NEUTRON SEARCH DETECTOR

KSAR1U.06

OPERATING MANUAL

2007

CONTENTS

Description and Operation

1.1. Area of Application

The Neutron Search Detector KSAR1U.06 (NSD) is designed for searching and localization of neutron radiation sources as well as verification of neutron alarms, generated by fix installed radiation monitors.

1.2. Technical specification

1.2.1. Static detection sensitivity of NSD to fission neutrons is not less than 20 cm^2.

1.2.2. NSD triggers an alarm when a neutron source 1.2×10^4 n/s is passed by with a speed of 0.5 m/s in a standard background conditions at the distance of (1±0.05) m of the closest approach. Alarm probability is 0.8 at 95% of confidence level.

1.2.3. False alarm rate is not more than one per 10 min at 95% confidence level.

1.2.4. Intrinsic NSD countrate at standard background conditions (0.015 n/s cm^2 at sea level) is not more than 0.3 cps.

1.2.5. The range of indicated ambient dose rate is 0.28÷700 $\mu Sv \cdot h^{-1}$ for fission neutrons at 25 % measurement uncertainties, and it is 0.14÷1400 $\mu Sv \cdot h^{-1}$ for gamma radiation over the energy range 0.06÷3.00 MeV at 35 % measurement uncertainties.

1.2.6. NSD battery life in SEARCH mode is not less than 16 h and not less than 4 h under continuous alarm conditions.

1.2.7. The outside dimensions are 300×160×130 mm.

1.2.8. The total weight of NSD is 4.3 kg.

1.2.9. NSD is insensitive to exposure to a ^{60}Co gamma ray source producing the dose rate 200 $\mu Sv \cdot h^{-1}$ at its surface.

1.2.10. NSD remains operational in a temperature range of -20°C to +50°C and relative humidity 90% at 35°C and less, in non-condensing conditions.

1.2.11. NSD is sealed to IP55.

1.3. Design and Operation of NSD

1.3.1. Neutron Search Detector KSAR1U.06 is a modern and efficient tool as primary search (detection) device or as a complimentary device to be used for verification of alarm signals generated by fix-installed radiation systems.

NSD KSAR1U.06 is developed and built in compliance with International Atomic Energy Agency recommendations and requirements “Technical / Functional Specifications for Border Radiation Monitoring Equipment Draft Rev. 18.5 /19 Dec. 2003”.

NSD has the following features:

- High efficiency moderated neutron detector with reasonable insensitivity to gamma radiation and strength to tuned-reed indicator and shock
- Geiger counter for gamma ray ambient dose rate measurement
- Switchable Visual (LCD illumination and LED), acoustic (tone height being proportional to alarm threshold exceeding value) and tuned-reed indicator of alarm
- Enhanced statistical algorithm moving-average criteria
- Friendly interface with both digital and graphical indication simplifying the neutron source localization process
- Single-handed operation
- Selectable under restricted access radiological safety alarm threshold shown on the display
- Rugged design for outdoor use in a wide range of temperature and humidity
- Illuminated large area display
- Rechargeable NiMH batteries providing at least 16 hours of continues operation
- Critical parameters setting re-settable to factory defaults under restricted access
- 3 operational buttons and 1 “power/ lighting” button
- 4096 records available in RAM
- USB ver. 2.0 interface

Fig.1 and Fig.2 shows the top view of NSD. Both neutron detector and electronics are integrated in one instrumental case. Rechargeable batteries and analog electronic socket are mounted on the either ends of the moderator block.

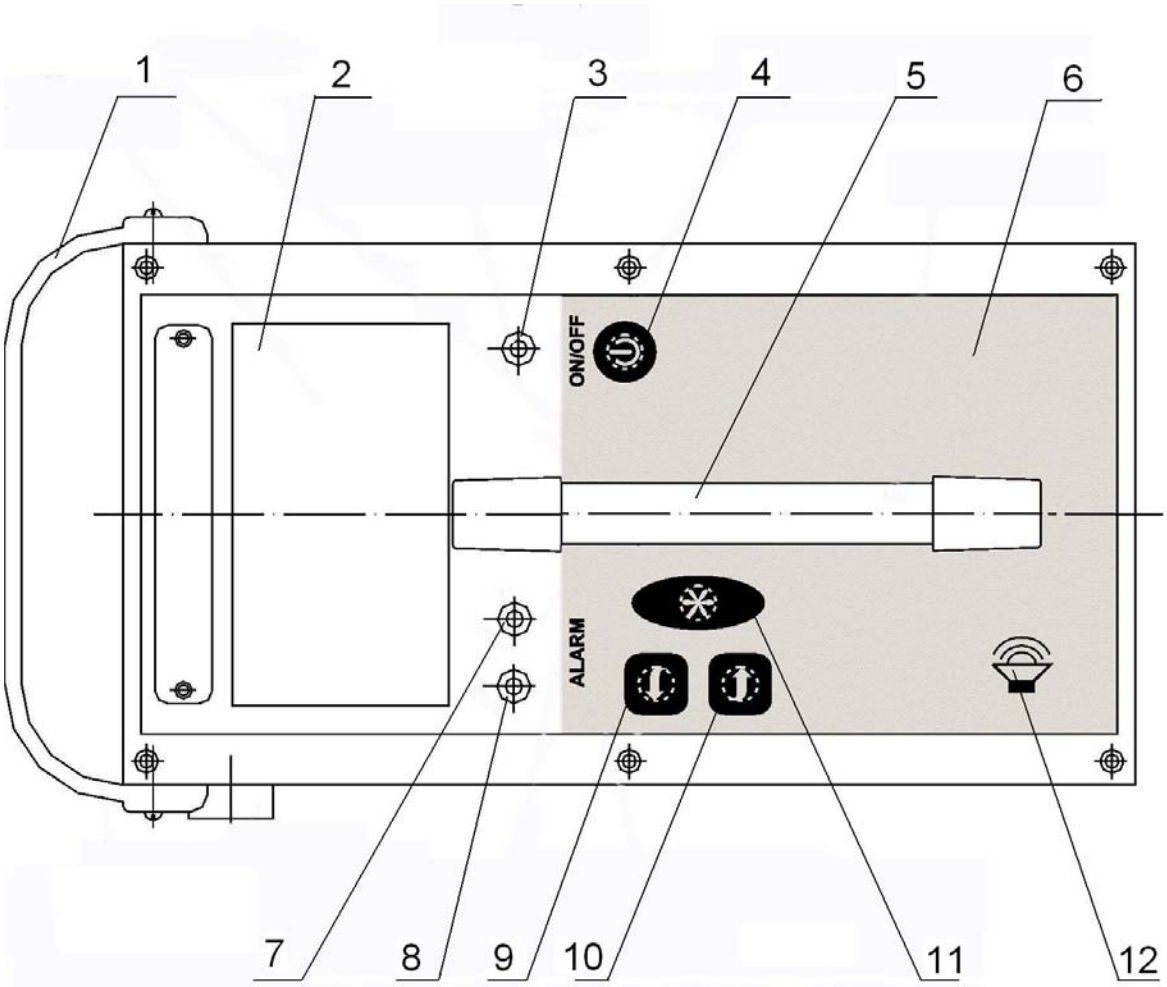

Figure 1. NSD top view

1 – handle
2 – LSD
3 – LED “Power”
4 – On/Off button
5 – handle
6 – film keyboard
7 – LED “Safety alarm”
8 – LED “Alarm”
9 – Left and Up button
10 – Right and Down button
11 – Confirm button
12 – crystal loudspeaker

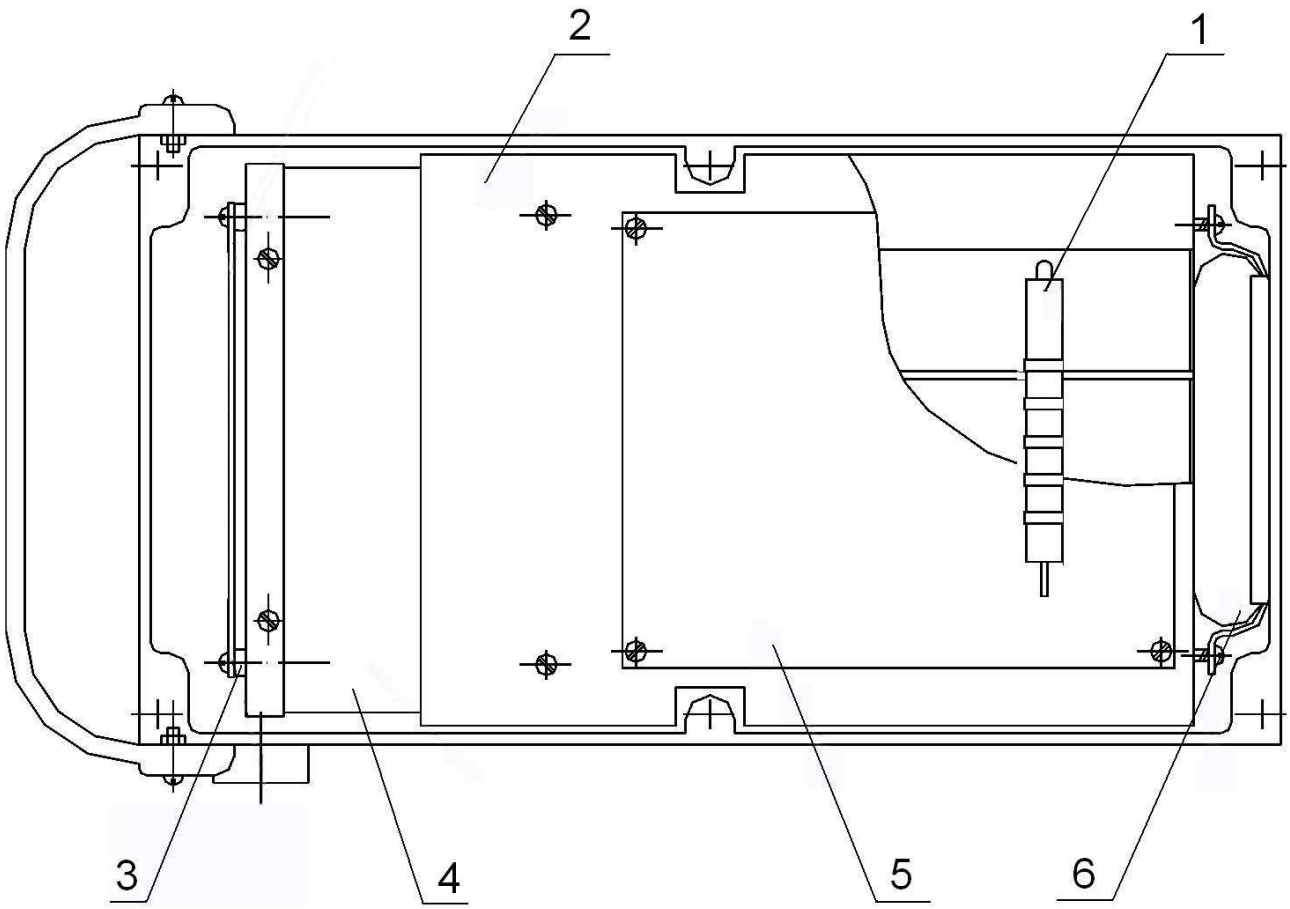

Figure 2. NSD top view without cover.

1 – GM counter

2 – neutron detector

3 – HV power supply

4 – analog electronics

5 – main board

6 – Ni-MH rechargeable battery

LCD, LED "Alarm", LED “Safety alarm”, operating buttons, connector for connection of the charger and PC via USB port (charger/USB), piezoelectric siren, and button "POWER ON/OFF" with power LED are mounted on the top cover of NSD case. Tuned-reed indicator generating an additional alarm signal is mounted inside the case.

NSD has two lightweight carrying handles.

Three ^{3}He proportional counters SNM-88, diameter 32 mm, 200 mm long, are assembled to form the neutron detector. ^{3}He pressure in the counters is 2.7 atmosphere. The counters are placed into polyethylene moderator to improve sensitivity to fission neutrons. Fission spectrum neutrons ambient dose rate is evaluated from the detected neutrons flux value.

GM counter SBM-20 is intended for detecting and evaluating of the gamma ray ambient dose rate over the energy range 0.06-3.00 MeV.

1.3.2. Ni-MH rechargeable battery (RB) 3.8 A·h/7.2 V provides power for NSD. RB serviceability is analyzed by power-on control circuit which prevents turning NSD on at low voltage. Power-on control circuit applies supply voltage U_{RB} to HV power supply, electronic keys, LED "Switch On", Divider, LF amplifier (LFA), and DC/DC low voltage converter (DC/DC LVS), after the signal from the button "Switch On" is received in case the output voltage on RB is satisfactory. Supply voltage U_{RB} is converted by DC/DC LVS to voltage +5V and -5V for CSA (Charge sensitive amplifier), discriminator, pulse former, and controller supply so that NSD is in "On" mode. Voltage U_{RB} is applied to analog-to-digital converter (ADC) input via divider.

ADC is built in controller. The divider transforms U_{RB} so as to get in the measurable by ADC voltage range. In case U_{RB} steps down below the specified level controller produces a signal to turn NSD off. Voltage +400 V is generated by HV power supply for GM counter that measures gamma ray ambient dose rate. Voltage +1600 V is generated for He-3 proportional counters. LED indicates the NSD "On" mode.

Signals generated by neutron detector (ND) follow to the discriminator via CSA. The discriminator produces logical signals, duration 40 μs, if ND signal amplitude exceeds $\bar{A}T/_4$. $\bar{A}T$ is an average pulse amplitude distribution value corresponding to the peak of thermal neutron full absorption in ^{3}He proportional counters. Logical signals come to the controller's counter where their number per unity of time is digitized. GM counter signals also come to the controller that conducts statistically data processing, via pulse former. The pulse shaper forms logical signals 40 μs length. NSD operation modes are changed with control and "Switch On" buttons. The "Switch On" button becomes functional when NSD is turned on.

Information from the controller comes to LCD so that NSD modes of operation and the results of data processing are indicated on the screen. Controller-PC data exchange interface is provided by USB-controller. LED "Alarm", LED "Safety alarm", vibrator, and crystal loudspeaker are triggered by controller through electronic keys, and through LF amplifier. LED illumination is controlled via electronic key.

In order to save in RAM circular buffer data obtained as the result of measurements and to supply the internal timer NSD is provided with the subsidiary Li-ion battery with capacity 0.07 A·h and voltage 3.6V (SB RAM).

1.3.3. Beneath there is the description of NSD operation.

1.3.3.1. NSD modes of operation are START UP, WARM UP, BACKGROUND, SEARCH, INTEGRAL, and SETUP. Press the button "Switch On" to turn NSD on and held it for. When it turns on NSD goes on to the START UP mode and checks the proper functioning of intrinsic systems. When monitor turns at the same time on LEDs "Alarm" and "Safety alarm" flashes, display illuminate, also acoustic alarm ringing and tuned-reed indicator of alarm switches on for approx. 3 second. Hardware and Software version, Serial number, time and date are displayed on the screen (Fig. 3). Duration of STARU UP mode is 10 s, mode can be canceled by pressing the button '*'.

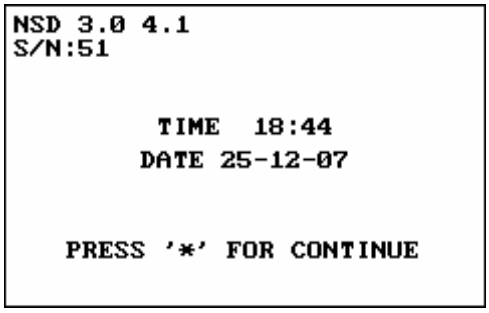

Figure 3. START UP mode screen view

1.3.3.2. WARM UP mode is active on completing the START UP mode. In this mode an electronic components are warming up. Fig. 4 shows the WARM UP screen view. Duration of this process is 60 s.

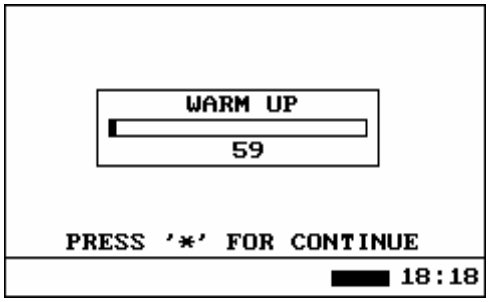

Figure 4. WARM UP mode screen view

Indication of current operational status and elapsed time progress indicator in WARM UP mode is displayed in the center of the screen.

The current time indication from the internal real time clock (RTC) microcontroller timer is displayed in the right lower corner. Since the timer is operated from the subsidiary Ni-MH battery, the current time is not lost when NSD is turned off.

Rectangle in the lower right corner of the screen indicates the RB status. Filled rectangle indicates the maximum RB charge, blank frame warns of forthcoming discharge of the NSD and that RB is to be charged. If the latter is the case acoustic signal (0,5 s, 0,5 kHz) is generated at 10 s intervals. If it is unnecessary to warm NSD up (e.g., a short-term break), WARM UP mode can be canceled by pressing the button '∗'.

1.3.3.3. On completion up warming, NSD turns into BACKGROUND mode. Fig. 5 shows BACKGROUND mode screen view.

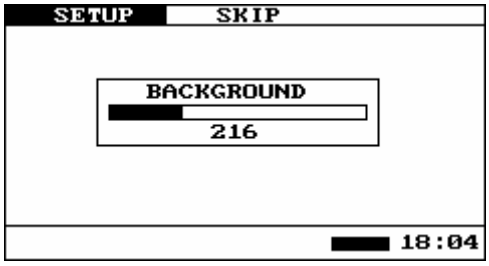

Figure 5. BACKGROUND mode screen view

Neutron background countrate is needed for searching neutron source measures while operating in SEARCH/INTEGRAL mode. BACKGROUND mode can be cancelled providing that there is previously taken background in the instrument's memory.
If during the background measurement no neutron counts were detected, the system warns about fatal malfunction (Fig. 6). Push '∗' button to repeated Background measurement.

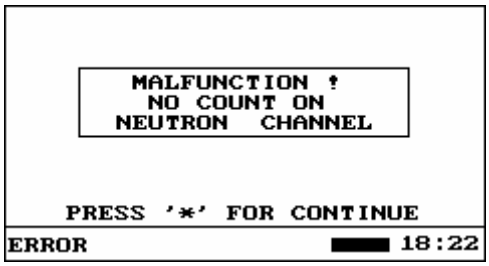

Figure 6. No neutron counts screen view

In BACKGROUND mode count rate in gamma-ray detection channel (GM counter) is analyzed. Contrary to above mentioned neutron malfunction, gamma-ray malfunctioning is not a fatal error and after displaying the corresponding message (Fig. 7) the NSD allows operator to continue operation by pressing '∗' button.

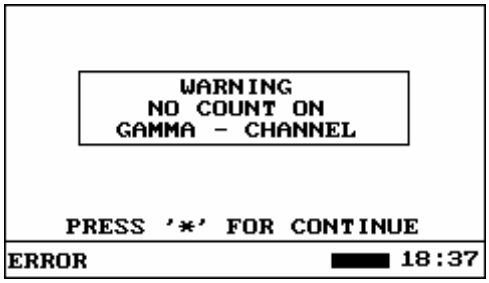

Figure 7. No gamma counts screen view

1.3.3.4. On completion operation in BACKGROUND mode, NSD turns into the SEARCH mode, that is used for searching and localization neutron sources as well as verification of alarms. Fig. 8 shows the SEARCH mode screen view.

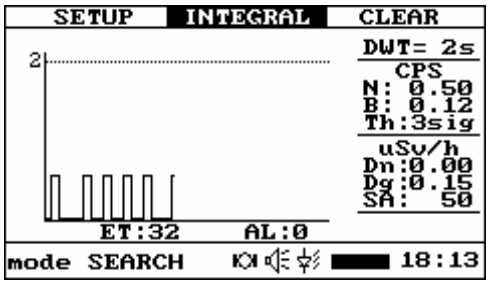

Figure 8. SEARCH mode screen view

The right upper corner of the screen indicates specified sampling time (DWT), neutron prompt count rate (N), average neutron background countrate (B) and alarm threshold in standard statistical deviation units (Th). Neutron (Dn) and gamma ray (Dg) ambient dose rate values and specified radiological safety alarm threshold (SA) in μSv·h-1 are indicated beneath. Definition of dose rate happens in 90 seconds and is not user-selectable in contrast to the sampling time and detection threshold. Dose rate control realizing in any mode of operation and on its exceeding over alarm threshold acoustic alarm turns on, LED “Safety alarm” flashes with the 0.25 Hz frequency and corresponding message is displayed.

To estimate a tendency of their change, obtained count rate values over the last 70 s are shown by diagram. Scaling is controlled automatically. For quick Y-axes rescaling “Clear” menu-item should be chosen.

Active alarm indicators (LED, acoustic and vibration) are displayed under the diagram with corresponding symbol. All three indicators are switchable and can be activated / deactivated independently in the SETUP mode.

Beneath there is a formalism of generating neutron alarm.

The system triggers an alarm if

$$N \geq B + Th \cdot \sqrt{B} + 2, \qquad \text{where}$$

N - is number of neutron counts within dwell time;

B - is background count rate within dwell time;

Th - sigma multiplier.

On exceeding of the prompt count rate value over specified alarm threshold, the corresponding indication is displayed (Fig. 9), LED “Alarm” flashes with 0,5 Hz frequency, acoustic alarm turns on, tone height is proportional to alarm threshold exceeding value.

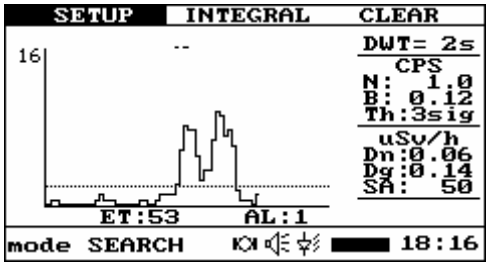

Figure 9. SEARCH mode screen view on exceeding alarm threshold

A number of troubles defines as number of intersection of thresholds, i.e. if detection happened and monitor keep trouble, then number of detection scales up to 1.

A circular buffer for alarm related information recording is provided for the device. Alarm time, date, sampling time, N, sigma multiplier and B are stored in one record. The buffer capacity is 4096 records. A single alarm is recorded in the list in the vicinity of 5 preceding and 5 posterior measurement intervals. Data from memory can be read out by the PC (ref. 1.3.3.8. PC link).

1.3.3.5. INTEGRAL mode is intended to detect and verify weak neutron sources that cannot be detected in the SEARCH mode because of the insufficient measurement time. Fig. 10 shows the INTEGRAL mode screen view.

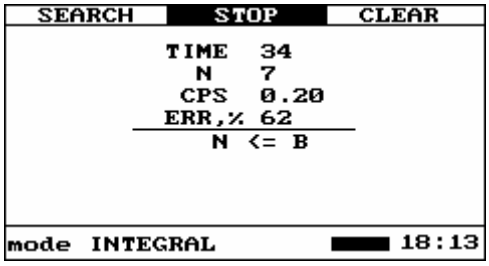

Figure 10. INTEGRAL mode screen view

NSD displays the following items in this mode:

TIME – Elapsed time

N – Number of neutron counts accumulated

CPS – Average count rate over the elapsed time, $CPS = {}^{N}\!/_{TIME}$

ERR – statistical uncertainty of average count rate with confidence level 0.95

The data are updated on the screen once a second.

NSD compares N and B and generates the message (Fig.11) $N > B$ if the condition $N > k\sqrt{N} + B$ is true. Constant k denotes confidence level 0.95 of the previous expression. Otherwise $N \le B$ message is displayed.

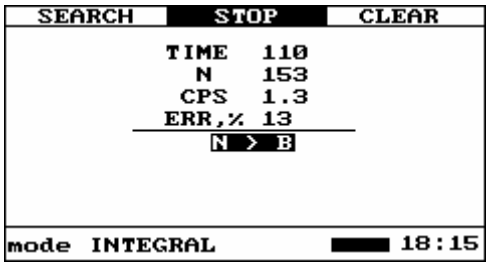

Figure 11. INTEGRAL mode screen view on exceeding background

“STOP” menu item stops current set, “CLEAR” nulls printed values, SEARCH returns NSD to the search mode.

1.3.3.6. SETUP mode is intended to optimize NSD performance to the user requirements and operation conditions. There are two access levels into SETUP mode:

- User adjustable subset of parameters;
- Password protected subset of parameters (PROTECTED OPTIONS).

Main menu of the SETUP mode is shown in Fig. 12.

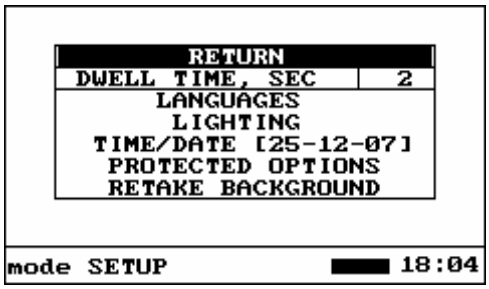

Figure 12. Main menu of the SETUP mode

Choosing of items realizing by “UP” and “DOWN” buttons, verifying of selection and changing of current installations by “*” button.

The device gets in BACKGROUND mode in case “RETAKE BACKGROUND” option is chosen. Sampling time in SEARCH mode is specified by the option “DWELL TIME” and varies from 1 to 5 s (step 1s).

1.3.3.6.1. NSD operates in three languages – Russian, English and Deutsch. The language is selected by means of submenu “LANGUAGES”.

Figure 13. Submenu “LANGUAGES”

1.3.3.6.2. Switch on/off illumination of the screen is controlled by “LIGHTING” submenu.

Figure 14. Illumination control panel

Display illumination remains switched off in case “ALWAYS OFF” option is chosen except only illumination switch on for 10 s at every press on the “Switch On” button provided for changing illumination conditions in the dark.

Display is permanently illuminated in “ALWAYS ON” mode.

“10 SEC” mode illuminates the display for 10 s at every press on any button, at changing operation modes (including automatic modes), at exceeding of the detection threshold in “SEARCH” mode, and at exceeding the radiological safety alarm threshold. Note, that display illumination is one of the most power consuming NSD part. Avoiding frequently use of “ALWAYS ON” option provides longer operational life time of NSD without recharging batteries.

1.3.3.6.3. Use “TIME/DATE” menu to change current time and date.

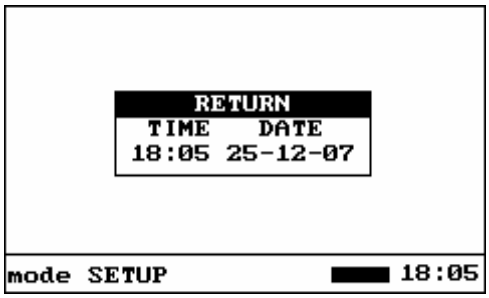

Figure 15. “TIME/DATE” mode screen view

1.3.3.6.4. To enter into PROTECTED OPTIONS, the password is required (Fig. 16).

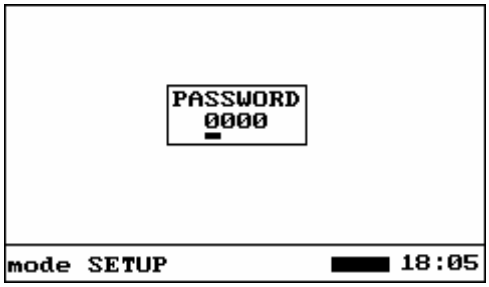

Figure 16. Entering password

A value above the marker shifts from 0 to 9 by pressing '*'. To shift to the next digit press LEFT button. When the last digit of the password is entered, in case the password is legal, the menu of the PROTECTED OPTIONS is displayed on the screen, otherwise message "ILLEGAL PASSWORD" appears on the screen. (Fig. 17). Pressing any button returns the device to the previous mode. The default password is given in the NSD certificate.

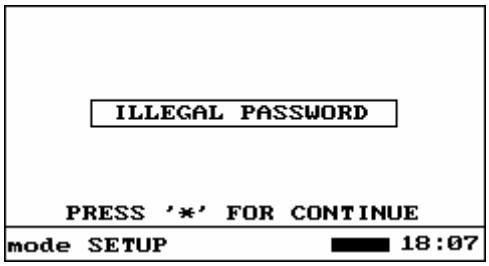

Figure 17. Illegal password entered.

1.3.3.6.5. Menu of the PROTECTED OPTIONS is shown in Fig. 18.

Figure 18. PROTECTED OPTIONS menu

All NSD options (except password) are set up in the manufacturer specified values when "Set Default" option is chosen (Table 1). In this case, the confirmation menu is displayed on the screen (Fig. 19).

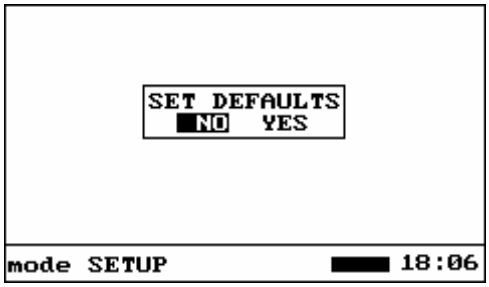

Figure 19. Confirmation menu of the "Set Default" option

1.3.3.6.6. Setting options in the BACKGROUND and SEARCH mode is realized in the submenu "MEASURE OPTIONS" (Fig. 20).

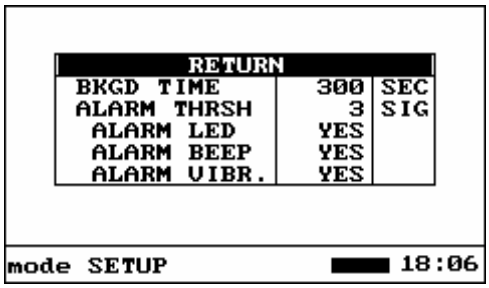

Figure 20. Submenu “MEASURE OPTIONS”

Duration of the background count rate measurement in the BACKGROUND mode is specified by the option “BKGD TIME” and takes on values 100, 200, 300, and 500s. Note, that at normal background conditions the background count rate is to be 0.05÷0.3 cps. Therefore, to get a sufficient statistical accuracy of the data the minimum duration 300 sec should be applied.

“ALARM TRSH” (sigma multiplier) parameter directly reflects to probability of detection and false alarm rate, because it sets alarm threshold (see expression in 1.3.3.4 for details). This value has the dimensions of the standard deviation unit and varies from 1 to 6.

“ALARM LED”, “ALARM BEEP”, and “ALARM VIBR.” options (See 1.3.3.4) activate / deactivate the corresponding alarm indicators. The options are YES/NO.

1.3.3.6.7. Radiological safety alarm threshold dose rate values are set in “SAFETY ALARM” submenu (Fig.21).

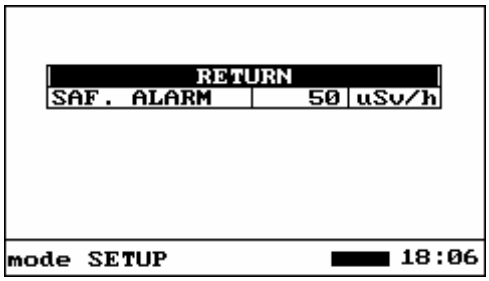

Figure 21. Alarm threshold total dose rate specifying menu

Alarm indication is turned on in case alarm threshold is exceeded: LED “Safety alarm” flash frequency is 0.25 Hz, permanent acoustic alarm appears and corresponding message is shown on the screen. Dose rate is monitored in all operational modes, and alarm threshold indication is of priority. For example, in case the search threshold and the radiological safety dose rate threshold are exceeded simultaneously, indication corresponds to the dose rate threshold.

1.3.3.6.8. Password can be changed into CHANGE PASSWORD submenu (Fig. 22):

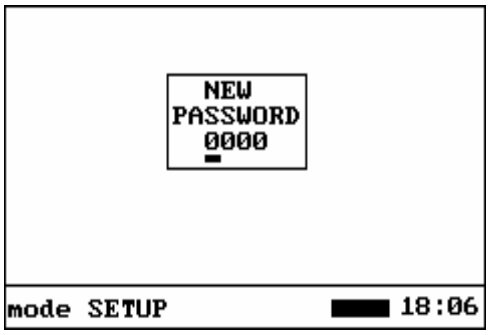

Figure 22. Setting up new password

Current password is shown on the screen. A value above the marker shifts from 0 to 9 by pressing '*'. To shift to the next digit press the LEFT or RIGTH button. When the last digit of the password is entered, new password is recorded into instrument's memory.

1.3.3.7. To turn NSD off, press "POWER ON/OFF" button and hold it for 5 s. Progress indicator appears on the screen.

1.3.3.8. NSD is linked with PC via USB-port, communication software is supplied. Executive instructions are provided to inquire about the current status of NSD and current neutron and gamma ray dose characteristics, to read the data on neutron alarms from the alarm list (See 1.3.3.4), to clear the alarm list, to inquire about the current measurement data in SEARCH or INTEGRAL mode, and to control NSD with the instructions that emulate pressing control buttons. The user can change the password to access to PROTECTED OPTIONS menu as well as synchronize the time in PC and NSD.

To link the device with PC:

- connect NSD to USB-port of PC with the cable supplied. NSD connector - mini USB type B – is located under the protective cover;
- switch NSD on;
- run program NSD4x.exe. To install the program, if it is not SetupNSD4x.exe from CD; should be started

The driver and communication software will be installed automatically.

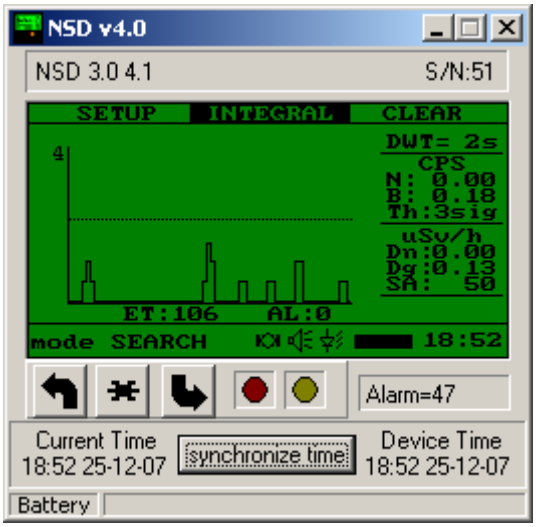

Fig.23 Communication and maintenance program

To change password right click on the NSD screen panel, then follow the instruction.

To read, save or clear alarm list – push right button on Alarm panel.

To synchronize the time in PC and NSD left click on synchronize button.

Table 1. Specified options

№	Option	Purpose	Value range	Default
1	DWELL TIME	Sampling time in SEARCH mode, s	1…5, step 1	2
2	BACKGROUND	Duration of background count rate measurement, s	100, 200, 300, 500	300
3	ALARM TRSH	Sigma multiplier, σ	2, 3, 4, 5, 6	3
4	ALARM LED	Activation / Deactivation of LED indicator under alarm condition	YES/NO	YES
5	ALARM BEEP	Activation / Deactivation of acoustic signal indicator under alarm condition	YES/NO	YES
6	ALARM VIBR.	Activation / Deactivation of vibro-indicator under alarm condition	YES/NO	YES
7	SAFETY ALARM	Radiological safety alarm threshold neutron dose rate, $\mu Sv \cdot h^{-1}$	20, 50, 100, 200, 500	100
8	LANGUAGE	Working language	Russian, English, German	English
9	LIGHTING	Display illumination	YES, NO, 10 s	10 s

2. Use for designed purpose

2.1. Operation restrictions

2.1.1. Rechargeable battery (RB) is charged in temperature range $+5^{o}C \div +40^{o}C$.

2.1.2. Operation of the device is not recommended at temperature below $-20^{o}C$ and above $+50^{o}C$.

2.2. Preparation NSD to operation

2.2.1 Make sure that remaining battery's capacity is sufficient for required time of operation. To charge the NSD batteries use ACS410 Treveller provided in delivery set. The charger operates at AC 100÷240 V/ 50÷60 Hz.

2.2.2. Connect charger to the chassis connector, marked as charger and located under protective cover on the left side of NSD case. The charger starts operation automatically as soon as NSD batteries are connected to the Charger connector. During the test phase, which usually takes about 10 s (red LED is flashing) the charger analyses batteries condition and defines the number of cells. The charge procedure should follow to the complete discharging. When red LED switch over to permanent light for charging, press the yellow button for about 2 seconds for discharging the batteries. After discharging, which can in individual cases takes several hours; the charger automatically switches to charging. After the charging procedure, the charger switches automatically over the trickle charge (green LED is on, red LED – off). During charging do not turn on the gadget to avoid early death of accumulators.

2.2.3. After pressing POWER ON/OFF button, NSD switches over the START UP mode (1.3.3.1), then subsequently to WARM UP and BACKGROUND (1.3.3.2 *и* 1.3.3.3), after which turns into SEARCH mode (1.3.3.4).

2.3. General recommendations on search, localization, and verification of neutron sources

2.3.1. On search, localization, and verification of examined object, operator moves NSD along it, or places it in immediate proximity of its surface.

2.3.2. In search or integral modes NSD bottom faces the object. The most sensitive point of the instrument is marked with cross on the bottom of the NSD. The reference point for gamma ray dose rate measurement is also marked with the cross and located on the top side of the instrument.

2.3.3. On search and localization of neutron source it is recommended to take into consideration that NSD detected minimum neutron intensity in the general case is in direct proportion to:

- the square of distance between the source and NSD,
- the square root of background flux density value,
- the square root of speed of the detector relatively to the neutron source.

2.3.4. On verification of low-active neutron sources in INTEGRAL mode account must be taken that minimum intensity of neutron and gamma ray activity of the source verified by NSD is:

- in direct proportion to the square of distance between the source and NSD,
- inversely as the square root of measurement time value.

Note. Optimal sampling time dT as a function of NSD - source relative speed V, and of the distance of closest approach H can be estimated by the relation:

$$dT = \frac{2H}{V}$$

2.3.5. Display message and LED/VIBRO/AQUISTIC signals (See 1.3.3.4) indicate neutron alarm.

2.3.6. Neutron source is localized visually by use of display indications, and by estimation of acoustic signal tone height (See 1.3.3.4).

3. Maintenance

3.1. Safety regulations

3.1.1. The detector is dangerous as it is a high voltage source. Internal HV power supply is HV source.

3.1.2. To avoid personnel being voltage-stricken, it is strictly prohibited to open the detector case when NSD is on.

3.1.3. Metal parts of the detector are designed in accordance with the safety standards/safety code/emergency decree for electrical installation with voltage above 1000 V. The case itself is made of nonconductive polycarbonate.

3.2. Maintenance regulations

3.2.1. User carries out maintenance and servicing of the device every three months at least. The list of maintenance procedures includes the following items:

- Clean external surfaces of the device and display screen with ethanol-wet cotton-like wiping cloth.
- Charge the batteries.

3.3. Availability testing

3.3.1. Unless specified, NSD is tested on adjustment of set up parameters in corresponding "SET DEFAULTS" options (See 1.3.3.6).

3.3.2. NSD serviceability testing is carried out under normal environmental conditions.

Availability testing is based on background rate measurement, absolute detection sensitivity and false alarm rate measurements.

To test absolute detection sensitivity and detection alarm threshold ^{252}Cf standard neutron source $(1\div9)\times10^4$ neutron/s intensity is used.

3.3.2.1. Absolute detection sensitivity testing is performed according to the following procedure.

- Place the detector in the testing room at not less than 1.5 m from the floor and 3 m from the walls and from the ceiling.
- Turn NSD on and make sure that it shifts in SEARCH mode.
- Make note about the background count rate. At sea level NSD background countrate should be within 0.05÷0.30 cps, corresponding to gross neutron flux density of 0.015 n/s·cm^2.
- Place standard ^{252}Cf neutron source at 1±0.02 m distance from the center of the sensitive surface of the detector and shift NSD into INTEGRAL mode.
- Exposure time in INTEGRAL mode should be sufficient to provide statistical uncertainty less than 10%.

– Stop measurement and use the data obtained (See 1.3.3.5) to calculate absolute detection sensitivity $R(cm^2 \cdot 1/n)$ according to the following expression:

$$R = \frac{N - B}{A \cdot TIME} \cdot 1.256 \times 10^5$$

where:
TIME is exposure time, s;
A is ^{252}Cf neutron source intensity, n/s;
N is number of detected neutrons over the exposure time, pulse;
B is number of background events over the exposure time, pulse;
Factor $1.256 \cdot 10^5$ is calculated from $4\pi\ l^2$, where l = 100 cm, cm^2.

3.3.2.2. False alarm rate test is performed in Search mode. EL indicator in the bottom of the panel corresponds to elapsed time since the last entering into search mode. AL indicator is the number of alarms detected. Proving that there is no any moving neutron source affecting on the NSD countrate, the false alarm rate is defined as ratio of AL to EL. Note, that due to the moving average approach (time shift is one half of the dwell time) used, the number indicated EL is, in generally, higher than the true value (one neutron excess may result either in one false alarm or two false alarms into neighbor time intervals).

NSD availability is proven if background count rate is within 0.05÷0.30 cps, *R* value is not less than 20 (pulse·cm^2)/n and the number of false alarms is not exceed 7 within 6000 measurement intervals.

4. TroubleShooting

Typical malfunction and the ways to default them are given in Table 2.

Table 2.

Problem	Possible cause	Directions to repair
NSD does not turn on	RB is dead	Charge SB (see 13.2.1)
Continuous operation time is less than that specified in 1.2.7	RB capacity is low	Repeat not less than 3 full discharge and full charge cycles
No gamma ray or neutron counts	Neutron counter unit and GM counter PSB malfunction	Send for repair to manufacturer
Instrument's RTC is always late, stops when instrument is off, user adjusted values of measurement parameters are lost after restart the instrument.	Li-ion battery for SRAM and RTC is low	Replace it with the new one
No PC connection	PC link cable fault	Replace the connecting cable.
	PC USB port fault	Repair USB port
	PC software failure	Reinstall PC software
	NSD software failure	Turn NSD off and on

5. Storage

The detector is stored in standard package at environment temperature range -20°C ÷ +40°C. Batteries shall be fully charged before storing. To prolong battery life, it is recommended to trickle charging not less than once per 3 months.

6. Transportation

The device is transported in standard package without speed and distance limitation. It shall be enclosed against sea water during sea transit. It shall be protected from the direct sunlight, weather protected, and protected from the hostile environment during rail transport. It shall be placed in hermetically sealed compartment during air conveyance. It shall be protected from the direct sunlight and weather protected during road transport.