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Organizational measures to ensure continuous monitoring of the Ground-Climate-Pipeline system

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Abstract. The article deals with organizational measures to ensure continuous monitoring of sections of the Ground-Climate-Pipeline System exposed to hazardous processes. Tasks of the personnel on work with a monitoring system are allocated. The requirements for determining the number and qualification of the monitoring system personnel are identified. The list of topics for the training of specialists at the managerial level is given.

1. Introduction

Currently, oil production and transportation require not only significant investments, but also the introduction of new technological solutions, complex methods, innovative approaches in the design of pipelines, construction, and operation [1].

Today pipeline transport in Russia is a platform for implementing many unique technical and technological solutions aimed at ensuring the safe operation of pipelines, reducing oil transportation costs, and the scale of possible incidents and accidents. More than 50% of the volume of the total number of oil products is transported through trunk pipelines [2-3].

The operation of pipelines in areas with high landslide danger involves a high risk of accidents and failures [4]. Leakages of oil products from trunk pipelines lead to significant economic damage to the company in the form of loss of a large volume of transported oil, environmental penalties, and overspending on emergency and recovery services [5-6].

Heavier penalties for environmental pollution [7] and the use of outdated equipment need to increase personnel qualification and the level of reliability of diagnostic systems. The monitoring system (MS) should function without failure, continuously 24 hours a day, seven days a week [8].

The article describes organizational measures to ensure continuous monitoring of the Ground-Climate-Pipeline System (GCP) state at the section exposed to hazardous processes (HP) [9].

2. Methods

The MS is implemented through the use of the possibilities of electronic computer technology; therefore, the requirements for the organization of labour and rest mode at work are established based on those for work with computers [10].

Training of the MS staff should be carried out within the framework of the training system for the relevant training programs for MS administrators and MS users [11].

In the frame of MS implementation, it is necessary to solve the following tasks (Table 1) [12].

Table 1. Tasks of personnel on work with the monitoring system.

Task name	Functions
Maintaining the cartographic block [13]	- creation, import, export, and search of cartographic objects; - visualization and content management of the electronic map; - launch of application tasks.
Conducting the block of hazardous processes simulation	- assessment of the value of displacement of soil masses and pipeline relative to each other; - assessment of position changes and pipeline failure in sections exposed to HP; - forecasting of ground subsidence; - analysis and forecast of HP development; - assessment of the stress-strain state of the GCP system at a selected section.
Conducting a block for assessment of external loads and impacts on the pipeline during the development of the HP	- modelling the interaction between the pipeline and the ground when the ground is displaced on slopes and assessment of the stress-strain state; - modelling the interaction between pipeline and soil during ground subsidence and stress-strain state assessment; - modelling the interaction between pipeline and soil during its heaving and stress-strain state assessment; - determining the stress-strain state of the pipeline in areas with karst; - assessment of the current ejection force in watered and marshy areas.
Conducting the block of external load assessment and impact on the pipeline in case of an earthquake	- processing of seismic information from data of installed seismic stations; - acquisition of synthesized accelerograms based on spectra of real earthquakes; - modelling of the interaction between pipeline and ground in case of seismic impact and assessment of stress-strain state.
Conducting the block of preparation of management decisions [14]	- assessment of possible oil spill volume and modelling of pollution spread over land and watercourses; - justification of the composition of forces and funds required for the localization and elimination of an oil spill accident; - determination of the amount of environmental and material damage in an oil spill accident; - solutions to reduce the damage from the accident.

To solve the problems associated with ensuring the safe operation of the pipeline in its potentially dangerous section by implementing organizational measures, it is proposed to create a system for their automatic generation based on the facts accumulated in the knowledge base, characterized by varying the degree of success of previously carried out organizational measures, depending on the situation recorded by the sensors.

Figure 1 shows a scheme for generating events.

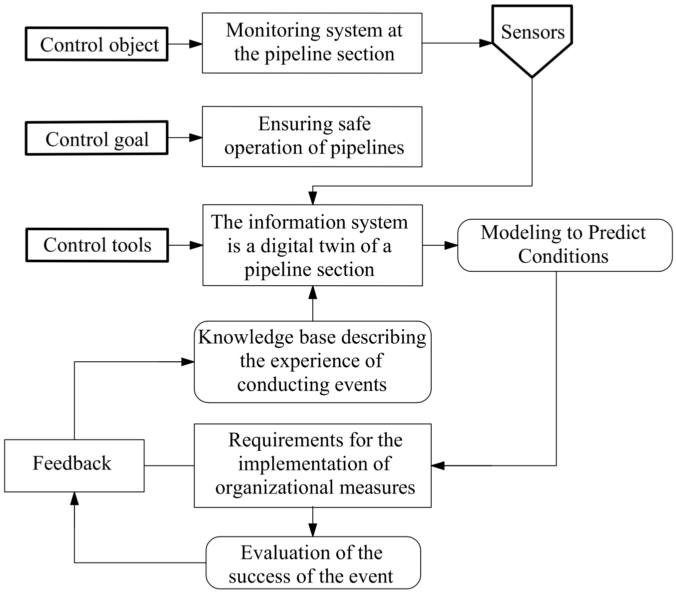

Figure 1. Scheme of automatic generation of organizational measures to ensure safe operation of the pipeline.

In the above scheme, organizational measures are considered as a means of pipeline management aimed at ensuring its safety. The result of management is a list of measures, the choice of which is based on the readings of the sensors of the monitoring system, the forecast of the state of the GCP system, and the experience of previous measures. There is the feedback that allows replenishing the knowledge base with a description of the experience, making the tool more flexible and reliable. An important feature of generating a list of organizational measures is that it is based on a forecast of possible states formed by a digital twin of a pipeline section, which includes a digital description of its soil, climate, pipeline elements, and their interaction in changing conditions. To form a list of measures, all types of forecasts are required, distinguished by their urgency and accuracy.

It is assumed that as records are accumulated in the knowledge base, the effectiveness of the list of organizational measures will grow. To ensure the growth of efficiency, artificial intelligence systems can be used.

Of fundamental importance is the classification of the variety of conditions of the situation, in response to which a list of organizational measures is formed. There are many signs for such classifications, for example, according to severity (the rate of rising of a critical parameter), according to the hazard indicated by colour (white, yellow, orange, red, or black), according to the severity of consequences (expected consequences).

Depending on the class of the situation, which can be recorded by sensors or predicted using the digital twin of the object, events are also classified according to the efficiency of implementation, timing, urgency, types of measure, and other signs.

The article considers an example of the daily measures of employees when they perform measures related to the observation and analysis of data from monitoring and forecasting systems.

3. Results

The number and qualification of the system personnel are determined taking into account the following requirements:

- the structure and configuration of the system should be designed and implemented to minimize the number of service personnel;

- the system structure should provide an opportunity to manage all available system functions for one administrator, as well as provide an opportunity to share responsibility for administration between several administrators;
- the system hardware and software complex shall not require twenty-four-hour maintenance and the presence of administrators;
- the staff complement of the personnel operating the system should be formed based on the regulatory documents of the Russian Federation and the Labour Code;
- all specialists must work with a normal work schedule not exceeding 8 hours per day.

Training on the following issues (topics) should be provided for managers:

- description of the general concept of the continuous automated MS in areas with a high degree of geological hazard;
- description of the structure of the continuous automated MS at sections with a high degree of geological hazard;
- data entry into the MS and the order of visualization of cartographic information and measurement results.

4. Conclusion

Development and implementation of automated monitoring technology, including continuous complex control of the oil pipeline and the surrounding groundmass, allows identifying sections with different levels of natural and anthropogenic load, calculating the strength of the oil pipeline, tracking the impact of hazardous processes on the technical condition of the oil pipeline, and developing effective measures. It is especially important for oil pipelines laid in difficult engineering and geological conditions, including landslide hazards. The organizational measures presented in the article will help to ensure continuous monitoring of the trunk pipeline, which will allow avoiding emergencies and minimizing the consequences of possible incidents.

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