Scholarly Publisher
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JOURNAL	World Science
p-ISSN	2413-1032
e-ISSN	2414-6404
PUBLISHER	RS Global Sp. z O.O., Poland

ARTICLE TITLE	METHODOLOGY FOR DETERMINING LEAKS AND ENERGY SAVING IN UNDERGROUND GAS STORAGE
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ARTICLE INFO	Lena Shatakishvili, Ketevan Berikashvili. (2024) Methodology for Determining Leaks and Energy Saving in Underground Gas Storage. *World Science*. 2(84). doi: 10.31435/rsglobal_ws/30062024/8134
DOI	https://doi.org/10.31435/rsglobal_ws/30062024/8134
RECEIVED	26 March 2024
ACCEPTED	12 May 2024
PUBLISHED	15 May 2024
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METHODOLOGY FOR DETERMINING LEAKS AND ENERGY SAVING IN UNDERGROUND GAS STORAGE

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DOI: https://doi.org/10.31435/rsglobal_ws/30062024/8134

ARTICLE INFO

Received: 26 March 2024
Accepted: 12 May 2024
Published: 15 May 2024

KEYWORDS

Determining Leaks, Energy Saving, Underground Gas Storage.

ABSTRACT

The main task of any functioning gas transportation system is to supply reliable gas to all customers. Create a new underground storage and expansion and optimization of existing underground gas reservoirs is one of the priority directions for the development of the gas industry. The aim of the work is to determine the methodology of leakage and losses of underground gas reservoirs. There is a presented an analysis of the hysteresis loop of the underground gas reservoir compaction-removal cycle and the corresponding leakage.

Citation: Lena Shatakishvili, Ketevan Berikashvili. (2024) Methodology for Determining Leaks and Energy Saving in Underground Gas Storage. *World Science.* 2(84). doi: 10.31435/rsglobal_ws/30062024/8134

The main task of any functioning gas transportation system is to ensure a reliable gas supply to all consumers. The creation of new, expansion and optimization of existing underground gas storage facilities is one of the priority areas for the development of the gas industry. This task must be carried out even taking into account the seasonality of product consumption by large industrial centers, as well as with maximum use of all the capabilities of the main gas pipeline. To solve this problem, underground gas storage facilities (UGS) are being developed. The main task of underground gas storage facilities is to accumulate gas during the summer-autumn period to equalize consumption in winter and spring, since consumer demand for gas increases during these seasons.

The results obtained in this work are based on the following studies [1-5]. Let's consider the theory of monitoring UGS parameters based on the use of the so-called. hysteresis diagrams - $(\mathbf{p}/\mathbf{Z}-\mathbf{V})$. Here $\mathbf{p}$ is the weighted average pressure over the area of the gas cavity; $\mathbf{Z}$ - degree of gas supercompression; $\mathbf{V}$ - The volume of gas in the underground gas storage facility is reduced to standard conditions. The technique for estimating cyclic parameters in underground gas storage systems using hysteresis diagrams is widespread abroad, primarily in the USA and Canada.

Hysteresis diagrams represent the dependence of the volume of gas $\mathbf{V}$ in an underground gas storage facility on the reduced gas pressure $\mathbf{p}/\mathbf{Z}$ in the gas cavity. Using hysteresis diagrams, you can observe all stages of the cyclic process of UGS operation.

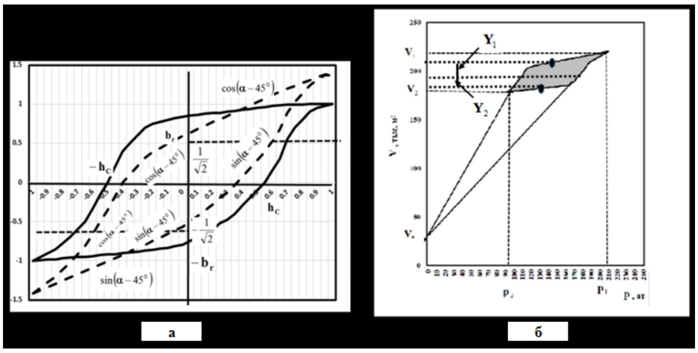
The purpose of the work is to express the process of gas injection and extraction using known methods of analytical calculation of symmetric and asymmetric hysteresis loops.

It is known that the simplest method is an ellipse; the Mittelstrasse function [6,7] or the universal Rayleigh formula [8,9] are also used. These simple formulas do not reflect the real picture, so we propose a modified method for calculating the hysteresis loop, which includes eight sections

[10,11]. Let us consider symmetrical hysteresis, which is normalized, i.e. its range in width and height is (-1; +1). In a real case, the appropriate scale should be used. Designations are shown in pic.. 1a. The rotation of the loop occurs according to well-known simple formulas.

The upper hysteresis loop I and II are two straight sections located at two given points (pic. 1a): between two points of the first (1;1) and the second $(\mathbf{h}_C, \mathbf{Y}_{1C})$ and $(0, \mathbf{b}_r)$. Similarly, we represent sections III and IV of the lower branch of the loop: coordinates of the third section $(-\mathbf{h}_C, \mathbf{Y}_{2C})$ and $(0, -\mathbf{b}_r)$; coordinates of the fourth section (-1;1). From here we get:

To determine the ordinates of the nonlinear four sections of the hysteresis loop, we use the relation [10]: from which we obtain



Pic. 1. a. Parts of the branches of the hysteresis loop I-IV, special symmetrical values of this argument $\mathbf{h}: 0,\ \pm\mathbf{h}_C,\ \pm 1$*; b. UGS Samgori (Georgia) - hysteresis diagram of the injection-withdrawal cycle.*

$$\begin{cases} \mathbf{Y}_{\mathbf{I,I}} = (\mathbf{h} - \mathbf{h}_C)\left(\dfrac{1 - \mathbf{Y}_{1C}}{1 - \mathbf{h}_C}\right) + \mathbf{Y}_{1C}; & \mathbf{Y}_{2,\mathbf{III}} = \mathbf{h}\left(\dfrac{\mathbf{b} - \mathbf{Y}_{2C}}{-\mathbf{h}_C}\right) - \mathbf{b}_r; \\ \mathbf{Y}_{\mathbf{I,II}} = \dfrac{\mathbf{h}}{\mathbf{h}_C}(\mathbf{Y}_{1C} - \mathbf{b}_r) + \mathbf{b}_r; & \mathbf{Y}_{2,\mathbf{IV}} = (\mathbf{h} + \mathbf{h}_C)\left(\dfrac{\mathbf{Y}_{2C} - 1}{\mathbf{h}_C - 1}\right) - \mathbf{Y}_{2C}. \end{cases} \qquad (1)$$

To determine the ordinates of the nonlinear four sections of the hysteresis loop, we use the relation [10]: $\mathbf{Y}_1 = \mathbf{A}\cos\alpha,\ \mathbf{Y}_2 = \mathbf{A}\sin\alpha$, from which we obtain:

$$\begin{cases} \mathbf{A} = \dfrac{\mathbf{Y}_1}{\cos\alpha}; & \mathbf{A} = \dfrac{\mathbf{Y}_{21}}{\sin\alpha}; \\ \mathbf{Y}_2 = \dfrac{\mathbf{Y}_1}{\cos\alpha}\sin\alpha; & \mathbf{Y}_1 = \dfrac{\mathbf{Y}_1}{\sin\alpha}\cos\alpha = \mathbf{Y}_2\,\mathbf{ctg}\alpha. \end{cases} \qquad (2)$$

The area of the hysteresis loop is determined by the following relationship:

$$\mathbf{S} = 2\left[\mathbf{Y}_{\mathbf{I,I}}(1 - \mathbf{tg}\alpha_{\mathbf{I}}) + \mathbf{Y}_{\mathbf{I,II}}(1 - \mathbf{tg}\alpha_{\mathbf{II}})\right]. \qquad (3)$$

Let's look at an example. The Georgian Oil and Gas Corporation (GOGC) plans to build an underground gas storage facility on the southern dome of the depleted Samgori oil field, near Tbilisi.

A preliminary feasibility study of the project was completed in 2019. Approximate parameters: $\mathbf{p}_1 = 215$ат; $\mathbf{p}_2 = 90$ат; $\mathbf{V}_1 = 215$ млн.м^3; $\mathbf{V}_2 = 178$ млн.м^3; $\alpha_1 = 31^0; \alpha_2 = 37^0$;

$\mathbf{tg\alpha}_1 = 0{,}577$; $\mathbf{tg\alpha}_2 = 0{,}753$; at; A hysteresis loop was constructed and the corresponding calculation was carried out. In this case, the loop area (i.e., energy loss) according to formula (3) is equal ≈ 213 to million MJ. Gas loss per cycle is equal to $\mathbf{V}_* \approx 26$mln/.m3.

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