BDBG-15S-09
DETECTING UNIT OF GAMMA RADIATION

Operating manual
BICT.418266.038-02 HE

CONTENTS

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-15S-09 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
SGDU - scintillation gamma radiation detecting unit

1 DESCRIPTION AND OPERATION

1.1 Purpose of use of the BDBG-15S-09 detecting unit

The BDBG-15S-09 detecting unit of gamma radiation (hereinafter called the detecting unit) is an intelligent device with full cycle of gamma radiation parameters processing and is designed to measure ambient dose equivalent rate $\dot{H}^*(10)$ of gamma radiation (hereinafter DER), as well as to return measurement results and amplitude spectrum of gamma radiation through the digital interface.

The detecting unit can be used in mobile robotic systems, pilotless aircrafts, computer-aided radiation monitoring systems.

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 measure ment	Standardized value according to the specifications
1 Measurement range of gamma radiation DER: a) built-in scintillation detector (high-sensitivity channel) b) built-in Geiger-Muller counter (low-sensitivity channel)	μSv/h	$0.01 – 10^6$ 0.01 – 50 $50 – 10^6$
2 Basic relative permissible error limit of gamma radiation DER measurement at ^{137}Cs calibration with confidence probability of 0.95, not more than	%	15

Name	Unit of measure ment	Standardized value according to the specifications
3 Scintillation detector sensitivity to Cs^{137} per 1 μSv/h, not less than	pulse/s	200
4 Energy range of registered gamma radiation	MeV	0.05 – 3.00
5 Energy dependence of measurement results of the detecting unit at gamma radiation DER measurement in the energy range of 0.05 MeV to 1.25 MeV	%	±25
6 Anisotropy of the detecting unit at gamma quanta incidence at angles from +60° 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
7 Operating supply voltage range of the detecting unit from external regulated power supply	V	7 - 32
8 Useful current of the detecting unit for overall range of measured gamma radiation DER, not more than	mA	30
9 Time of operating mode setting and measurement time of the detecting unit, not more than	min	1
10 Unstable readings of the detecting unit during 24-hour continuous operation, not more than	%	5
11 Complementary permissible error limit at measurement caused by ambient temperature change from - 30 °C to +50 °C	%	2 per each 10 °C deviation from 20 °C
12 Interface	-	RS-485 or UART (Rx, Tx-3.3 V)
13 Dimensions of the detecting unit, not more than	mm	103×57×29
14 Weight of the detecting unit without fastening elements, not more than	kg	0.25

1.2.2 Use environment

1.2.2.1 Concerning the resistance to climatic and other environmental factors, the detecting unit meets the requirements of ГОСТ 12997-84 standard for group C4 with addendums outlined below.

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

- air temperature from - 30 °C to +50 °C;
- relative humidity up to (95±3) % at 30 °C temperature and lower temperatures with humidity condensation;
- atmospheric pressure form 84 kPa to 106.7 kPa.

1.2.2.3 The detecting unit is resistant to sinusoidal vibrations according to group N1 in compliance with ГОСТ 12997-84 standard.

1.2.2.4 The detecting unit is resistant 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/s^2.

1.2.2.5 The detecting unit in 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/s^2, shock pulse duration of 16 ms, and number of shocks 1000±10.

1.2.2.6 The detecting unit is resistant to the influence of magnetostatic fields or alternating (50 Hz±1 Hz) magnetic fields of 400 A/m voltage.

1.2.2.7 The detecting unit provides a function of the built-in detectors performance control with generation of check information.

1.2.3 Ingress protection rating of the detecting unit is IP65 according to DSTU EN 60529:2014.

1.2.4 Reliability factors

1.2.4.1 Mean time to failure of the detecting unit - not less than 10000 hrs.

1.2.4.2 First overhaul period of the detecting unit – not less than 10000 hrs.

1.2.4.3 Mean time to restore normal operation of the detecting unit should be no more than 2 hrs excluding time for verification.

1.2.4.4 Average service life of the detecting unit- not less than 10 years.

1.2.5 Information about precious materials content

The detecting unit contains no precious materials.

1.3 Delivery kit of the detecting unit

The delivery kit of the detecting unit consists of units and maintenance documentation, given in Table 1.2

Table 1.2 - Delivery kit of the detecting unit

Type	Name	Q-ty	Note
BICT.418266.038-02	BDBG-15S-09 detecting unit of gamma radiation	1	
BICT.418266.038-02 HE	Operating manual	1	
BICT.412915.029	Package	1	
HR10A-7P-4S(73)	Socket with plug	1	For connecting cable

1.4 Design and operation principle of the detecting unit

1.4.1 Design description

1.4.1 The detecting unit is structurally designed as a rectangular parallelepiped with side bevels and rounded corners in metal dust- and damp-proof housing (Figure 1).

The BDBG-15S-09 unit consists of a body, which is formed by the basis (1) and the cover (2) as well as other components located inside it. The main node in the BDBG-15S-09 unit is a printed circuit board, where Geiger-Muller counter and gamma radiation scintielectronic detector are located on one side, while on the other side - other components of the scheme. The base (1) contains metrological marks - symbols "+" denoting the geometric centers of the counter and the detector. On the right side of the base, there is a fixed connector (plug) HR10A-7R-4P (3), which is used for connection with an external cable system with outlet HR10A-7P-4S.

Rubber gaskets and a dust cup are used to protect the detecting unit's housing and connector against dust and moisture.

The components of the body, the cover and base, as well as the printed circuit board are secured with each other by four countersunk screws. A dust cup is used to protect the connector when stored (4).

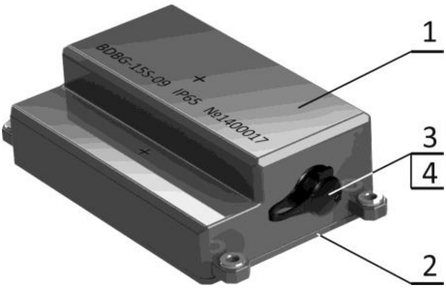

Figure 1

1.4.2 Operation principle of the detecting unit

The detecting unit consists of an ARM-microcontroller, a high sensitivity detector, a low sensitivity detector, a supply voltage former, a heat sensor and RS-485 or UART (Rx, Tx – 3.3 V) interface node.

The scintielectronic gamma detector based on CsJ(Tl) scintillator of 9 cm^3 volume and semiconductor photomultiplier are used as the high sensitivity detector.

The energy-compensated Geiger-Mueller counter (GM counter) is used as the low sensitivity detector.

The microcontroller performs a full cycle of processing of all gamma radiation parameters and gives a ready gamma radiation DER result and an amplitude spectrum through the interface node by the protocol, which is provided in Appendix A.

Gamma radiation DER for high sensitivity detector is calculated on the basis of transformation of the amplitude spectrum of gamma radiation into the dose rate. There are 1024 amplitude spectrum channels.

1.5 Labeling and sealing

1.5.1 On top of the housing base of the detecting unit there are the name of the device (design letters), ingress protection rating, as well as the manufacture date and serial number according to the numbering system of the producer enterprise.

1.5.2 Sealing is performed by the producer enterprise by attaching special film seals onto the side surfaces of the unit in the joints of base and cover.

1.5.3 Removal of seals and repeated sealing is performed by the producer enterprise after repair and verification of the detecting unit.

1.6 Packing

1.6.1 The detecting unit kit is delivered in a cardboard box.

1.6.2 The packing box with the detecting unit kit is placed into a plastic sachet, which is welded after packing performed.

2 PROPER USE

2.1 Operating limitations

2.1.1 The detecting unit is a complex electronic 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 hereof.

2.2 Preparation of the detecting unit for operation and its use

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 verification of the detecting units, if operating with ionizing radiation sources, the radiation safety requirements stated in the valid regulatory documents НРБУ-97 and ОСПУ-2005 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 Make records about re-activation and putting the detecting unit in operation.

2.2.3 Preparation to operation

2.2.3.1 Make a cable for connecting the detecting unit with external system under the scheme given in Appendix B.

2.2.3.2 Securely fasten the detecting unit in the place of its operational use.

2.2.3.3 Connect the detecting unit to the external system with the connecting cable and ensure cable fixation in the operating position.

2.2.3.4 Supply power to the detecting unit and check how it communicates with the external system according to the protocol outlined in Appendix A.

2.2.4 Gamma radiation DER measurement

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 form the data display system

Reliable (within the certified error) information on the measured level of gamma radiation DER appears at the output of the detecting unit no later than in 1 min after measurement start given the levels of gamma radiation DER close to the natural background value.

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		long-term storage	
	everyday use	periodical use (annually)		
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
Verification	-	+	+	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 housing surface and component parts of the detecting unit is performed if required.

Deactivate the component parts surface 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. One of the following decontamination solutions of compound 8, 9 or 10 (Appendix 3 of ГОСТ 29075-91 standard) 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.

Note

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 for ionizing radiation measuring instruments established at the object of use.

3.1.3.2 Delivery kit completeness check

Check if the delivery kit of the detecting unit is complete according to 1.2. 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.

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 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 housing.

3.1.3.4 Refreshment of damaged painting

Refresh damaged painting of the detecting unit housing with the help of the ЕП-140 enamel (light gray). 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 Verification of the device

3.1.3.5.1 Devices should be verified during operation (periodic verification at least once a year) and after repair according to verification methods, which are determined by regulations of the central executive body, which ensures the formation of state policy in the field of metrology and metrological activities, or by national standards.

3.1.3.5.2 Presentation of verification results

Positive results of periodic or after-repair verification are recorded in the table of Appendix E or by issuing a verification certificate for the legislatively regulated measurement equipment.

If the device is acknowledged unfit for use after its verification, it gets the certificate of inadequacy.

4 CERTIFICATE OF ACCEPTANCE

The BDBG-15S-09 detecting unit of gamma radiation of ВІСТ.418266.038-02 type with ______________________ serial number meets the ТУ У 26.5-22362867-035 standard technical requirements, is verified and accepted for use.

Date of manufacture _________________________

Quality Control Department:

Stamp here

____

(signature)

5 PACKING CERTIFICATE

The BDBG-15S-09 detecting unit of gamma radiation of ВІСТ.418266.038-02 type with ____________________ serial number is packed by the PE “SPPE “Sparing-Vist Center” in accordance with the ТУ У 26.5-22362867-035 standard technical requirements.

Date of packing ____________________

Stamp here

Packed by ____________________ (signature)

Packed product accepted by ___________________ (signature)

6 WARRANTY

6.1 The manufacturer warrants that the detecting unit meets the technical requirements, provided that the user observes the operating, shipping and storage terms described in the BICT.418266.038-02 HE operating manual.

6.2 The warranty period of the detecting unit shall terminate and be of no further effect in 24 months after the date of putting it into operation or after the warranty period of storage terminates.

6.3 The warranty period of storage of the detecting unit is 6 months after the manufacture date.

6.4 Warranty and post-warranty repair shall be done only by the manufacturer.

6.5 In case of defects elimination (according to the claim), the warranty period is prolonged for the time when the detecting unit has not been used because of the detected defects.

6.6 After the warranty period terminates, the repair of the detecting unit is performed under separate contracts.

6.7 In case of mechanical damage or removal of seals, the repair is done at the user’s expense.

7 REPAIR

7.1 In case of failure or troubles during the warranty period of the detecting unit or after its completion, the user should draw up a statement about the necessity of repair, and deliver the dosimeter to the manufacturer at the address:

PE "SPPE "Sparing-Vist Center"
79026, Ukraine, Lviv, 33 Volodymyr Velyky
Tel.: (+38032) 242 15 15, fax: (+38032) 242 20 15

7.2 All claims shall be registered in the Table 7.1

Table 7.1

Date of failure	Claim summary	Action taken	Note

7.3 Optionally the manufacturer can provide assistance for periodic verification of the detecting unit.

8 STORAGE AND PUTTING IN PROLONGED STORAGE

8.1 Before putting in operation, the detecting unit should be stored in the packing of the producer enterprise in storehouses under 1 (Л) conditions in compliance with ГОСТ 15150-69 standard. The storage period should not exceed one year. Shipping time is included in the storage period of the device.

8.2 If necessary to prolong the storage period, or if the storage conditions are stricter than stated in 8.1, the user should temporarily close the detecting unit down according to ГОСТ 9.014-78. Temporary closing-down according to the ВЗ-10 protection option is recommended. Silicagel, used during temporary closing-down, according to ГОСТ 3956-76 is recommended to be placed into fabric bags under ГОСТ 3956-76 or paper packages under ТУ 13-7308001-069-84. It is allowed to perform not more than two temporary closing-downs. Before putting in prolonged storage or repeated use, silicagel should be dried in compliance with ГОСТ 3956-76. Total time of the detecting unit storage with the account of the repeated closing-down should not exceed 10 years.

8.3 Additional information about detecting unit storage shall be recorded in Appendix B.

9 SHIPPING

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

9.2 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.

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

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

10 DISPOSAL

Disposal of the detecting unit shall be carried out in accordance with DSTU 4462.3.01:2006, DSTU 4462.3.02:2006, Laws of Ukraine "On Environmental Protection" and "On Waste": 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

COMMUNICATIONS PROTOCOL OF THE DATA DISPLAY SYSTEM AND THE DETECTING UNIT

A.1 Data frames exchange between the detecting unit and the data display system is done via the RS-485 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.

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

A.3 This detecting unit supports data communications protocol version with a 4 bit address field (v1.2), and version - with an 8-bit address field (v1.3).

A.3.1 Communications protocol with 4-bit address field (v1.2).

To receive a measured DER value 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 a measured value of temperature from the detecting unit (with integrated heat sensor), 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 heat sensor will be given.

To receive a 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 detecting unit’s address the data display system should transmit **"Address change**" frame to the detecting unit. No later than in 5 ms to 500 ms the detecting unit will respond with the **"Confirmation"** frame. *Attention!* The field of the address entry of the **"Confirmation"** frame will contain the previous address value. In case of normal reception, the detecting unit records the new address value in the nonvolatile memory and not later than in 5 seconds starts responding to the frames with the new address.

To simplify the work with several detecting units (up to 15) that are simultaneously connected to the data display system via one RS-485 interface, broadcast address 0Fh is used. The use of broadcast addresses is allowed only in the **“DER query”**, **“Temperature query”** and **“Serial # query”** frames. All detecting units respond to the frame with such address (broadcast query).

When responding to the broadcast query each detecting unit does it with delay T, which is calculated by the formula:

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

where Adr – detecting unit’s address.

Broadcast query allows you to conveniently implement auto-detection of the detecting units that are connected/disconnected to the data display system during system operation.

“DER query” 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	0	0	0	A3	A2	A1	A0	D7...D4 – **“DER query”** frame code D3...D0 – detecting unit’s address*

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

“Current DER” 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	0	0	1	A3	A2	A1	A0	D7...D4 - **“Current DER”** frame code D3...D0 - detecting unit’s address
DER0 (low byte)								DER, fixed point number, Least significant bit(LSB) = 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 true D2=1 - result is false* D7=0 – DER LSB = 0.01 μSv/h D7=1 – DER LSB = 0.1 μSv/h
control								arithmetical checksum with a carry

- if the statistical error of measurement exceeds maximum permissible error of measurement the result is deemed to be false.

“Temperature query” 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
1	0	0	0	A3	A2	A1	A0	D7...D4 - **“Temperature query”** frame code D3...D0 - detecting unit’s address*

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

"Current temperature" 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
1	0	0	0	A3	A2	A1	A0	D7...D4 - "**Temperature**" frame code D3...D0 - detecting unit's address
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	
control								arithmetical checksum with a carry

"Serial # query" 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	0	1	A3	A2	A1	A0	D7...D4 - "**Serial # query**" frame code D3...D0 - detecting unit's address*

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

"Serial #" 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	0	1	A3	A2	A1	A0	D7...D4 - -"**Serial #1**" frame code D3...D0 - detecting unit's address
Serial #_0 (low byte								Serial # of the detecting unit
Serial #_1								
Serial #_2								
Serial #_3 (high byte)								
control								arithmetical checksum with a carry

“Address change” 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	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 - 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
1/0	0	1	1	A3	A2	A1	A0	D7 = 0 - error D7 = 1 – failure D6...D4 – **“Confirmation”** frame code D3...D0 – OLD address of the detecting unit

A.3.2 Communications protocol with an 8-bit address field (v1.3).

To receive a measured DER value from the detecting unit, the data display system should transmit the **“DER query1”** 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 a measured value of temperature from the detecting unit (with integrated heat sensor), the data display system should transmit the **“Temperature query1”** 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 heat sensor will be given.

To receive a serial number of the detecting unit and coefficient of response delay to the broadcast query, the data display system should transmit the **“Serial # query_1”** 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 coefficient of response delay to the broadcast query.

To change the detecting unit’s address the data display system should transmit **"Address change1**" frame to the detecting unit. No later than in 5 ms to 500 ms the detecting unit will respond with the **"Confirmation1"** frame. *Attention!* The field of the address entry of the **"Confirmation1"** frame will contain the previous address value. In case of normal reception, the detecting unit records the new address value in the nonvolatile memory and not later than in 5 seconds starts responding to the frames with the new address.

To simplify the work with several detecting units (up to 255) that are simultaneously connected to the data display system via one RS-485 interface, broadcast address 0FFh is used. The use of broadcast addresses is allowed only in the **“DER query1”**, **“Temperature quer1”** and **“Serial # query_1”** frames. All detecting units respond to the frame with such address (broadcasts query).

When responding to the broadcast query each detecting unit does it with delay T, which is calculated by the formula:

$$T = 5\ \text{mS} + t \times 8\ \text{mS}\,, \qquad \text{(A.2)}$$

if the response delay coefficient to the broadcast query t falls within the range of 0 to 15;

or by the formula:

$$T = (5\ mS + t \times 8\ mS) + 125\ mS\ , \qquad (A.3)$$

if the response delay coefficient to the broadcast query t falls within the range of 16 to 255.

Broadcast query allows you to conveniently implement auto-detection of the detecting units that are connected/disconnected to the data display system during system operation.

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

Frame **«Expert».**

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

1. Frame **«Expert» BLOCK = 9 in BDBG** (query for a new spectrum accumulation start)
2. Frame **«Expert» BLOCK = 9 in BDBG** (reply about accumulation start)
3. Frame **«Expert» BLOCK = 0 in BDBG** (query 0 ÷ 127 spectrum channels)
4. Frame **«Expert» BLOCK = 0 from BDBG** (reply 0 ÷ 127 spectrum channels)
5. Frame **«Expert» BLOCK = 1 in BDBG** (query 128 ÷ 255 spectrum channels)
6. Frame **«Expert» BLOCK = 1 from BDBG** (reply 128 ÷ 255 spectrum channels)
7. Frame **«Expert» BLOCK = 2 in BDBG** (query 256 ÷ 383 spectrum channels)
8. Frame **«Expert» BLOCK = 2 from BDBG** (reply 256 ÷ 383 spectrum channels)
9. Frame **«Expert» BLOCK = 3 in BDBG** (query 384 ÷ 511 spectrum channels)
10. Frame **«Expert» BLOCK = 3 from BDBG** (reply 384 ÷ 511 spectrum channels)
11. Frame **«Expert» BLOCK = 4 in BDBG** (query 512 ÷ 639 spectrum channels)
12. Frame **«Expert» BLOCK = 4 from BDBG** (reply 512 ÷ 639 spectrum channels)
13. Frame **«Expert» BLOCK = 5 in BDBG** (query 640 ÷ 767 spectrum channels)
14. Frame **«Expert» BLOCK = 5 from BDBG** (reply 640 ÷ 767 spectrum channels)
15. Frame **«Expert» BLOCK = 6 in BDBG** (query 768 ÷ 895 spectrum channels)

16. Frame **«Expert» BLOCK = 6 from BDBG** (reply 768÷ 895 spectrum channels)
17. Frame **«Expert» BLOCK = 7 in BDBG** (query 896 ÷ 1023 spectrum channels)
18. Frame **«Expert» BLOCK = 7 from BDBG** (reply 896 ÷ 1023 spectrum channels)
19. Frame **«Expert» BLOCK = 8 in BDBG** (query for obtained spectrum parameters)
20. Frame **«Expert» BLOCK = 8 from BDBG** (reply with parameters of obtained spectrum, end of accumulated spectrum acceptance within time, indicated **BLOCK = 8**).

To receive the following fragments of accumulated spectrum it is necessary to repeat operations from 3 to 20 inclusive, but so that a new query for fragment of the accumulated spectrum occurred not more 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**.

“DER query1” 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	0	0	0	D7…D0- **“DER 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 – 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*
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 true D2=1 - result is false* D7=0 - DER LSB = 0.01 µSv/h D7=1 - DER LSB = 0.1 µSv/h
control								arithmetical checksum with a carry

* - if the statistical error of measurement exceeds maximum permissible error of measurement the result is deemed to be false.

"Intensity query for 100 msec" 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 100 msec" 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.

"Temperature query1" 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	1	0	0	0	D7…D0-"**Temperature query1**" 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 –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	1	0	0	0	D7…D0- "**Temperature query1**" 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 heat sensor D7=1-failure of heat sensor
control								arithmetical checksum with a carry

"Serial # query1" 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	1	D7…D0-"**Serial # query1**" 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 –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 address
0	0	0	0	0	1	0	1	D7…D0-"**Serial #_1**" frame code
Serial #_0 (low byte)								Serial # of the detecting unit
Serial #_1								
Serial #_2								
Serial #_3 (high byte)								
current constant								D7…D0 – current coefficient of response delay to broadcast query
control								arithmetical checksum with a carry

"Address change1" 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
current address								D7...D0 – detecting unit's address
0	0	0	0	0	1	1	0	D7…D0- **"Address change1" frame code**
new address								D7…D0-new address of the detecting unit
new constant								D7…D0- new coefficient of response delay to broadcast query
control								arithmetical checksum with a carry

"Confirmation 1" 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
OLD address								D7…D0 - OLD address of the detecting unit
0	0	0	0	1	0	0	0	D7…D0-**"Temperature query1"** frame code
1/0	0	0	0	0	0	1	1	D7 = 0 - normal D7 = 1 - error D6...D0 - **"Confirmation1"** frame code
control								arithmetical checksum with a carry

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

0x0B – Expert (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
0	0	0	0	1	0	1	1	D7…D0–**“Expert”** 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 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.

Given **BLOCK = 0..8** – 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.

“Expert” 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
0	0	0	0	1	1	0	1	D7…D0–**“Expert”** 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 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.

Given **BLOCK = 0..7**

D7	D6	D5	D4	D3	D2	D1	D0	
Low byte								Pulse number in the channel 0+(BLOCK x 128)
High byte								
Low byte								Pulse number in the channel 1+(BLOCK x 128)
High byte								
…								…
Low byte								Pulse number in the channel 126+(BLOCK x 128)
High byte								
Low byte								Pulse number in the channel 127+(BLOCK x 128)
High byte								

Given **BLOCK = 8**

D7	D6	D5	D4	D3	D2	D1	D0	
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. 0xEE - BDBG-15S
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								
239 reservation bytes								

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;
254 reservation bytes								

[1] – the counter of spectrum accumulation period is reset and spectrum accumulation starts again.

"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 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'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								

Given **BLOCK = 0** continuation

D7	D6	D5	D4	D3	D2	D1	D0	
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-15S-09
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**

<table>
<tr><td>D7</td><td>D6</td><td>D5</td><td>D4</td><td>D3</td><td>D2</td><td>D1</td><td>D0</td><td></td></tr>
<tr><td>1</td><td>0</td><td>0</td><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td><td>Password (0x8C)</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>a</td><td>a = 1 – spectrum accumulation started[1];
a = 0 – failure to start spectrum accumulation;</td></tr>
<tr><td colspan="8">2067 reservation bytes</td><td></td></tr>
</table>

[1] – the counter of spectrum accumulation period is reset and spectrum accumulation starts again.

A.4 Checksum for data communications using v1.3 protocol is calculated according to Figure A.1.

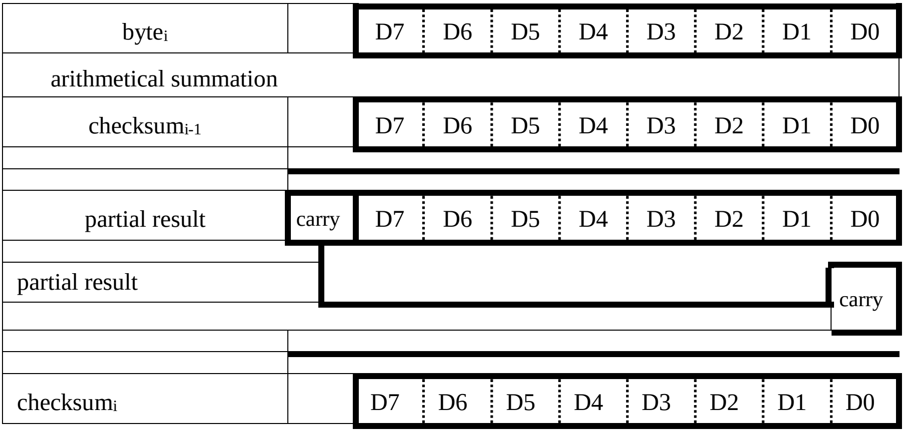

Figure A.1 - Checksum calculation algorithm

APPENDIX B

HR10A-7R-4P(73) interface connection serves to connect the main system to the detecting unit. The connection contains the following signals:

Signal	Contact
Circuit A (RS-485) or Rx (3.3 V)	1
Circuit B (RS-485) or Tx (3.3 V)	2
Supply voltage (7 V-30 V)	3
Total	4

APPENDIX C

STORAGE

Date		Storage conditions	Position, name and signature of the responsible official
of placing in storage	of removing from storage		

APPENDIX D

TROUBLE RECORD DURING USE

Date and time of trouble Operating mode	Type (external manifestation) of trouble	Cause of trouble, number of operation hours of the failed element	Action taken and claim note	Position, name and signature of the person responsible for solving the problem	Note

APPENDIX E

PERIODIC VERIFICATION OF KEY SPECIFICATIONS

Verified specification		Verification date							
Name	Value according to the technical requirements	20		20		20		20	
		Actual value	Measured by (position, signature)	Actual value	Measured by (position, signature)	Actual value	Measured by (position, signature)	Actual value	Measured by (position, signature)
Basic relative error limit of at gamma radiation DER	15 %								

APPENDIX F

REPAIR

Name and type of the component part	Reason for repair	Date		Name of the repair organi-zation	Number of hours worked before repair	Type of repair	Name of repair	Position, name and signature of the responsible official	
		of arriving for repair	of repair completion					who performed the repair	who accepted after repair

APPENDIX G

VERIFICATION AND INSPECTION RESULTS

Date	Type of verification or inspection	Result of verification or inspection	Position, name and signature of the person responsible for verification	Note