BINDING TECHNIQUE ON THE GROUND IN THE STUDY OF THE EFFECTS OF MAN-CAUSED ACCIDENTS

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The technique of determining the coordinates of the point of measuring device location during the researches in contaminated areas and near the radiation- and chemically-dangerous objects is proposed. It is shown the optimal way is the integrated usage of different methods: linear resection using laser range finders; tachymeters; GPS systems.

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1. INTRODUCTION

As a result of various man-caused accidents at chemically - and radiation-dangerous facilities the surrounding area can be contaminated. To select the optimal measures to mitigate the consequences of such accidents, it is necessary to study the characteristics of the contaminated areas and objects, the availability of sources of radiation exposure, etc. In particular, such problems arose in the study of radiation environment near the "Shelter" object of Chornobyl nuclear power plant [1], [2]. Traditional methods can lead to increased risk for the personnel staff. The experience of the research [1] showed that it is appropriate to create the universal system for control measurement control in complex radiation environment. The execution of joint projects at ISP NPP and NSC KIPT within the State program of basic and applied research on the use of nuclear materials and nuclear and radiation technologies in the development of industries (YAMRT) showed that such system should include following subsystems: Remote control and data transfer [3], the orientation in space [4], visualization [5], determination of the location on the ground, optimization the number and frequency of measurements depending on the gradient of the contamination characteristics, autonomous data recording, determining the environment temperature etc. This article considers the subsystem of binding on the ground in the measurements at radiation-dangerous conditions using the experience of field work near the "Shelter" object of Chornobyl nuclear power plant.

2. GENERAL METHODOLOGICAL APPROACH

During studying of radiation environment it is necessary to solve two types of problems:

1. "Direct problem" - quickly determine the coordinates of the measurement point;
2. "Inverse problem" - quickly find the measurement point on the given coordinates.

To solve the "direct" problem it is necessary to bind the measurement point with required accuracy, which in most cases can be done only by instrumental methods.

Depending on the work conditions, the instrumental binding of measurement point can be done in different ways:

- Binding the facility location to the objects with known coordinates using the tape and/or marking cord;
- Binding the facility location to the objects with known coordinates using photos and video equipment;
- Traditional theodolite binding with optical instruments;
- Binding the facility location to the objects with known coordinates using laser range finders;
- Using the electronic tachymeter;
- Using satellite navigation;
- System with accelerometers as sensors of motion from the point with known coordinates of the point of measurement.

Binding of the facility location using tape and/or marking cord results in equipment contamination and increasing time spent in radiation exposure.

The accuracy of binding the facility location to the objects with known coordinates using photos and video equipment is limited by angular resolution of

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the used photo-and video equipment and the necessity to use complex software and highly skilled personnel. Therefore, in most cases, this method can be used as an additional one for planning the measurements.

The traditional theodolite binding by means of optical devices requires highly skilled personnel, is time-consuming, and in radiation conditions can be used only to create reference points.

To use the laser range finders for determining the facility location, it is necessary to pre-select multiple control points with known coordinates as accurately as possible. Use the laser range finders can reduce requirements for staff skill, shorten the work, to reduce the required number of personnel in contaminated areas.

The use of electronic tachymeters may be appropriate for measurements on large open areas with large number of measurement points. The main disadvantages are the high cost of equipment and the needs in highly qualified geodesy experts.

Binding of the facility location with the required accuracy using satellite navigation systems (GPS) is possible only with a clear view of the signal. This method is only possible one during the measurements in the contaminated area and far from objects with known coordinates. Under these conditions GPS-system can be applied to solve the "inverse" problem.

To solve the "inverse" problem is also advisable to use the accelerometers to calculate the change in the space orientation while moving for a few meters from the point with known coordinates. In this method point coordinates are defined more exactly by one of the above methods. During measurements far from objects with known coordinates the position of the reference point is determined using GPS.

Accelerometers can be also used to solve the "direct" problem, it is impossible to use more accurate and more complex methods.

Here are the criteria and the specifics of the most promising methods.

3. DETERMINATION OF COORDINATES USING A LASER RANGE FINDER

Using laser rangefinder coordinates can be determined by linear resection.

From the measuring point P with unknown coordinates (X, Y) (Fig. 1) we measure the distance S_1 to the reference point A (in this case - the object near the "Shelter" object) with known coordinates ($X_A Y_A$) and the distance S_2 to the reference point B (in this example - a corner of the stair-lift unit of "Shelter" object) with known coordinates (XB, YB).

The problem has two solutions (see Fig. 1), so it is necessary to take into account the correct position of the measuring point P with respect to the reference points A and B.

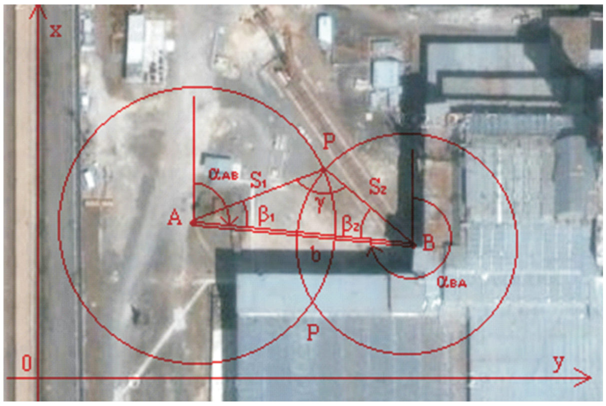

Fig. 1. *Coordinate determination by linear resection method near the "Shelter" object*

Thus, to solve the task there are the following data:

- known data: the coordinates of reference points A (XA, YA) and B (XB, YB);
- measured data: the distances S_1 and S_2;
- Unknown elements: the coordinates of the point of measurement P (X, Y);
- X, Y coordinates and the resection angle γ are calculated using simple operations.

Root mean square (RMS) error is calculated by the formula:

$$M_{OP} = \sqrt{m_{Ax}^2 + m_{Ay}^2 + m_{Bx}^2 + m_{By}^2 + m_p^2}, \quad (1)$$

$$m_p = \frac{\sqrt{m_{S1}^2 + m_{S1}^2}}{Sin\gamma}, \quad (2)$$

where M_{OP} - error of measuring point P coordinates;

m_{Ax}, m_{Ay}, m_{Bx}, m_{By} - errors of coordinates of reference points A and B respectively;
m_p - error of the measurement point P positioning with respect to the reference points A and B;
m_{S1}, m_{S2} - error of the S_1 and S_2 distances.

To illustrate the dependence of the error in determining the point P position with respect to the reference points A and B on the resection angle we done calculations for a error of 10 mm which is typical for laser range up to 100 meters (Fig. 2).

We see that error significantly increases at small and large values of the resection angles, but except the angles very close to 0° and 180° error is acceptable.

A similar dependence for the rangers at a distance greater than 100 m and an accuracy of 1 meter (type "Konus Range 600") is shown in Fig.3.

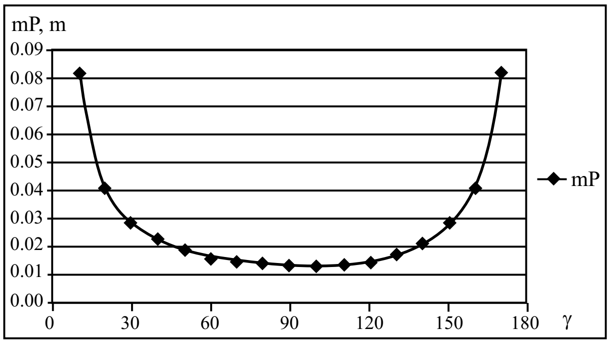

Fig.2. *The dependence of the error in determining the point P position with respect to the reference points A and B on the resection angle for the range finder error 10 mm*

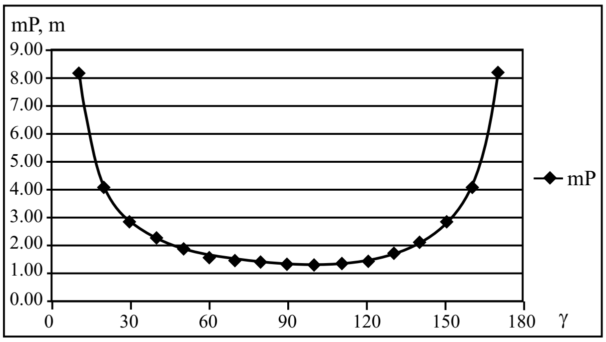

Fig.3. *The dependence of the error in determining the point P position with respect to the reference points A and B on the resection angle for the range finder error 1 m*

4. THE USE OF ELECTRONIC TACHYMETER

Another way of using laser range finders is to use the servo-motor tachymeter (for example, an electronic tachymeter TRIMBLE S6, Fig. 4).

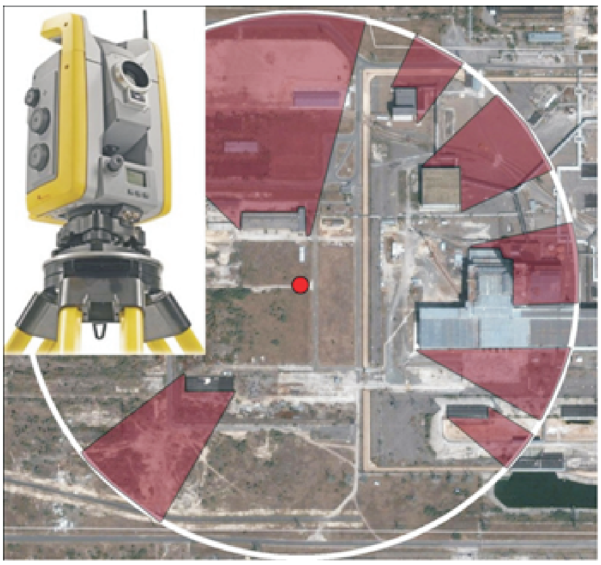

Fig.4. *Measurements by the tachymeter is in the local area for the "Shelter" object*

This tachymeter has integrated servo/angle sensors with electromagnetic direct drive.

When operating in Autolock regime the reflective prism is automatically captured and tracked when you move it within 800 yards of tachymeter with an accuracy of 2″. The presence of radio modem allows remote control and data acquisition, which is very important when measurements are done at radiation dangerous conditions.

Servo-motor tachymeter must be placed to a point with known coordinates and oriented to determine the coordinates. Tachymeter location must be chosen in such a way that all measuring points are in the view and at the distance less than 800 meters. When tachymeter captured the reflective prism placed on the measuring device, all further device movements will be recorded in the tachymeter memory. Tachymeter can be used for measurements at large open areas with large number of measurement point (for example, in the preparation of radiation maps).

Possible scheme of the measurements near the "Shelter" object, in the area of mounting sliding the arch of the new safe confinement is shown at Fig. 4 (satellite view with the point of possible tachymeter location and zone of possible measurement points).

5. THE USE OF GPS SYSTEM

Binding of the facility location with required accuracy using satellite navigation systems (GPS) is possible only with a clear view of the signal. There are three ways to use the system GPS for field studies depending on the measurement conditions and requirements.

1. Using standard autonomous GPS-navigators. The advantages of this method - the simplicity, the disadvantages - lack of direct connection of the recorded data and the coordinates of the measurement point, which can lead to errors.

2. Connecting a standard GPS sensor to mass-produced measuring device in parallel with any of the detection units and the automatic addition of geographical coordinates to measurement results. Dosimeter DKS-96 is an example of such device and it is compatible with devices produced by Garmin company. At the switching on DKS-96 automatically detects GPS sensor. Recorded measurement results can be read by a personal computer for further processing.

3. It is appropriate to equip all new devices for radioecological measurements with GPS-modules (e.g. produced by Transystem Inc. Locosys company).

Application of GPS system together with remote data control and transfer system [3] can significantly speed up the process of data collecting, and reduce the influence of dangerous factors for staff due to possibility of quick analysis of results and measurement process correction.

6. THE USE OF ACCELEROMETERS

The accelerometer is a device that can measure the acceleration of the subject that it receives at the movement relative to its zero position. These properties make it possible to use the accelerometer to determine the current position of the device as it moves through the measurement zone.

While solving the "direct" problem accelerometer is nulled outside the radiation dangerous zone at the start point (with known coordinates), the measuring device (with accelerometer) is moved to the point of measurement, the displacement in all directions is read and coordinates of the measuring point are calculated.

While solving the "inverse" problem accelerometer is nulled in the known point, the displacement (in 3 axes) necessary to reach the measuring point with given coordinates is calculated, the measuring device is moved to the desired point in accordance with accelerometer indication (while accelerometer indication does not coincide with the calculated). If necessary, the coordinates are checked by other methods. To search for further point location accelerometer is nulled and reading is done from the current measurement point to prevent the accumulation of errors by integrating a large number of movements.

3D - microelectromechanical acceleration sensors of type LIS331DLH/M/F (produced by STMicroelectronics) are example of such devices. Three sensors with dimensions 3mm×3mm×1mm track movement in six directions, when the sensor moves up or down in all three axes (x, y, z), support number of intelligent features, including Economic mode, the automatic renewal of active work, the discovery of gravity and the standard SPI/I2C digital interface.

Wireless position sensors ARD-100 (produced by Satel) with 3D accelerometer can be used to determine position during the measurements in places which is difficult of access. They work together with Satel Integra-128 WRL, and with the ACU-100 controllers. Position sensors are tuned up in space and transfer radio signals at a frequency of 868.0…868.6 MHz.

Thus, required measurements can be done when staff is in radiation-safe conditions. These problems, in particular, must be solved when planning construction works in the radiation-dangerous conditions, such as in the areas of mounting and sliding the arch of the New Safe Confinement, the dismantling of unstable building structures of the existing "Shelter" object etc.

7. CONCLUSIONS

To reduce the dangerous staff influence during studying the territories and objects contaminated by industrial accidents, in the storages of radioactive, chemical and other dangerous materials process of measurements must be carefully planned, including the best reference points choosing.

During studying of radiation environment it is necessary to solve two types of problems: "Direct problem" and "Inverse problem".

The method of linear resection using a laser range finder (if there are reference points with known coordinated in the measurement zone), the tachymeter (at the large open spaces with a lot of measurement points), GPS (with a clear view of the signal) can be used to solve the "direct problem".

The displacement sensors based on a 3-D accelerometers (if there are reference points with known coordinated in the measurement zone), and GPS can be used to solve the "inverse" problem.

The proposed approach will optimize the process of measurement in dangerous conditions and reduce the risk of harmful effects on the staff.

For further staff safety improvement it is appropriate to develop a method of optimization the number of measuring points, taking into account the gradient of the spatial distribution of the measured quantity (dose rate, surface contamination density, the volume air pollution, etc.).

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МЕТОДИКА ПРИВЯЗКИ НА МЕСТНОСТИ ПРИ ИЗУЧЕНИИ ПОСЛЕДСТВИЙ ТЕХНОГЕННЫХ АВАРИЙ

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Предложена методика определения координат точки размещения измерительной установки при проведении исследований на загрязненных территориях и вблизи радиационно- и химически опасных объектов. Показано, что оптимальным является комплексное использование разных методов: линейной засечки с применением лазерных дальномеров, тахеометров, системы GPS.

МЕТОДИКА ПРИВ'ЯЗКИ НА МІСЦЕВОСТІ ПРИ ВИВЧЕННІ НАСЛІДКІВ ТЕХНОГЕННИХ АВАРІЙ

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Запропоновано методику визначення координат точки розміщення вимірювальної установки при проведенні досліджень на забруднених територіях та поблизу радіаційно- та хімічно небезпечних об'єктів. Показано, що оптимальним є комплексне використання різних методів: лінійної засічки із застосуванням лазерних далекомірів, тахеометрів, системи GPS.