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LOGISTICAL APPROACH TO MONITORING OPERATION OF UNDERGROUND GAS STORAGES (UGS)

Summary. The main problems in the operation of UGS are associated with the security operation that requires continuous environmental monitoring. Monitoring should be carried out over the parameters of operation of UGS and environmental indicators. From positions of logistic approach their relationship should be analyzed within a single system. This will effectively set the abnormal deviations and make timely corrective action to operational parameters.

Keywords: underground gas storage, monitoring, logistics, system, operating parameters, performance.

PODEJŚCIE LOGISTYCZNE DO MONITOROWANIA OPERACJI PODZIEMNEGO ZGAZOWANIA WĘGLA (UGS)

Streszczenie. Głównym problemem w operacji podziemnego zgazowania węgla jest bezpieczeństwo jej przeprowadzenia, które wymaga ciągłego monitorowania środowiska przebiegu tego procesu. Monitorowanie powinno być podejmowane zgodnie z parametrami UGS i wskaźnikami środowiskowymi. W podejściu logistycznym wzajemne powiazanie tych parametrów powinno być analizowane w ramach pojedynczego systemu, co pozwoli skutecznie zapobiegać nieprawidłowym odchyleniom i sprawi, że cała operacja będzie przebiegała zgodnie z harmonogramem i założonymi parametrami operacyjnymi.

Słowa kluczowe: podziemne zgazowanie węgla, monitoring, system logistyczny, operacyjne parametry efektywnościowe.

1. Introduction

To ensure energy security of the Kaliningrad region in 2013 began operation of underground gas storage (UGS). UGS are designed to compensate for interruptions in supply of natural gas, smoothing of uneven consumption, strategic storage reserves and other tasks. For example, during the year maximum daily selection of gas exceeds the minimum by more than three times, and the supply of gas via trunk gas pipelines is virtually a constant speed. It is required to enforce rigid norms and rules of industrial and environmental safety while optimizing costs for gas storage and operation of UGS.

Analysis of various sources shows that the main problems associated with UGS to ensure performance and safety of operation [1, 2]. It also shows in numerous foreign publications [6-13]. Addressing them requires constant monitoring of performance and the environment. Since these indicators are interrelated, their control and correction is most effective within a single system. The analysis of such a system on the logistic approach assumes that between its interconnected elements circulate information which is relevant to evaluate situations and make effective management decisions.

The key point is the control of physical flows (indicators) in real time with processing and communication by electronic data interchange.

2. The conditions and objects monitoring

The operation of UGS due to the interrelationships of basic processes and the presence of associated factors and conditions (Fig. 1).

The values of technological parameters, required to prevent harm to the environment, as well as on the stability and tightness of underground storage facilities in the different periods of construction and operation is regulated [1, 3].

Potential risk and complications in the process of creation and operation of UGS are the following main reasons:

a) **geological** – related with the structure and properties of the earth's surface and lying beneath the array;

b) **technologica**l – related to complications arising due to inefficient operation of UGS;

b) **technical** – due to violations in the installation of wells, columns and other pieces of equipment.

Control and monitoring during operation of underground storages are exposed:

- gas - storage object;
- control aquifers;

- potable aquifers;
- the earth's surface, its displacement and structure within the boundaries of UGS operation;
- the composition of the atmosphere.

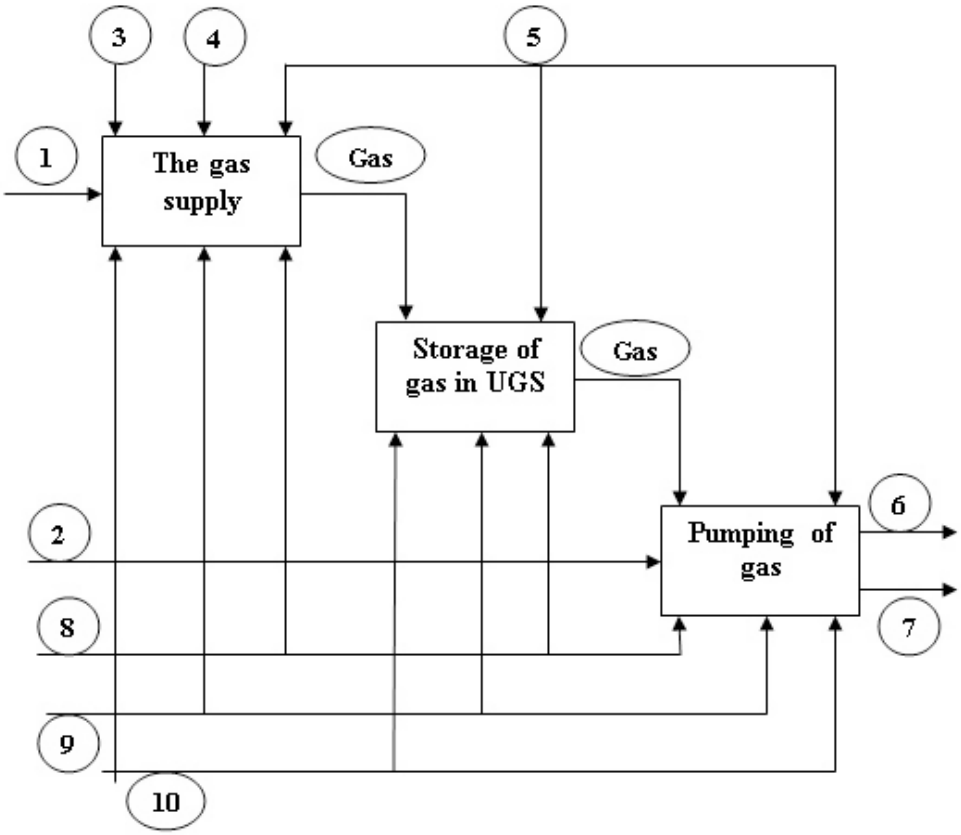

Fig. 1. Graphical representation of the main processes in the UGS and their links:1 – the gas from the main gas pipeline; 2 – graph sampling gas; 3 – schedule of gas pumping; 4 – completion technology; 5 – target quality; 6 – gas to consumers; 7 – a set of documents; 8 - employees; 9 - infrastructure; 10 – production and the environment

Rys. 1. Graficzny schemat głównych procesów w UGS i połączeń:1 – gaz z głównego gazociągu; 2 – próbkowanie graficzne gazu; 3 – harmonogram pompowania gazu; 4 – technologia zakończania; 5 – jakość docelowa; 6 – gaz do odbiorców; 7 – komplet dokumentów; 8 – pracownicy; 9 – infrastruktura; 10 – produkcja i środowisko

Source: Own work.

All the process during the operation of UGS facilities and their control is governed by the Rules mentioned above.

The main causes of physical risks in the operation of underground gas storage are [4, 5]:

- reducing the volume of reservoirs in rock salt under the action of rock pressure;
- the lower pressure aquifers, exploited underground water intakes;
- increasing pressures of horizon disposal of brine etc.

Mechanical equipment and describe IOPS in terms of its elements in the process of operation should be under constant supervision of operators and maintenance services [3].

During routine inspections, particular attention should be paid to gas leakages through flanged, threaded and welded joints, the seal packing of valves, inter-column pressures. When it detects the fault and passes gas wells should be immediately blocked and action is being taken for replacement of defective components and parts or the transfer of the wells in repair. Inspection intervals should be established enterprises management.

Given the potential danger of technogenic UGS, after each unit process equipment maintenance number of hours regardless of the technical condition it is necessary to conduct preventive maintenance [2].

The analysis using the method of expert estimates [2] have shown that, to ensure the safety of operation of UGS is the most important task is the establishment of a monitoring system, providing integrated control of all factors attendant to operation, and quantitative indicators. The sequence of development of the monitoring process is presented in Fig. 2.

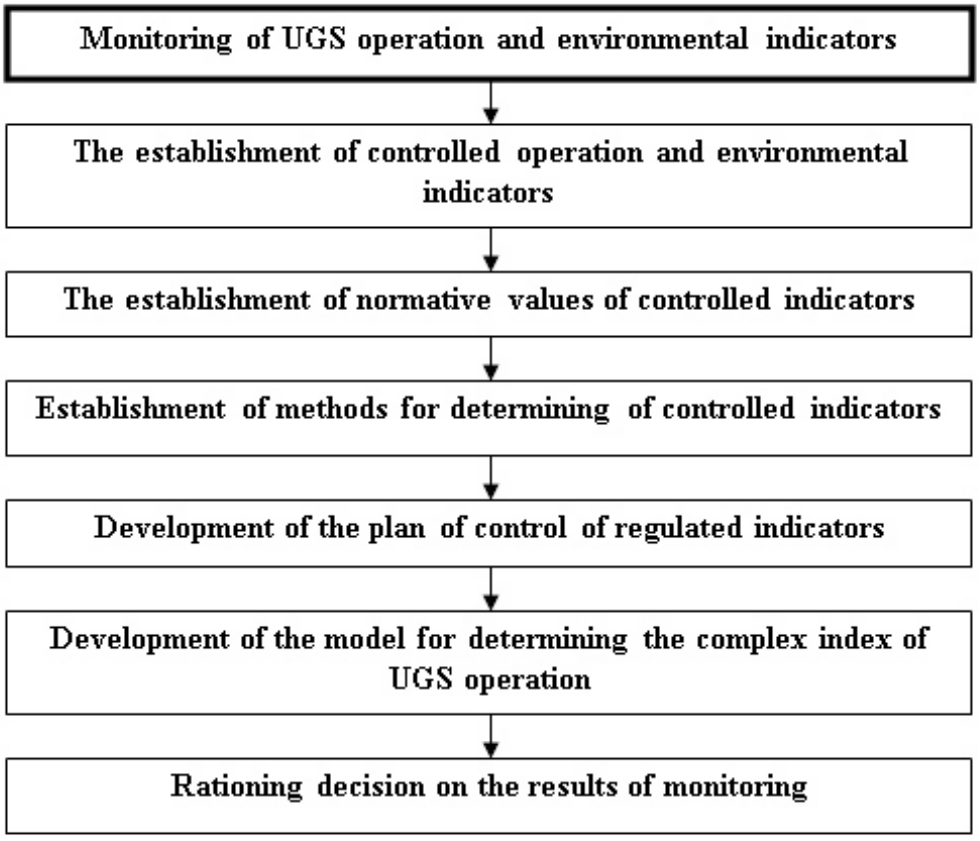

Fig. 2. Algorithm development UGS monitoring process
Rys. 2. Algorytm rozwoju procesu monitorowania UGS
Source: Own work.

The functioning of the monitoring system determines whether the allocation of major elements (Fig. 3), which is the object of its control, with further detail on the hierarchy of interaction.

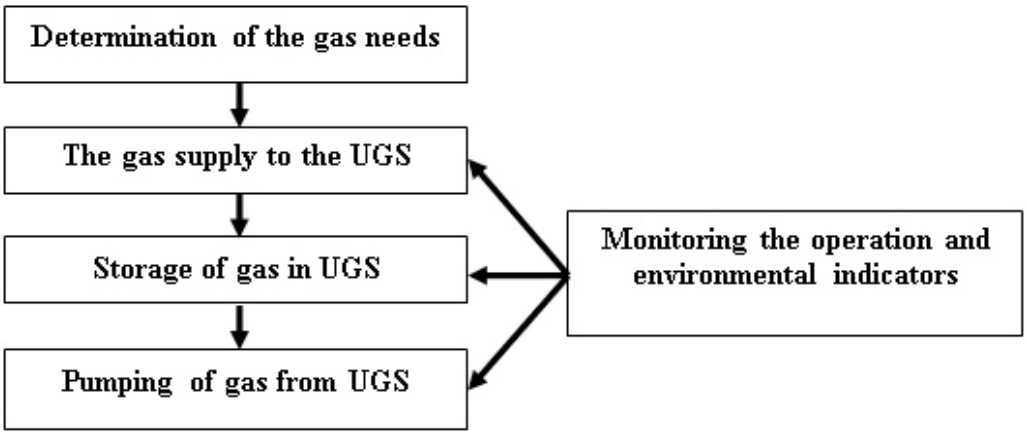

Fig. 3. The key activity of the monitoring process of operation of the underground gas storage
Rys. 3. Główne obszary procesu monitorowania operacji podziemnego zgazowania węgla
Source: Own work.

Logistic approach requires constant interaction of the elements of the production system by integrating into it the information system (Fig. 4).

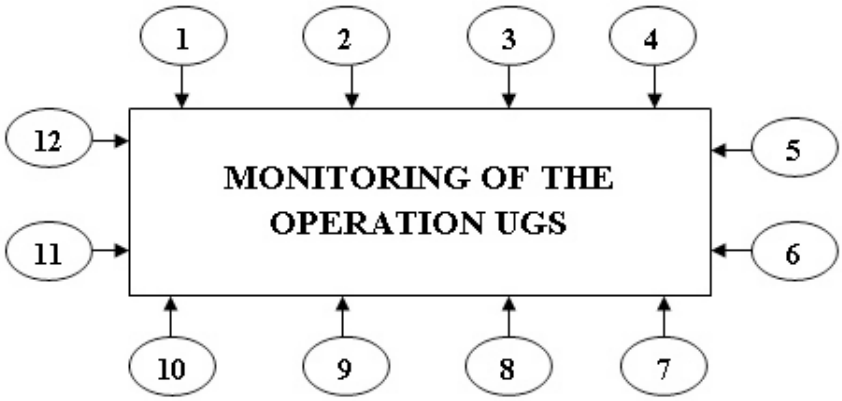

Fig. 4. Information model of the monitoring process during the operation of UGS:1 – standards and technical regulations; 2 – the characteristics of the gas in the main gas pipeline; 3 – regulations of pumping gas into UGS; 4 – indicators completion technology; 5 – schedule of pumping gas; 6 – characteristics of gas in UGS; 7 – indicators of technical condition of UGS elements; 8 –indicators of gas from UGS; 9 – schedule of gas; 10 – quality objectives; 11 – characteristics of gas supplied to consumers; 12 – indicators of the environment

Rys. 4. Model informacyjny procesu monitorowania UGS:1 – normy i przepisy techniczne; 2 – charakterystyka gazu w głównym gazociągu; 3 – zasady wtłaczania gazu do UGS; 4 – system wykrywania końca procesu; 5 – harmonogram pompowania gazu; 6 – charakterystyka gazu w UGS; 7 – czujniki stanu technicznego elementów UGS; 8 – czujniki gazu z UGS; 9 – harmonogram gazu; 10 – cele jakościowe; 11 – charakterystyka gazu dostarczanego do odbiorców; 12 – czujniki środowiska
Source: Own work.

3. The main elements of the monitoring system

Environmental monitoring − a complex system of observations, evaluation and forecast of changes of environmental condition under impact of natural and anthropogenic factors. We reduce from regulatory documents [3, 4] in a single structure, methods, objects, and indicators of control in the operation of UGS (Table 1).

Table 1

Methods, objects, and UGS monitoring indicators

METHODS	OBJECTS	INDICATORS
Industry	gas − storage facility	- structure; - volume; - Dew point
	control horizons	- pressure; - temperature; - the volume of formation fluid
	well	- pressure; - temperature; - the volume of formation fluid
Hydrochemical	gas − storage facility	the content of impurities
	control horizons	dissolved gas content
Geophysical (radiometry, thermometry)	gas − storage facility	gas saturation
	control horizons	gas saturation
	well	technical staff
Gasdynamical	commercial gas	- physico-chemical composition; - specific gravity; - calorific value; - Dew point
End table		
Analytical (Modeling of geologicaland technological conditions)	gas − storage facility	- volume; - shell tightness; - losses
	well	- performance; - pressure
	technological chain	pressure and loss

Source: Own work.

Additional monitoring using appropriate methods should be steel ducts (integrity, quality welded joints, susceptibility to corrosion risk, the condition of protective coatings and metal tubes), and compressor equipment (noise level).

To create effective conditions for preventative maintenance and order management pieces of equipment must be considered that the periodicity of monitoring underground and the settings on them vary considerably [1, 3], for example:

- 1 time per month − the number of injected and extracted gas;
- 1 time per month − commercial quality gas;
- 1 time per month (in the summer) − the technical condition of wells;
- 1 time per quarter − potable aquifers;
- 1 every 3 years − environmental and geochemical studies, etc.

The annual slice of the structure of the monitoring cycle [1, 2] (Fig. 5) allows all the objects to classify its types and to establish reasonable logistics system for order management of spare parts.

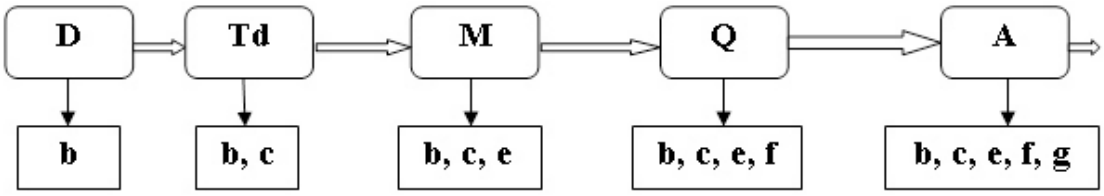

Fig. 5. Structure of the annual cycle of monitoring objects describe IOPS in terms
Rys. 5. Schemat rocznego cyklu monitoringu z podziałem na grupy pod względem częstototliwości kontroli
Source: Own work.

Fig. 5 in the top row symbols denote objects corresponding to the frequency control: b – daily; c – decadal; e – monthly; f – quarterly; g – annual.

In works [1, 2] it is shown that for the processing and analysis of monitoring results during the operation of UGS is advisable to use qualitative approach that gives a comprehensive assessment. The unified monitoring system will enable automated record the results and show the effectiveness of integrated and violations of the processes of operation of UGS, as well as to respond quickly to any discrepancies.

4. Conclusions

In 2013, for ensuring energy security of Kaliningrad region to put into operation an underground gas storage facility. Operation of underground storages can reliably meet the

needs of the region in natural gas regardless of the time of year, temperature fluctuations, force majeure. In accordance with departmental documents during the operation of UGS facilities need to comply with rigid norms and rules of industrial safety and, especially, the requirements for environmental protection. In relation to all objects, including cars and the equipment, observance of regulations, inspections and repairs.

The safety of operation of UGS for the environment is a major problem. Therefore, the establishment of a monitoring system of the underground and the environment in accordance with departmental documents during operation of the UGS is the need to comply with rigid norms and rules of industrial safety and, especially, the requirements for environmental protection. In respect of all objects, including machines and equipment, compliance with rules, is the most important task, requiring the use of logistic approach. This is reinforced by the need for systematic monitoring and analysis of indicators, which requires embedding an information system in production.

A system of monitoring appropriate to establish in accordance with the process approach, which allows to present the work of the UGS as a chain of interrelated basic processes.

In connection with the operation of underground gas storage is carried out through many processes, and monitoring and control include a plurality of indicators for the processing of their results it is advisable to use qualimetrical approach, which is increasingly used in various fields. The automated locking system and demonstrate the results of the monitoring and control will allow you to see a picture of the effectiveness of the processes of operation of UGS and respond quickly to any discrepancies. It is in this direction need to continue.

Bibliography

1. Nordin V., Belkina N.: The monitoring system of the Kaliningrad gas storage. “Technical and technological service problems”, No. 2(28), 2014, p. 34-37.
2. Nordin V., Belkina N.: Recommendations on the monitoring system of underground gas storage. “Management Systems In Production Engineering”, No. 3, 2014, p. 100-105.
3. GOST R 53239-2008. Storage of natural gas underground. The monitoring rules in the creation and exploitation. Entered into force 01.01.2010.
4. Building regulations 34-02-99. Underground storage of gas, oil and products of their processing. Adopted on 1 July 1999 by the decision of Gosstroy of Russia dated 17.05.99 No. 36.
5. Teplov M., Grohotov V., Fedchuk V.: The risk of exploitation of underground storage facilities in rock salt. “Gas industry”, No. 9, 1999, p. 67-72.

6. Evans D.J., Chadwick R.A.: Underground gas storage: An introduction and UK perspective. Electronic resource: http://sp.lyellcollection.org/content/313/1/1.full.
7. Evans D.J., West J.M.: An appraisal of underground gas storage technologies and incidents, for the development of risk assessment methodology. Prepared by the British Geological Survey for the Health and Safety Executive, 2008. Electronic resource: http://www.hse.gov.uk/ research/rrpdf/rr605.pdf.
8. Katz D.L.: Monitoring Gas Storage Reservoirs. "Society of Petroleum Engineers". Electronic resource: https://www.onepetro.org/conference-paper/SPE-3287-MS.
9. Keeley D.: Failure rates for underground gas storage. Prepared by the Health and Safety Laboratory for the Health and Safety Executive, 2008. Electronic resource: http://www.hse.gov.uk/research/rrpdf/rr671.pdf.
10. Mayberry A.K.: Safe Operations of Underground Storage Facilities for Natural Gas. Electronic resource: https://www.federalregister.gov/articles/2016/02/05/2016-02228.
11. Ming Lu.: Rock engineering problems related to underground hydrocarbon storage. "Journal of Rock Mechanics and Geotechnical Engineering", Vol. 2, Issue 4, p. 289-297. Electronic resource: http://www.sciencedirect.com/science/article/pii/S1674775515300627.
12. Musy G.: Leak detection methods for underground storage tanks. 28 July, 2008. Electronic resource: http://www.processonline.com.au/content/materials-handling-logistics/article/ 1227374745
13. Webb D.: Leak in California turns focus on underground gas storage. Electronic resource: http://www.gjsentinel.com/news/articles/.

Omówienie

Bezpieczeństwo środowiska jest głównym problemem procesu podziemnego zgazowania węgla. W związku z tym opracowanie systemu monitorowania środowiska zgodnie z resortowymi dokumentami jest koniecznością i oznacza przestrzeganie sztywnych norm i zasad bezpieczeństwa oraz higieny pracy, a przede wszystkim wymogów dotyczących ochrony środowiska. W odniesieniu do wszystkich obiektów, w tym maszyn i urządzeń, stosowane jest podejście logistyczne. Jest ono wzmocnione przez potrzebę systematycznego monitorowania i analizy wskaźników, która wymaga osadzania systemu informacyjnego w procesie produkcji.