PORTABLE RADIATION MONITOR
PM1402M
OPERATING MANUAL

CONTENTS

1 INTRODUCTION

The PM 1402M portable radiation monitor is designed for the following purposes:

- search for (detection of and locating) radioactive materials from their gamma and X-ray (subsequently referred to as photon), neutron, alpha and beta radiation;
- measurement of the surface contamination by alpha- and beta-active substances;
- measurement of the dose equivalent rate (DER) of photon radiation $\dot{H}$*(10);
- accumulation, storage and transmission of scintillation gamma-spectra to a personal computer (PC);
- measurement of the DER of neutron radiation.

Applications of the monitor with different detectors connected

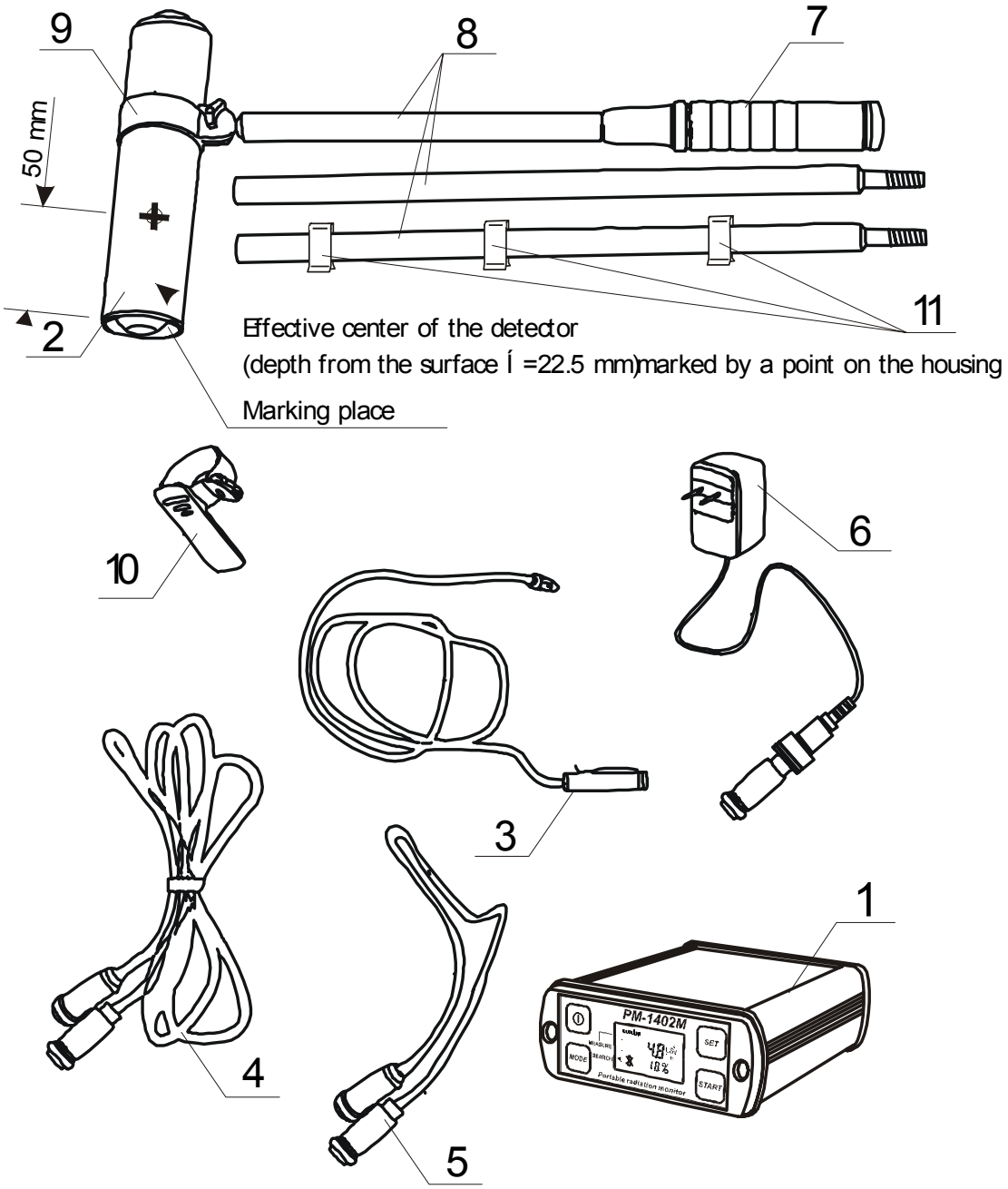
Gamma radiation detector BD-01	• Search for photon radiation sources; • Measurement of the DER of collimated photon radiation
Gamma radiation detector BD-02	• Accumulation, storage and transmission of scintillation gamma-spectra to PC; • Search for photon radiation sources; • Measurement of the DER of collimated photon radiation
Gamma radiation detector BD-03	• Measurement of the DER of photon radiation; • Search for photon radiation sources
Gamma radiation detector BD-03-01	• Measurement of the DER of photon radiation
Neutron radiation detector BD-04	• Measurement of the DER of neutron radiation; • Search for neutron radiation sources
Alpha and beta radiation detector BD-05	• Measurement of the flux of alpha and beta radiation; • Search for alpha and beta radiation sources

Note - Because POLIMASTER is constantly improving and upgrading the products, design and software of the monitor can be changed without further notice.

2 DELIVERY KIT

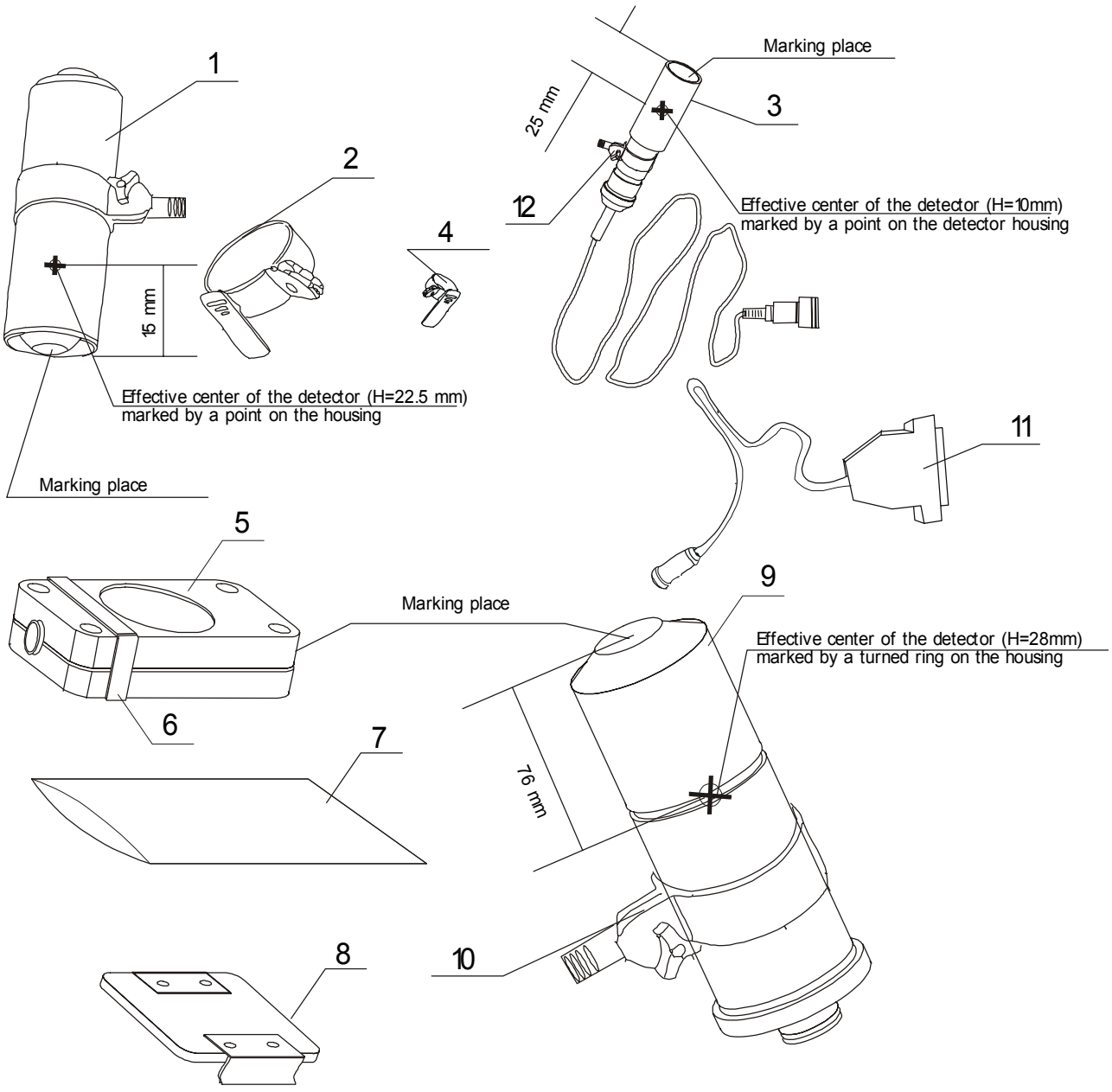
The mandatory and optional components of the monitor are listed below (see also Figs. 1, 2, 3 and 4).

Item	Quantity	Note
The PM 1402M portable radiation monitor including:		Quantity and types of detectors and accessories are specified in the order form according to the Appendix B
Mandatory components		
Processing unit	1	
Detector	1	One detector or a set of detectors
Operating manual	1	
Case	1	
Package	1	
Options		
Gamma radiation detector BD-01	1	
Gamma radiation detector BD-02	1	
Gamma radiation detector BD-03	1	
Gamma radiation detector BD-03-01	1	
Neutron radiation detector BD-04	1	
Alpha and beta radiation detector BD-05	1	
Vibration alarm device	1	
Charger	1	
Accessories including:		
Bracket N 1	1	Complete with BD-01 or BD-02
Bracket N 2	1	Complete with BD-01 or BD-02
Bracket N 3	1	Complete with BD-03 or BD-03-01
Bracket N 4	1	Complete with BD-03
Bracket N 5	1	Complete with BD-04
Bracket N 6	1	Complete with BD-05
Extension tube N 1	1	
Extension tube N 2	2	
Handle	1	
Cable N 1	1	
Cable N 2	1	
Cable N 3	1	Complete with BD-02
Clamp	6	
Shielding cover	5	Complete with BD-05
Protective screen	1	Complete with BD-05
Application program (diskette)	1	Complete with BD-02



1- Processing unit,
2 - Gamma detector BD-01,
3 - Vibration alarm device,
4 - Cable N 1,
5 - Cable N 2,
6 - Charger,
7 - Handle,
8 - Extension tubes N1 and N2,
9 - Bracket N1 to attach detectors BD-01 and BD-02 to an extension tube,
10 - Bracket N 2 to attach detectors BD-01 and BD-02 to a belt,
11 - Clamp to hold the cable to an extension tube.

Fig. 1



1- Gamma detector BD-02,
2- Bracket N 2 to attach detectors BD-01 and BD-02 to a belt,
3 - Gamma detector BD-03,
4 - Bracket N 4 to attach detector BD-03 to a belt,
5 - Alpha and beta detector BD-05,
6 - Bracket N 6 to attach detector BD-05 to an extension tube,
7 - Shielding cover,
8 - Protective screen,
9 - Neutron detector BD-04,
10 - Bracket N 5 to attach detector BD-04 to an extension tube,
11 - Cable N 3 to connect the processing unit to PC,
12 - Bracket N 3 to attach detector BD-03 to an extension tube.

Fig. 2

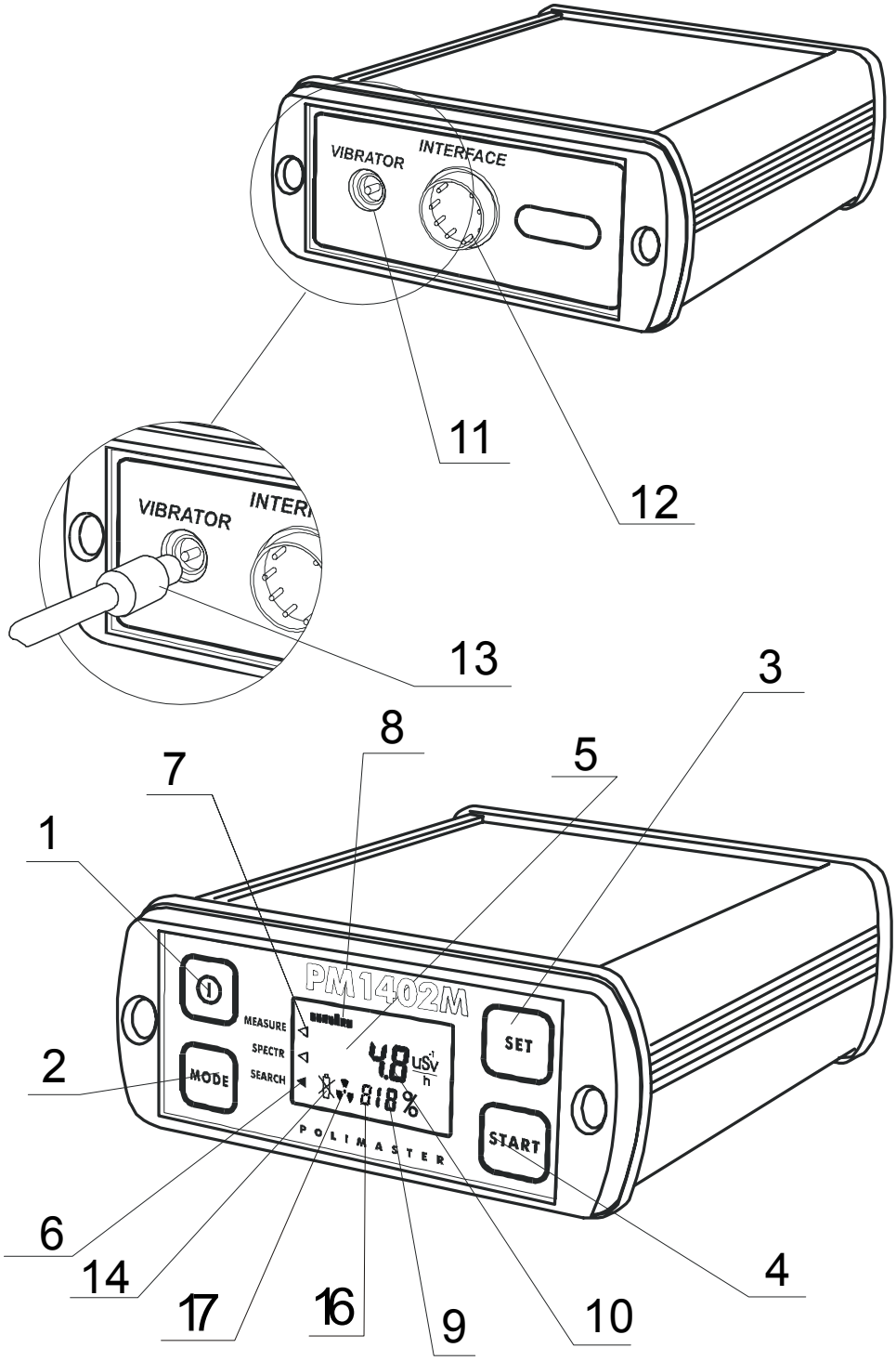
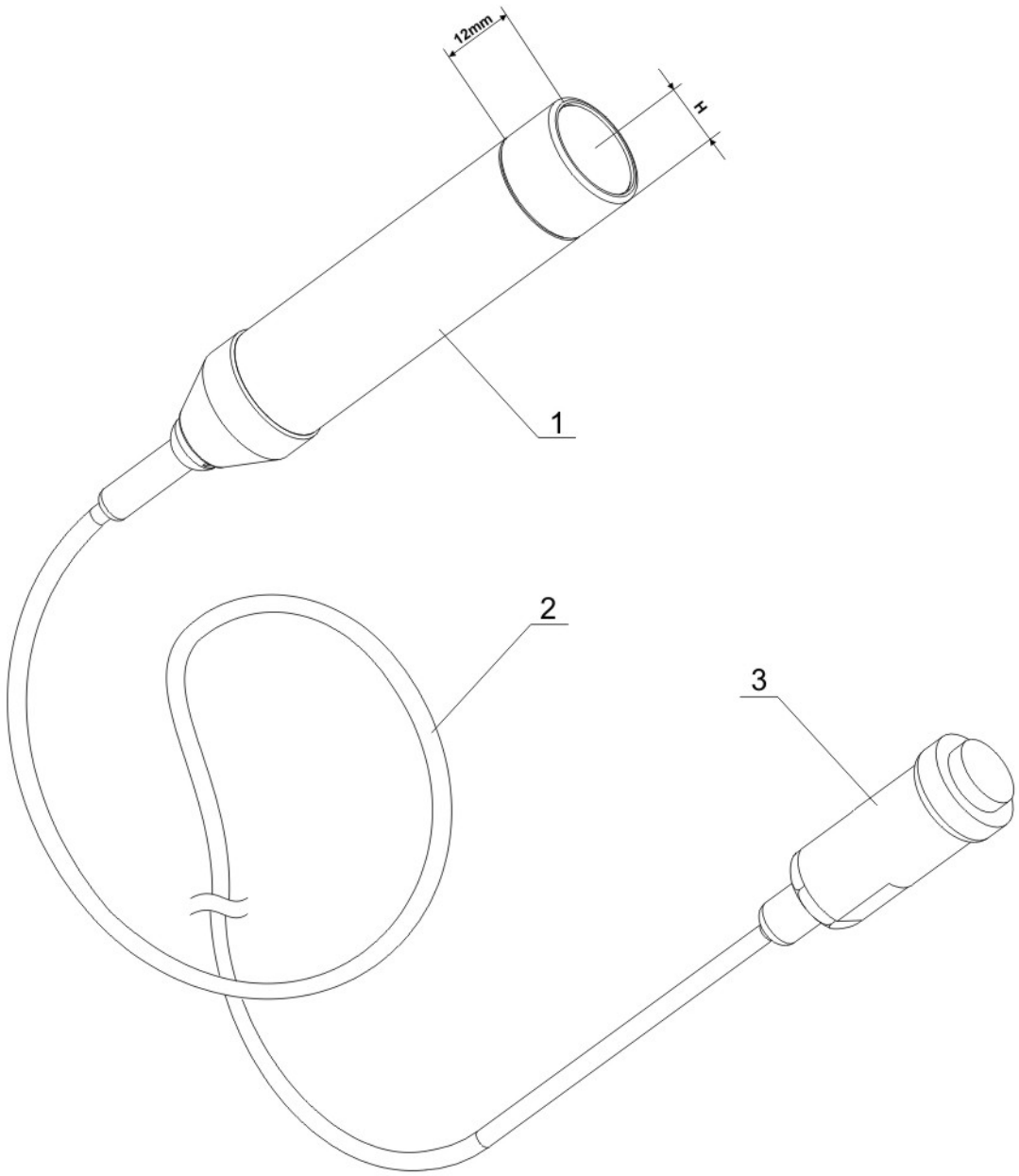


Fig.3. Processing unit



1 - Gamma detector BD-03-01 Effective center of the detector (H=10 мм). Marked by a turned ring by the housing
2 Connecting cable (L=30 м).
3 Jack of the detector

Fig.4

3 SPECIFICATIONS

3.1 The monitor with the gamma detector BD-01

Sensitivity ♦, at least	**200 cps/(μSv/h)**
Count rate indication	**1 - 14000 cps**
Measurement range of the dose equivalent rate ♦ (DER) $\dot{H}$ *(10)	**0.05 - 40 μSv/h**
Energy range	**0.06 - 1.5 MeV**
Energy response plot should not differ from a typical plot (Appendix A, Fig. A.1) more than	**± 20 %**
DER ♦ threshold range (step of 0.01 μSv/h)	**0.1 - 40 μSv/h**
Accuracy of DER measurement ♦ ($\dot{H}$ is the dose rate, μSv/h; A =1 μSv/h)	**± (20 + A/$\dot{H}$) %**
Additional relative error of DER♦ measurements due to temperature variations	**± 20 %**
Maximum allowable DER value within 5 minutes	**4 mSv/h**
Count time: • in *background mode* • in *search mode*	 **30 s** **2 s**
Measurement time of DER higher than 0.07 μSv/h at ± 15 % variation coefficient and 0.95 confidence level, no more than	**30 s**
Battery lifetime (on a full battery charge) at DER up to 0.3 μSv/h and temperature from 0 to 50 ^{0}C no less than • without audio and vibration alarms • with audio alarm • with vibration alarm (lifetime is halved at temperature from 0 to -30 ^{0}C)	 **100 h** **25 h** **10 h**
Weight of BD-01	**300 g**
Dimensions of BD-01	**∅ 45 x 188 mm**

♦ at collimated ^{137}Cs radiation (662 keV).

3.2 The monitor with the gamma detector BD-02

Sensitivity ♦, at least	**30 cps/(μSv/h)**
Count rate indication	**1 - 8 000 cps**
Measurement range of the dose equivalent rate ♦ (DER) $\dot{H}$ *(10)	**0.1 - 200 μSv/h**
Energy range	**0.06 - 1.5 MeV**
Energy response plot should not differ from a typical plot (Appendix A, Fig.A.2) more than	**± 20 %**
DER ♦ threshold range (step is the least significant digit)	**0.1 - 200 μSv/h**
Accuracy of DER measurement ♦ ($\dot{H}$ is the dose rate, μSv/h; A =2 μSv/h)	**± (20 + A/$\dot{H}$) %**
Additional relative error of DER♦ measurements due to temperature variations	**+ 20 ÷ - 30 %**
Maximum allowable DER value within 5 minutes	**20 mSv/h**
Count time: • in *background mode* • in *search mode*	 **200 s** **2 s**
Measurement time of DER higher than 0.1 μSv/h at ± 15 % variation coefficient and 0.95 confidence level, no more than	**100 s**
Battery lifetime (on a full battery charge) at DER up to 0.3 μSv/h and temperature from 0 to 50 ^{0}C no less than • without audio and vibration alarms • with audio alarm • with vibration alarm (lifetime is halved at temperature from 0 to -30 ^{0}C)	 **100 h** **25 h** **10 h**
Energy resolution for ^{137}Cs (0.662 MeV), no more than	**10 %**
Number of spectra stored in non-volatile memory, at least	**110**
Number of channels	**512**
Capacity of a channel	**65 535 counts**
Weight of BD-02	**280 g**
Dimensions of BD-02	**∅ 45 x 131 mm**

♦ at collimated ^{137}Cs radiation (662 keV).

3.3 The monitor with the gamma detector BD-03

Measurement range of the dose equivalent rate (DER) $\dot{H}$ *(10)	**0.15 - 10^5 μSv/h**
Energy range	**0.02 - 1.5 MeV**
Sensitivity ♦, at least	**0.15 cps/(μSv/h)**
Count rate indication	**1 – 28000 cps**
Energy response plot should not differ from a typical plot (appendix A, Fig.A.3) more than: - in the energy range from 0.035 to 1.5 MeV - in the energy range from 0.02 to 0.035 MeV	 **± 25 %** **± 20 %**
DER threshold range (step is the least significant digit)	**0.15 - 10^5 μSv/h**
Accuracy of DER measurement ($\dot{H}$ is the dose rate, μSv/h; A =3 μSv/h)	**± (20 + A/$\dot{H}$) %**
Additional relative error of DER♦ measurements due to temperature variations	**± 20%**
Maximum allowable DER value within 5 minutes	**10 Sv/h**
Count time: • in *background mode* • in *search mode*	 **600 s** **2 s**
Measurement time of DER higher than 0.15 μSv/h at the ± 25 % variation coefficient and the 0.95 confidence level, no more than	**600 s**
Battery lifetime (on a full battery charge) at DER up to 0.3 μSv/h and temperature from 0 to 50 ^{0}C no less than • without audio and vibration alarms • with audio alarms • with vibration alarms (lifetime is halved at temperature from 0 to -30 ^{0}C)	 **100 h** **25 h** **10 h**
Protection degree of the instrument's case	**IP67 according to EN60529/IEC529**
Length of a connecting cable no less then	2 m
Weight of BD-03	**100 g**
Dimensions of BD-03	**∅ 21 x 113.5 mm**

♦ at collimated ^{137}Cs radiation (662 keV).

3.4 The monitor with the gamma detector BD-03-01

Measurement range of the dose equivalent rate (DER) $\dot{H}$ *(10)	**10 – 10^7 μSv/h**
Energy range	**0,08 - 1,5 MeV**
Energy response in the energy range from 0,08-to 1,5 MeV relative to 0.662 MeV (^{137}Cs), no more than	**± 25 %**
DER threshold range (step is the least significant digit)	**10 – 10^7 μSv/h**
Accuracy of DER measurement [$\dot{H}$ is the dose rate, μSv/h; A =100 μSv/h, B - $2 \cdot 10^{-6}$ $(\mu Sv/h)^{-1}$]	**± (20 + A/$\dot{H}$ + B·$\dot{H}$) %**
Additional relative error of DER♦ measurements due to temperature variations	**± 20%**
Maximum allowable DER value within 5 minutes	**100 Sv/h**
Measurement time of DER higher than 10 μSv/h at the ± 25 % variation coefficient and the 0.95 confidence level, no more than	**600 s**
Battery lifetime (on a full battery charge) at DER up to 0.3 μSv/h and temperature from 0 to 50 ^{0}C no less than • without audio and vibration alarms • with audio alarms • with vibration alarms (lifetime is halved at temperature from 0 to -30 ^{0}C)	 **100 h** **25 h** **10 h**
Protection degree of the instrument's case	**IP67 according to EN60529/IEC529**
Length of a connecting cable no less then	**30 m**
Weight of BD-03-01	**0,7 kg**
Dimensions of BD-03-01	**∅ 21 x 100 mm**

♦ at collimated ^{137}Cs radiation (662 keV).

3.5 The monitor with the neutron detector BD-04

Measurement range of the dose equivalent rate ♦ (DER)	**1 - 5000 μSv/h**
Energy range	**thermal - 14 MeV**
Sensitivity ♦, at least	**0.45 cps/(μSv/h)**
Count rate indication	**1 - 3000 cps**
DER ♦ threshold range (step is the least significant digit)	**1 - 5000 μSv/h**
Accuracy of DER measurement ♦ ($\dot{H}$ is the dose rate, μSv/h; A =10 μSv/h)	**± (30 + A/$\dot{H}$) %**
Additional relative error of DER♦ measurements due to temperature variations	**± 20 %**
Battery lifetime (on a full battery charge) at DER up to 1 μSv/h and temperature from 0 to 50 ^{0}C no less than • without audio and vibration alarms • with audio alarm • with vibration alarm (lifetime is halved at temperature from 0 to -30 ^{0}C)	 **24 h** **18 h** **9 h**
Weight of BD-04	**490 g**
Dimensions of BD-04	**∅ 59 x 207 mm**

♦ for Pu-α-Be source

3.6 The monitor with the alpha and beta detector BD-05

Measurement range of the flux (φ) of : - alpha radiation - beta radiation	 **1 – 5 10^5 $cm^{-2}min^{-1}$** **10 - 10^6 $cm^{-2}min^{-1}$**
Cutoff energy range of beta radiation	**0.15 - 3.5 MeV**
Sensitivity , at least: - for alpha radiation (^{239}Pu) - for beta radiation (^{90}Sr + ^{90}Y)	 **2 counts cm^2** **0.5 counts cm^2**
Energy response plot should not differ from a typical plot more than	**± 30 %**
Count rate indication: - for alpha radiation - for beta radiation	 **1 – 25000 cps** **1 – 14000 cps**
Flux threshold range (step is the least significant digit) - alpha radiation - beta radiation	 **1 - 5 10^5 $cm^{-2}min^{-1}$** **10 - 10^6 $cm^{-2}min^{-1}$**
Accuracy of φ measurement: - alpha radiation at energy 5.15 MeV (^{239}Pu),(A =10 cm^{-2} min^{-2})	**± (20 + A/φ) %**
- beta radiation (^{90}Sr + ^{90}Y), (A =100 cm^{-2} min^{-2})	**± (20 + A/φ) %**
Additional relative error of φ measurements due to temperature variations	**± 20 %**
Additional error of the alpha-particles flux measurements due to the 1 R/h ^{60}Co gamma radiation or due to the beta radiation produced by 3.7 kBq (^{90}Y+^{90}Sr) source at a distance of 50 mm	**± 25 %**
Additional error of the beta-particles flux measurements due to the 1 mR/h ^{60}Co gamma radiation	**± 25 %**
Battery lifetime (on a full battery charge) at alpha-particles flux no more than 10 cm^{-2} min^{-1} , beta-particles flux no more than 50 cm^{-2} min^{-1} and temperature from 0 to 50 ^{0}C no less than • without audio and vibration alarms • with audio alarm • with vibration alarm (lifetime is halved at temperature from 0 to -30 ^{0}C)	 **20 h** **17 h** **8 h**
Weight of BD-05	**310 g**
Dimensions of BD-05	**64 x 40 x 118 mm**

3.7 General

Environmental: temperature range humidity at 25 °C	 **-30 to + 50 °C** **(LCD: -10 to + 50 °C)** **up to 98 %**
Power	**five 'AA' size NiCd rechargeable batteries**
Weight of the processing unit	**350 g**
Dimensions of the processing unit	**32 x 85 x 107 mm**
Weight of the vibration alarm device	**50 g**
Dimensions of the vibration alarm device	**∅10 x 46 mm**

4 DESIGN AND THEORY OF OPERATION

4.1 Design

The monitor includes three main units (see Fig.1):

- portable processing unit 1 in a hermetic protective housing;
- detector 2 (one of the units **BD-01** to **BD-05** may be connected as a detector, **BD-01** is shown as a detector in Fig.1, the others are illustrated in Fig.2);
- vibration alarm device 3.

The detector is attached to the 0.2 to 1 m long extension tube (tubes) 8 with the brackets N 1, 3, 5 and 6 (Figs. 1, 2). The processing unit 1 is connected to the detector 2 by the 1.5 m long cable 4. To make the measurement more comfortable when the extension tubes are used, the cable is held with clamps 11 (Fig. 1). The cable 4 is connected to the processing unit with the connector 12 located on the back of the processing unit (Fig. 3). When the monitor operates without the extension tubes, the processing unit and the detectors **BD-01** and **BD-02** may be fasten to the waist-belt or clothes. A clip for fastening the processing unit to the cloth is located on the bottom surface of the unit. In this case the detectors are attached with the brackets N 2 and 4, and a short cable N 2 (Fig.1) is used to connect the processing unit and a detector.

The vibration alarm device 3 (Fig. 1) is connected with a cable to the jack 11 of the processing unit (Fig.3). The vibration alarm device is provided with a clip for fastening it to the waist-belt or clothes.

The LCD 5 and control buttons are located on the front panel of the processing unit (Fig. 3).

The control buttons are designed for the purposes as follows:

1 - "I" button is used to turn the unit ON/OFF and to turn on the LCD backlight; to turn the unit ON/OFF press the button and fix it for 2-3 seconds, and to turn on the LCD backlight press and release the button.

2 - MODE button is used to select the operation mode ("search", "measurement" or "spectrum accumulation"); this button is also used in the *set mode* to decrease by one the value to be set.

3 - SET button is used to view or to set the parameters; press and release the button to view the preset value of the coefficient n and the calculated value of the alarm threshold in the *search mode,* the DER alarm threshold (μSv/h) or the flux alarm threshold (cm^{-2} min^{-1}) - in the *measurement mode,* and a number of the accumulated spectra - in the *spectrum accumulation*

mode. It is necessary to press and fix this button to set the above parameters in the *set mode*.

4 - START button is used to update the background in the *search mode*, or to restart the measurement in the *measurement mode*; to start the spectrum accumulation in the *spectrum accumulation mode*; press this button once again to store the accumulated spectrum of selected number in the non-volatile memory. In the *set mode* press and release this button to increase by one the value to be set.

The LCD displays the following marks (Fig. 3):

6 - the *search mode* mark corresponds to the inscription "search";

7- the *measurement mode* mark corresponds to the inscription "measure";

8 - the analog scale (bar graph) including 19 segments serves to indicate:

- the time left till the self-tests completion (a number of segments decreases);
- the time left till the completion of the background updating (a number of segments increases until the scale is completely filled);
- the value of excess over the threshold (in relative units) in the *search mode*;
- the measured value relative to either the DER, or the flux threshold in the *measurement mode*; when the scale is completely filled, the set DER threshold is reached;

9 - 2-digit 7-segment indicator is designed to show the coefficient n in the range from 1 to 7 in the *search mode*; the variation coefficient (%) at the 0.95 confidence level in the *measurement mode;* the variation coefficient (%) at the 0.95 confidence level in channel with the maximum count in the *spectrum accumulation mode;*

10 - 4.5-digit 7-segment indicator displays:

* "OFF" when the monitor is turned OFF;
* "test" when the monitor operates in the *test mode*;
* the measured DER or flux values, or the preset DER or flux thresholds in the *measurement mode;*
- the count rate (in cps), or the calculated threshold, as well as "HI" in the *search mode*;
- the number of channel with the maximum count during the spectrum accumulation, or the number of the stored spectrum in the *spectrum accumulation mode*;
- "CAL" when the monitor operates in the *background mode*.

14 - the mark indicates that the battery voltage dropped below the preset value (the battery needs to be charged);

15 - the spectrum accumulation mark corresponds to the inscription "spectr";

16 - 1-digit 7-segment indicator serves to display "A" indicating that the alpha radiation is measured, or "b" indicating that the beta radiation is measured, or " ñ " indicating that the neutron radiation is measured;

17 - the radiation sign is indicated when the count rate exceeds 20000 cps., or the DER of gamma radiation exceeds 20000 μSv/h, or the flux of alpha or beta radiation exceeds 20000 cm^{-2} min^{-1}.

4.2 Component modules

The block diagram of the monitor is given in Fig. 5.

The monitor consists of the modules as follows:

- detector,
- processing unit;
- vibration alarm device.

The detectors are designed as separate units connected with a cable to the processing unit. All the detectors show similar design, some their characteristic features are described below.

The **detector BD-01** consists of:

- a 14 x 14 x 50 mm CsI(Tl) scintillator with a photodiode;
- an amplifier-shaper;
- a converter.

The scintillator-photodiode (PD) transforms gamma-quanta to electric pulses that come to the input of the amplifier-shaper.

The amplifier-shaper converts electric signals from PD to quasi-Gauss output pulses that are cabled to the processing unit.

The converter produces a bias voltage of 30 V that comes to PD to reduce its output capacitance.

The **detector BD-02** is similar to the **detector BD-01** in design, but differs in size of the CsI(Tl) crystal (10 x 10 x 10 mm) and by the setting parameters of the amplifier-shaper.

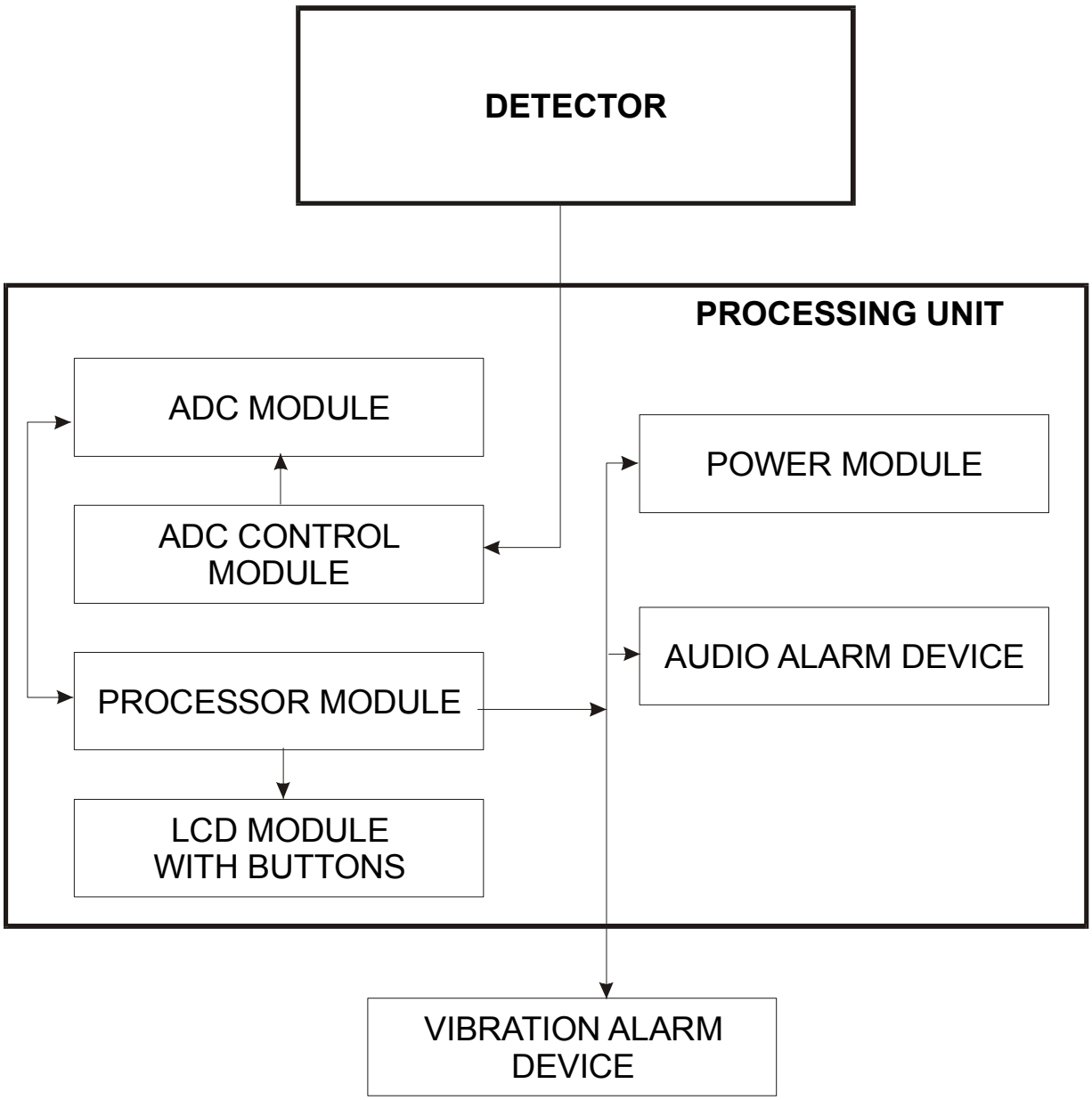


Fig.5 - Block diagram of the monitor

The **detector BD-03** (**BD-03-01, fig.4)** consists of:

- a Geiger-Mueller counter,
- a high voltage transformer (+5 V $\rightarrow$ 520 $\pm$ 10 V) with an output voltage stabilization circuit;
- an amplifier-shaper;
- a stabilization voltage module (+5 V).

The stabilized voltage from the high voltage transformer is delivered to the counter, which outputs pulses when gamma-quanta come into the counter. These pulses are transformed in the amplifier-shaper and are cabled to the input of the processing block for mathematical processing according to an algorithm.

The **detector BD-04** consists of:

- a moderated neutron counter;
- a high voltage transformer (+5 V$\rightarrow$1350 V $\pm$1%) with the output voltage stabilization circuit;
- an amplifier-shaper.

The detector transforms irradiating neutrons into electric pulses, that are shaped in the amplifier-shaper and cabled to the input of the processing unit. The high voltage transformer creates a high voltage, as well as a voltage of $\pm$5 V.

The **detector BD-05** consists of:

- a proportional counter with a mica window;
- a controlled high voltage converter (+5 V$\rightarrow$1350 V $\pm$20 V and +5 V$\rightarrow$1000 V$\pm$20 V) with an output voltage stabilization circuit;
- an amplifier-shaper.

When measuring the beta radiation the output voltage of 1350 V is set at the high voltage converter output on command from the processing unit. When the alpha radiation is measured the output voltage of 1000 V is set. Signals from the counter are converted in the amplifier and then cabled to the processing unit input. The high voltage converter creates a high voltage, as well as a voltage of $\pm$5 V.

Each detector is equipped with a chip storing the unique number of the detector. Numbers of all the detectors being parts of this specific monitor are stored in the non-volatile memory of the processing unit. This makes impossible the use of detectors from the other monitors, as each detector when it was calibrated by the manufacturer was provided with its unique calibration coefficients.

The **processing unit** is housed in a hermetic case and consists of:

- an analog-to-digital converter (ADC) module;
- a processor module;
- an ADC control module;
- a power module;
- an LCD module with control buttons;
- an audio alarm device.

The ADC module is a 12-bit analog-to-digital converter with a built-in sample-and-hold circuit and a serial transfer channel that is synchronized by the processor.

The processor module is based on a 16-bit RISC processor and performs:

- testing of the monitor every time as it is turned on;
- reception and synchronization of data from the ADC module;
- mathematical processing of data received;
- entering commands and selection of appropriate operation modes according to the entered commands;
- control over all the operation modes;
- output of the information processing results to the LCD;
- control over the audio and vibration alarm devices;
- checking battery voltage;
- information exchange with PC through the RS-232 port.

The power module consists of five "AA" size rechargeable batteries and an electronic key circuit that are controlled by the processor and provide the necessary voltage to the units of the monitor.
The LCD module with control buttons is mounted onto a separate board and serves to display the test results, operation modes and measurement results and to enter data with the control buttons. The LCD module contains also a control circuit of the electroluminescent backlight which is turned on/off by the processor and is controlled over by the "I" button.

The audio alarm device is designed to produce audible tones to signal the completion of the *self-test* and to signal an alarm condition in the *search mode*. The rate at which audible tone repeats will increase when the monitor comes nearer to a gamma radiation source. The audio alarm will be also activated when the preset DER or flux threshold is exceeded in the *measurement mode*.

The vibration alarm device is designed to produce signals that the operator senses as mechanical pulsation inside of the device housing when the preset alarm threshold is exceeded in the *search mode*. In the *search mode* the vibration alarm device operates in similar way that the audio alarm device does. It allows a secret search for gamma radiation sources and is good in situations when sound tones are damped by noise.

4.3 Operation modes

The monitor operates in the following *modes*:

- self-test mode;
- search mode;
- measurement mode;
- spectrum accumulation mode;
- background mode;
- set mode;
- communication with PC.

The modes of operation and operational features depend on a detector connected to the monitor (see section 6 "Operation procedures").

The available operation modes of the monitor are given in Table 1.

Table 1

Operation modes of the monitor with different detectors *

Mode	Detector BD-01	Detector BD-02	Detector BD-03 (BD-03-01)	Detector BD-04	Detector BD-05
Self-tests	+	+	+ (+)	+	+
Search	+	+	+ (-)	+	+
Measurement of:					
DER of gamma radiation	+	+	+ (+)	-	-
DER of neutron radiation	-	-	-(-)	+	-
Flux of alpha and beta radiation	-	-	-(-)	-	+
Spectrum accumulation	-	+	-(-)	-	-
Background accumulation	+	+	+	+	+
Set	+	+	+ (+)	+	+
Communication with PC	-	+	+ (-)	-	-

* "+" mode is available, "-" mode is not available.

Attention! The monitor with any detector connected can not operate in two modes simultaneously, but operates in one of the available modes.

The battery voltage is measured in any operation mode. When the battery voltage drops below the preset value, the LCD will display the mark 14 (Fig. 3). In this case it is necessary to charge the batteries (see section 5.3).

The monitor also checks the operation of the detector. The LCD will display "HI" if the count rate exceeds the higher preset limit (see also sections 6.1 - 6.5).

The monitor provides the LCD backlight if the button 1 is pressed and released (Fig. 3).

To turn the monitor OFF, press and fix the button 1 until the LCD will display "OFF".

4.3.1 Self-test mode

The monitor will go through the *self-test mode*, whichever detector is connected to it.

The monitor will go into this mode immediately after it is turned ON by pressing the button 1 (Fig. 3). The following tests will run:

- LCD test;
- test of a detector connected to the monitor;
- processor test;
- non-volatile memory test;
- audio alarm test.

When tests will be running, the LCD will display "test". The time left till the completion of all the tests will be indicated in relative units on the analog scale.

In the *self-test mode* the processor checks whether the identification number of the connected detector corresponds to that stored in the monitor memory. If the numbers do not agree, the LCD will indicate error (see section "Troubleshooting").

After all the tests have been completed, the monitor will produce an audible signal and will go into either the *background*, or *measurement mode* depending on the type of a detector connected to it.

4.3.2 Background mode

This mode is an auxiliary one and is used when the monitor operates in the *search mode* for the accumulation and storage of the background radiation value, which is used by the processor for calculation of the alarm threshold (see below). When the detector **BD-01** is connected, the monitor will automatically go into this mode after the *self-tests* have been completed.

When the detectors **BD-02, BD-03**, **BD-04** or **BD-05** are connected, the monitor will automatically go into the *background mode* if it is switched to the *search mode.*

Later on, to go into the *background mode* from the *search mode* it is necessary to press and release the START button.

During the background accumulation the LCD will display "CAL." (calibration), and the analog scale will show a gradual increase of a number of filled segments until the scale will be completely filled.

The radiation background is measured in the *background mode.* The processor will count pulses coming from the detector and the analog scale will indicate in relative units the time passed since the beginning of the background measurement. When the scale is filled, the background measurement is completed. The duration of the background mode depends on the background level. If the gamma radiation background corresponds to the natural background value, the measurement will run for no longer than 30 seconds with connected **BD-01**, 200 seconds - with **BD-02**, and 600 seconds - with **BD-03**. The background mode duration will decrease, if the background radiation level increases.

The processor calculates the average count rate N_b (cps) over the background measurement time and the threshold value P:

$$P = N_b * T_c + n*\sigma, \quad (1)$$

with

$$\sigma = \sqrt{N_b * T_c}, \quad (2)$$

where:

T_c - count time in the *search mode* (2 seconds);

σ - meansquare deviation of the value calculated using the equation (2) for Poisson distribution of the pulses;

n - number of meansquare deviations (**coefficient n**).

When the *background measurement* is completed, the LCD will display for several seconds the average count rate during the background measurement N_b (cps) and then the monitor will automatically go into the *search mode*.

To reset the monitor for the new background level, press and release the START button, the LCD will display "CAL" and the background accumulation will restart.

4.3.3 Search mode

The monitor will automatically go into the *search mode* after the *background mode* is completed, or it may be switched to the *search mode* by pressing and releasing the MODE button.

In the *search mode* the processor will count pulses coming from the detector in 250 millisecond periods and store in memory the sum of pulses of eight of these periods, i.e. for 2 seconds. The number of pulses for the last (recent) period is added to the sum every 250 milliseconds and the oldest count is discarded. Therefore, the number of pulses N_c stored in the processor memory is updated every 250 milliseconds. The current value N_c is compared to the alarm threshold P every 250 milliseconds.

If the current value of the pulse count exceeds the alarm threshold, i.e. $N_c > P$, an audio alarm will sound. The rate at which audio tone repeats will increase when the excess of N_c over P becomes more important.

When the vibration alarm device is connected, the audible signals will not sound, instead, the mechanical pulsation will be produced by the vibration alarm device. The rate of pulsation will also increase when the excess of N_c over P becomes more important.

In the *search mode* the LCD displays the current value of the average count rate in counts per second (cps, line S^{-1}), as well as a variation coefficient (%) calculated at the 0.95 confidence level.

4.3.4 Measurement mode

In the *measurement mode* the monitor measures either the dose equivalent rate (DER) of photon or neutron radiation, or the flux of alpha or beta radiation, depending on the detector selected.

The monitor will go into this mode if the MODE button is pressed and released. When the **BD-01** or **BD-02** detectors are connected the LCD will display the DER value of gamma radiation (μSv/h for ^{137}Cs).

With connected **BD-02, BD-03, BD-03-01** and **BD-04** the monitor will automatically go into the *measurement mode*, when the monitor is switched on and the self-tests are completed. In the case if the detector **BD-03 or BD-03-01** is selected, the LCD will display the DER value of gamma radiation in μSv/h, and with **BD-04** - the DER value of neutron radiation in μSv/h (for a Pu-α-Be source) and "ñ" indicating the neutron radiation *measurement mode*.

With the connected detector **BD-05**, the monitor will also automatically go into the *measurement mode*, after the *self-test mode* has been completed. The LCD

will display "A" indicating the alpha radiation flux *measurement mode*, or "b" indicating the beta radiation flux *measurement mode*, as well as the measured value of the alpha or beta flux in cm^2 min^{-1}. To switch to the alpha or beta radiation flux *measurement mode* press and release the MODE button.

In the *measurement mode* the LCD will display every 2 seconds the measured DER or flux value B calculated from the equation:

$$B = f(N_0), \qquad (3)$$

where N_0 is the average value of the count rate calculated for the measurement time, and

$f(N_0)$ is a polynomial which coefficients depend on which of the detectors is connected and are set by the manufacturer in the course of the monitor calibration.

The lower LCD line displays a variation coefficient of indicated values (%) calculated at the 0.95 confidence level.

The analog scale indicates the measured value as a fraction of the preset threshold (DER or flux).

If the measured value exceeds the preset threshold, the monitor will produce an audible signal (or pulsation - if the vibration alarm device is connected).

4.3.5 Spectrum accumulation mode

When operating in the *spectrum accumulation mode* the monitor will accumulate scintillation gamma-spectra and will store them in the non-volatile memory. The monitor operates in this mode in the only case when the detector **BD-02** is connected.

The monitor may be switched to this mode by pressing and releasing the MODE button.

When the monitor operates in the *spectrum accumulation mode*, the LCD will display the number of the channel with the maximum count, as well as a variation coefficient (%) in the same channel; the coefficient is calculated at the 0.95 confidence level. When operating in this mode, it is possible to initiate the accumulation of the scintillation gamma-spectra, to check the number of the spectrum accumulated, or to change it if necessary.

4.3.6 Set mode

The monitor may be switched to this mode by pressing and releasing the SET button.

When operating in this mode it is possible to check either the threshold value (recalculated for one second) and the set coefficient **n** (in the *search mode*), or the DER or flux threshold (in the *measurement mode*), or the number of the spectrum accumulated (in the *spectrum accumulation mode*), as well as to change the above parameters if necessary.

To check the set parameters press and release the SET button. In the *search mode* the LCD will display the set coefficient **n** in the lower line (indicated by δ), and the threshold value in the upper line (indicated by S^{-1}). In the *measurement mode* the LCD will display the preset threshold (in μSv/h or in cm^{-2} min^{-1}). In the *spectrum accumulation mode* the LCD will display the number under which the accumulated spectrum will be stored in the non-volatile memory.

To go into the *set mode* for changing the above parameters, press and fix the SET button (see sections 6.1 - 6.5).

4.3.7 Communication with PC

In this mode it is possible to transmit to PC the gamma-spectra accumulated and stored in the non-volatile memory of the monitor for their viewing and studying (see section 6.2.2).

5 PREPARATION FOR USE

5.1 General instructions

Before starting the monitor operation the user must study the current manual.

Using the cable N 1 or N 2 (see Fig.1, positions 4, 5) connect the detector to the connector 12 of the processing unit (Fig. 3).

CAUTION: *To avoid damage of detectors, do not connect them to the operating processing unit. Before connecting detectors be sure that the processing unit is turned OFF, i.e. the LCD displays OFF.*

The detector can be attached to the extension tube (tubes) (see Fig.1). Besides, the detector can be fastened to the belt or clothes of the user by means of brackets 10 (Fig.1), or 2 and 4 (Fig. 2) with a clip. In this case the shorter cable N 2 may be used (Fig.1, position 5).

The vibration alarm device can be used if necessary by connecting the cable to the jack 11 on the back of the monitor (see Fig. 3). To avoid spontaneous disconnection of the vibration alarm device its cable is fixed in this jack. To disconnect the vibration alarm device pull the ribbed ring 13 of the cable (Fig. 3).

CAUTION! care should be taken when pulling the ribbed ring to avoid rupture of the cable.

5.2 Safety precautions

When the monitor surface is contaminated by alpha and/or beta radioactive particles, the radioactive substances must be removed from the detector, connecting cable and shielding cover using a damp cloth moistened with ethyl alcohol.

5.3 Battery charging

When the battery voltage drops below the acceptable level, the LCD will display the mark 14 (Fig. 3).

To charge the battery connect the cable of the charger 6 (Fig.1) to the connector 12 of the processing unit (Fig. 3) and insert the plug of the charger to the supply line of 220 V. It will take approximately 14 hours to charge a fully discharged battery.

5.4 Turning on and self-tests

When the monitor is turned OFF the LCD will display OFF.

To turn the monitor ON press and release the button 1 (Fig. 3). If the monitor is operative and the battery voltage is normal, the monitor will go through a series of self-tests, with all segments, signs and indicators displayed on the LCD, accompanied by the audible signal. Then the LCD will display "test" and the analog scale with decreasing number of segments.

With the connected detector **BD-01** after the monitor has completed the self-tests it will go into the *background mode*. The LCD will display "CAL." and the analog scale with filling up segments.

After the background accumulation has been completed, the LCD will display for one second the measured count rate value, and the monitor will go into the *search mode*. The LCD will display the *search mode* mark.

With the detectors **BD-02, BD-03, BD-03-01, BD-04** or **BD-05** connected to the processing unit, the monitor will go into the *measurement mode* after completing the self-tests, and the LCD will display the mark of this mode and the measured DER or flux values.

To turn the monitor OFF press and fix the "I" button for 3 - 5 seconds.

6 OPERATION PROCEDURES

6.1 OPERATION OF THE MONITOR WITH THE GAMMA DETECTOR BD-01

The monitor with the connected detector **BD-01** can be used to search for (to detect and to locate) photon radiation sources, as well as to measure the DER value of photon radiation (as against ^{137}Cs).

Before starting the work it is advised to set the parameters used in searching (coefficient **n**) and measurement (DER threshold) procedures.

Follow the operations described in the section 5.4. When the *self-tests and background modes* are completed, the monitor will automatically go into the *search mode*. The coefficient n = 4 is set in the monitor and will be used for calculating the alarm threshold value, if the user did not set another value of the coefficient **n** (see section 4.3.2).

6.1.1 Coefficient n setting

The coefficient **n** (number of meansquare deviations) changes the threshold value, see equation (1). It is evident that **the smaller** is the value of the coefficient **n**, **the smaller** is the threshold value, **the higher** is the sensitivity of the monitor in the *search mode*. However, the probability of false alarms will also increase. A relationship of these parameters may be seen from the Table 2, which cites the calculated values of the detectable excess over the background (a level when the count rate is 20.0 cps is taken as an example), the threshold value (recalculated to a second) and a probability of false alarms.

Table 2 - Detectable excess over the background (δ, %),threshold value (P1, cps) and probability of false alarms (p, %) at various values of the coefficient n

Background value (cps)	**n**	**δ,** %	**P_1,** cps	**p,** %
20.0	1	15.8	23.2	16.6
-"-	2	31.6	26.3	2.6
-"-	3	47.4	29.5	0.2
-"-	4	63.2	32.6	0.01
-"-	5	79.0	35.8	$<$0.01
-"-	6	94.9	38.9	$<$0.01
-"-	7	110.7	42.1	$<$0.01

To set the coefficient **n** it is necessary to switch the monitor to the *search mode* (if the monitor operated in the *measurement mode*) by pressing and releasing the MODE button. The sign 6 (Fig. 3) displayed on the LCD indicates that the monitor is operating in the *search mode.* Then it is necessary to go into the *set*

mode by pressing and fixing the SET button. The LCD will display the flashing preset number **n** (in the lower line marked δ). A depression of the START button will increase this number by 1, and a depression of the MODE button will decrease it by 1. The setting range of the coefficient n is 1 to 7. The monitor will go out of the *set mode* after a repeated depression of the SET button, or automatically in 20 seconds.

NOTE - The entered value of the coefficient **n** is stored by the microprocessor and will be used during the monitor operation *until it is turned OFF*. But if the monitor is turned OFF and then turned ON again the value of the coefficient **n** will be automatically set equal to **4**.

6.1.2 Dose rate threshold setting

When measuring the DER of photon radiation the monitor operating in the *measurement mode* will produce an alarm signal indicating an excess over the preset DER threshold value (see section 6.1.4).

To set the DER threshold it is necessary to switch to the *measurement mode* by pressing and releasing the MODE button. The LCD will display the mark 7 (Fig. 3) indicating that the monitor operates in the *measurement mode*. To go into *the set mode* it is necessary to press and fix the SET button. The LCD will display the preset threshold value (μSv/h as against ^{137}Cs) with the last figure flashing. A depression of the START button will increase this figure by 1, and a depression of the MODE button will decrease it by 1. To shift this flashing figure left by one position press and release the SET button, to shift the flashing figure right by one position press and release the "I" button. The monitor will go out from the *set mode* either by pressing the SET button when the higher-order figure is set, or automatically in 20 seconds.

NOTES

1) The set threshold value will be retained even after the monitor is turned OFF and will be used when it is turned ON again.

2) The set **digital** threshold value is stored for each detector and is automatically restored in the case of further connection of the given detector.

3) In the measurement mode, the LCD may display “LO”, which is indicative of two possibilities: either the measured background value is below the lower threshold for the given detector, or the detector has failed. To make sure the detector is operable, bring the detector to the source, where the background value is deliberately higher than the lower threshold for the given detector. In this case the ‘LO” indication should disappear.

It is advisable to set and check up the desirable threshold value immediately before starting the measurements.

6.1.3 Search for photon radiation sources

General guidelines

In *the search mode* the monitor may be used for searching (detecting and locating) photon radiation sources. When searching photon radiation sources the detector should be held within 5 - 15 cm over the surface of an object to be inspected. The effective center of the detector should be directed onto the scanned object, but care should be taken to avoid contacts of the detector with the surface.

At any stage of detecting and locating the photon radiation sources the DER of photon radiation (as against ^{137}Cs) may be obtained in the place where the monitor operates by switching it to the *measurement mode.*

When the monitor operates at a temperature below - 10 °C, the LCD may display erroneous readings. In this case the audio or vibration alarm devices should be used to detect and locate photon radiation sources. When the normal conditions with temperatures higher than -10°C are restored, the LCD will resume its normal operation.

Mechanical shocks may cause false alarms. However, this does not mean that the monitor is damaged.

When the work with the monitor is completed, to turn the monitor OFF press and fix for 2-4 seconds the "I" button until "OFF" is displayed.

Detection of photon radiation sources

The efficiency of the photon radiation sources detection is dependent on the close proximity of the detector to the article or person to be inspected, and the velocity of its movement along the object. If the source which radiation exceeds the preset threshold value P is detected (see sections 4.3.2 - 4.3.3), the audible alarm will sound. The rate at which the audio tone repeats will increase when the detector moves closer to a source.

When detecting photon radiation sources under conditions when the audible signals produced by the monitor may not be heard as are damped by noise, the vibration alarm device should be used. In this case audible signals will not sound, but mechanical pulsation will occur inside of the vibration alarm device. The rate of pulsation will also increase when the detector moves closer to a photon radiation source.

It should be remembered that both the sensitivity of the monitor and the rate of false alarms depend not only on the set coefficient **n** as indicated in section 6.1.1, but also on the background value, which the monitor stored while in the *background mode*. As the changes of the natural background level may be significant, it is advised to perform the background accumulation (by pressing the START button) just before inspecting persons, articles and vehicles.

The coefficient **n** is to be set to 2 - 4. In this case the probability of false alarms will slightly increase, but false signals (sound or pulsation) are not regular and, therefore, may be easily distinguished from alarm signals produced if a photon radiation source is detected, when the rate at which the audio tone repeats will increase when the monitor moves closer to photon radiation sources.

Locating photon radiation sources

When the photon radiation source is detected or a stationary control system sounds, the photon radiation source is to be located. The coefficient **n** is advised to be set to 4 - 6.

To locate the photon radiation source the detector should be held within 10 cm of the object to be searched and moved slowly (no faster than 10 cm per second) along the scanned object. As the detector moves closer to the photon radiation source, the rate at which audio tone repeats or the rate of pulsation (in the case when the vibration alarm device is connected) will increase.

When the maximum rate is achieved a continuous audio alarm will sound, but the rate of pulsation (if the vibration alarm device is connected) will not change. In this case the background updating is required before the photon radiation source locating will be continued. It is necessary to press the START button **keeping the distance to the object unchanged**. The monitor will automatically perform the background updating and then the photon radiation source locating may be continued.

If in the *search mode* the count rate exceeds the upper allowable limit (14000 cps for the detector **BD-01**), the LCD will indicate "HI". The audible and /or vibration alarm will continue their normal operation (the rate of signals increases as the detector moves closer to a source), and the source locating may be continued.

6.1.4 Measurement of the photon radiation dose rate

Set the DER threshold by following the procedure described in section 6.1.2 and *giving particular attention* to the NOTE.
Switch the monitor to the *measurement mode* by pressing the MODE button. The LCD will display the mark 7 (Fig. 3) indicating the *measurement mode* and

the DER value of photon (gamma and X-ray) radiation in μSv/h (as against ^{137}Cs).

The DER value will be displayed every two seconds in the LCD upper line, and the variation coefficient (%) at the 0.95 confidence level - in the lower line. To restart the measurement process press and release the START button. The DER value may be read when the required variation coefficient is obtained.

Audible sounds or pulsation, as well as a completed LCD analog scale will indicate the excess of the DER threshold. Audible signals will sound all the time when the measured DER is over the threshold value.

If the DER value is over the upper allowable limit in the *measurement mode* (50 μSv/h for the detector **BD-01**), the LCD will indicate "HI".

NOTES 1) The monitor with the connected detector **BD-01** is designed firstly for effective detection of the photon (gamma and X-ray) radiation sources.

2) The monitor with the detector **BD-01** is not energy compensated and, therefore, it is highly sensitive in the low-energy range (60 - 300 keV), which enable the most efficient detection of nuclear materials.

3) As a photon radiation measuring device, the monitor is calibrated only against ^{137}Cs collimated radiation, therefore, its readings in the *measurement mode* may disagree with the DER values measured using other dosimeters, which does not indicate that the monitor is faulty.

6.2 OPERATION OF THE MONITOR WITH THE GAMMA DETECTOR BD-02

The monitor with the connected detector **BD-02** is mainly designed for the accumulation, storage and transmission to PC of scintillation gamma-spectra.

6.2.1 Spectra accumulation and storage

Follow the procedure described in section 5.4. After completing the *self-test* and *background* modes the monitor will automatically go into the *measurement mode*. Bring the detector nearer to the object to be examined.

NOTE - When the monitor operates in the *spectrum accumulation mode* the count rate must not be higher than 8000 cps (in the *search mode*) or 200 μSV/h (in the *measurement mode).*

Switch the monitor to the *spectrum accumulation mode* by pressing the MODE button. The operation mode mark 15 (Fig. 3) will point to the inscription "spectr", and the display will show "-.-.-.-" in the upper line.

Press the START button to begin the spectrum accumulation. The LCD will display:

- a number of pulses in the channel with the maximum count (in the upper line),
- a variation coefficient (%) of measured values in this channel at the 0.95 confidence level (in the lower line).

When the necessary variation coefficient is obtained, the spectrum accumulation can be stopped by pressing and releasing the START button. The LCD will display in the upper line the number under which the previous spectrum has been stored plus 1, and in the lower line - the inscription "SP".

Press the START button again to **store** the **spectrum** in the non-volatile memory (under the number indicated). If it is not necessary to store the spectrum press the MODE button to exit from the *spectrum accumulation mode.*

Setting the spectrum number to be stored

To change the number of the spectrum to be stored, press and fix the SET button. The figure to be changed will be flashing in the LCD upper line. It is possible to perform the following operations:

- to select a figure to be changed, the flashing figure may be shifted left by pressing the SET button, and right by pressing the "I" button;
- to increase the flashing figure by 1 by pressing and releasing the START button;
- to decrease the flashing figure by 1 by pressing and releasing the MODE button.

The number of spectrum may be set in the range from 00 to 110.

To go out of the *set mode* press and fix the SET button, or the monitor will automatically exit from this mode in 20 seconds.

6.2.2 Transmission of spectra stored to PC

To view and study spectra stored in the non-volatile memory, these must be transmitted to PC.

To transmit the accumulated and stored spectra to PC, switch the monitor to the *mode of communication with PC* by connecting the connector 12 (Fig.3) of the processing unit by cable N 3 (Fig. 2, position 11) to the serial port of PC.

ATTENTION! If the monitor is operating with the connected detector BD-02, the monitor must be turned OFF before disconnecting the detector BD-02 and connecting the cable N 3.

The special software (application program) is included into the delivery kit of the monitor and all instructions are given in the READ.ME file.

The communication is initialized by PC, and no actions with the processing unit are required even if the monitor is turned OFF. During the communication with PC, the LCD will display "PC".

6.2.3 Search for photon radiation sources and measurement of the dose rate

The monitor with the connected detector **BD-02** may be used for searching (detecting and locating) radioactive sources and for measuring the DER of photon radiation (as against ^{137}Cs) like in the case with the connected detector **BD-01**. Therefore, in the *search mode* the monitor may perform all the operations described in sections 6.1.1. and 6.1.3, and in the *measurement mode* - those described in section 6.1.4.

However, the sensitivity of the detector **BD-02** is much less than that of the detector **BD-01** (see section 3 "Specifications"). Therefore, it is not expedient to use it for searching (detecting and locating) photon radiation sources.

It should be also remembered that the detector **BD-02** is characterized by the higher DER measurement limits. Therefore, the message "HI" will be indicated when the values of 250 μSv/h and 8 000 cps. are exceeded (see sections 6.1.3. and 6.1.4.).

6.3 OPERATION OF THE MONITOR WITH THE GAMMA DETECTOR BD-03 (BD-03-01)

The monitor with the connected detector **BD-03** or **BD0-03-01** is mainly designed for measuring the DER of photon radiation. The monitor with the connected detector **BD-03** may be used for searching photon radiation sources like in case when it operated with the connected detector BD-01. To measure the photon radiation dose rate, unscrew the protective cover from the detector BD-03.
NOTE – The detector BD-03-01 doesn't have the removable protective cover.

6.3.1 Measurement of the photon radiation dose rate

To measure the photon radiation dose rate, **unscrew** the protective cover from the detector **BD-03.**

Perform the operations described in the section 5.4. After completing the *self-test mode* the monitor will automatically go into the *measurement mode.*

The LCD will display the mark 7 (see Fig. 3) indicating the *measurement mode* operation and the DER of photon (gamma and X-ray) radiation in μSv/h.

Set the DER threshold by following the procedure described in section 6.1.2 and *giving particular attention* to the NOTE.

The LCD will display the DER value updated every two seconds - in the upper line, and the variation coefficient (%) at the 0.95 confidence level - in the lower line. To restart the measurement process press and release the START button. When the required variation coefficient is obtained, the DER value may be read out.

Audible signals or pulsation, as well as a completely filled analog scale on the LCD will indicate that the DER threshold is exceeded. Signals will sound all the time when the measured DER value is over the threshold.

If the DER value exceeds the upper limit ($1.5 \cdot 10^5$ μSv/h for the detector **BD-03,** $1.5 \cdot 10^7$ μSv/h for the detector **BD-03-01**) when the monitor operates in the *measurement mode*, the LCD will indicate "HI".

NOTE - If the measured DER value is over 20000 μSv/h, the LCD lower line will display "E 3" and the radiation sign 17 (Fig. 3) instead of the variation coefficient. In this case the measured DER (μSv/h) is equal to the number indicated in the upper line multiplied by 1000 (10^3).

6.3.2 Search for photon radiation sources

The monitor with the connected detector **BD-03** may be also used for searching photon radiation sources. Therefore, in the *search mode* the monitor may perform all the operations described in sections 6.1.1. and 6.1.3.
However, the sensitivity of the detector **BD-03** is much less than that of the detector **BD-01** (see section 3 "Specifications"). Therefore, it is not expedient to use it for *detecting* photon radiation sources.

The monitor with the detector **BD-03** may be used for *locating* rather intense sources of photon radiation, as the *search mode* is expedient in the only cases when the count rate is over 5 cps.

If the count rate exceeds the upper limit (28000 cps for the detector **BD-03**) when the monitor operates in the *search mode*, the LCD will display "HI".

NOTE - If in the *search mode* the count rate exceeds 20000 cps., the LCD will display in the lower line "E 3" and the radiation sign 17 (Fig. 3) instead of the variation coefficient. In this case the count rate (in cps) is equal to the figure indicated in the upper line multiplied by 1000 (10^3).

The monitor with the detector **BD-03** may be used for *searching* photon radiation sources when operating in the *measurement mode* as well. For this purpose while in the *measurement mode* press and fix the START button until the mark 6 (Fig.3) indicating the *search mode* is displayed. Then every pulse produced will be accompanied by an audible signal. When the monitor moves closer to a source, the rate of these signals will increase.

This feature allows locating the photon radiation sources at the DER values higher than 40 μSv/h, i.e. when the upper limit of measurements of the detector **BD-01** is exceeded. (It should be remembered that the main application of this detector **BD-01** is detecting and locating the photon sources).

6.4 OPERATION OF THE MONITOR WITH THE NEUTRON DETECTOR BD-04

The monitor with the connected detector **BD-04** is designed for measuring the DER of neutron radiation (in μSv/h, as against a Pu-α-Be source), as well as for searching neutron radiation sources.

6.4.1 Measurement of the neutron radiation dose rate

Perform the operations described in the section 5.4. After completing the *self-test mode* the monitor will automatically go into the *measurement mode.*

The LCD will display the mark 7 (Fig. 3) indicating the *measurement mode* and the DER value of neutron radiation in μSv/h.

Set the DER threshold by following the procedure described in section 6.1.2 and *giving particular attention* to the NOTE.

The LCD will display the DER value updated every two seconds - in the upper line, and the sign "n" (indicating that the neutron radiation is measured) and the variation coefficient (%) at the 0.95 confidence level - in the lower line. To restart the measurement process, press and release the START button. When the required variation coefficient is obtained, the DER value may be read out.

Audible signals or pulsation, as well as a completely filled analog scale on the LCD will indicate that the DER threshold is exceeded. Signals will sound all the time when the measured DER value is over the threshold.

If the DER value exceeds the upper limit (6000 μSv/h for the detector **BD-04**) when the monitor operates in the *measurement mode*, the LCD will indicate "HI".

NOTE - As a neutron radiation dosimeter, the monitor is calibrated against a Pu-α-Be source radiation only, therefore its readings in the *measurement mode* may disagree with the DER values measured using other dosimeters, which does not mean, however, that the monitor is faulty.

6.4.2 Search for neutron radiation sources

The monitor with the connected detector **BD-04** may be used for searching neutron radiation sources and when operating in the *search mode* may perform all the operations described in sections 6.1.1. and 6.1.3.
However, the *search mode* is expedient in the only cases when the count rate exceeds 5 cps.

If in the *search mode* the count rate exceeds the upper limit (3000 cps for the detector **BD-04**), the LCD will indicate "HI".

The monitor with the connected detector **BD-04** may be used for searching neutron radiation sources when operating in the *measurement mode* as well. For this purpose press and fix the START button until the mark 6 (Fig. 3) indicating the *search mode* is displayed. Then every pulse produced will be accompanied by an audible signal. The rate at which audible tone repeats will increase when the monitor moves closer to a source. It is advised to use the monitor in this mode to locate neutron radiation sources in the cases when the count rate is below 5 cps.

6.5 OPERATION OF THE MONITOR WITH THE ALPHA AND BETA DETECTOR BD-05

The monitor with the connected detector **BD-05** is designed for measuring the flux value and for searching alpha and beta radiation sources.

6.5.1 Measurement of the flux of alpha and beta radiation

Connect the detector **BD-05** to the processing unit. Remove the screen 8 (Fig. 2) protecting the inlet window of the detector from mechanical shocks. Place the detector onto the surface to be scanned so that the inlet window will be close to the surface.

To avoid the radioactive contamination of the processing unit prevent it from contacts with the surface to be inspected.

CAUTIONS! The inlet window is made of material with very low surface density. To avoid damage of the detector do not subject the inlet window and protective screen to mechanical and environmental shocks.

Perform all the operations described in section 5.4. After completing the *self-test mode* the monitor will automatically go into the *measurement mode.*

The LCD will indicate the *measurement mode* mark 7 (see Fig. 3), as well as the following information:

- the alpha radiation flux value updated every two seconds (in **cm^{-2} min^{-1}**, *units are not displayed*) - in the upper line;
- the sign "A" indicating that the measurement of **alpha radiation** is performed, as well as the variation coefficient (%) calculated at the 0.95 confidence level - in the lower line.

Set the alpha radiation flux threshold by performing the operations described in section 6.1.2 like when setting the DER threshold and *giving particular attention* to the NOTE.

To start the measurement press and release the START button. When the required variation coefficient is obtained the alpha radiation flux value may be read out (in **cm^{-2} min^{-1}**).

The excess of the flux threshold will be indicated by audible or pulsation signals, as well as by completely filled analog scale on the LCD. Signals will sound all the time when the measured flux is over the threshold.
To measure the flux of **beta radiation put a shielding cover on the detector** (cover 7, Fig. 2).

Press and release the MODE button. The monitor will go into the alpha radiation *background mode*. After completion of this mode press and release the MODE button again. The LCD will display the mark 7 (Fig. 3) indicating the measurement mode, as well as the following information:

- the beta radiation flux value updated every two seconds (in **cm^{-2} min^{-1}**, *units are not displayed*) - in the upper line;
- the sign "b" indicating that the measurement of **beta radiation** is performed, as well as the variation coefficient (%) calculated at the 0.95 confidence level - in the lower line.

Set the threshold of the beta radiation flux threshold by performing the operations described in the section 6.1.2 like when setting the DER threshold and *giving particular attention* to the NOTE.

To start the measurement process press and release the START button. When the required variation coefficient is obtained, write the LCD reading $\varphi_{\gamma\beta}$.

Remove the cover and put the screen on the detector (screen 8, Fig. 2).

To start the measurement process press and release the START button. When the required variation coefficient is obtained, write the LCD reading φ_{γ}.

Calculate the beta radiation flux (in **cm^{-2} min^{-1}**) from the equation:

$$\varphi_{\beta} = \varphi_{\gamma\beta} - \varphi_{\gamma}$$

Audible or pulsation signals, as well as the completely filled analog scale on the LCD will indicate that the flux threshold is exceeded. Signals will sound all the time when the measured flux is over the threshold.

If the flux value exceeds the upper limit ($6 \cdot 10^5$ cm^{-2} min^{-1} when measuring alpha radiation, and $1.2 \cdot 10^6$ cm^{-2} min^{-1} when measuring beta radiation) when the monitor operates in the *measurement mode* the LCD will indicate "HI".

NOTE - If the measured flux of alpha or beta radiation is over 20000 cm^{-2} min^{-1}, the LCD lower line will display "E 3" and the radiation sign 17 (Fig. 3) instead of the variation coefficient. In this case the measured flux (in cm^{-2} min^{-1}) is equal to the number indicated in the upper line multiplied by 1000 (10^3).

6.5.2 Search for alpha and beta radiation sources

The monitor with the connected detector **BD-05** may be also used for searching alpha and beta radiation sources and in the *search mode* may perform all the operations described in sections 6.1.1 and 6.1.3. However, the *search mode* is expedient in the only cases when the count rate exceeds 5 cps.

When searching alpha and beta radiation sources, the detector should be held as close to the surface to be inspected as possible. To avoid the radioactive contamination of the detector, take care to prevent it from contacts with the surface being scanned.

If the count rate exceeds the upper limit (25000 cps when measuring alpha radiation and 14000 cps when measuring beta radiation) when the monitor operates in the *search mode*, the LCD will indicate "HI".

NOTE - If in the *search mode* the count rate exceeds 20000 cps, the LCD will display in the lower line "E 3" and the radiation sign 17 (Fig. 3) instead of the variation coefficient. In this case the count rate (in cps) is equal to the figure indicated in the upper line multiplied by 1000 (10^3).

The monitor with the connected detector **BD-05** may be used for searching alpha and beta radiation sources when operating in the *measurement mode* as well. For this purpose press and fix the START button until the mark 6 (Fig. 3) indicating the *search mode* is displayed. Then every pulse produced will be accompanied by an audible signal. The rate at which audible tone repeats will increase when the monitor moves closer to a source. It is advised to use the monitor in this mode to locate alpha or beta radiation sources in the cases when the count rate is below 5 cps.

NOTE - When working with the detector **BD-05** turn the monitor OFF **only** in the beta radiation measurement mode or beta radiation search mode.

7 TROUBLESHOOTING

Trouble	Possible cause	Solution
1 In self-test mode, LCD indicates:		
E-00	Microprocessor is faulty.	Send the monitor to the manufacturer for repair or replacement
E-01	1. Detector (BD) is not connected.	1. Connect the detector.
	2. Defective cable.	2. Correct a defect.
	3. Detector is faulty.	3. Send the detector to the manufacturer for repair or replacement
E-02	The connected detector is not complete with this monitor	Connect the detector complete with this monitor
2 In any mode LCD indicates HI	1. Detector is faulty.	1, 2. Send the monitor to the manufacturer for repair or replacement
	2. Processing unit is faulty.	
	3. Radiation source is near the detector	3. Remove the source
3 Vibration alarm device is inoperative.	1. Break in the cable.	1. Remove the break.
	2. Vibration alarm device is faulty	2. Send the device to the manufacturer for repair or replacement
4 The LCD indicates the mark 14 (Fig.2). The monitor automatically turns OFF	Battery discharge	Recharge the battery

8 MAINTENANCE

The maintenance of the monitor is provided by the user. It is advisable:

1)To inspect the monitor for mechanical damage, scratches or other defects. The protective glass of the LCD should not have any cracks.

2) To keep the monitor clean, to wipe it with soft and clean cloth without solvents.

3)To charge the battery if needed following the instructions given in section 5.3 of the present manual.

4) To check the operation of the monitor following the instructions given in section 5.4 of the present manual.

5) In case of contamination of the monitor components (processing unit, detectors, vibration alarm device, extension tubes, handle, cables, brackets) by radioactive substances, these must be removed from the contaminated surfaces using a cloth moistened with ethyl alcohol.

9 STORAGE

The monitor is to be stored in package at the air temperature from +5 ^{0}C to +40 ^{0}C and a relative humidity up to 80 %.

The monitor without package is to be stored at the air temperature from +10 ^{0}C to +35 ^{0}C and a relative humidity up to 80 %.

The storage place should be free of dust and vapours of strong chemicals that may cause corrosion.

10 SHIPPING

The monitor may be shipped by any kinds of transport for any distance at a temperature from -50 ^{0}C to +50 ^{0}C.

When carried by sea, monitors in package should be placed in hermetic plastic bags with silicagel.

When carried by air, monitors in package should be placed in hermetic compartments.

11 WARRANTY

11.1. The manufacturer warrants this monitor to be free from defects in workmanship and materials for a period of 18 months from the date of sale indicated in the warranty certificate provided that the customer followed all the safety and operation instructions given the current manual.

11.2. Warranty does not cover monitors:

- without the operating manual;
- subjected to the customer service;
- with mechanical damages due to violation of the storage and exploitation requirements.

11.3. The warranty period is prolonged for the period of warranty repair.

APPENDIX A

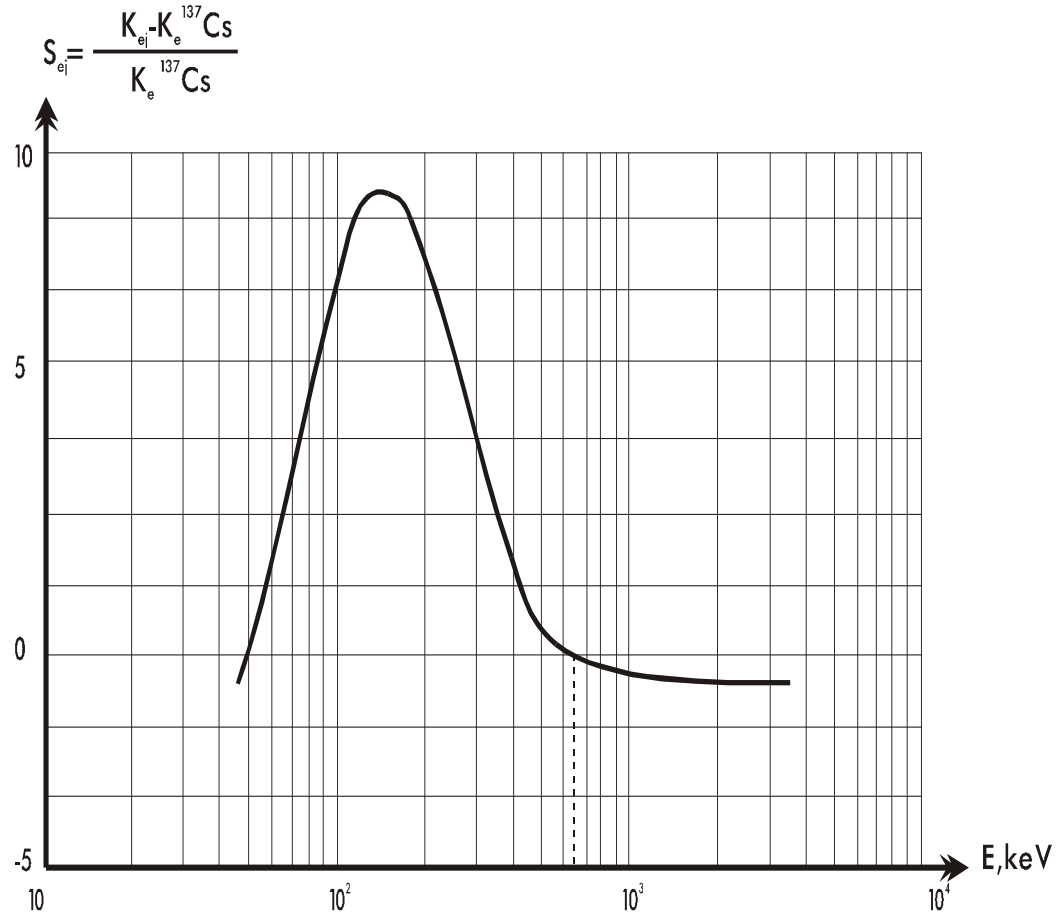


Fig. A.1
A typical plot of the energy response (as against ^{137}Cs) of the monitor with the gamma detector BD-01

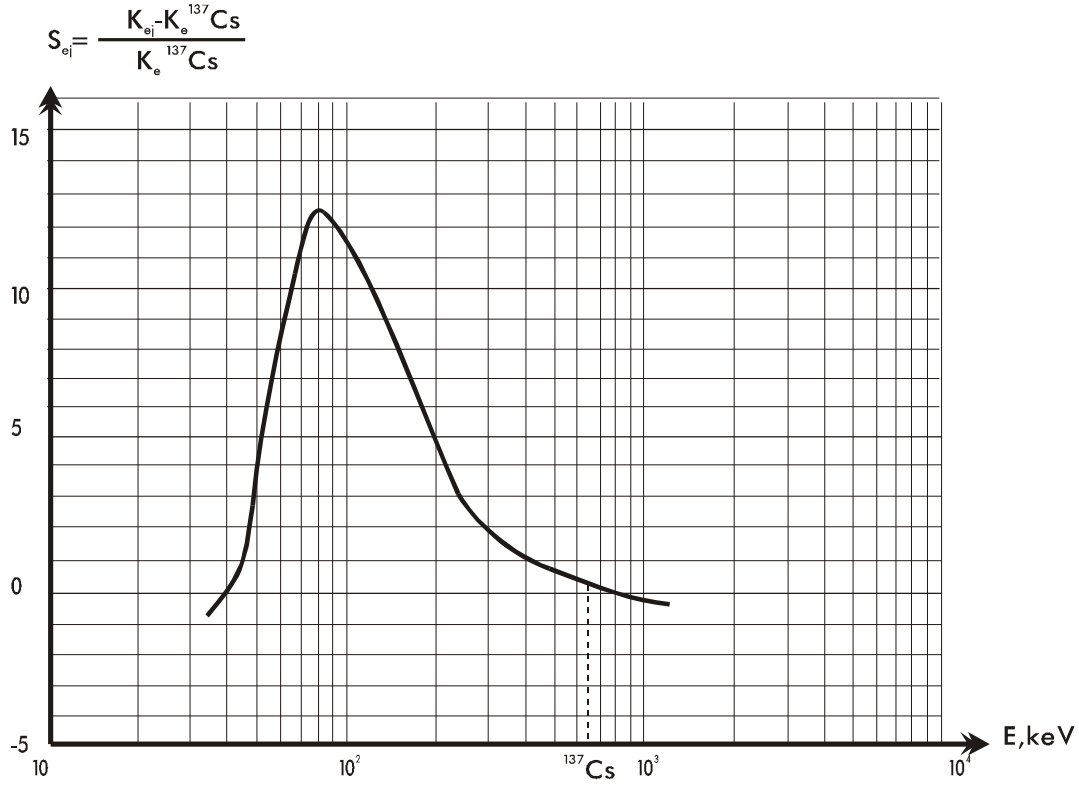


Fig. A.2
A typical plot of the energy response (as against ^{137}Cs) of the monitor with the gamma detector BD-02

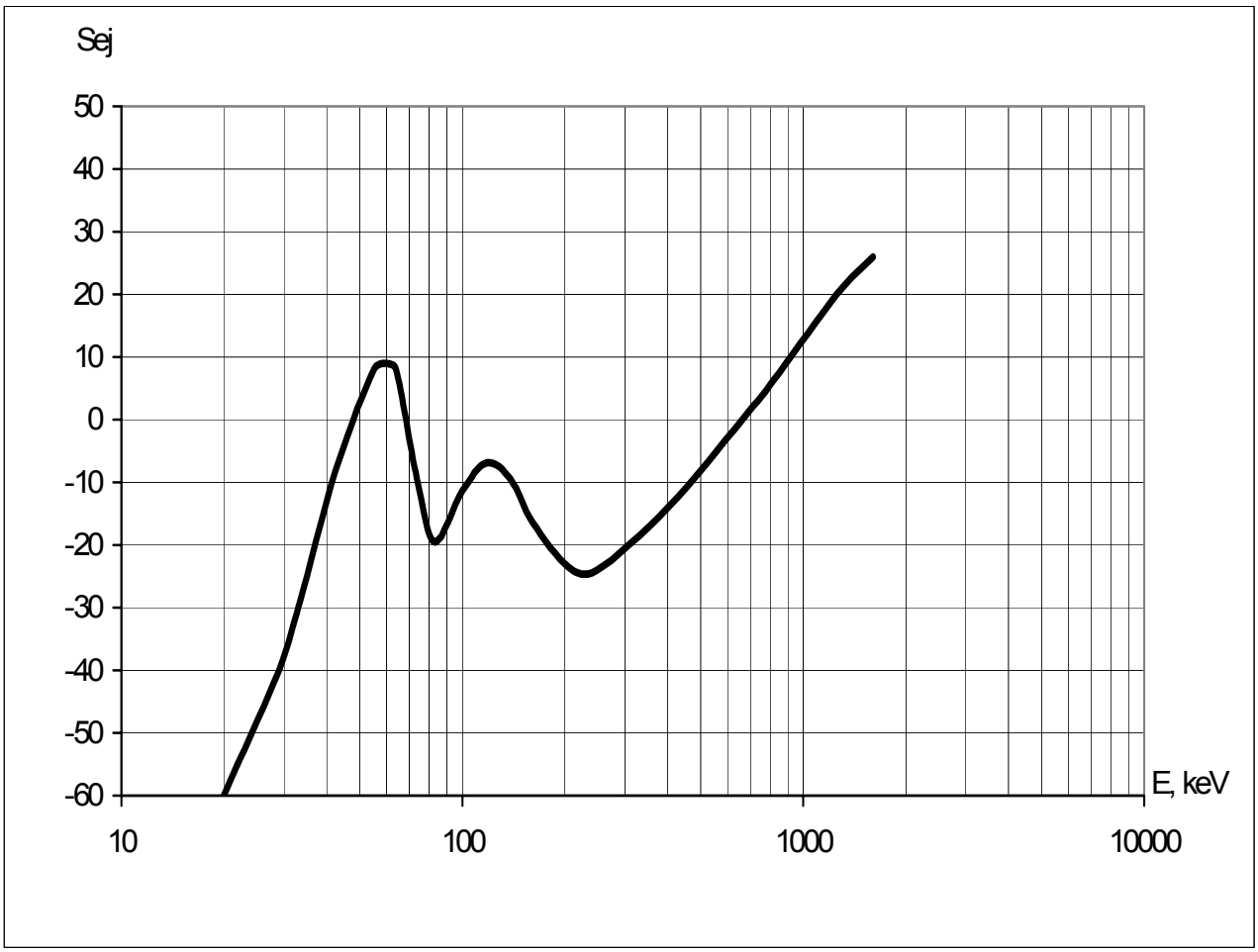


Fig. A.3
A typical plot of the energy response (as against ^{137}Cs) of the monitor with the gamma detector BD-03

APPENDIX B

Order Form

Item	Quantity in the kit	Ordered quantity	Note
The PM 1402M portable radiation monitor including:			
Mandatory components			
Processing unit	1		
Detector	1		One detector or a set of detectors
Operating manual	1		
Case	1		
Package	1		
Options			
Gamma radiation detector BD-01	1		
Gamma radiation detector BD-02	1		
Gamma radiation detector BD-03	1		
Gamma radiation detector BD-03-01	1		
Neutron radiation detector BD-04	1		
Alpha and beta radiation detector BD-05	1		
Vibration alarm device	1		
Charger	1		
Accessories including:			
Bracket N 1	1		Complete with BD-01 or BD-02
Bracket N 2	1		Complete with BD-01 or BD-02
Bracket N 3	1		Complete with BD-03, BD-03-01
Bracket N 4	1		Complete with BD-03
Bracket N 5	1		Complete with BD-04
Bracket N 6	1		Complete with BD-05
Extension tube N 1	1		
Extension tube N 2	2		
Handle	1		
Cable N 1	1		
Cable N 2	1		
Cable N 3	1		Complete with BD-02
Clamp	6		
Shielding cover	5		Complete with BD-05
Protective screen	1		Complete with BD-05
Application program (diskette)	1		Complete with BD-02

Notes

1 The detectors BD-01 and BD-02 are supplied with one set of brackets (bracket N1 and bracket N2).

2 By the order, some accessories which are used for remote inspection of objects (brackets N1 - N6, extension tubes N1 and N2, handle, clamps, cable N 2) may be excluded.

Additional requirements

_____

_____

_____

Company _____

Phone _____ Fax _____

Address_____

Authorized person _____