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Application of geodetic devices for the operation of underground pipelines

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Abstract: The article deals with geodetic devices used for the operation of underground pipelines under the conditions of the northern territories of Russia. The electronic total station Trimble M3, the GPS-device Javad GPS Maxor and the pipeline locators Leica DigiCat 650i and Ridgid SeekTech SR-20 are taken into consideration, and their characteristics and accuracy are analyzed.

1. Introduction
Geodetic devices are used at all stages of geodetic support in design planning, construction, reconstruction, and operation of engineering structures. Since such works are carried out everywhere, new territories are currently under development, and new utility lines are being installed, issues regarding the application of different geodetic devices are of crucial and practical importance. By using the devices under new conditions in underdeveloped territories, we get the opportunity to gather new data on the use of different technologies and tools. Underground utilities (networks) include linear structures located below the surface of the earth. Depending on the type of liquids and gases, pipelines are divided into heating pipelines, gas pipelines, water supply, water discharge and drainage systems, and other linear structures [1].

For the positioning of underground networks, the underground space of a human settlement along its streets is used. The density of engineering networks is determined by the size of the territory of the city (settlement), the height of the buildings, and the level of development of the municipal services in the city (settlement).

2. Research
At present time, the most common surveying method in case of linear surveys for the operation of underground utilities is the tacheometric method using electronic total stations.

During the surveying process, the electronic total station is installed at surveying stations, while range rods with reflectors are installed at alignment stations. When pointing at the reflectors, horizontal angles and vertical angles are automatically determined, as well as distances to adjacent points. The results of these measurements are stored in the device memory, thereafter the information is sent to a computer with a special program software for further processing.

There is a wide range of electronic devices that provide high accuracy, for example, the devices Leica, Sokkia.
For the present research, the geodetic support process for the operation of a section of the main gas pipeline in the Beryozovsky District of the Khanty-Mansi Autonomous Okrug was taken into consideration.

The Beryozovsky District is characterized by a variety of landscapes, different types of soil and vegetation. The moistening degree is quite high. The climate of this territory is harsh continental with cold and long winters, and hot but short summers. The average annual air temperature is -3.3 °C, the average air temperature in January is -22.7 °C, while in the hottest month, July, it is +16.1 °C. The absolute minimum temperature is registered in December with -55 °C, and the absolute maximum temperature reaches +35 °C in June. Such temperature drops influence the choice of geodetic instruments for work. The territory of the district is located in the zone of seasonal permafrost, which must be taken into account when conducting various types of engineering work and during the subsequent operation of utilities, especially as regards underground ones.

Precipitation in the district is consistent, especially during the warm period from April to October with 376 mm, while in the cold period from November to March it reaches 127 mm, whereas the annual precipitation is equal to 503 mm [2]. Westward winds are prevalent during the year. In January winds are mainly southeastward, while in July – northward and eastward. In the warm part of the year, northeastward winds prevail, in the cold period – southeastward. The average annual wind speed is 2.4 m/s, the average in January amounts to 2.1 m/s, while in July to 2.4 m/s.

For the geodetic support of works concerning the operation of the utility at study, the electronic total station Trimble M3 was used.

The Trimble M3 device is reliable, quite simple to manage, and has a small weight. Useful options such as the presence of a pointer to the target, an alignment indicator, as well as a display in case of “angle to the right”, should be noticed. Despite the presence of more advanced models, the device provided the required accuracy during the work (Table 1). To transfer data to other devices, the total station possesses RS-232C and USB ports, and a Bluetooth connection option [3].

This device has an integrated Trimble Access field program software. The program is relatively simple, and at the same time has significant data processing capabilities. The program allows the visualization of surveying results and preliminary calculations. Using the program, DXF file can be uploaded in the form of an active map, staking can be made, and the results of executive surveying can be compared with the design drawing. In addition, there is a large set of functions for geodetic calculations.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear measurement accuracy with reflectors</td>
<td>±2 mm+2 mm/km</td>
</tr>
<tr>
<td>Linear measurement accuracy without reflectors</td>
<td>±3 mm+2 mm/km</td>
</tr>
<tr>
<td>Measuring range with reflectors</td>
<td>up to 3000 m</td>
</tr>
<tr>
<td>Angle accuracy</td>
<td>2”</td>
</tr>
</tbody>
</table>

Alongside classical methods of large-scale topographic surveys, satellite technology is used.

The essence of a topographic survey using satellite receivers consists in the determination of the planimetric coordinates and heights of terrain points in real time with an error of 2-3 cm. In this case, at least two receivers are used: a basic receiver (at a point with known coordinates) and a movable one (at the point to be determined) [4].

The main advantage of GPS-surveying is that during field measurements the surveyor, controlling the GPS receiver, is personally present at the points to be determined and examines the characteristics of the working area as well as the object. The preliminary processing of measurement data is usually performed directly on the field, then the results are transferred to a computer with a special software for the rendering of topographic plans. During field rendering, the performer can identify errors and correct them, identify areas with insufficient data and survey them in more detail.
In the present case, the device used for GPS-surveying was the GPS-receiver Maxor by the Javad Navigation Systems Maxor company. The Javad GPS Maxor device is a geodetic receiver of high-accuracy class, and it stands out for its reliability and the possibility of high-speed measurements.

The device allows to process GPS and GLONASS signals. The GPS Maxor receiver, depending on the installed chip, can operate with a frequency of GPS L1 and GPS L1+L2 [5]. At the same time, the accuracy in the determination of the baseline length in static mode and fast static mode is 0.3 cm + 1.0 ppm in plan view and 0.5 cm + 1.5 ppm in height. In kinematic mode and on-line mode, the accuracy of distance determination is 1.0 cm + 1 ppm in plan view and 1.5 cm + 1 ppm in height. In offline mode, it is possible to determine a location with an accuracy of two meters [5].

The components of the device are protected by a single durable and compact aluminium alloy casing, which also contains a Li-Ion high-capacity battery (up to 25 hours of continuous operation) and an integrated charger.

One advantage of this device is the possibility of its application under the cold temperatures of the northern territories of Russia.

Of particular note is a very important technology developed for GNSS by Javad Maxor, that is the RAIM technology (Receiver Autonomous Integrity Monitoring), designed to assess and maintain the integrity of the GPS signal reception. The technology is unique in that it eliminates the reception of an excessive number of coordinates and the false determination of the position of an object, which occurs in cases when more satellites than necessary are fixed. This is especially true when simultaneously receiving signals from different systems [5].

For an effective work in the reconstruction, operation, and installation of new pipelines, as well as the production of geodetic works related to the maintenance of these kind of utilities, special devices for the research of underground pipelines have been developed.

To determine the direction of the lines of underground utilities, electronic search devices such as pipeline locators and pipe-and-wire detectors are used, and where these devices cannot be used, trial pitting is carried out [6].

The mechanism and operation principle of pipeline locators is based on the determination of the level of electromagnetic induction, namely, the locator consists of a generator and a receiver which determine the presence of an electromagnetic field. The generator is necessary for tracing the so-called passive lines through which electric current does not flow, that is usually a different kind of pipe, for the search for which electric current of small force is supplied through a special connection [6].

While surveying pipelines, an acoustic method is used to diagnose the state of underground pipelines, which is based on the search for noise from a liquid or gas moving along an engineering network [7].

State-of-art pipeline locators are resistant to adverse weather conditions, these devices are usually compact and easy to transport, equipped with powerful batteries with a large capacity for long-term operation under difficult conditions without charging. Therefore, pipeline locators are widely used in the search and diagnosis of various defects of underground structures [6]. The range of different types of pipeline locators is quite wide [8].

Devices by the Leica company can be included among the most well-known and frequently used geodetic devices, which can guarantee high precision in engineering and geodetic surveys. The pipeline locator Leica Digicat 650i guarantees the necessary precision, being a universal detector that can be used both in passive and active scanning modes. The device allows for the determination of the location and depth of underground electrical conduit networks according to their proper or induced electromagnetic emission.

The device Leica Digicat 650i can be used for the preliminary survey of land plots, which increases safety in the execution of ground works with machine-based or manual excavation. This is especially important taking into account the damp and frozen soil of the northern regions, where the territory of the Khanty-Mansi Autonomous Okrug – Yugra is located. The reliability and efficiency of ground works is increased thanks to the preservation of the integrity of the pipelines. In addition, the pipeline locator Leica Digicat 650i simplifies the research, identification and tracking of linear facilities, in particular if maintenance or technical support of pipelines and traces are needed. In order to trace non-metallic pipelines and to search for damages or obstructions, optional gadgets included in the Leica Digisystem surveying set are used, allowing for a diminishment in the ground work volume.
The pipeline locator Digicat 650i can work on different frequencies and register alternating magnetic fields (Table 2).

Table 2. Main characteristics of the pipeline locator Leica Digicat 650i.

<table>
<thead>
<tr>
<th>Passive Modes</th>
<th>Signal fixation</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Mode</td>
<td>50-60 Hz</td>
<td>Up to 3 m</td>
</tr>
<tr>
<td>Radio Mode</td>
<td>15-60 kHz</td>
<td>Up to 2 m</td>
</tr>
<tr>
<td>Auto Mode</td>
<td>Combined scanning</td>
<td>2-3 m</td>
</tr>
</tbody>
</table>

When introducing the sonde in non-metallic pipelines, the pipeline locator Leica Digicat 650i in the active Generator Mode can detect signals with a frequency of 8, 33 or 8+33 kHz.

The obtained results are displayed on an LCD with automatic backlighting; in addition, the detector Leica Digicat 650i includes the function of audio notification through headphones or speaker drivers.

Important characteristics of the device Leica Digicat 650i are the presence of a 32-Mb integrated memory and the possibility of wireless interface connection Bluetooth. This features offer the possibility to save data obtained during surveying up to 999 records over 80 hours of work, to control the conditions of the pipeline locator and to determine the depth of pipeline networks from remote. For this purpose tablets, netbooks and other computer systems with the software Logicat installed on can be used. Also data are compatible with the CSV format, making it easier to export and elaborate them using other softwares.

Using GPS-surveying devices allows for the determination of the coordinates of detected networks in real time while showing the depth at which they are running [9].

At our surveying site, a pipeline locator Rigid SeekTech SR-20 was used to identify defects in underground utilities. The device operates in three different modes: active search, passive search, and sensing option [9].

In the passive search mode, the device receives the signals of all the pipelines installed on the site. After switching to the broadband mode, the device will detect all the objects located close to each other and recognize each of their types. All data on the objects, their condition, type, defects, direction, location, and distance (depth) are displayed on the device screen.

The body of the Rigid SeekTech SR-20 device is made of high-strength plastic, and a special case is available for transportation. The temperature range for operation stretches from -20 °C to +50 °C. The device is one of the best instruments for the search for underground pipelines at a depth of up to 10 meters [9]. At the same time, if compared with other devices, SeekTech provides the maximum accuracy and reliability of the results, as well as the highest tracing speed. This pipeline locator is the only device that uses multi-directional antennas, directional arrows, and a display that allows to quickly and easily read the obtained information [9].

At present time, the most recent device of this type in the equipment array by SeekTech is the pipeline locator Rigid Sr-24. It is widely used for accurate detection of underground engineering networks, cables and metal pipes, as well as other types of pipelines. The antennas of the SR-24 point in different directions, thereby, receive the signal field at its full and simplify signal acquisition. The receiver displays the location and direction of engineering networks on the screen. Acoustic and visual alerting for the operator in the event of a disturbed signal field form or other errors is present.

For other types of identification of underground utilities pipe-and-wire detectors are used. In those cases and places where the determination of underground utilities with the help of pipe-and-wire detectors is not possible, the trial pitting method is applied [6]. Trial pitting can be also carried out in order to control the data obtained by electrical methods, to clarify and supplement the available accounting materials, and to check their quality. The trial pitting method is labor consuming and expensive, therefore it is applied only in extreme cases when it is impossible to recur to other methods.
3. Conclusions

Different devices for the geodetic support of the operation of linear underground utilities under the conditions of the northern districts of Russia were analyzed. These devices have proven a high level of reliability and efficiency in the execution of engineering and geodetic surveys, guarantee the necessary precision of works and are thus recommended for use on the territory of cold regions.

Acknowledgments
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Reference
[4] G Kin 2002 G KinP (ONTA)-02-262-02 Instruktsiya po razvitiyu s”emochnogo obosnovaniya i s”emke situatsii i rel’efa s primeneniem global’nykh navigatsionnykh sistem GLONASS i GPS [Geographical and Cartographical Instructions, Norms and Regulations (Basic Normative and Technical Act)-02-262-02 Instruction for the development of surveying control and the surveying of planimetry and relief with the application of the global navigation systems GLONASS and GPS] (online) available at: http://docs.cntd.ru/document/1200030413