

BDBG-09S
DETECTING UNIT OF GAMMA RADIATION

Operating manual
BICT.418266.032-02 HE

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This operating manual (the OM) is intended to inform the user about principles of operation, rules of application, maintenance, storage and shipping of the BDBG-09S detecting unit of gamma radiation.

The OM contains the following abbreviations:

- DER - ambient dose equivalent rate $\dot{H}^*(10)$ of gamma radiation;
- PC - personal computer;
- GMC - Geiger-Muller counter;
- SDUGR - scintillation detecting unit of gamma radiation.

1 DESCRIPTION AND OPERATION

1.1 Purpose of use of the BDBG-09S detecting unit

The BDBG-09S detecting unit of gamma radiation (hereinafter called the detecting unit) is designed to measure ambient dose equivalent rate $\dot{H}^*(10)$ of gamma radiation (hereinafter DER).

The BDBG-09 S detecting unit can be used within computer-aided systems for radiation monitoring instead of the BDBG-09 detecting unit in terms of gamma radiation DER and temperature measurements without changing the software.

1.2 Technical specifications

1.2.1 Key specifications are presented in the Table 1.1.

Table 1.1 – Key specifications of the detecting unit

Name	Unit of measurement	Standardized value according to the specifications
1 Measurement range of gamma radiation DER with the SDUGR	$\mu\text{Sv/h}$	0.01 – 50
2 Measurement range of gamma radiation DER with the GMC	$\mu\text{Sv/h}$	50 – 10^6
3 Main relative permissible error limit of gamma radiation DER measurement at ^{137}Cs calibration with confidence probability of 0.95	%	$15+1/\dot{H}^*(10)$, where $\dot{H}^*(10)$ is a numeric value of gamma radiation DER in $\mu\text{Sv/h}$
4 Energy range of registered gamma radiation	MeV	0.05 – 3.00
5 Energy dependence of the detecting unit's measurement results during gamma radiation DER measurement in the energy range of 0.05 - 1.25 MeV	%	± 25
6 Anisotropy of the detecting unit at gamma quanta incidence at angles from $+60^\circ$ to -60° horizontally and vertically relative to the main measurement direction, marked by a "+" symbol, does not exceed: - for ^{137}Cs and ^{60}Co isotopes - for ^{241}Am isotope	%	25 60

Table 1.1 (continued)

Name	Unit of measurement	Standardized value according to the specifications
7 Operating supply voltage range of the detecting unit from external regulated power supply	V	7 - 32
8 Consumption current of the detecting unit for overall range of measured gamma radiation DER, not more than	mA	30
9 Setup time of operating mode and measurement time of the detecting unit, not more than	min	3
10 Unstable readings of the detecting unit for a 24-hour continuous operation, not more than	%	5
11 Complementary permissible error limit of measurement caused by ambient temperature change from - 40 °C to +50 °C	%	5 per each 10 °C deviation from (20 ± 5) °C
12 Interface	-	RS-485
13 Dimensions of the detecting unit without fastening elements, not more than	mm	60x60x170
14 Weight of the detecting unit without fastening elements, not more than	kg	0.5

1.2.2 Use environment

1.2.2.1 Concerning the resistance to climatic and other environmental factors, the detecting unit meets the requirements outlined below.

1.2.2.2 The detecting unit is resistant to the influence of the following climatic factors:

- air temperature from - 20 °C to 40 °C;
- relative humidity up to 100 % at 40 °C temperature and lower temperatures with humidity condensation;

- atmospheric pressure from 84 kPa to 106.7 kPa.

No requirements to other climatic factors.

1.2.2.3 The detecting unit is resistant to sinusoidal vibrations.

1.2.2.4 The detecting unit is tolerant to shocks with the following parameters:

- shock pulse duration – from 5 ms to 10 ms;
- number of shocks – 1000±10;
- maximum shock acceleration – 100 m/s².

1.2.2.5 The detecting unit in a shipping container is resistant to the influence of:

- ambient air temperature from - 40 °C to 60 °C;
- relative humidity up to (95 ± 3) % at 35 °C temperature;
- shocks with acceleration of 98 m/s², shock pulse duration of 16 ms, and number of shocks – 1000±10.

1.2.2.6 The detecting unit withstands constant or alternating (50 Hz±1 Hz) magnetic fields of 400 A/m voltage.

1.2.2.7 The detecting unit is immune to gamma radiation of exposure dose rate equal to equivalent dose rate up to 100 Sv/hour during 5 min.

1.2.2.8 The detecting unit supports the operability control of the built-in detectors with formation of check information.

1.1.2.9 Regarding the interference immunity, the detecting unit is referred to as the automation equipment (AE) that operates in electromagnetic environment of medium hardness.

1.1.2.10 The detecting unit belongs to II aseismic class, hardness degree 3 (design elevation – up to 70 m).

1.3 Delivery kit of the detecting unit

The delivery kit of the detecting unit consists of units and maintenance documentation, given below.

1.3.1 BICT.418266.023-02 BDBG-09S detecting unit 1 pc.

1.3.2 BICT.745265.001 Corbel 1 pc.

1.3.3 BICT.418266.032-02 HE Operating manual 1 copy.

Note – One copy per one consignment of the detecting units.

1.3.4 BICT.418266.032-02 Φ O Logbook 1 copy.

1.3.5 BICT.412915.003-05 Package 1 pc.

1.3.6 BICT.412911.001 Assembly parts kit (APK) 1 pc.

Notes

1 APK is applied by the user at the production of the connecting cable for connection to the system. Belden 8102 cable (not included in the kit) is recommended.

2 The connecting cable can be supplied in a separate order.

1.3.7 BICT.412919.001 technological kit for calibration and testing of the detecting units is supplied on customer's request in a separate order.

1.4 Design and operation principle of the detecting unit

1.4.1 Design description

The detecting unit (according to Figure 1 (a)) consists of the detecting unit (1), a connecting cable (2), a detent (3) and a corbel (4) used to fasten the detecting unit to the wall.

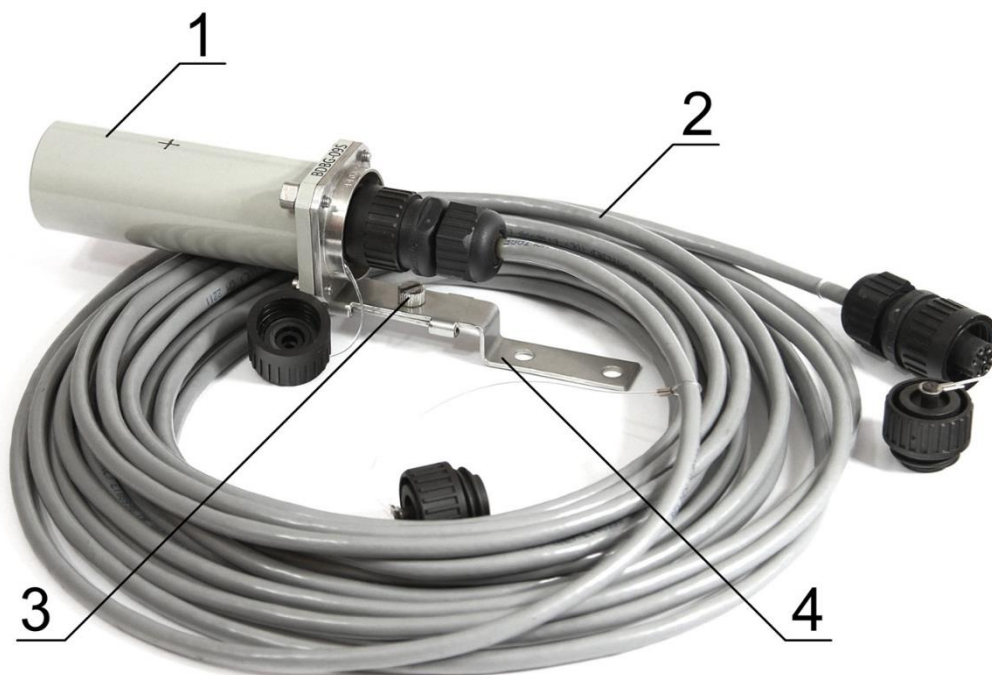


Figure 1 (a)

Alternatively, the detecting unit can be fastened to the surface where it will be directly installed is shown in Figure 1 (b). The Figure 1 (b) shows that the barrel of the detecting unit with a reference point (5), indicating the direction towards the radioactive source, is attached with its base (2) to the surface using a plank (3). The connecting cable is connected to the connector (4).

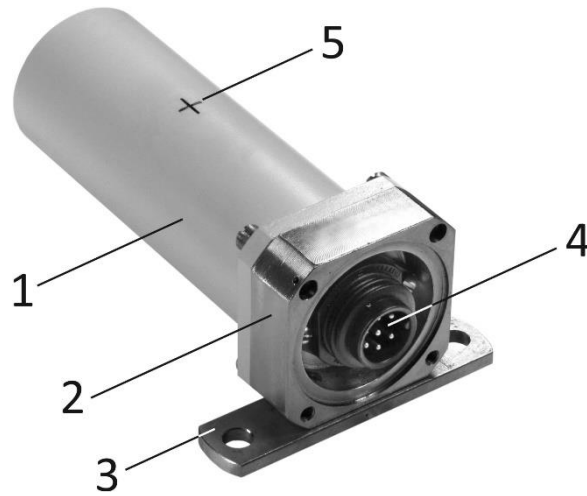


Figure 1 (b)

1.4.2 Operation principle of the detecting unit

The detecting unit consists of a microcontroller, a high sensitivity detector, a low sensitivity detector, a supply voltage former, a temperature detector and an RS-485 interface node.

Operation of the detecting unit is based on the method of gamma radiation transformation into voltage pulse sequence at the detectors' outlet. The high sensitivity scintillation detecting unit (SDUGR) based on a CsI(Tl) scintillator with 9 cm³ volume and sensitivity for ¹³⁷Cs not less than 200 cps per 1 μSv/h coupled with a semiconductor photomultiplier and a low-sensitive Geiger-Mueller counter (GMC) of CBM-21 type are used as detectors in the detecting unit.

The microcontroller processes the pulse flow from the detectors, and forms gamma radiation DER value, which corresponds to the flow. The microcontroller also calculates a maximum value of DER measurement statistical error for each gamma radiation DER value. At the same time the microcontroller runs the power supply of the detectors and continuously controls their operability. If requested by the data display system, the microcontroller sends a protocol frame via RS-485 interface nod. The protocol frame contains information about current gamma radiation DER, maximum statistical error in its measurement, and results of the operability control of the detectors.

The supply voltage former transforms voltage from the external power supply to 3.3 V voltage for powering secondary part of the detecting unit circuit as well as to 350 V for powering the low sensitivity detector and to 27 V – for the high sensitivity detector.

1.5 Measuring instruments, tools and equipment

1.5.1 A list of measuring instruments, tools and equipment necessary for control, setting and current repair of the detecting unit is presented in the Table 1.2.

Table 1.2 – List of measuring instruments, tools and equipment

Name	Standardized document or main technical requirements
1 Special-purpose testing unit with ^{137}Cs source of ОСГН type	Gamma radiation DER from source at measuring point in the range from 10 $\mu\text{Sv/h}$ to 50 $\mu\text{Sv/h}$
2 Stopwatch	Measurement range – from 1 s to 59 min
3 Voltmeter	Measurement range of direct current intensity from 10^{-7} A to 1 A
4 ИПС-06 stabilized power source	Output voltage - from 0 V to 30 V. Output current - from 0 A to 2.5 A
5 УПГД-3В Standard equipment	Gamma radiation DER range from 0.8 $\mu\text{Sv/h}$ to 1.0 Sv/h
6 Technological set	BICT.412919.001 BICT.468353.001 Serial port adapter BICT.436231.001 Power unit BICT.685621.002 Service cable BICT.685622.002 Service cable BICT.467371.001 CD with technological software
7 Personal computer	IBM-compatible personal computer with installed Windows OS, technological software and free serial port
Note - Other measuring instruments that satisfy the specified accuracy are permitted	

1.6 Labeling and sealing

1.6.1 The case of the detecting unit is marked with engraving according to the design document of the producer enterprise. Labeling contains:

- trademark of the producer enterprise;
- design letter and type of the detecting unit;
- "+" symbol that determines main direction of measurement;
- serial number according to the numbering system of the manufacturer;
- specifications marking;
- pattern approval mark;
- EAN bar-code marking;
- accordance mark;
- IP67 ingress protection rating for the detecting unit;
- date of manufacture.

Note – Technical specifications, trademark of the producer enterprise, accordance mark, pattern approval mark, ingress protection rating, and bar-code marking can be printed on the individual packing of the detecting unit.

1.6.2 Sealing of the device is performed by the producer enterprise.

1.6.3 Removal of seals and repeated sealing is performed by the organization in charge of repair of the units.

1.6.4 Labeling of the shipping container contains main (consignee and destination), additional (consigner of goods and origin), and informational (gross and net weight in kg) letterings, as well as handling marks No.1 “Fragile – Handle with care”, No.3 “Protect from humidity”, No.11 “This side up”.

The type of the detecting unit and the quantity of the detecting units in packing box is labeled under the main letterings.

The shipping container with the packed detecting units is sealed by the representative of the Quality Control Department of the producer enterprise.

1.7 Packing

1.7.1 The detecting unit and the maintenance documentation are packed in a special cardboard box, which should be placed into a transparent plastic sachet, which is welded after packing performed.

1.7.2 At shipping, the detecting units are packed into unitized shipping containers (boxes). Inside surfaces of the walls, bottom and cover of the box should be furnished with corrugated cradboard.

Note – Other types of unitized containers (containers, cartons) are allowed.

2 PROPER USE

2.1 Operating limitations

2.1.1 The detecting unit is a complex electronic physical device that should be serviced competently.

2.1.2 Study this document before you start using the detecting unit. All requirements stated in the technical documents for the detecting unit should be precisely met.

2.1.3 The detecting unit should operate under the conditions that do not fall outside the use requirements outlined in section 1.2.2.

2.2 Preparation of the detecting unit for operation

2.2.1 Safety measures

2.2.1.1 The detecting unit contains no external parts exposed to voltages hazardous for life.

2.2.1.2 During calibration and testing of the detecting units, if operating with ionizing radiation sources, the radiation safety requirements stated in valid regulatory documents should be met.

2.2.2 Volume and order of external examination

2.2.2.1 Before using the detecting unit, unpack it and check if the delivery kit is complete. Examine for mechanical damage.

2.2.2.2 Before using the detecting unit that was on temporary closing-down, re-activate it and check its operability.

2.2.2.3 Register the re-activation and putting the detecting unit in operation in the logbook.

2.2.3 Guidelines on switching on and testing the detecting unit with description of testing procedure of the detecting unit in operation

2.2.3.1 Prepare the PC-based data display system for operation. Do the following:

- unpack the interface adapter with BICT.468353.001 power unit (hereinafter the adapter) and service cables;

- connect the adapter to the power unit;

- connect the adapter to the free serial port of the personal computer (hereinafter the PC) with the help of the BICT.685622.002 service cable.

Caution! Connection of the adapter to the RS-232 serial port of the PC can be performed only if the adapter and the PC are switched off. Otherwise, the adapter and the PC serial port can breakdown.

Note – The PC should have installed OS Windows and technological software. Technological software should be installed as described in the Appendix A.

2.2.3.2 Prepare the detecting unit for operation. Do the following:

- unpack the detecting unit;

- connect the detecting unit to the adapter with the help of the BICT.685621.002 service cable.

2.2.3.3 Switch the PC on, connect the power unit of the adapter to (220±22) V industrial network. Start the bdbg_s.exe program and prepare it to gamma radiation DER measurement. Do the following:

- select a serial port with the connected adapter in the **Setup** tab;

- proceed to the **Work** tab and press the **Measurement** button.

2.2.3.4 Measure gamma background DER indoors. To do this, wait until a probable value of measured DER appears in the **MEASURED RATE** zone of the bdbg_s.exe program window. Value probability (measurement result error remains within the equipment certificate) is indicated by DER measurements in black color. Wait circa 20 s to get a probable value of background levels. If DER measurement is stable, the total integration time is up to 30 s (if DER levels are near-background), what gives an opportunity to reduce the statistical error of measurements. As DER increases, time decreases to 1 s.

2.2.4 List of possible troubles and troubleshooting

2.2.4.1 The list of possible troubles and troubleshooting is presented in the Table 2.1.

Table 2.1 - List of possible troubles and troubleshooting

Trouble	Probable cause	Troubleshooting
1 The detecting unit does not respond to protocol frames from the data display system	1 The cable between the detecting unit and the data display system is damaged	1 Repair the cable

Table 2.1 (continued)

Trouble	Probable cause	Troubleshooting
2 Information evidence of the high sensitivity detector failure (D0 bit is set in the byte of the self-testing results of the detecting unit)	2 Failure of the high sensitivity detector, which is a part of the detecting unit	2 Send the detecting unit for repair to the repair services or to the producer enterprise
3 Information evidence of the low sensitivity detector failure (D1 bit is set in the byte of the self-testing results of the detecting unit)	3 Failure of the low sensitivity detector, which is a part of the detecting unit	3 Send the detecting unit for repair to the repair services or to the producer enterprise

2.2.4.2 If troubles presented in the Table 2.1 failed to be eliminated, or more complicated faults occur, the detecting unit should be sent for repair to the repair services or to the manufacturer.

2.3 Use of the detecting unit

2.3.1 Safety measures during use of the detecting unit

2.3.1.1 Safety measures during use of the detecting unit fully comply with the requirements presented in 2.2.1 of the OM.

2.3.1.2 The direct use of the detecting unit is not dangerous for the maintenance personnel and is environmentally friendly.

2.3.2 Operation procedure of the detecting unit

2.3.2.1 Assembling of the detecting unit

For assembling of the detecting unit, do the following:

- unpack the detecting unit and the corbel, used to fasten the detecting unit to the wall;
- fix the corbel vertically to the wall;
- corbel the detecting unit;
- connect the detecting unit to the data display system with the help of the BICT.685621.001 cable;
- fix the cable in the operating position.

2.3.2.2 Measurement of gamma radiation DER

After source voltage is supplied from the data display system to the detecting unit, the latter (not later than in 10 s) starts automatic measurement of gamma radiation DER, and processing of protocol frames from the data display system.

Probable (error within the equipment certificate) information about measured gamma radiation DER level will appear on the outlet of the detecting unit not later than in 3 min after the beginning of measurement when DER levels are near-background. Measurement time decreases, as gamma radiation DER level increases.

3 MAINTENANCE

3.1 Technical maintenance of the detecting unit

3.1.1 General instructions

The list of operations during technical maintenance (hereinafter the TM) of the detecting unit, order and peculiarities of operational phases are given in the Table 3.1.

Table 3.1 – List of operations during maintenance

List of operations	Maintenance type			OM item No.
	during		during	
	everyday use	periodical use (annually)	long-term storage	
External examination	-	+	+	3.1.3.1
Delivery kit completeness check	-	-	+	3.1.3.2
Operability check	+	+	+	3.1.3.3
Refreshing damaged painting	-	+	+	3.1.3.4
Testing	-	+	+	3.2
Registration of operations in the performance records table	-	+	-	3.1.3.5

Note – “+” symbol means the operation is applicable during this maintenance type, “-” symbol means the operation is not applicable.

3.1.2 Safety measures

Safety measures during maintenance fully comply with safety measures presented in 2.2.1 of the OM.

3.1.3 Maintenance procedure of the detecting unit

3.1.3.1 External examination

3.1.3.1.1 External examination of the detecting unit should be performed in the following order:

- a) check the technical condition of the detecting unit surface, integrity of seals, absence of scratches, traces of corrosion, and surface damage;
- b) check the condition of connectors in the cable connection point.

Clean the metal parts of the detecting unit with the oiled cloth after operation in the rain or after special treatment (deactivation).

3.1.3.1.2 Deactivation of the case surface and component parts of the detecting unit is performed if required.

Deactivate the surface of the component parts of the detecting unit by cleaning it with the decontamination solution.

Boric acid (H_3BO_3 12÷16 g/l) is recommended to be used as the decontamination solution. The following decontamination solutions are also permitted:

- 5 % solution of citric acid in ethyl alcohol C_2H_5OH (96 % concentration);
- boric acid – 16 g/l, $Na_2S_2O_3 \cdot 5H_2O$ – 1 % solution;
- standard synthetic detergents.

Expenditure rate of decontamination solution during deactivation of the detecting unit surface is 0.2 l. Use cotton gloves, surgical gloves and sheeting during deactivation.

To deactivate, wipe thoroughly the contaminated areas with a cloth moistened with decontamination solution, then with a cloth moistened with warm water and wipe dry.

Notes

1 Before deactivating the detecting unit, put on cotton gloves and rubber (surgical) gloves, observing safety requirements for operation with chemical solutions.

2 Deactivation of the detecting unit can be done according to the procedure established at the object of use for ionizing radiation measuring instruments.

3.1.3.2 Delivery kit completeness check

Check if the delivery kit of the detecting unit is complete according to 1.3. Check the technical condition, the placement of the component parts of the detecting unit, and the presence of the maintenance documentation.

3.1.3.3 Operability check of the detecting unit

3.1.3.3.1 Operability check of the detecting unit in the process of its use is performed automatically. Operability check of the detecting unit during its long-term storage is performed according to 2.2.4.

3.1.3.3.2 The procedure of pre-repair fault detection and rejection

Use the following criteria to evaluate the necessity of sending the detecting unit for repair and type of repair:

- for mid-life repair:

a) deviation of parameters from control values during periodical verification of the detecting unit;

b) minor defects of the cable or the connectors that do not affect their hermiticity and correct readings of measurement results;

- for major repair:

a) at least one non-operating measuring channel;

b) mechanical damages that affected the hermiticity of the detecting unit case or the cable.

3.1.3.4 Refreshment of damaged painting

Refresh damaged painting of the detecting unit case with the help of the HII-1125 enamel. Thoroughly select the color tone to avoid a considerable difference of lacquer coating. Remove contamination from the segment that needs painting. Brush on a level layer of paint on the surface.

3.1.3.5 Registration of operations in the performance records table.

Register actual operation hours of the detecting unit in section 11 of the logbook.

3.2 Testing of the detecting unit

Testing of the detecting unit is performed according to the „Testing procedure” presented below.

The detecting units should be tested after manufacture and repair. The detecting units in use should undergo periodical testing at least once a year.

3.2.1 Testing operations

During testing, the operations presented in the Table 3.2 should be performed.

Table 3.2 – Verification operations

Operation name	Verification procedure No.
1 External examination	3.2. 4.1
2 Testing	3.2. 4.2
3 Calculation of main relative permissible error limits of gamma radiation DER measurement	3.2.4.3

3.2.2 Testing facilities

The following measuring instruments and equipment should be used during testing:

- УПГД-3В X∂1.456.183 TY standard equipment;
- stopwatch;
- voltmeter in accordance with ГООТ 8711-93;
- MB-4M aspirated psychrometer;
- M-67 control aneroid barometer;
- IBM-compatible personal computer with installed OS Windows, technological software and free serial port;
- BICT.412919.001 technological set, including:
 - BICT.468353.001 serial port adapter
 - BICT.436231.001 power unit
 - BICT.685621.002 service cable
 - BICT.685622.002 service cable
 - BICT.467371.001 CD with technological software.

Usage of other measurement equipment that meets the specified accuracy is allowed.

3.2.3 Testing conditions

Testing should be carried in compliance with the following conditions:

- ambient air temperature in the range of (20 ± 5) °C;
- relative air humidity in the range of (65 ± 15) %;
- atmospheric pressure from 84 kPa to 106.7 kPa;
- natural background level of gamma radiation, not more than 0.25 $\mu\text{Sv/h}$;
- power source voltage in the range of (12.0 ± 0.5) V.

3.2.4 Testing procedure

3.2.4.1 External examination

During external examination the detecting unit should fulfill the following requirements:

- the delivery kit should be completed as described in section 3 of the BICT.418266.032-02 ΦO logbook;
- labeling should be accurate;
- QCD seals should not be violated;
- the detecting unit should be free from mechanical damage that may affect its performance.

Note – The delivery kit completeness is checked only at manufacture.

3.2.4.2 Testing

The detecting unit should be tested according to 2.2.3.

3.2.4.3 Calculation of main relative error at gamma radiation DER measurement

3.2.4.3.1 Prepare the УПГД-3В standard equipment of gamma radiation for operation.

3.2.4.3.2 Fix the detecting unit in the УПГД-3В carriage holder, so that the mechanical center of gamma quanta beam coincides with the center of detectors. The detector center is marked with a «+» on the case of the detecting unit.

3.2.4.3.3 Prepare the PC-based data display system for operation according to 2.2.3.1 of the OM. Connect the detecting unit to the adapter with the help of the BICT.685621.002 service cable and perform the operations according 2.2.3.3 of the OM.

3.2.4.3.4 In three minutes perform five measurements of gamma background DER indoors with 10 s interval.

3.2.4.3.5 Register the received readings in the protocol. Calculate the average value of gamma radiation DER by the formula:

$$\overline{\dot{H}^*} = \frac{\sum_{i=1}^5 \dot{H}^*_i(10)}{5} \quad (3.1)$$

3.2.4.3.6 Place the УПГД-3В carriage with the detecting unit in a position, where gamma radiation DER from ^{137}Cs source is equal to $\dot{H}^*_0(10) = (0.8 \pm 0.1) \mu\text{Sv/h}$.

3.2.4.3.7 In three minutes perform five measurements of DER with 10 s interval.

Register the received readings in the protocol.

3.2.4.3.8 Calculate the actual value of gamma radiation DER $\overline{\dot{H}^*}(10)$ expressed in microsieverts per hour by the formula:

$$\overline{\dot{H}^*}(10) = \overline{\dot{H}^*_{\Sigma}}(10) - \overline{\dot{H}^*_{\phi}}(10) \quad (3.2)$$

where $\overline{\dot{H}^*_{\Sigma}}(10)$ - is an average value of the detecting unit readings form the source and external gamma background, calculated by the formula (3.1), $\mu\text{Sv/h}$;

$\overline{\dot{H}^*_{\phi}}(10)$ - is an average value of the detecting unit readings at measurement of gamma background indoors, $\mu\text{Sv/h}$.

3.2.4.3.9 Calculate the main relative error limit of gamma radiation DER measurement, expressed in percentage, following the procedure specified in ДСТУ ГОСТ 8.207:2008 standard.

3.2.4.3.10 Calculate the confidence limit of relative random error of measurement results ($\delta\overline{\dot{H}^*}(10)$) by the formula:

$$\varepsilon = t \cdot S \quad (3.3)$$

where $t = 2.78$ – is a Student coefficient at confidence probability of $P = 0.95$, $n = 5$;

S - is a relative root-mean-square deviation of measurement results, calculated by the formula:

$$S = \frac{1}{\overline{\dot{H}^*}(10)} \sqrt{\frac{\sum_{i=1}^n (\dot{H}^*_i(10) - \overline{\dot{H}^*}(10))^2}{n(n-1)}} \quad (3.4)$$

3.2.4.3.11 Calculate the limit of relative residual bias of measurement results by the formula:

$$\Theta = 1,1 \sqrt{\left(\frac{\bar{H}^*(10) - \dot{H}^*_0(10)}{\dot{H}^*_0(10)}\right)^2 + \left(\frac{\delta \dot{H}^*_0(10)}{2}\right)^2} \quad (3.5)$$

where $\delta \dot{H}^*_0(10)$ - is a limit of main relative permissible error of gamma radiation DER of УПГД-3В.

3.2.4.3.12 If $\frac{\Theta}{S} < 0.8$, then $\delta \bar{H}^*(10) = \varepsilon \cdot 100$.

3.2.4.3.13 If $\frac{\Theta}{S} > 8$, then $\delta \bar{H}^*(10) = \Theta \cdot 100$.

3.2.4.3.14 If $0.8 < \frac{\Theta}{S} < 8$, then $\delta \bar{H}^*(10) = K \cdot S_{\Sigma} \cdot 100$,

where K – is a coefficient that depends on the ratio of random errors and residual bias, and is calculated by the formula:

$$K = \frac{\varepsilon + \Theta}{S + \frac{\Theta}{\sqrt{3}}}, \quad (3.6)$$

S_{Σ} – a total standard mean-square deviation of measurement results is estimated by the formula:

$$S_{\Sigma} = \sqrt{S^2 + \left(\frac{\Theta}{\sqrt{3}}\right)^2} \quad (3.7)$$

3.2.4.3.15 Place the УПГД-3В carriage with the detecting unit in a position, where gamma radiation DER from ^{137}Cs source equals to $\dot{H}^*_0(10) = (8.0 \pm 1.0) \mu\text{Sv/h}$. Perform the operations 3.2.4.3.7 - 3.2.4.3.14 of the OM with the difference that measurement results should be taken after the probable value of measured gamma radiation DER appears in the **MEASURED RATE** zone of the bdbg_s.exe program window. Value probability is indicated by gamma radiation DER measurements in black color.

3.2.4.3.16 Place the УПГД-3В carriage with the detecting unit in a position, where gamma radiation DER from ^{137}Cs source equals to $\dot{H}^*_0(10) = (80.0 \pm 10.0) \mu\text{Sv/h}$. Perform five measurements of gamma radiation DER with 10 s interval after the probable value of measured gamma radiation DER appears in the **MEASURED RATE** zone of the bdbg_s.exe program window. Value probability is indicated by gamma radiation DER measurements in black color. Register the results in the protocol, and perform operations 3.2.4.3.9 - 3.2.4.3.14 of the OM.

3.2.4.3.17 Perform operations 3.2.4.3.16 of the OM for gamma radiation DER from ^{137}Cs source with the value of $\dot{H}^*_0(10) = (800 \pm 100) \mu\text{Sv/h}$.

3.2.4.3.18 Perform operations 3.2.4.3.16 of the OM for gamma radiation DER from ^{137}Cs source with the value of $\dot{H}^*_0(10) = (8 \pm 0.1) \text{mSv/h}$.

3.2.4.3.19 Perform operations 3.2.4.3.16 of the OM for gamma radiation DER from ^{137}Cs source with the value of $\dot{H}^*_0(10) = (80 \pm 10) \text{mSv/h}$.

3.2.4.3.20 Perform operations 3.2.4.3.16 of the OM for gamma radiation DER from ^{137}Cs source with the value of $\dot{H}^*_0(10) = (800 \pm 100) \text{mSv/h}$.

3.2.4.3.21 The detecting unit is acknowledged to have passed the testing, if the limit of main relative error of measurement of each level of gamma radiation DER does not exceed $15 + 1/\dot{H}^*(10)$, where $\dot{H}^*(10)$ is a numeric value of gamma radiation DER, equivalent to $\mu\text{Sv/h}$.

3.2.4.4 Presentation of testing results.

3.2.4.4.1 Positive results of periodic testing shall be certified by the issuance of a certificate of the established form in accordance with the legislation in the field of metrology and metrological activity or by an entry in the "Certificate of acceptance" section in the logbook for the detecting unit.

3.2.4.4.2 The detecting units that do not meet the requirements of the testing procedure are not allowed for manufacture and use, and get the certificate of inadequacy in accordance with the legislation in the field of metrology and metrological activity.

4 REPAIR

4.1 In case of failure or troubles during the warranty period of the detecting unit, the user should contact the producer enterprise by e-mail (see below) to receive the address of the nearest service center:

*PE "SPPE "Sparing-Vist Center"
Tel.: (+38032) 242 15 15, fax: (+38032) 242 20 15
E-mail: sales@ecotest.ua.*

5 STORAGE AND PUTTING IN PROLONGED STORAGE

5.1 Before putting in operation, the detecting unit should be stored in the packing of the producer enterprise in storehouses under special conditions. The storage period should not exceed one year. Shipping time is included in the storage period of the device.

5.2 If necessary to prolong the storage period, or if the storage conditions are stricter than stated in 5.1, the consumer should temporarily close the detecting unit down. Temporary closing-down according to the B3-10 protection option is recommended. Silicagel, used during temporary closing-down, is recommended to be placed into fabric bags or paper packages. It is allowed to perform not more than two temporary closing-downs. Before putting in prolonged storage or repeated use, silicagel should be dried. Total time of the detecting unit storage with the account of the repeated closing-down should not exceed 10 years.

6 SHIPPING

6.1 The detecting units should be shipped under the conditions similar to those presented in 1.2.2.5.

6.2 The detecting units can be shipped by railway, motor, water and air transport. When shipped by railway transport, the detecting units should be placed in a box car. When carried by motor transport, they should be placed in a closed car or van, by water transport – in a ship's hold, and by air transport – in pressurized compartments.

6.3 During shipping of the detecting units, observe the handling marks inscribed on the shipping containers.

6.4 Total time of shipping of the detecting units in packing of the producer enterprise should not exceed one month.

7 DISPOSAL

Disposal of the detecting unit is performed as follows: metals are recycled or melted, and plastic parts are dumped.

Disposal of the detecting unit is not dangerous for the service personnel, and is environmentally friendly.

The detecting unit should be disassembled in accordance with the procedure established by the user enterprise.

APPENDIX A

TECHNOLOGICAL SOFTWARE BDBG_S.EXE PROGRAM

User Guide

1 The technological software is developed to indicate real-time gamma radiation DER and ambient air temperature, measured by the BDBG-09S detecting unit, to view and change the address of the detecting unit, as well as to indicate its serial number.

* - only for the detecting units with the embedded temperature detector.

2 The technological software can be used by the enterprises and organizations for repair and testing of the BDBG-09S detecting units.

3 The technological software can operate on the IBM-compatible personal computer (PC) with installed Windows 98 and further versions of the operating system.

4 Connection of the BDBG-09S detecting unit to the PC, and power supply of the BDBG-09S is done with the help of the USB <--> RS-485 interface adapter.

5 The technological software includes:

- bdbg_s.exe program;
- USB serial port driver.

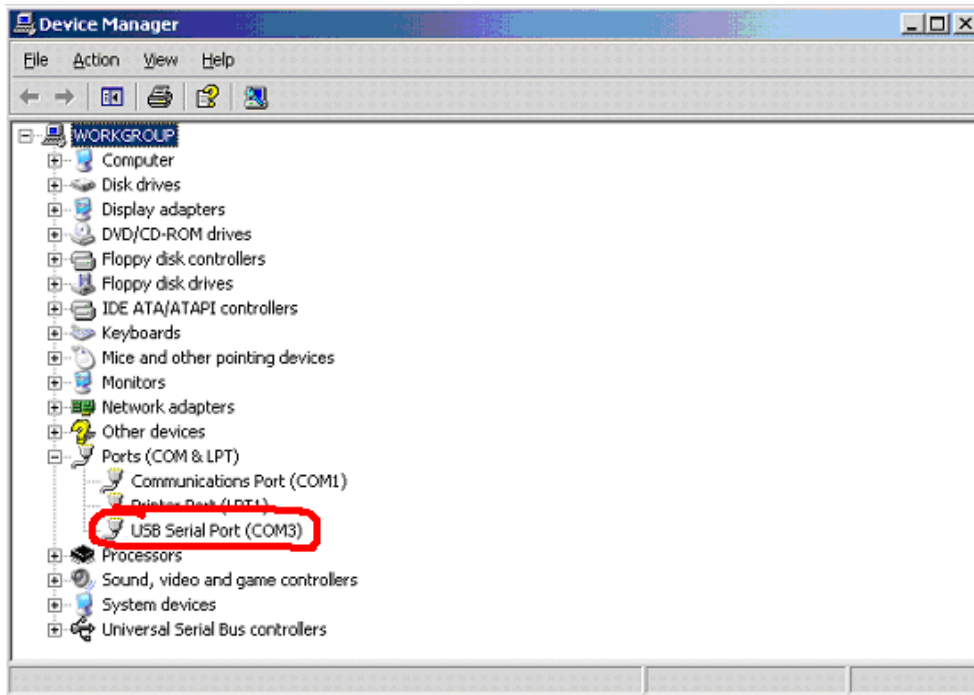
6 Technological software installation

6.1 If the BDBG-09S detecting unit is connected to the PC by means of the USB <--> RS-485 interface adapter, installation of USB serial port drivers is required.

6.2 To install USB serial port drivers, you must run **CDM v2.10.00 WHQL Certified.exe with administrator rights** from the installation disc and follow the prompts of the program.

Connect the USB <--> RS-485 interface adapter to a free USB connector of the PC and the power unit to the interface adapter, and wait for the new hardware installation.

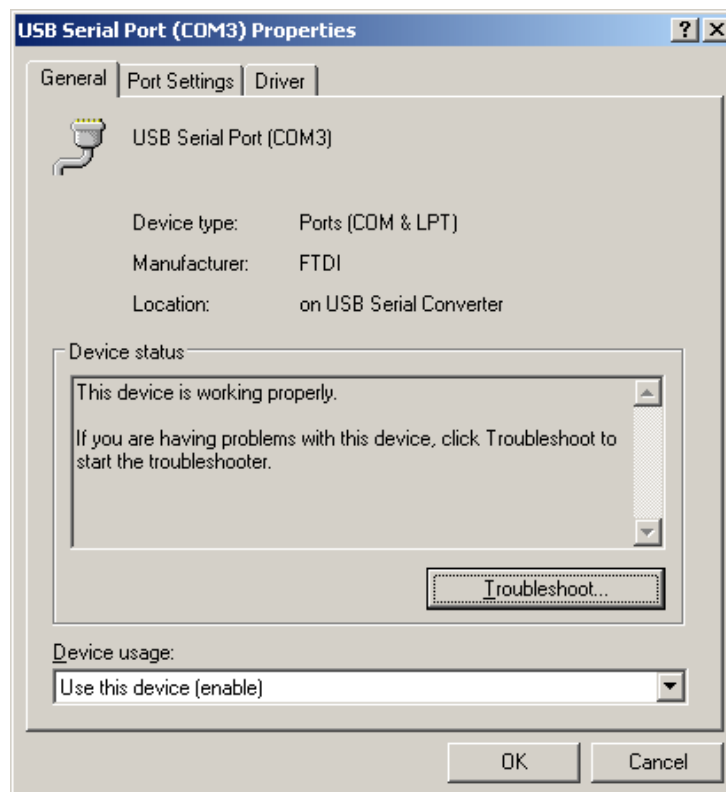
The device is consequently created in the list of PC devices: USB Serial Port.



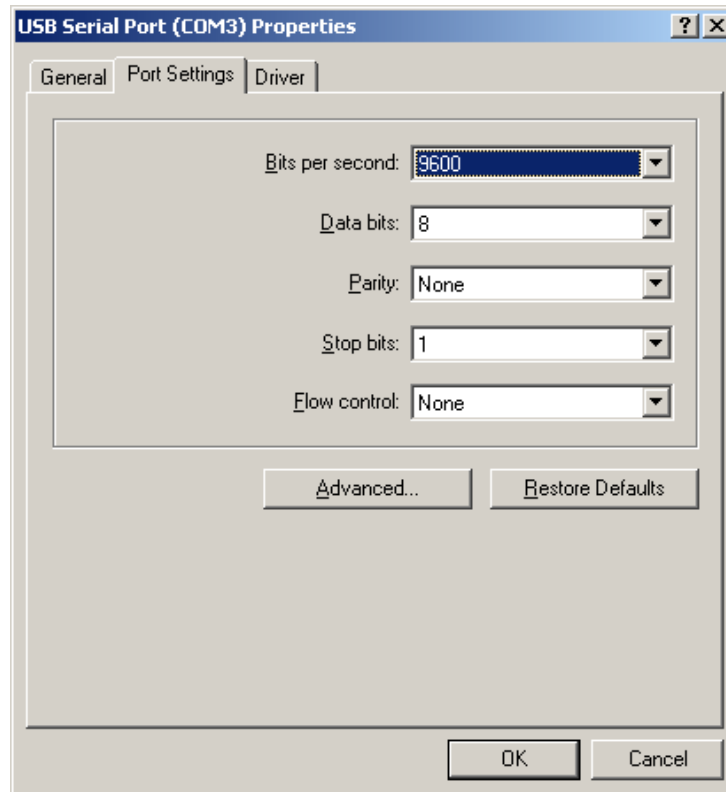
If the new USB Serial Port does not appear, repeat the steps above and restart the PC. You can download the latest version of the drivers from www.ftdichip.com.

For proper functioning of the bdbg_s.exe program set the minimum value of **1mS** in the **Latency Timer** option of the USB serial port. Do the following:

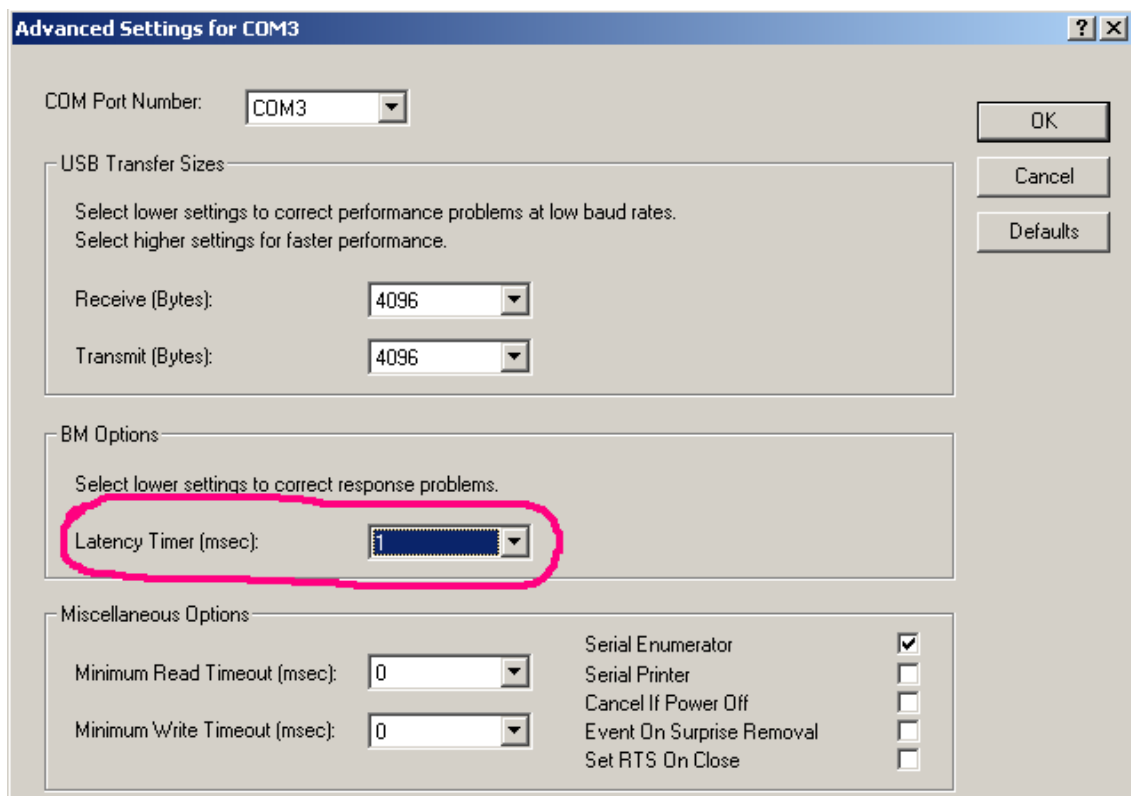
- open the **Properties** window: **USB Serial Port (COM__)**;



- select the **Port Settings** tab



- click **Advanced**



- change the value of **Latency Timer** for **1 mS**;
- finish input by clicking **OK**.

7 Deinstallation of the technological software

7.1 To remove the technological software, uninstall the PortTalk driver. To do this, start the `uninstall.exe` program from the `Drivers\PortTalk` folder of the installation disk.

7.2 If the USB Serial Converter and the USB Serial Port drivers are installed, it is necessary to uninstall them by launching the `ftdiunin.exe` program, located in the `Drivers\FTDI_Drivers` folder of the installation disk.

8 Bdbg_s.exe program

8.1 After the `bdbg_s.exe` program is successfully launched, the program window is displayed and the **Setup** tab is activated (Figure A.1).

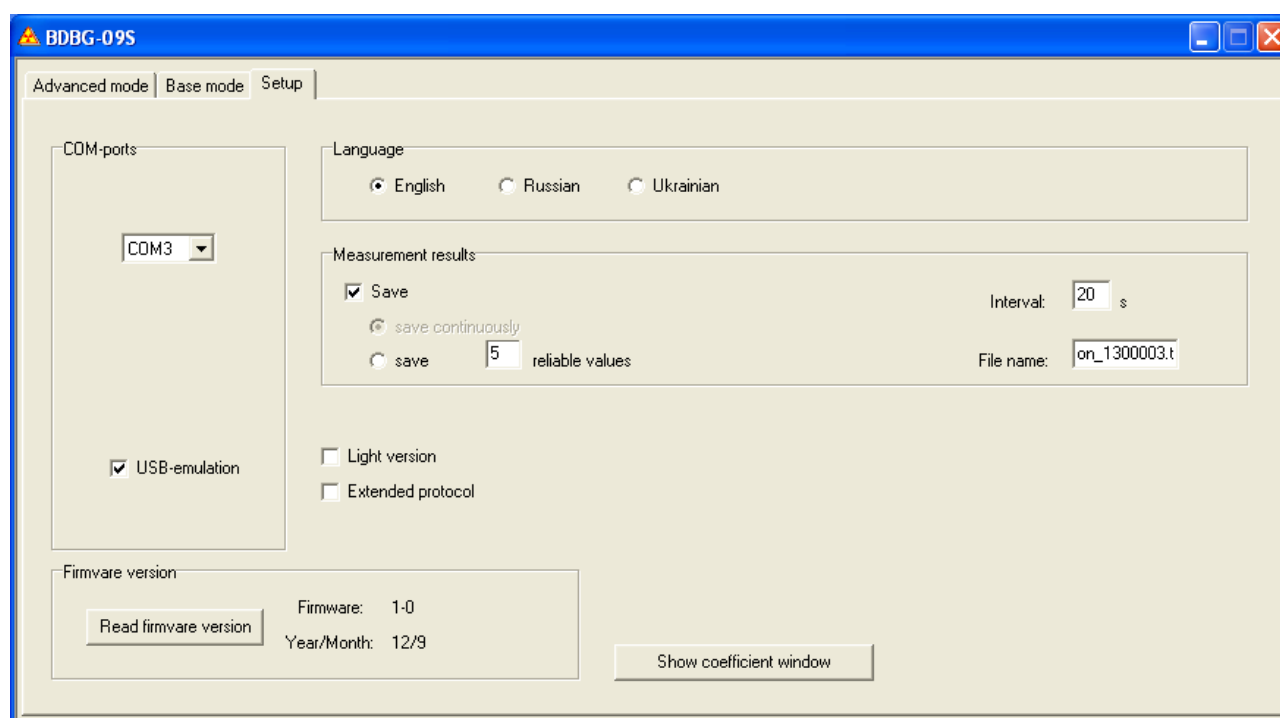


Figure A.1 – Bdbg_s.exe program window with the active **Setup** tab

Firstly, choose the interface language among English, Russian and Ukrainian.

Further select a COM-port, to which the detecting unit is connected through the adapter. Select the checkbox on the USB-emulation indicator while operating with the COM-port emulated via USB. If the wrong COM-port is selected, the corresponding diagnostic messages will be displayed.

The **Measurement results** group serves to save measurement results on the disk in a text file. The file name is set in the corresponding input line. To save measurement results, select the checkbox on the **Save** indicator, choose the saving mode: **save continuously** or **save N reliable values**, and set saving interval in seconds. You can view the earlier saved measurement results with the help of any programs intended for viewing and editing the text files (*.txt) (for instance, Notepad). The example of measurement results, saved with the help of the `bdbg_s.exe` program, is given in the Appendix C.

The **Light version** indicator is used for operation with the BDBG-09S detecting unit version for everyday use without the low sensitivity detector.

The **Extended protocol** indicator allows choosing operation with the detecting unit using extended protocol (v1.3).

The **Firmware version** group features the **Read firmware version** button that allows you to read the software version embedded in BDBG-09S and the date of its development.

After closing the `bdbg_s.exe` program, all selected settings are saved in the `bdbg_s.ini` file, and the next time the program is launched, the `bdbg_s.exe` program will already contain them.

Next, select the **Base mode** tab (Figure A.2).

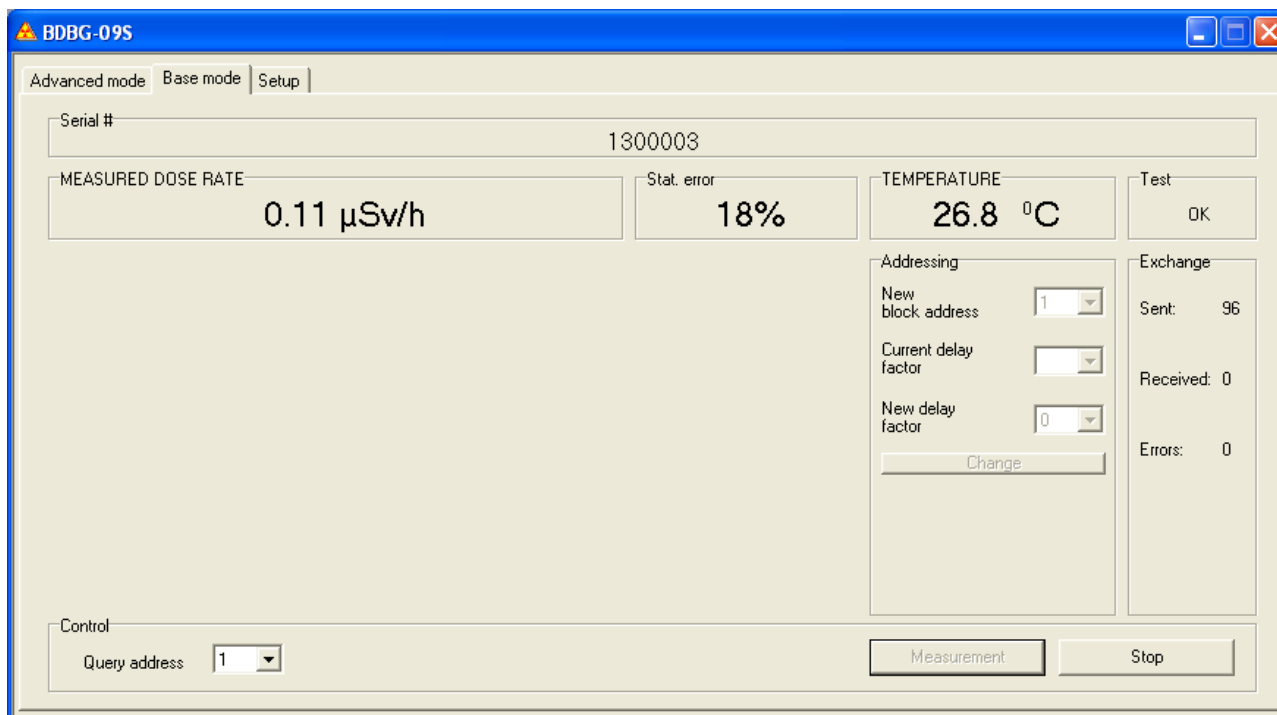


Figure A.2 – Bdbg_s.exe program window with the active **Base mode** tab

The following grouped data will be displayed on the monitor:

- **Serial #** – indicates a serial number of the detecting unit.
- **MEASURED DOSE RATE** – indicates DER measurement result, received from the detecting unit. It can be indicated in two colors: grey and black. Indication color is grey until maximum statistical error of measurement result exceeds maximum permissible error according to the specifications. The maximum statistical error decreases in the process of integration. When the latter becomes equal or lower than the maximum permissible error (according to the specifications) the indication color turns black.
- **Stat. error** – indicates maximum statistical error of DER measurement result.
- **TEMPERATURE** – indicates temperature readings, received from the detecting unit.
- **Test** – indicates a self-testing result of the detecting unit. When the detecting unit functions properly, the **OK** message is indicated. **High sensitive** is indicated at failure of the high sensitivity detector, and **Low sensitive** at failure of the low sensitivity detector. Failure message appears in red color.

After the program is started, the first five groups contain no data until the beginning of exchange with the detecting unit upon clicking the **Measurement** button (buttons are described below). If the exchange process is broken (for example, when the cable is disconnected from the detecting unit), information in the first five groups is cleared.

- **Addressing.** The address of the detecting unit is saved to its nonvolatile memory. It can be changed, as well as the calibration factors. Set a new required address in the **New block address** input field and then click **Change**.

If the detecting unit is operated using extended protocol (v1.3), the current response delay factor to the broadcast query is displayed in the **Current delay factor** field. This factor is also stored in the nonvolatile memory of the detecting unit and can be changed. To change it, set a required value in the **New delay factor** field and click **Change**.

Caution! After clicking the **Change** button, values from the input fields **New block address** and **New delay factor** are simultaneously sent to the detecting unit. Therefore, before clicking **Change** make sure all values of the input fields are correct.

If the detecting unit is operated using the v1.2 protocol, the **Current delay factor** and the **New delay factor** fields are unavailable and data is not transferred to the detecting unit.

- **Exchange** – exchange parameters for COM-port exchange with the detecting unit.
- **Sent** – byte sent to the detecting unit.
- **Received** – byte received from the detecting unit

- **Errors** – errors during exchange with the detecting unit. A big number of errors can be the evidence of the cable fault between the detecting unit and the adapter, or the adapter and the PC.

At the bottom of the **Base mode** window, the **Control** group is located that consists of two buttons: **Measurement**, **Stop**, and the **Query address** input field.

With the **Query address** input field, the address of the detecting unit, which will be used for operation, is set.

Buttons provide the following functions:

- **Measurement** – clicking this button starts a continuous process of querying the detecting unit, receiving and displaying DER measurement results. Queries are sent to the detecting unit at a one-second interval.

- **Stop** – clicking this button terminates the exchange process, started with the **Measurement** button. Clicking this button does not clear the data from the **MEASURED RATE**, **Stat. error**, and **Test** groups.

The **Advanced mode** tap offers an alternative operating mode of the program (Figure A.3), allowing to make use of BDBG-09 S functional capabilities to the full extent.

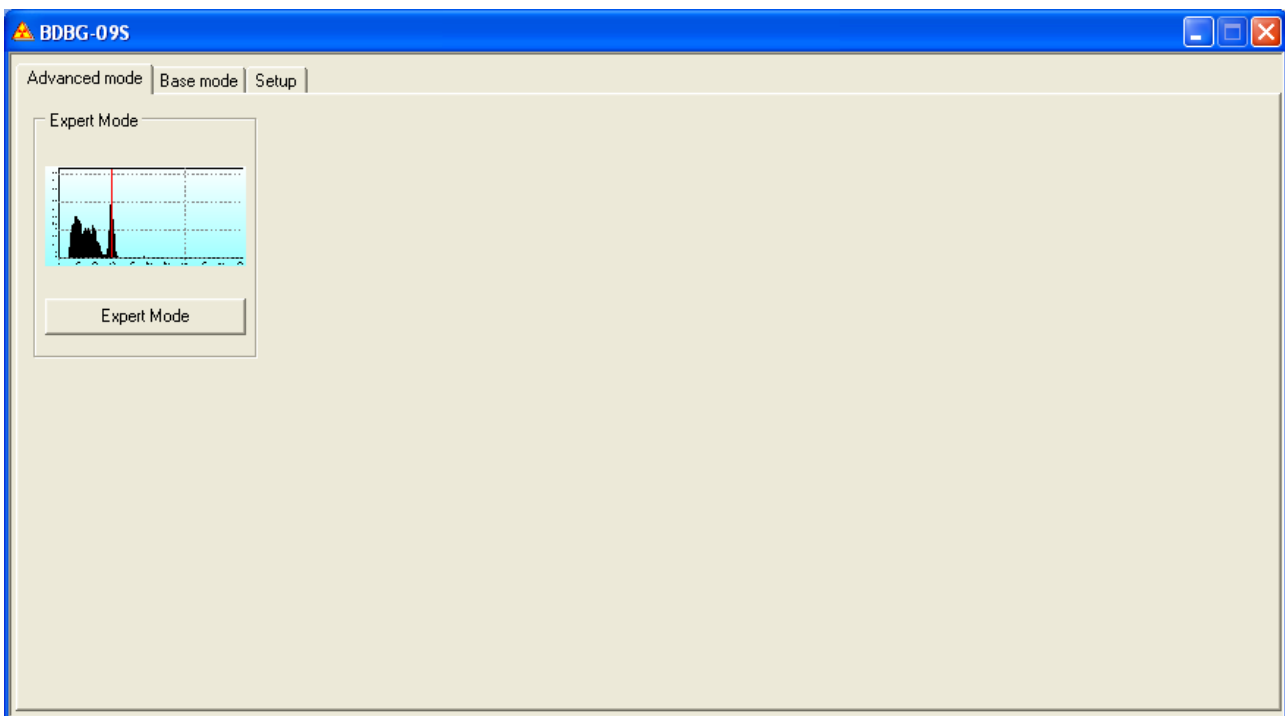


Figure A.3 – Bdbg_s.exe program window with the active **Advanced mode** tab

The **Expert mode** group features the **Expert mode** button that makes the **Expert mode** window appear (Figure A. 4). This button will be available as long as the **Measurement** button on the **Base mode** tab is also available.

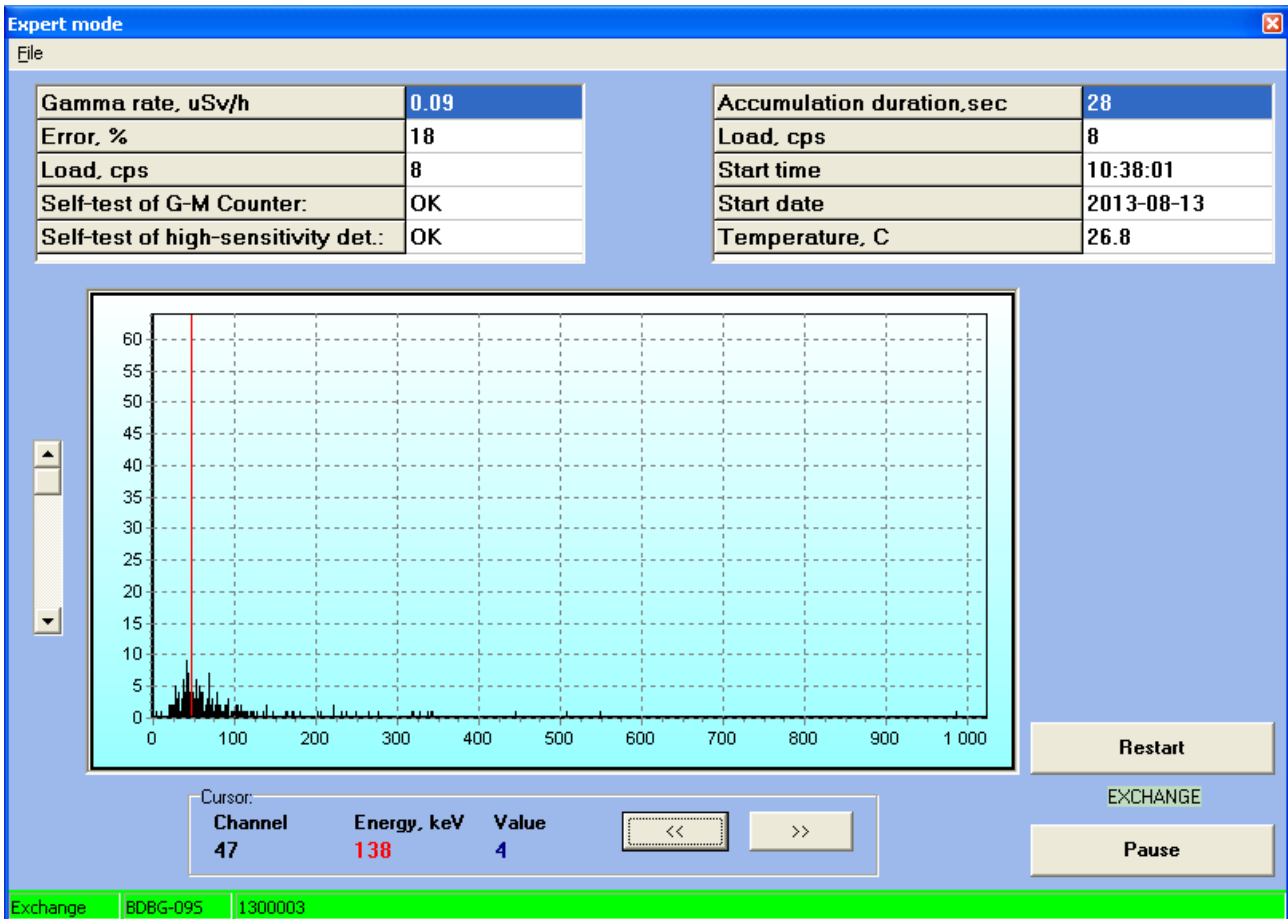


Figure A.4 – Additional **Expert mode** window of the bdbg_s.exe program

The information displayed on the screen is grouped as follows:

- **Gamma rate** – shows DER measurement results received from the detecting unit.
- **Error** – shows a maximum statistical error of a DER measurement result.
- **Load** – shows counts per second from the detectors of the detecting unit.
- **Self-test of G-M Counter** – shows the operability check results of the GMC.
- **Self-test of high-sensitivity det.** – shows the operability check results of the SDUGR.
- **Accumulation duration** – shows the length of time in seconds from the start of the spectrum accumulation.
- **Start time** – shows a start time of the spectrum accumulation.
- **Start date** – shows a start date of the spectrum accumulation.
- **Temperature** – shows temperature results received from the detecting unit.

There is a group below, displaying a spectrum accumulated by the SDUGR of BDBG-09S. The spectrum channels are plotted horizontally whereas the values corresponding to the number of pulses for this channel are distributed vertically. To the left of the window there is a scroll area that allows adjustment of the vertical zoom.

If a certain fragment of the spectrum has to be zoomed in, this fragment should be selected with a left click of a mouse from left to right (press the left mouse key at the beginning of the selectable fragment and move the cursor to the right without releasing the mouse button to make a black rectangular frame appear. Expand the frame until a necessary fragment is completely selected, then release the mouse button.)

To return to a previous zoom level, make selection of any fragment of the spectrum from left to right so that the mouse cursor be positioned beyond the boundaries of a field, displaying the spectrum, and then release a button.

In the bottom right corner, there are two buttons to start a new spectrum accumulation (**Restart**) and stop/continue it (**Pause/Continue**). After opening the **Expert mode** window spectrum accumulation starts automatically. This process is indicated by a blinking **EXCHANGE** label under the **Restart** button and a green colored group in the bottom pane of the window with a name of the unit and its serial number. When acquisition is finished, the color of this group turns red.

The **Cursor** group provides more detailed information about a spectrum channel the cursor points to:

Channel – indicates the number of the channel the cursor points to.

Energy – indicates the energy corresponding to that channel.

Value – indicates the number of pulses in this channel.

Except for this, this group includes two buttons (<< and >>) that allows moving the cursor more accurately.

In the upper right corner there is the drop-down **File** menu through which you can save a received spectrum (**Save**), open a previously saved spectrum for viewing (**Open**) and close the **Expert mode** window (**Exit**).

APPENDIX B

COMMUNICATIONS PROTOCOL OF THE DATA DISPLAY SYSTEM AND THE DETECTING UNIT

B.1 Data frames exchange between the detecting unit and the data display system is done via the RS-485 interface in a half-duplex mode.

Exchange parameters:

- rate: 19200 bps;
- data word length: 8 bit;
- parity bit: none;
- stop bit: 1.

Time interval between the bytes in one frame should not exceed 1 ms. Time interval between the frames should not be less than 5 ms.

B.2 After the supply voltage from the data display system is transmitted to the detecting unit, the latter not later than in 30 s automatically starts gamma radiation DER measurement and processing of data frames from the data display system.

B.3 This detecting unit supports data communications protocol version with both 4-digit field address (v1.2), and 8-digit field address (v1.3).

B.3.1 Communications protocol with the 4-digit field address (v1.2).

To receive the measured value of DER from the detecting unit, the data display system should transmit the “**DER query**” frame to the detecting unit. The detecting unit will respond in 5 ms to 15 ms with the “**Current DER**” frame, where current DER, maximum statistical error of its measurement, and self-testing results of the detecting unit will be displayed.

To receive the measured value of temperature from the detecting unit (with embedded temperature detector), the data display system should transmit the “**Temperature query**” frame to the detecting unit. The detecting unit will respond in 5 ms to 15 ms with the “**Current temperature**” frame, where current temperature and condition of the temperature detector will be transferred.

To receive the serial number of the detecting unit, the data display system should transmit the “**Serial # query**” frame to the detecting unit. The detecting unit will respond in 5 ms to 15 ms with the “**Serial #**” frame with the displayed serial number.

To change the address of the detecting unit, the data display system should transmit the “**Address change**” frame to the detecting unit. In 5 ms to 500 ms the detecting unit will respond with the “**Confirmation**” frame. *Caution!* In the address field of the “**Confirmation**” frame the old value of address will be recorded. In the event of successful reception of a new value, the detecting unit records it in the nonvolatile memory, and not later than in 5 s starts responding to the frames with a new address.

To make operation with several detecting units (up to 15 units) easier that are simultaneously connected to the data display system via single RS-485 interface, the **0Fh** broadcast address is provided. The use of this address is permitted only in the “**DER query**”, “**Temperature query**” and “**Serial # query**” frames. All detecting units respond to the query with such address (broadcast query).

When the detecting units respond to the broadcast query, each of them does it with delay T, which is calculated by the formula:

$$T = 5\text{mS} + \text{Adr} \times 8 \text{ mS}, \quad (\text{B.1})$$

where Adr is the address of the detecting unit.

The broadcast query also enables easy realization of autodetection of the detecting units that connect/disconnect to/from the data display system in the process of system operation.

“DER query” frame format –the data display system to the detecting unit

D7	D6	D5	D4	D3	D2	D1	D0	
0	1	0	1	0	1	0	1	Byte 55h - start-of-frame character
1	0	1	0	1	0	1	0	Byte AAh
0	0	0	0	A3	A2	A1	A0	D7...D4 - “DER query” frame code D3...D0 - detecting unit address *

* - **0Fh** address – broadcast address. All detecting units respond to the query with such address.

“Current DER” frame format –the detecting unit to the data display system

D7	D6	D5	D4	D3	D2	D1	D0	
0	1	0	1	0	1	0	1	Byte 55h - start-of-frame character
1	0	1	0	1	0	1	0	Byte AAh
0	0	0	1	A3	A2	A1	A0	D7...D4 - “Current DER” frame code D3...D0 - detecting unit address
DER0 (low byte)				DER,				
DER1				fixed point number,				
DER2				Least significant bit (LSB) = 0.01 μSv/h				
DER3 (high byte)				Statistical error of measurement				
Byte				D0,D1 - self-testing results of the detecting unit				
				D0=1 - failure of the high sensitivity detector				
				D1=1 - failure of the low sensitivity detector				
				Reliable measurement result character				
				D2=0 - result is reliable				
				D2=1 - result is not reliable *				
				D7=0 - LSB DER = 0,01 μSv/h				
				D7=1 - LSB DER = 0,1 μSv/h				
control				arithmetical checksum with a carry				

* - measurement result is accepted as not reliable if the statistical error of measurement exceeds the maximum permissible error of the measurement

“Temperature query” frame format – the data display system to the detecting unit (for the detecting units with embedded temperature detector)

D7	D6	D5	D4	D3	D2	D1	D0	
0	1	0	1	0	1	0	1	Byte 55h - start-of-frame character
1	0	1	0	1	0	1	0	Byte AAh
1	0	0	0	A3	A2	A1	A0	D7...D4 - “Temperature query” frame code D3...D0 - detecting unit address *

* - **0Fh** address – broadcast address. All detecting units respond to the query with such address.

“Current temperature” frame format – the detecting unit to the data display system

D7	D6	D5	D4	D3	D2	D1	D0	
0	1	0	1	0	1	0	1	Byte 55h - start-of-frame character
1	0	1	0	1	0	1	0	Byte AAh
1	0	0	0	A3	A2	A1	A0	D7...D4 - “Temperature” frame code D3...D0 - detecting unit address
2 ³	2 ²	2 ¹	2 ⁰	2 ⁻¹	2 ⁻²	2 ⁻³	2 ⁻⁴	Temperature, binary number
D7	X	X	X	S	2 ⁶	2 ⁵	2 ⁴	S=0-above-zero temperature S=1-below-zero temperature D7=0-normal operation of temperature detector D7=1-failure of temperature detector
control							arithmetical checksum with a carry	

“Serial # query” frame format – the data display system to the detecting unit

D7	D6	D5	D4	D3	D2	D1	D0	
0	1	0	1	0	1	0	1	Byte 55h - start-of-frame character Byte AAh
1	0	1	0	1	0	1	0	
0	1	0	1	A3	A2	A1	A0	D7...D4 - “Serial # query” frame code D3...D0 - detecting unit address *

* - **0Fh** address – broadcast address. All detecting units respond to the query with such address.

“Serial #” frame format – the detecting unit to the data display system

D7	D6	D5	D4	D3	D2	D1	D0	
0	1	0	1	0	1	0	1	Byte 55h - start-of-frame character Byte AAh
1	0	1	0	1	0	1	0	
0	1	0	1	A3	A2	A1	A0	D7...D4 - “Serial #” frame code D3...D0 - detecting unit address *
Serial No. _0 (low byte)								Serial No. of the detecting unit
Serial No. _1								
Serial No. _2								
Serial No. _3 (high byte)								
control								arithmetical checksum with a carry

“Address change” frame format – the data display system to the detecting unit

D7	D6	D5	D4	D3	D2	D1	D0	
0	1	0	1	0	1	0	1	Byte 55h - start-of-frame character Byte AAh
1	0	1	0	1	0	1	0	
0	1	1	0	A3	A2	A1	A0	D7...D4 - “Address change” frame code D3...D0 - current address of the detecting unit
0	0	0	0	NA3	NA2	NA1	NA0	D3...D0 - new address of the detecting unit
control								arithmetical checksum with a carry

“Confirmation” frame format –the detecting unit to the data display system

D7	D6	D5	D4	D3	D2	D1	D0	
0	1	0	1	0	1	0	1	Byte 55h - start-of-frame character Byte AAh
1	0	1	0	1	0	1	0	
1/0	0	1	1	A3	A2	A1	A0	D7 = 0 - normal operation D7 = 1 - error D6...D4 - “Confirmation” frame code D3...D0 - OLD address of the detecting unit

B.3.2 Communications protocol with the 8-digit field address (v1.3).

To receive the measured value of DER from the detecting unit, the data display system should transmit the “**DER1 query**” frame to the detecting unit. The detecting unit will respond in 5 ms to 15 ms with the “**Current DER1**” frame, where current DER, maximum statistical error of its measurement, and self-testing results of the detecting unit will be displayed.

To receive the measured value of temperature from the detecting unit (with embedded temperature detector), the data display system should transmit the “**Temperature1 query**” frame to the detecting unit. The detecting unit will respond in 5 ms to 15 ms with the “**Current temperature1**” frame, where current temperature and condition of the temperature detector will be transferred.

To receive the serial number of the detecting unit and the response delay factor to broadcast query, the data display system should send the “**Serial #_1 query**” frame to the detecting unit. The detecting unit will respond in 5 ms to 15 ms with the “**Serial #_1**” frame with the displayed serial number and the response delay factor to the broadcast query.

To change the address of the detecting unit and the response delay factor to the broadcast query, the data display system should transmit the “**Address1 change**” frame to the detecting unit. In 5 ms to 500 ms the detecting unit will respond with the “**Confirmation1**” frame. *Caution!* In the address field of the “**Confirmation1**” frame the old value of address will be recorded. In the event of successful reception of a new value and response delay factor to the broadcast query, the detecting unit records it in the nonvolatile memory, and not later than in 5 s starts responding to frames with a new address.

To make operation with several detecting units (up to 255 units) easier that are simultaneously connected to the data display system via single RS-485 interface, the 0FFh broadcast address is provided. The use of this address is permitted only in the “**DER1 query**”, “**Temperature1 query**” and “**Serial #_1 query**” frames. All detecting units respond to the query with such address (broadcast query).

When the detecting units respond to the broadcast query, each of them does it with delay T, which is calculated by the formula:

$$T = 5 \text{ mS} + t \times 8 \text{ mS}, \quad (\text{B.2.1})$$

if the response delay factor to the broadcast query t is within the range from 0 to 15;
or by the formula:

$$T = (5 \text{ mS} + t \times 8 \text{ mS}) + 125 \text{ mS} , \quad (\text{B.2.2})$$

if the response delay factor to the broadcast query t is within the range from 16 to 255.

The broadcast query also enables easy realization of autodetection of the detecting units that connect/disconnect to/from the data display system in the process of system operation.

To receive gamma radiation spectrum from the detecting unit there are two frames «Expert» and «Expert1».

Frame «Expert».

The information display system should transmit the following sequence **BLOCK** in "Expert" frame:

1. Frame "Expert" **BLOCK = 9 in BDBG** (query for the new spectrum accumulation)
2. Frame "Expert" **BLOCK = 9 from BDBG** (response to accumulation start)
3. Frame "Expert" **BLOCK = 0 in BDBG** (query 0 ÷ 127 spectrum channels)
4. Frame "Expert" **BLOCK = 0 from BDBG** (response 0 ÷ 127 spectrum channels)
5. Frame "Expert" **BLOCK = 1 in BDBG** (query 128 ÷ 255 spectrum channels)
6. Frame "Expert" **BLOCK = 1 from BDBG** (response 128 ÷ 255 spectrum channels)
7. Frame "Expert" **BLOCK = 2 in BDBG** (query 256 ÷ 383 spectrum channels)
8. Frame "Expert" **BLOCK = 2 from BDBG** (response 256 ÷ 383 spectrum channels)
9. Frame "Expert" **BLOCK = 3 in BDBG** (query 384 ÷ 511 spectrum channels)
10. Frame "Expert" **BLOCK = 3 from BDBG** (response 384 ÷ 511 spectrum channels)
11. Frame "Expert" **BLOCK = 4 in BDBG** (query 512 ÷ 639 spectrum channels)
12. Frame "Expert" **BLOCK = 4 from BDBG** (response 512 ÷ 639 spectrum channels)
13. Frame "Expert" **BLOCK = 5 in BDBG** (query 640 ÷ 767 spectrum channels)
14. Frame "Expert" **BLOCK = 5 from BDBG** (response 640 ÷ 767 spectrum channels)
15. Frame "Expert" **BLOCK = 6 in BDBG** (query 768 ÷ 895 spectrum channels)
16. Frame "Expert" **BLOCK = 6 from BDBG** (response 768 ÷ 895 spectrum channels)
17. Frame "Expert" **BLOCK = 7 in BDBG** (query 896 ÷ 1023 spectrum channels)
18. Frame "Expert" **BLOCK = 7 from BDBG** (response 896 ÷ 1023 spectrum channels)
19. Frame "Expert" **BLOCK = 8 in BDBG** (query of the obtained spectrum parameters)
20. Frame "Expert" **BLOCK = 8 from BDBG** (response with the obtained spectrum parameters, end of the accumulated spectrum reception in a time specified in **BLOCK = 8**)

To receive the next fragments of the accumulated spectrum one should repeat the operations from 3 to 20 inclusive, but so that a new query of the accumulated spectrum fragment took place no sooner than 2 s after the previous **Frame "Expert" BLOCK = 0 in BDBG**.

Frame «Expert1».

The data display system should transmit to the detecting unit the following sequence **BLOCK** in "Expert1" frame:

1. Frame «Expert1» **BLOCK = 9 in BDBG** (query for a new spectrum accumulation start)
2. Frame «Expert1» **BLOCK = 9 in BDBG** (reply about accumulation start)
3. Frame «Expert1» **BLOCK = 0 in BDBG** (query 0 ÷ 1023 spectrum channels)
4. Frame «Expert1» **BLOCK = 0 from BDBG** (reply 0 ÷ 1023 spectrum channels)

To receive the following fragments of accumulated spectrum it is necessary to repeat operations from 3 to 4, but so that the new query for fragment of the accumulated spectrum occurred not more than 2 s after the previous frame "Expert1" **BLOCK = 0 in BDBG**.

“DER1 query” frame format –the data display system to the detecting unit

D7	D6	D5	D4	D3	D2	D1	D0	
0	1	0	1	0	1	0	1	Byte 55h - start-of-frame character
1	0	1	0	1	0	1	0	Byte AAh
0	1	1	1	0	0	0	0	D7...D4-protocol v1.3 character
address								D7...D0- detecting unit address *
0	0	0	0	0	0	0	0	D7...D0-“ DER1 query ” frame code
control								arithmetical checksum with a carry

* - 0FFh address – broadcast address. All detecting units respond to the query with such address.

“Current DER1” frame format –the detecting unit to the data display system

D7	D6	D5	D4	D3	D2	D1	D0	
0	1	0	1	0	1	0	1	Byte 55h - start-of-frame character
1	0	1	0	1	0	1	0	Byte AAh
0	1	1	1	0	0	0	0	D7...D4- protocol v1.3 character
address								D7...D0- detecting unit address
0	0	0	0	0	0	0	1	D7...D0-“ Current DER1 ” frame code
DER0 (low byte)								DER, fixed point number, Least significant bit = 0.01 µSv/h
DER1								
DER2								
DER3 (high byte)								
Byte								Statistical error of measurement
D7	0	0	0	0	D2	D1	D0	D0,D1 - self-testing results of the detecting unit D0=1 - failure of the high sensitivity detector D1=1 - failure of the low sensitivity detector Reliable measurement result character D2=0 - result is reliable D2=1 - result is not reliable * D7=0 - LSB DER = 0,01 µSv/h D7=1 - LSB DER = 0,1 µSv/h
control								arithmetical checksum with a carry

* - measurement result is accepted as not reliable if the statistical error of the measurement exceeds the maximum permissible error of the measurement

"Intensity query for 100msec" frame format - data display system to detecting unit:

D7	D6	D5	D4	D3		D2	D1	D0	
0	1	0	1	0		1	0	1	Byte 55h - start-of-frame character
1	0	1	0	1		0	1	0	Byte AAh
0	1	1	1	0		0	0	0	D7...D4-protocol v1.3 character
address									D7...D0-detecting unit's address*
0	0	0	0	0		1	0	0	D7...D0-" Intensity for 100msec " frame code
control									arithmetical checksum with a carry

* - 0FFh address – broadcast address. All detecting units respond to the query with such address.

"Intensity for 100msec" frame format - detecting unit to data display system:

D7	D6	D5	D4	D3	D2	D1	D0	
0	1	0	1	0	1	0	1	Byte 55h - start-of-frame character
1	0	1	0	1	0	1	0	Byte AAh
0	1	1	1	0	0	0	0	D7...D4-v1.3 protocol character
address								D7...D0 - detecting unit's address
0	0	0	0	0	1	0	0	D7...D0-" Intensity for 100msec " frame code
Rate0 (low byte)								Rate for 100msec(unsigned integer)
Rate 1								
control								arithmetical checksum with a carry

This package can be used to organize search mode because the intensity here is provided without real-time integration.

“Temperature1 query” frame format – the data display system to the detecting unit (for the detecting units with embedded temperature detector)

D7	D6	D5	D4	D3	D2	D1	D0	
0	1	0	1	0	1	0	1	Byte 55h - start-of-frame character
1	0	1	0	1	0	1	0	Byte AAh
0	1	1	1	0	0	0	0	D7...D4- protocol v1.3 character
address								D7...D0- detecting unit address*
0	0	0	0	1	0	0	0	D7...D0-“ Temperature1 query ” frame code
control								arithmetical checksum with a carry

* - **0FFh** address – broadcast address. All detecting units respond to the query with such address.

“Current temperature1” frame format – the detecting unit to the data display system

D7	D6	D5	D4	D3	D2	D1	D0	
0	1	0	1	0	1	0	1	Byte 55h - start-of-frame character
1	0	1	0	1	0	1	0	Byte AAh
0	1	1	1	0	0	0	0	D7...D4- protocol v1.3 character
address								D7...D0- detecting unit address
0	0	0	0	1	0	0	0	D7...D0-“ Temperature1 query ” frame code
2 ³	2 ²	2 ¹	2 ⁰	2 ⁻¹	2 ⁻²	2 ⁻³	2 ⁻⁴	Temperature, binary number
D7	X	X	X	S	2 ⁶	2 ⁵	2 ⁴	S=0-above-zero temperature S=1-below-zero temperature D7=0-normal operation of temperature detector D7=1-failure of temperature detector
control								arithmetical checksum with a carry

“Serial #_1 query” frame format – the data display system to the detecting unit

D7	D6	D5	D4	D3	D2	D1	D0	
0	1	0	1	0	1	0	1	Byte 55h - start-of-frame character Byte AAh
1	0	1	0	1	0	1	0	
0	1	1	1	0	0	0	0	D7...D4- protocol v1.3 character
address								D7...D0- detecting unit address*
0	0	0	0	0	1	0	1	D7...D0-“ Serial#_1 query ” frame code
control								arithmetical checksum with a carry

* - 0FFh address – broadcast address. All detecting units respond to the query with such address.

“Serial #_1” frame format – the detecting unit to the data display system

D7	D6	D5	D4	D3	D2	D1	D0	
0	1	0	1	0	1	0	1	Byte 55h - start-of-frame character Byte AAh
1	0	1	0	1	0	1	0	
0	1	1	1	0	0	0	0	D7...D4- protocol v1.3 character
address								D7...D0- detecting unit address
0	0	0	0	0	1	0	1	D7...D0-“ Serial#_1 ” frame code
Serial No._0 (low byte)								Serial No. of the detecting unit
Serial No._1								
Serial No._2								
Serial No._3 (high byte)								
current constant								D7...D0-current response delay factor to broadcast query
control								arithmetical checksum with a carry

“Address1 change” frame format – the data display system to the detecting unit

D7	D6	D5	D4	D3	D2	D1	D0	
0	1	0	1	0	1	0	1	Byte 55h - start-of-frame character Byte AAh
1	0	1	0	1	0	1	0	
0	1	1	1	0	0	0	0	D7...D4- protocol v1.3 character
current address								D7...D0- current address of the detecting unit
0	0	0	0	0	1	1	0	D7...D0-“ Address1 change ” frame code
new address								D7...D0- new address of the detecting unit
new constant								D7...D0- new response delay factor to broadcast query
control								arithmetical checksum with a carry

“Confirmation1” frame format –the detecting unit to the data display system

D7	D6	D5	D4	D3	D2	D1	D0	
0	1	0	1	0	1	0	1	Byte 55h - start-of-frame character Byte AAh
1	0	1	0	1	0	1	0	
0	1	1	1	0	0	0	0	D7...D4- protocol v1.3 character
OLD address								D7...D0- OLD address of the detecting unit
1/0	0	0	0	0	0	1	1	D6...D0-“ Confirmation1 ” frame code D7 = 0 - normal operation D7 = 1 - error
control								arithmetical checksum with a carry

“Expert” frame format – data display system to the detecting unit
0x0B – Expert (spectrum, DER, temperature, error);
0x0E – Firmware;

D7	D6	D5	D4	D3	D2	D1	D0	
0	1	0	1	0	1	0	1	Byte 55h - start-of-frame character
1	0	1	0	1	0	1	0	Byte AAh
0	1	1	1	0	0	0	0	D7...D4- protocol v1.3 character
address								D7...D0- address of the detecting unit*
0	0	0	0	1	0	1	1	D7...D0- “ Эксперт ” frame code
byte								Number of spectrum block BLOCK ⁽¹⁾
The structure of the following data is defined by the spectrum block number BLOCK . (see description below). The length of these data is always equal to 2 bytes regardless of the BLOCK value.								
control								arithmetical checksum with a carry

⁽¹⁾ - spectrum block number **BLOCK** defines the structure of the following data. Given the value of **BLOCK**, equal from 0 to 7, the query is sent for corresponding fragments (blocks) of spectrum including 128 channels (256 bytes) each. Given the value of **BLOCK**, equal to 8, the query is sent for parameters of the obtained spectrum. Given the value of **BLOCK**, equal to 9, the mode of spectrum accumulation is switched on/off.

At **BLOCK = 0..8** – values of two succeeding bytes is disregarded.

At BLOCK = 9

D7	D6	D5	D4	D3	D2	D1	D0	
1	0	0	0	1	1	0	0	Password (0x8C)
0	0	0	0	0	0	0	a	a = 1 - accumulated spectrum is reset to 0 ⁽¹⁾ ;

⁽¹⁾ - the counter of spectrum accumulation duration is reset and spectrum accumulation is started.

“Expert” frame format – data display system to the detecting unit

D7	D6	D5	D4	D3	D2	D1	D0	
0	1	0	1	0	1	0	1	Byte 55h - start-of-frame character
1	0	1	0	1	0	1	0	Byte AAh
0	1	1	1	0	0	0	0	D7...D4- protocol v1.3 character
address								D7...D0- address of the detecting unit*
0	0	0	0	1	1	0	1	D7...D0- “Expert” frame code
byte								Number of spectrum block BLOCK ⁽¹⁾
The structure of the following data is defined by the spectrum block number BLOCK . (see the description below). The length of these data is always equal to 256 bytes regardless of the BLOCK value.								
control				arithmetical checksum with a carry				

⁽¹⁾ - spectrum block number **BLOCK** defines the structure of the following data (see tables below). Given the value of **BLOCK**, equal from 0 to 7, the corresponding fragments(blocks) of spectrum including 128 channels (256 bytes) each are transmitted. Given the value of **BLOCK**, equal to 8, the parameters of the obtained spectrum are transmitted. Given the value of **BLOCK**, equal to 9, the mode of spectrum accumulation is switched on/off.

At BLOCK = 0..7

D7	D6	D5	D4	D3	D2	D1	D0	
Low byte								Number of pulses in a channel
High byte								0+(BLOCK x 128)
Low byte								Number of pulses in a channel
High byte								1+(BLOCK x 128)
...								...
Low byte								Number of pulses in a channel
High byte								126+(BLOCK x 128)
Low byte								Number of pulses in a channel
High byte								127+(BLOCK x 128)

At BLOCK = 8

D7	D6	D5	D4	D3	D2	D1	D0	
Low byte								Accumulation duration of received spectrum, s.
High byte								
DER0 (low byte)								DER, fixed point number, Least significant bit (LSB) = 0.01 μ Sv/h
DER1								
DER2								
DER3 (high byte)								
Byte								Statistical error of measurement
0	D6	0	0	0	D2	D1	D0	D0, D1 - self-testing results of the detecting unit D0=1 - failure of the high sensitivity detector D1=1 - failure of the low sensitivity detector Reliable measurement result character D2=0 - result is true D2=1 - result is false * D6=1 - measurement from the Geiger-Muller counter D6=0 - measurement from the high sensitivity detector
2 ³	2 ²	2 ¹	2 ⁰	2 ⁻¹	2 ⁻²	2 ⁻³	2 ⁻⁴	Temperature, binary number S=0- above-zero temperature S=1- below-zero temperature D7=0- normal operation of temperature detector D7=1- failure of temperature detector
	X	X	X	S	2 ⁶	2 ⁵	2 ⁴	
Low byte								Pulses per second (integrated)
High byte								
Byte								Model of the device 0xCC - BDBG-09S
Serial №_0 (low byte)								Serial No. of the detecting unit
Serial №_1								
Serial №_2								
Serial №_3 (high byte)								
Year								Firmware version
Month								
Release version								
Debug version								
239 reserved bytes								

At BLOCK = 9

D7	D6	D5	D4	D3	D2	D1	D0	
1	0	0	0	1	1	0	0	Password (0x8C)
0	0	0	0	0	0	0	a	a = 1 - spectrum accumulation is started ⁽¹⁾ ; a = 0 - unable to start spectrum accumulation;
254 reserved bytes								

⁽¹⁾ - the counter of spectrum accumulation duration is reset and spectrum accumulation is started.

**“Expert1” frame format –data display system to detecting unit
0x8B – Expert1 (spectrum, DER, temperature, error)**

D7	D6	D5	D4	D3	D2	D1	D0	
0	1	0	1	0	1	0	1	Byte 55h - start-of-frame character
1	0	1	0	1	0	1	0	Byte AAh
0	1	1	1	0	0	0	0	D7...D4-protocol v1.3 character
address								D7...D0 - detecting unit's address
1	0	0	0	1	0	1	1	D7...D0-“Expert1” frame code
byte								Spectrum block number BLOCK ⁽¹⁾
The structure of the following data is determined by spectrum block number BLOCK . (see description below). The length of these data is always equal to 2 bytes regardless of the BLOCK value.								
Control								arithmetical checksum with a carry

⁽¹⁾ - spectrum block number **BLOCK** defines the structure of the following data. Given the value of **BLOCK**, equal 0, the query is sent for corresponding full spectrum including 1024 channels and parameters of the obtained spectrum. Given the value of **BLOCK**, equal to 9, the mode of spectrum accumulation is switched on/off.

Given **BLOCK = 0** – the value of the next two bytes is ignored.

Given **BLOCK = 9**

D7	D6	D5	D4	D3	D2	D1	D0	
1	0	0	0	1	1	0	0	Password (0x8C)
0	0	0	0	0	0	0	a	a = 1 - accumulated spectrum resetting ⁽¹⁾ ;

⁽¹⁾ - the counter of spectrum accumulation period is reset and spectrum accumulation starts.

“Expert1” frame format - detecting unit to data display system

D7	D6	D5	D4	D3	D2	D1	D0	
0	1	0	1	0	1	0	1	Byte 55h - start-of-frame character
1	0	1	0	1	0	1	0	Byte AAh
0	1	1	1	0	0	0	0	D7...D4-protocol v1.3 character
address								D7...D0 - detecting unit's address
1	0	0	0	1	1	0	1	D7...D0-“Expert1” frame code
Byte								Spectrum block number BLOCK ⁽¹⁾
The structure of the following data is determined by spectrum block number BLOCK . (see tables below). The length of these data is always equal to 2069 bytes regardless of the BLOCK value.								
Control								arithmetical checksum with a carry

⁽¹⁾ - spectrum block number **BLOCK** defines the structure of the following data (see tables below). Given the value of **BLOCK**, equal 0, the corresponding full spectrum including 1024 channels and parameters of the obtained spectrum are transmitted. Given the value of **BLOCK**, equal to 9, the mode of spectrum accumulation is switched on/off.

Given **BLOCK = 0**

D7	D6	D5	D4	D3	D2	D1	D0	
Low byte								Pulse number in the channel 0
High byte								
Low byte								Pulse number in the channel 1
High byte								
...								...
Low byte								Pulse number in the channel 1022
High byte								
Low byte								Pulse number in the channel 1023
High byte								
Low byte								Obtained spectrum accumulation period, s.
High byte								
DER0 (Low byte)								DER, fixed point number, Least significant bit = 0.01 µSv/h
DER1								
DER2								
DER3 (High byte)								
Byte								Statistical error of measurement
0	D6	0	0	0	D2	D1	D0	D0,D1 - self-testing results of the detecting unit D0=1 - failure of the high sensitivity detector D1=1 - failure of the low sensitivity detector Reliable measurement result character D2=0 - result is true D2=1 - result is false * D6=1 - measurements from GM counter D6=0 - measurements from high sensitivity detector
2 ³	2 ²	2 ¹	2 ⁰	2 ⁻¹	2 ⁻²	2 ⁻³	2 ⁻⁴	Temperature, binary number S=0- above-zero temperature S=1- below-zero temperature D7=0- normal operation of heat sensor D7=1-failure of heat sensor
D7	X	X	X	S	2 ⁶	2 ⁵	2 ⁴	
Low byte								Pulses per second (integrated)
High byte								
Byte								Device model. 0xDD - BDBG-09S
Serial #_0 (Low byte)								Serial # of the detecting unit
Serial #_1								
Serial #_2								
Serial #_3 (High byte)								
Year								Firmware version
Month								
Release version								
Debug version								

Given **BLOCK = 9**

D7	D6	D5	D4	D3	D2	D1	D0	
1	0	0	0	1	1	0	0	Password (0x8C)
0	0	0	0	0	0	0	a	a = 1 - spectrum accumulation started ⁽¹⁾ ; a = 0 - failure to start spectrum accumulation;
2067 reservation bytes								

⁽¹⁾ - the counter of spectrum accumulation period is reset and spectrum accumulation starts again.

“Firmware” frame format - data display system to the detecting unit

D7	D6	D5	D4	D3	D2	D1	D0	
0	1	0	1	0	1	0	1	Byte 55h - start-of-frame character
1	0	1	0	1	0	1	0	Byte AAh
0	1	1	1	0	0	0	0	D7...D4- protocol v1.3 character
address								D7...D0- address of the detecting unit*
0	0	0	0	1	1	1	0	D7...D0- “Firmware” frame code
control								arithmetical checksum with a carry

“Firmware” frame format - data display system to the detecting unit

D7	D6	D5	D4	D3	D2	D1	D0	
0	1	0	1	0	1	0	1	Byte 55h - start-of-frame character
1	0	1	0	1	0	1	0	Byte AAh
0	1	1	1	0	0	0	0	D7...D4- protocol v1.3 character
address								D7...D0- address of the detecting unit*
0	0	0	0	1	1	1	0	D7...D0- “Firmware” frame code
Byte								Year
Byte								Month
Byte								Release version
Byte								Debug version
Byte								Device model. 0xCC - BDBG-09S
Byte								Reserved byte
Byte								Reserved byte
Byte								Reserved byte
Byte								Reserved byte
Byte								Reserved byte
Byte								Reserved byte
control								arithmetical checksum with a carry

B.4 Checksum for data communications using both v1.2 protocol, and v1.3 protocol is calculated according to Figure B.1.



Figure B.1 – Checksum calculation algorithm

B.5 CA6GS 932326-100 HIRSCHMANN interface connection serves to connect the data display system to the detecting unit. The interface connection contains the following signals:

Signal	Contact
(RS-485) Circuit A	1
(RS-485) Circuit B	2
Reserve	3
Supply voltage	4
Total	5
Shield	6
Shield	7

APPENDIX C

EXAMPLE OF MEASUREMENT RESULTS SAVED WITH THE HELP OF BDBG_S.EXE PROGRAM

Date	Time	DER	Max. stat. error	Tests results	Temperature
BDBG-09S/15S-09/15S-23 #1800020					
Response delay factor to broadcast query:1					
22.10.2018	11:29:00	0.07 μ Sv/h	19%	OK	
22.10.2018	11:29:06	0.07 μ Sv/h	15%	OK	23.8
22.10.2018	11:29:11	0.07 μ Sv/h	15%	OK	23.8
22.10.2018	11:29:16	0.07 μ Sv/h	15%	OK	23.8
22.10.2018	11:29:21	0.07 μ Sv/h	15%	OK	23.8
22.10.2018	11:29:25	0.08 μ Sv/h	15%	OK	23.8
22.10.2018	11:29:31	0.08 μ Sv/h	15%	OK	23.8
22.10.2018	11:29:36	0.07 μ Sv/h	15%	OK	23.8
22.10.2018	11:29:41	0.07 μ Sv/h	15%	OK	23.8
22.10.2018	11:29:46	0.07 μ Sv/h	15%	OK	23.8
22.10.2018	11:29:50	0.07 μ Sv/h	15%	OK	23.8
22.10.2018	11:29:56	0.07 μ Sv/h	15%	OK	23.8
22.10.2018	11:30:01	0.07 μ Sv/h	15%	OK	23.8
22.10.2018	11:30:05	0.07 μ Sv/h	15%	OK	23.8
22.10.2018	11:30:11	0.07 μ Sv/h	15%	OK	23.8
22.10.2018	11:30:16	0.07 μ Sv/h	15%	OK	23.8
22.10.2018	11:30:21	0.08 μ Sv/h	15%	OK	23.9
22.10.2018	11:30:26	0.07 μ Sv/h	15%	OK	23.8
22.10.2018	11:30:30	0.07 μ Sv/h	15%	OK	23.8
22.10.2018	11:30:36	0.07 μ Sv/h	15%	OK	23.8
22.10.2018	11:30:41	0.08 μ Sv/h	15%	OK	23.8
22.10.2018	11:30:46	0.08 μ Sv/h	15%	OK	23.8
22.10.2018	11:30:51	0.08 μ Sv/h	15%	OK	23.9
22.10.2018	11:30:55	0.08 μ Sv/h	15%	OK	23.8
22.10.2018	11:31:01	0.07 μ Sv/h	15%	OK	23.8
22.10.2018	11:31:06	0.07 μ Sv/h	15%	OK	23.8
22.10.2018	11:31:11	0.07 μ Sv/h	15%	OK	23.9
22.10.2018	11:31:16	0.07 μ Sv/h	15%	OK	23.8
22.10.2018	11:31:20	0.08 μ Sv/h	15%	OK	23.8
22.10.2018	11:31:26	0.07 μ Sv/h	15%	OK	23.8
22.10.2018	11:31:31	0.07 μ Sv/h	15%	OK	23.9
22.10.2018	11:31:35	0.07 μ Sv/h	15%	OK	23.9
22.10.2018	11:31:41	0.07 μ Sv/h	15%	OK	23.9
22.10.2018	11:31:46	0.07 μ Sv/h	15%	OK	23.8
22.10.2018	11:31:51	0.07 μ Sv/h	15%	OK	23.8
22.10.2018	11:31:56	0.07 μ Sv/h	15%	OK	23.8
22.10.2018	11:32:00	0.07 μ Sv/h	15%	OK	23.9
22.10.2018	11:32:06	0.07 μ Sv/h	15%	OK	23.9
22.10.2018	11:32:07	Data exchange stopped			

APPENDIX D

RECOMMENDATIONS ON CHOICE OF CABLE TO CONNECT BDBG-09S DETECTING UNIT TO DATA DISPLAY SYSTEM

To provide stable operation of the BDBG-09S detecting unit, and stable data communications between the BDBG-09S detecting unit and the data display system, you should use the cable with the following parameters:

- number of twisted pairs: not less than 2 (pairs not in use should be connected to minus of power supply from the side, where power is supplied to the cable);
- conductor cross section: from 0.22 to 0.75 mm²;
- wave impedance: from 100 to 120 Ohm;
- collective screen: yes;
- screen material: foil + copper plating (if an individual metal shielding cover is applied, it is possible to use a cable without additional screen of copper plating);
- outer diameter: from 6 to 12 mm (to preserve hermiticity of Hirschmann CA6LD connection);
- resistance to mechanical and climatic factors: depending on the use conditions;
- active resistance per unit length: depending on the cable length according to the formula (D.1) (it is determined based on the necessity to provide supply voltage of the detecting unit within tolerance limits at maximum useful current):

$$R_{rul} \leq \frac{U_{ci} - U_{min}}{2 \cdot l \cdot I_{max}}, \quad (D.1)$$

where

R_{rul} - active resistance per unit length, Ohm/m;

U_{ci} – voltage at cable input (not more than 13 V), V;

$U_{min} = 7$ V – minimum permissible supply voltage of the BDBG-09S detecting unit according to the OM;

$I_{max} = 0.03$ A – maximum useful current of the BDBG-09S detecting unit according to the OM;

l – cable length, m.

- unit-length capacitance: depending on the cable length according to the formula (D.2) (it is determined based on the necessity to provide build-up time at transferring one data bit less than ¼ of all transference time of this bit):

$$C_{ulc} \leq \frac{1}{S \cdot 4 \cdot R_{rul} \cdot l^2}, \quad (D.2)$$

where

C_{ulc} - unit-length capacitance, F/m;

R_{rul} - active resistance per unit length, Ohm/m;

S – data exchange rate, 19200 bps;

l – cable length, m.