPT-SNL-HD-EmPulse hardware and software technology has been effectively employed to come up with the following solutions:

1) Location of tubing and casing leaks;

2) Location of the source of excess annulus pressure;

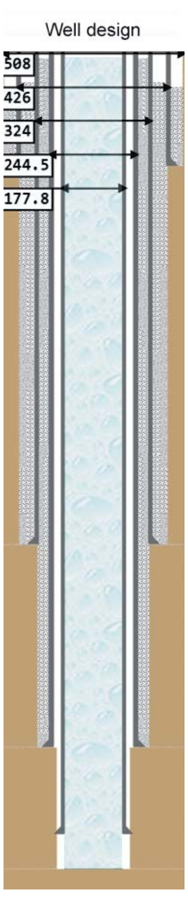
3) Tracing the gas flow path even behind several pipe strings.

Analysis of the integrated survey data identified the following causes of excess annulus pressure:

1) Poor cement bonding;

2) Incorrect selection of metal pipes in terms of corrosion resistance;

3) Inadequate sealing properties of pipe collars.



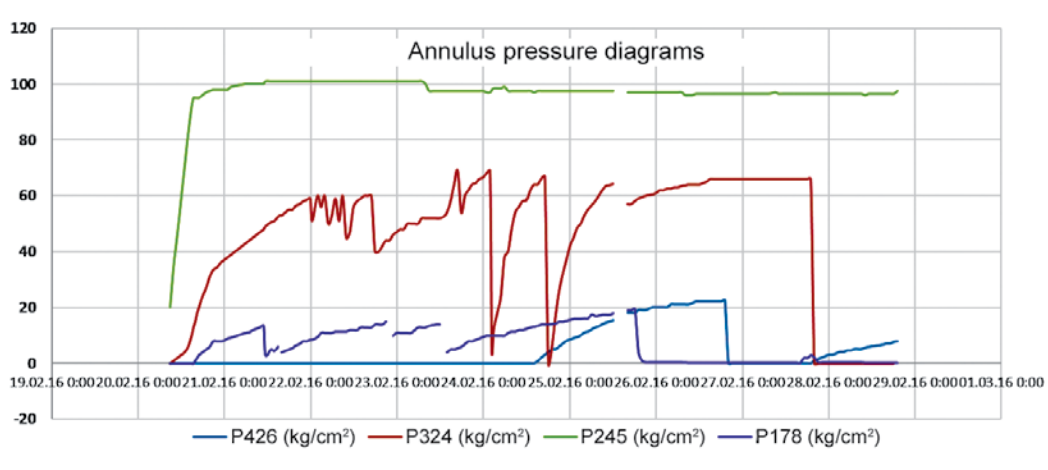


Fig. 1. Pressure dynamics in the 177.8/244.5-mm, 244.5/324-mm and 324/426-mm annuli.

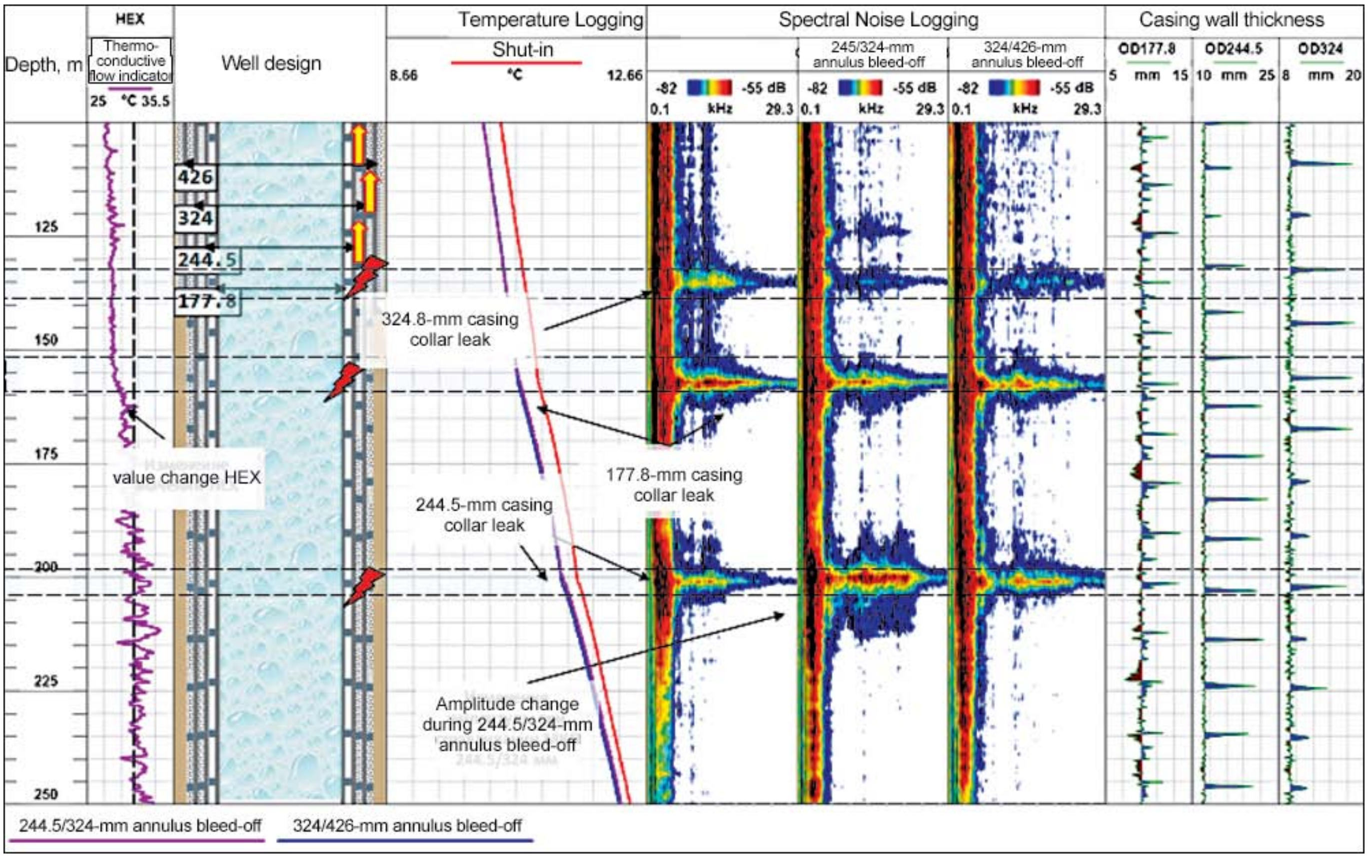


Fig. 2. Cross-flows behind casing and collar leaks identified by the integrated well survey: (1) Temperature gradient and thermoconductive flow indicator data variations along with a high-amplitude noise anomaly at 157.3-m depth indicated a collar leak in the 177.8-mm string; (2) Spectral Noise Logging data detected a noise amplitude change in the depth interval 199-211 m during pressure bleeding from the 244.5/324-mm annulus, and temperature data from the depth interval 202.0-203.0 m indicated a temperature anomaly, which signalled a collar leak in the 244.5-m string at 203-m depth; (3) Noise observed in the interval 132-138 m was caused by a collar leak in the 324-mm intermediate casing string.

The location and characterisation of the leaks enabled the operating company to avoid well abandonment and facilitated workover planning. The flow pattern observed during pressure bleeding from both annuli suggested that this flow could be eliminated by cementing the 177.8-mm string and setting an additional casing string.

Abbreviations

SNL – Spectral Noise Logging
SNL-HD – High Definition Spectral Noise Logging
HPT logging – High Precision Temperature Logging
UGS – Underground gas storage
EAP – Excess annulus pressure

References

Ahmed S. Eldaoushy, Moudi Al-Ajmi, Maali Al-Shammari, Aslanyan A., Aslanyan I., Prosvirkin S., Farakhova R. Quantification of Reservoir Pressure in Multi- Zone Well under Flowing Conditions Using Spectral Noise Logging Technique, Zubair Reservoir, Raudhatain Field, North Kuwait. *Abu Dhabi International Petroleum Exhibition and Conference.* Abu Dhabi, UAE. 2015. Available at: https://www.onepetro.org/conference-paper/SPE-177620-MS

Al Marzouqi Ayesha Rahman, Al-saiidKeshka Ashraf, Bahamaish Jamal Nasir, Aslanyan A., Aslanyan I., Filenev M., Andreev A., Sudakov V., Farakhova R., Barghouti J., Al Junaibi Tariq Abdulla. Integrating Reservoir Modelling, High-Precision Temperature Logging and Spectral Noise Logging for Waterflood Analysis. *Abu Dhabi International Petroleum Conference and Exhibition*. Abu Dhabi, UAE. 2012. Available at: https://www.onepetro.org/conference-paper/SPE-157149-MS

Ansari A., Libdi Z., Khan N., Aslanyan A., Aslanyan I., Volkov M., Arbuzov A., Achkeev A., Shnaib F., Makhiyanov R. Triple-Barrier Thickness Scanning Using Through-Tubing Pulse-Magnetic Logging Tool. *SPE Russian Petroleum Technology Conference*. Moscow, Russia. 2015. Available at: https://www.onepetro.org/conference-paper/SPE-176655-MS

Aslanyan A., Aslanyan I., Karantharath R., Minakhmetova R., Kohzadi H., Ghanavati M. Spectral Noise Logging Integrated with High-Precision Temperature Logging for a Multi-Well Leak Detection Survey in South Alberta. *SPE Offshore Europe Conference and Exhibition*. Aberdeen, Scotland, UK. 2015. Available at: https://www.onepetro.org/conference-paper/SPE-175450-MS

Aslanyan A., Aslanyan I., Minakhmetova R., Maslennikova Y., Karantharath R., Hadhrami B., Zaaima Al Gafri. Integrated Formation MicroImager (FMI) and Spectral Noise Logging (SNL) for the Study of Fracturing in Carbonate Reservoirs. *Abu Dhabi International Petroleum Exhibition and Conference*. Abu Dhabi, UAE. 2015. Available at: https://www.onepetro.org/conference-paper/SPE-177616-MS

Maslennikova Y.S., Bochkarev V.V., Savinkov A.V., Davydov D.A. Spectral Noise Logging Data Processing Technology. Proc. *SPE Russian Oil and Gas Exploration and Production Technical Conference and Exhibition*. Moscow, Russia. 2012. Available at: https://www.onepetro.org/conference-paper/SPE-162081-RU

Suarez N., Otubaga A., Mehrotra N., Aslanyan A., Aslanyan I., Khabibullin M., Wilson M., Barghouti J., Maslennikova Y. Complementing Production Logging with Spectral Noise Analysis to Improve Reservoir Characterisation and Surveillance. *SPWLA 54th Annual Logging Symposium*. New Orleans, Louisiana. 2013. Available at: https://www.onepetro.org/conference-paper/SPWLA-2013-TTT

Information about authors

Artur M. Aslanyan – PhD in Physics and Mathematics, Chief Technology Advisor, TGT Service LLC
Russia, 420108, Kazan, Magistralnaya str., 59/1, bld. 2
Phone: +7 843 210-17-74. E-mail: ama@tgtoil.com

Maksim V. Volkov – Well Integrity Expert, TGT Service LLC
Russia, 420108, Kazan, Magistralnaya str., 59/1, bld. 2
Phone: +7 843 210-17-74. E-mail: maxim.volkov@tgtoil.com

Stanislav V. Soroka – Director of the Tool Factory, TGT Service LLC
Russia, 420108, Kazan, Magistralnaya str., 59/1, bld. 2
Phone: +7 843 210-17-74. E-mail: stanislav.soroka@tgtoil.com

Andrey A. Arbuzov – PhD in Physics and Mathematics, Head of R&D Department, TGT Service LLC
Russia, 420108, Kazan, Magistralnaya str., 59/1, bld. 2
Phone: +7 843 210-17-74
E-mail: andrey.arbuzov@tgtoil.com

Danis K. Nurgaliev – DSc in Geology and Mineralogy, Professor and Pro-Rector for Research, Kazan Federal University
Russia, 420008, Kazan, Kremlevskaya str., 18
Phone: +7 843 233-74-07. E-mail: danis.nourgaliev@kpfu.ru

Dmitriy V. Grishin – Deputy Director General and Chief Engineer, Gazprom UGS
Russia, 117420, Moscow, Nametkina str., 12A
Phone: +7 495 428-45-09
E-mail: D.Grishin@phg.gazprom.ru

Roman S. Nikitin – Deputy Director General and Chief Geologist, Gazprom UGS
Russia, 117420, Moscow, Nametkina str., 12A
Phone: +7 495 428-45-01
E-mail: R.Nikitin@phg.gazprom.ru

Aleksey N. Malev – Head of the Geology and Geophysics Department, Gazprom Georesource
Russia, 117149, Moscow, Bolotnikovskaya str., 18/2
Phone: +7 495 921-05-46
E-mail: a.maljov@gazpromgeofizika.ru

Roza N. Minakhmetova – Lead Expert, Centre of Experts, TGT Service LLC
Russia, 420108, Kazan, Magistralnaya str., 59/1, bld. 2
Phone: +7 843 210-17-74
E-mail: roza.minakhmetova@tgtoil.com

Manuscript received July 25, 2016