SatisGeo

Instruments for Geophysics & Environment

GS-512i
Portable Gamma Ray Spectrometer

OPERATION MANUAL

2015

CONTENTS

1. INTRODUCTION

Spectrometer GS-512i is a digital portable instrument designed for gamma ray energy spectra measurement. The GS-512i is powered by internal batteries or external power supply. The GS-512i basic set-up with GSP-3 scintillation probe is designed for field measurement of natural and artificial radionuclides and their quantitative determination. Radionuclides, sources of gamma radiation, emit gamma quanta of specific energies. Gamma ray spectrometers detecting gamma radiation, transform the energy of gamma quanta into electrical signals - voltage pulses of amplitude proportional to the energy of gamma quanta. Pulse amplitude analyser selects signals after their amplitudes into separate channels that correspond to given energy of gamma radiation. A group of channels, corresponding to an interval of gamma ray energy, is commonly designated as an energy window. Gamma ray energy intervals of interest are designated by an abbreviation ROI (Region Of Interest).

Field gamma ray spectrometry is applied in raw materials exploration, geophysical mapping, monitoring of the natural radiation environment, assessment of radioactivity of building materials and of anthropogenic objects.

Radioactivity of rocks is mostly determined by detection of gamma rays. Substantial sources of rock gamma radiation are potassium K, uranium U and thorium Th, emitting gamma quanta in the energy interval up to 2615 keV. Gamma spectrometric determination of potassium is based on detection of radioactive isotope ^{40}K , whose abundance in natural K isotopes is 0.012 %. The isotope ^{40}K emits gamma rays of the energy 1461 keV, determination of K is a direct one, and the results are in the field of geology and geophysics expressed in percentage of mass concentration [% K]. Gamma spectrometric determination of U in field conditions is carried out by the detection of 1764 keV ^{214}Bi gamma rays, a product of ^{238}U disintegration series, determination of U is indirect, and the results are expressed in ppm eU. Gamma spectrometric determination of Th in field conditions is realised by detection of 2615 keV ^{208}Tl gamma rays, a product of ^{232}Th disintegration series, determination of Th is indirect, and the results are expressed in ppm eTh. Gamma ray spectrometers record also gamma rays, as total count, in a broad energy region of interest. In a field application, the GS-512i gamma ray spectrometer determines the total count, K, U and Th by detection of gamma rays in four energy regions of interest (energy windows) ROI 1, ROI 2, ROI 3 and ROI 4 . The total count, summarising the instrument response to all sources of gamma radiation in a broad energy window, is expressed in equivalent uranium concentration [ppm Ueq] (1 ppm = 1 μg/g).

Determination of nuclear fall out is based on detection of its gamma rays. Nuclear fall out is formed by a large number of artificial radionuclides released into the atmosphere, which are

transferred at a large distance. Nuclear fall out radionuclides are accumulated in surface soil layer of 2 - 20 cm thickness. Half lives T of nuclear fall out radionuclides are in a very broad time interval, isotopes ^{137}Cs (T = 30 years), emitting gamma rays 662 keV, and ^{134}Cs (T= 2.06 years), emitting gamma rays 605 keV and 696 keV are indicative for the earth surface nuclear fall out contamination. The radiation level and isotopic composition of nuclear fall out, at the initial stage of contamination, can be judged by registered gamma ray energy spectra analysis.

Cosmic radiation is a significant component of the natural radiation. Its interaction with atmospheric air gives origin of radiation that is detected at the earth surface. Intensity of cosmic radiation increases progressively with altitude. The cosmic radiation component, due to high energy, can be detected separately from the natural radiation of K, U and Th. The gamma ray spectrometer GS-512i detects cosmic radiation in specific built-in region of interest, monitoring the gamma rays exceeding the energy 3000 keV.

Gamma-ray spectrometer GS-512i, in standard outfit, comprises the measuring probe with the scintillation NaI(Tl) 76x76 mm detector and a 512 channel amplitude analyser controlled by a microcomputer. This conception has several construction and user advantages. It enables simple control of the shape of the whole measured or recorded energy gamma ray spectrum, giving evidence of the correctness of measurement, and a simple procedure enables setting and control of energy windows (ROIs), making the instrument flexible for various assays. The GS-512i calibration is for the user simplified and calibration constants calculation is fully automated.

Precision of gamma ray spectrometry analyses significantly depends on the instrument function stability. The energy spectrum position stability is fundamental. Spectrometer GS-512i is outfitted with the automatic energy spectrum stabilization using the reference radionuclide, selectable for the specific instrument use. Automatic energy spectrum stabilization eliminates fully all spectrum shifts, caused by temperature dependence of the detector and electronic circuits. The microprocessor calculates from the measured spectrum accurate position of the reference source peak and by the change of the shaping amplifier gain keeps the reference peak, and thus the whole spectrum, at a fixed channel position. The channel position of the reference peak is simply changed from the keyboard, what enables the use of various reference gamma rays sources.

The GS-512i spectrometer immediately after field measurement of the rock radioactivity calculates by a matrix method concentrations of K, U, Th and displays them in a sequence. The total count figure is displayed in equivalent uranium concentration [ppm Ueq], K in [% K], U in [ppm eU] and Th [ppm eTh]. The instrument also allows to display registered counts per minute in selected energy windows (regions of interest, ROIs).

The GS-512i digital memory stores resultant data (station measurement identification and TC, K, U, Th data) from a station assay and the whole 512 channel gamma ray spectra.

16 MB digital memory enables to store up to 7500 measured spectra. The stored data are kept in the memory after instrument switch off or after removal of power supply batteries.

The gamma ray spectrometer GS-512i enables a data transfer to the computer through the built-in interface USB or Bluetooth. The Bluetooth connection is useful for receiving GPS data from an external unit.

The gamma ray spectrometer GS-512i performs a series of tests, checking the measurement or the instrument or the correctness of operator's instrument control. Error messages are displayed on the instrument console and accompanied by an audio signal. Within the measurement period, the operator is informed on correct instrument function by the test, that calculates and displays accurate reference peak position, energy resolution and actual instrument dead time. The resolution is defined with FWHM, the full width of an energy measured at one-half of its maximum amplitude with continuum removed.

The gamma ray spectrometer GS-512i is powered by six LR6 AA type alkaline batteries, or NiMN accumulators, that can be recharged in the instrument. The working capacity of one set of batteries is 8 - 15 hours of net working time, in dependence on batteries type and environmental temperature. The unit can be also powered from an external power supply. The built-in digital voltmeter measures the condition of the power sources. It is displayed graphically as the icon in the upper right corner.

2. TECHNICAL SPECIFICATIONS

2.1 The Detection Probe

	GSP-2	GSP-3	GSP-4
Size of Crystal:	$\varnothing$51x51mm (103cm^3)	$\varnothing$76x76mm (346 cm^3)	$\varnothing$101x101mm (824cm^3)
Size of Photo-multiplier:	$\varnothing$51 mm	$\varnothing$76 mm	$\varnothing$127 mm
Detector:	Sodium iodide, thallium activated NaI(Tl) scintillation crystal and photo-multiplier as a monoline scintiblock		
Energy resolution:	FWHM for the energy 662 keV ^{137}Cs Better than 8.0 %		Better than 9.0%
High voltage:	Stabilised high voltage power supply for the photomultiplier, range 800 - 1000 V adjustable inside detection probe after its opening		
Pulse rise time:	0.5 μs		
Pulse fall time:	5 μs		
Maximum output voltage:	+ 3 V		
Gain setting:	10-turn potentiometer, accessible after detection probe housing removal. Recommended setting 0.5 V +/- 5 % for the energy 662 keV		
Output impedance:	100 Ω		
Detection probe housing:	Aluminium, with water resistant seals and thermal insulation		
Reference source:	^{137}Cs, activity <10 kBq (0.28 microcurie) removable, accessible in an external mount at the base of the detection probe		
Outline Dimensions:	$\varnothing$85x393 mm	$\varnothing$122x400 mm	$\varnothing$190x480 mm
Weight:	1.6 kg	4.6 kg	6.8 kg
Temperature range: Operating Storage	-10°C to +50°C -20°C to +70°C		-10°C to +50°C -10°C to +60°C

2.2   GS-512i Spectrometer Console

2.2.1 Input Amplifier and Automatic Gain Control

Input signal: 0 - 3 V from detection probe output

Pulse shaping: Semi-Gaussian, 1μs time constant with pole zero cancellation

                         Active base line restoration

                         Pile up rejector

Gain: Automatic microprocessor digital control over a range +/- 25 %

2.2.2 Analog to Digital Converter

Type: Successive Approximation ADC, 16Bit, 1,33 MSPS

Conversion time: 0.8 μs

Channel width: 5 mV

Input voltage range: 50 mV to 2.5 V

Differential non-linearity: Max. 1 % in the range 50 mV to 2.5 V

Integral non-linearity: Max. 0.3 % in the range 50 mV to 2.5 V

Zero drift: 2 mV/10 $^\circ$C

Maximum input count rate: 50000 counts per second with a peak displacement,

                             due to zero shift, inferior to 1 %

2.2.3 512-Channel Analyzer

Mean access time from ADC: 0.2 μs

Number of channels: 512

Maximum counts per channel: $2^{32} - 1$

Dead time correction: Measurement in live time

Sample period: 00:00:01 - 23:59:59 (hh:mm:ss)

Number of energy windows: 8 (ROIs)

ROI setting range: 1 - 511 channel, optional

2.2.4 Digital Spectrum Stabilizer

Reference peak setting:	Within the range of channels 40 / 140
	The automatic spectrum stabilization can be switched off.
Control mode:	Gain control of shaping amplifier
Control range:	+/- 25 %
Stabilization sensitivity:	0.5 % (10^{-1} channel)
Period of control adjustment:	Selectable
Reference source:	^{137}Cs 662 keV reference peak setting in the channel 110.0 corresponds to energy calibration 6 keV/channel.

2.2.5 Internal Data Memory

Memory capacity: 7500 spectra (16 MB), independent on power supply batteries state

2.2.6 General Specifications

Display:	Graphical LCD, screen resolution 240x128 dots with LED backlight
Keyboard:	20 push-buttons membrane-type, dust resistant, water-tight, waterproof
Audio indication:	Piezoelectric buzzer, frequency 4 kHz
Interface:	USB, Bluetooth
Power supply	- internal: 6 alkaline battery LR6 AA 1.5 V
	or 6 accumulators type NiMN 1.2V
	- external: 8 - 15 V / 400 mA
	(do not use the charger as the external powwer supply)
Battery life:	Minimum 12 hours at ambient temperature + 20 °C
Dimensions:	228 x 83 x 110 mm
Weight:	1.5 kg with batteries
Temperature range:	Operating range -10 to +55 °C
	Storage range -20 to +70 °C

2.3   GS-512i Spectrometer Set

2.3.1 Standard Set of GS-512i Spectrometer

GS-512i Spectrometer Console	1 p.c.
GSP-3 Detection Probe with crystal NaI(Tl) 3"x3"	1 p.c.
Cable (Detection Probe - Spectrometer Console)	1 p.c.
Reference Radiation Source EG 1 ^{137}Cs (10 kBq)	1 p.c.
Interface Cable (for interconnecting GS-512i to PC)	1 p.c.
CD (with calibration and communication programs)	1 p.c.
Instruction Manual	1 p.c.
Screwdriver No. 4	1 p.c.
Harness Assembly and Shoulder Strap (leather)	1 p.c.
Transportation Padded Case	1 p.c.
NiMN Accumulators	6 pcs
Charger	1 p.c.

2.3.2 GS-512i Optional Accessories

GSP-4 Hand Carry Detection Probe (with crystal NaI(Tl)4"x4")	1 p.c.
GSP-2 Hand Carry Detection Probe (with crystal NaI(Tl)2"x2")	1 p.c.

The use of the instrument with other detection probes, than are delivered by the instrument producer, is not recommended.

3.   DESCRIPTION OF THE INSTRUMENT

3.1   Detection Probe

The detection probe contains a sodium iodide, thallium activated NaI(Tl) scintillation detector tightly enclosed with a photomultiplier in a scintiblock, a high-voltage supply and a preamplifier. The detection probe is thermally insulated by a polyurethane foam housed in an aluminium case. The unit is equipped with a handle and a connector enabling connection to spectrometer console by a cable. A reference radiation source, typically cesium ^{137}Cs, of activity 10 kBq, is mounted in screw removable case at the base of the probe.

The activity of the reference radiation source is low and does not qualify the source in the category of radioactive sources under international regulations. There is no danger for the user of the equipment, nevertheless the source is registered and should only be operated by a person acquainted with basic rules of work with radioactive substances.

Although the scintiblock is shock-proof mounted in the detection probe, care should be taken to avoid mechanical shocks and vibrations.

Keep the detection probe clean. Contamination of the probe must be avoided particularly when measuring strongly active samples or in the course of calibration.

3.2   GS-512i Spectrometer Console

The spectrometer console contains circuits for processing and analysing the measured signals including: a pole - zero circuit, shaping amplifier with digitally controlled gain, successive approximation analog - digital converter, microprocessor, memory and other auxiliary circuits.

The unit is housed in a shockproof metal case and equipped with circular connector for the connection to the detection probe, placed in the upper part of the right vertical wall of the case. The external power supply connector, serving also for charging of accumulators directly in spectrometer console, is in its lower part. The USB interface connector is placed in the middle of the left vertical wall of the case. The battery compartment, separated from the instrument electronics, is placed in the lower part of the console. The compartment is accessible by unscrewing of 2 screws.

All spectrometer controls are placed at its top desk. The keyboard is a membrane type, has 20 push-buttons and is watertight. No internal electronic adjustment is accessible.

3.3   GS-512i Spectrometer Operating Controls

[ON/OFF]   Push-button for switching the instrument on and off.

[ENTER]   Push-button for the display of main operation menu, for commencing of any activity and for measured data or modified operating parameters storage in the memory.

[ESC]   Push-button for terminating of an activity, without storage of data in the memory, and for the return to the main operation menu.

[DATA]   Push-button for display of various parameters of the given reading, including radioelements concentrations and counts per minute registered in ROIs.

[SPECT]   Push-button for display of gamma ray spectrum.

[0] - [9]   Push-buttons for entering of figures. Push-buttons also shift the cursor to selected functions of the main menu.

[∧]   Push-button used to shift the cursor.

[∨]   Push-button used to shift the cursor.

[>]   Push-button used to shift the cursor.

[<]   Push-button used to shift the cursor.

[NEXT]   Push-button used to move to the next item.

3.4   Main Menu

After switching the instrument on, by means of the push-button [ON/OFF], initial logo appears on the display.

After pressing any push-button or after 3 seconds, the main menu appears.

The backlight is switched off automatically 10 seconds (default value is 10 s, other options selectable) after the last pressing of a push-button. The backlight can be switched off all the time to save power consumption. (See the item 4. BACKLIGHT of the setup - system menu.)
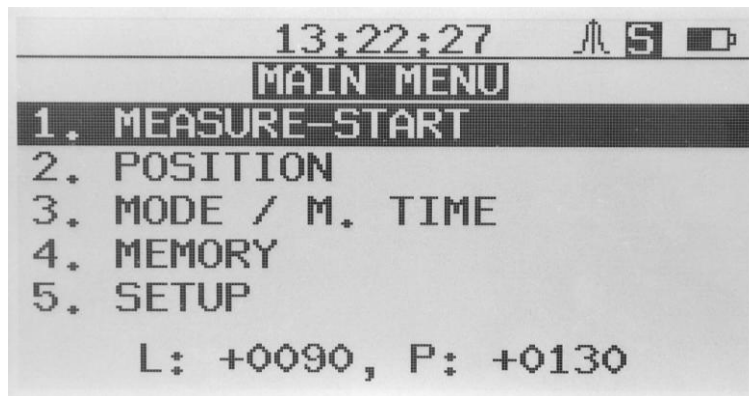
The backlight is switched off automatically 10 seconds (default value is 10 s, other options selectable) after the last pressing of a push-button. The backlight can be switched off all the time to save power consumption. (See the item 4. BACKLIGHT of the setup - system menu.)

The first icon in the upper right corner of the screen indicates that stabilization is on, the letter S means mode SINGLE is set (M stands for MONITOR), the last icon indicates status of batteries.

Move in the main menu and item selection is marked by a cursor, graphically indicated by the inverted line. Push-buttons [∨] and [∧] serve for a cursor move in the main menu.

Menu items 1 - 5 are directly selectable by pressing numerical push-buttons [1] - [5] on the keyboard.

Push-button [ENTER] serves for item function activation and to confirm the newly specified parameters. Push-button [ESC] serves for return to the main menu without modification of parameters.

1. MEASURE – START

Item activates measurement with parameters set up in other items of the main menu.

2. POSITION

Item serves for setting of a number of a profile (line L), position on a profile (P) and step of measurement on a profile (see chap. 7.1.2).

3. MODE / M. TIME

Item selects instrument measurement mode: SINGLE or MONITOR (see chap. 6) and sets time of measurement (see chap. 5.2).

4. MEMORY

Item serves for listing of the items stored in the data memory. Further, it enables to erase the data memory.

5. SETUP

Item serves for setting up of various parameters of the instrument (see chap. 3.5).

3.5   Setup Menu

The setup menu serves for setting up various parameters, see bellow. It is activated in the main menu, item 5.

Move in the setup menu and item selection is marked by a cursor, graphically indicated by the inverted line. Push-buttons [∨] and [∧] serve for a cursor move in the main menu.

Menu items 1 - 6 are directly selectable by pressing numerical push-buttons [1] - [6] on the keyboard.

Push-button [ESC] serves for return to the main menu.

Push-button [ENTER] serves for item function activation and to confirm the newly specified parameters.

Push-button [ESC] serves for return to the setup menu without modification of parameters.

```
              18:57:23        S  .
                SETUP MENU
   1. STABILIZATION
   2. ROIS
   3. CONSTANTS
   4. CALIBRATION
   5. SYSTEM
   6. INFO
```
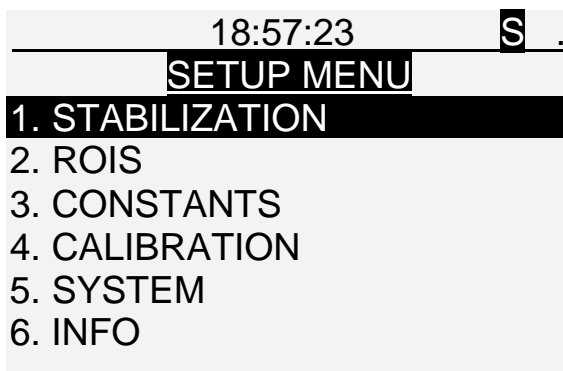
1. STABILIZATION

Item sets up stabilization on / off, gain, interval of stabilization and reference channel (see chap. 5.4).

2. ROIS

Item sets up limits of ROIs (region of interest or energy windows, see chap. 5.3).

3. CONSTANTS

Item displays calibration constants.

4. CALIBRATION

Item allows to calibrate the instrument (see chap. 9).

5. SYSTEM

Item allows to set up various parameters (see chap. 3.6).

6. INFO

Item displays the serial number of the instrument and version of the software.

3.6 System Menu

The system menu serves for setting up various parameters, see bellow. It is activated in the setup menu, item 5.

```
            18:57:23          S  .
            SYSTEM  MENU
1. BLUETOOTH
2. DATE / TIME
3. OFF TIME
4. BACKLIGHT
```
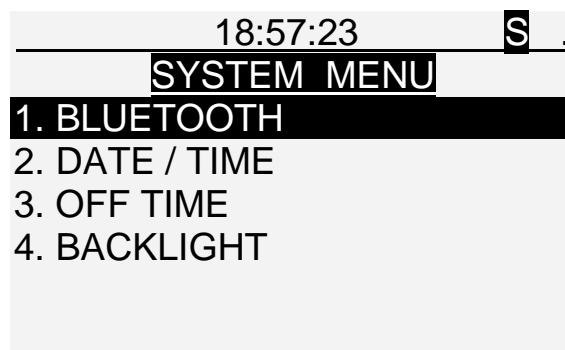
1. BLUETOOTH

Item enables the instrument to be connected via Bluetooth to a PC or to a GPS external unit (receiver), see chap. 10.

2. DATE / TIME

Item sets up real date (yy.mm.dd, where y- year, m – month, d – day) and time (hh:mm:ss, where h - hours, m - minutes, s - seconds).

The cursor indicates the number to edit. Editing of numerical values is carried out by means of push-buttons [0],[1],[2],...[9], [∨] and [∧]. Move the cursor by [<], [>] and [NEXT].

The push-button [ENTER] stores the modified date and time into the memory. The push-button [ESC] returns the control to the system menu without any change of the date and time.

3. OFF TIME

Item serves for setting the switch-off time (see chap. 4.4).

4. BACKLIGHT

Item serves for switching the backlight on / off or setting the time to elapse.

4.   PUTTING THE INSTRUMENT INTO OPERATION

4.1   Installation and Replacement of Batteries

The producer delivers the instrument with batteries installed. Access to the battery compartment is from the base part of the spectrometer console case, after removal of two screws. Six batteries should be placed into the battery compartment in compliance with indicated polarity. Once the batteries have been installed, and the battery compartment closed, the instrument is ready for use.

When the batteries are being charged, or the instrument is switched off, the present set up instrument parameters and the stored data in the data memory are retained.

If the instrument is stored for a longer period, remove always batteries from the battery compartment. This will prevent the instrument from leakage of flat batteries.

Apart from alkaline batteries, rechargeable NiMN batteries can also be used. These power supply batteries can be recharged without being removed from the instrument by means of a special mains charger, which is supplied with the instrument as an accessory. The instrument can be powered from an external power supply (from 12 V car battery or mains voltage adapter). This is effective for stationary instrument use or under ambient temperature conditions below 0 °C, when the capacity of ordinary batteries fall off sharply.

The voltage of batteries is checked at initial instrument switching on, and successively every second at instrument operation. The condition of the batteries is displayed as the icon in the upper right corner.

If the batteries voltage drops to 6 V, a message is displayed: "Battery low! Auto power off in 20 s!" indicating the instrument automatic switch off after 20 s. After pressing [ENTER] or [ESC] the instrument switches off immediately. This prevents the rechargeable batteries from deep discharge and their damage.

4.2   On/Off Operation

The first control of batteries and of the instrument correct function is possible with the spectrometer console even without the connected detection probe.

The instrument is switched on by pressing the push-button [ON/OFF]. The display shows the initial logo. Pressing any push-button once initiates the main menu display with the first item 1. MEASURE – START being marked by the cursor. The spectrometer is ready to measure.

Pressing the push-button [ON/OFF], the instrument can be switched off anytime from the keyboard.

Parameters and constants of the instrument, as well as data stored in the memory are retained after the instrument has been switched off, or when power supply batteries are being replaced.

4.3   Automatic Instrument Switch Off

The instrument will be automatically switched off, if during the pre-selected switch-off time there is no keyboard operation, transmission of data via USB interface, the measurement is not being performed, or the power supply batteries voltage drops below 6 V.

The time, after which the instrument with no operation will be switched off, can be set up by activating the item 3. OFF TIME of the setup system menu.

Shift the cursor to particular line of the item 3. OFF TIME and press [ENTER].

```
            18:57:34            S   .

         SET AUTO POWER OFF


         OFF TIME: HH.MM  00:10


```
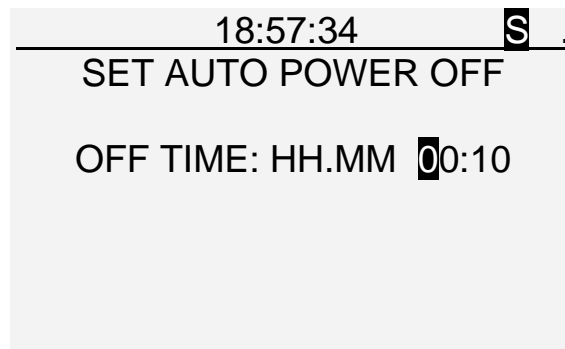
Cursor in the activated item moves to the time indication.

Push-buttons [<], [>], [0], [1], [2], ...,[9] serve for the requested time set up.

Selected time parameter is confirmed and stored into the memory by pressing the push-button [ENTER] and the instrument control returns to the system menu.

The push-button [ESC] returns the control to the system menu without change of the time parameter.

The pre-selected default value is 10 minutes, i.e. 00:10.

5. BASIC SETTING OF THE INSTRUMENT

5.1 Producer's Basic Set-up Parameters

All functions of the instrument are controlled by the microcomputer. Energy windows, calibration constants and basic instrument parameters are factory set up and stored, making the instrument ready for measurement immediately after it has been switched on by the push-button [ON/OFF], and the item 1. MEASURE – START activated.

The pre-set parameters are:

Line 0, position 0, step 10 – see chap. 7.1.2.

Measurement time for 00:04:00 – see chap. 5.2.

Mode of measurement SINGLE – see chap. 6.1.

Reference peak set on channel 110.0, provided a ^{137}Cs 662 keV energy line is used for automatic spectrum stabilization. This setting gives an energy calibration 6 keV/channel – see chap. 5.4.

Time of instrument automatic switching off is 10 minutes – see chap. 4.3, item 3. OFF TIME of the system menu.

Calibration results:

Energy windows (ROIs) – see chap. 5.3, item 2. ROIS of the setup menu.

Calibration constants – item 3. CONSTANTS.

Above specified instrument default parameters and calibration results can be modified. The modified parameters are retained in the memory after the instrument has been switched off, or during batteries replacement, until their new modification.

5.2 Measurement Time

The measurement time is displayed and can be set in the main menu, item 3. MODE / M. TIME.

```
              18:57:34            S   .
           SET MODE / M. TIME


              O  SINGLE
              O  MONITOR



   M.  TIME:          00:10:00
```
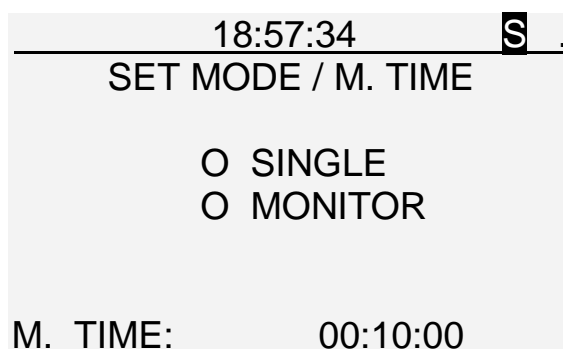
Change of this parameter can be carried out by moving the cursor on the item by pressing the push-button [NEXT]. Push-buttons [<], [>] move the cursor on time identifiers, push-buttons [0], [1], [2],...,[9], [∨], [∧], select the new measurement time. The measurement time can be set up from 1 s (i.e. 00:00:01) up to 1 day (i.e. 23:59:59). The default value is 4 minutes (i.e. 00:04:00). The modified time of measurement is confirmed and stored in the instrument memory by pressing the push-button [ENTER]. Push-button [ESC] returns the instrument control to the main menu, without changing the measurement time.

5.3   Energy Windows – ROIs

ROI (Region Of Interest) is energy window.

Setting the cursor on the item 2. ROIS in the setup menu, and pressing the push-button [ENTER], 8 energy windows (ROI1 to ROI8) channel limits are displayed in two screens.

To switch between the screens press [<] or [>].

```
            18:57:34            S  .
               SET ROIS
    ROI1          140  511
    ROI2          220  252
    ROI3          268  300
    ROI4          387  453
```

```
            18:57:34            S  .
               SET ROIS
    ROI5           0    0
    ROI6           0    0
    ROI7           0    0
    ROI8           0    0
```

ROI1 indicates channel limits and registered counts in the total count (TC) energy window.

ROI2 indicates channel limits and registered counts in the potassium (K) energy window, covering the ^{40}K 1461 keV gamma energy line (33 channels).

ROI3 indicates channel limits and registered counts in the uranium (U) energy window, covering the ^{214}Bi 1764 keV gamma energy line (33 channels).

ROI4 indicates channel limits and registered counts in the thorium (Th) energy window, covering the ^{208}Tl 2615 keV gamma energy line (67 channels).

The first four ROIs cannot be changed, they are connected with calibration.

ROI1 is used for calibration and the calibration constant C5 depends on it.

ROI2, ROI3 and ROI4 are results of the last calibration.

Four additional energy windows ROI5 to ROI8 can be set up for the identification and determination of other radionuclides.

Channel limits can be selected in the range 0 - 511 channel. Upper ROI limit must be higher or equal to the lower limit.

For monitoring of low gamma ray energies, the reference radiation source can be removed from the detection probe, automatic spectrum stabilization switched off, and the total count energy window can be set up in the range of channels 20 - 511, monitoring thus the energy range 120 - 3000 keV.

Editing of energy windows:

Push-buttons [>], [<], and [NEXT] shift the cursor over channel limits without changing the numerical value.

Push-buttons [0],[1],[2],...,[9], [∨], [∧], introduce new channel limit value of an energy window.

Push-button [ENTER] confirms the modified energy window limits (ROIs), stores them into the instrument memory and the instrument control returns to the main menu.

Push-button [ESC] interrupts editing of ROIs and the instrument control returns to the main menu without any change of energy windows limits.

5.4   Stabilization

The gain of the shaping amplifier is digitally controlled by the microcomputer so that the peak of the reference radiation source is maintained in a selected channel. If low radioactivity is being measured, i.e. in the course of geophysical mapping, it is convenient to use cesium ^{137}Cs, of the energy 662 keV, as the reference source.

The energy calibration of 6 keV/channel then corresponds to the position of the reference peak in channel 110. The reference peak position is periodically checked, and the gain is adjusted, if it is necessary.

If high radioactivity is being measured, e.g. measurement of U mineralisation, the gain stabili-zation on the ^{137}Cs 662 keV reference peak is disturbed by the intensive 609 keV peak of ^{214}Bi, a product of U disintegration series. A warning is displayed: "U limit reached for Cs stabilization". In that case, barium ^{133}Ba with an energy of 356 keV should be used as the reference source. The energy calibration of 6 keV/channel then corresponds to the position of the ^{133}Ba reference peak in the channel 59.

There is another solution: to remove the reference source and use the natural peak 609 keV while setting the reference channel to 101.

Setting of reference peak accumulation interval and position:

Shift the cursor on the item 1. STABILIZATION in the setup menu and press the push-button [ENTER]. This enables editing of parameters used for stabilization. A list of options appears on the display.

```
          18:57:23           S  .
             SET STABILIZATION

O  ON              GAIN   +03.0%
O  OFF             S. I.    20 s
                   REF. Ch.  110
```

The automatic digital spectrum stabilization can be switched off. In that case, concentrations of K, U, Th are not calculated.

GAIN can be set manually. Manual pulse amplitude gain adjustment is expressed in percent, against the factory pre-set value, in the range +/- 25 %. Usual digital stabilization of the reference peak position adjusts the pulse amplitude gain automatically, manual gain setting is exceptional.

Editing of numerical values is carried out by means of push-buttons [0],[1],[2],...,[9].

Signs +/- are changed by the push-buttons [∨], [∧].

Push-buttons [<] and [>] shift the cursor on identifiers horizontally.

S. I. is the time interval of spectrum accumulation. Accumulated spectrum is used for calculation of the exact reference peak position and gain adjustment. Pre-selected (default) spectrum accumulation time interval is 20 s, values in the range 5 s to 600 s can be introduced.

REF. Ch. is reference peak position. It can be set in the range of channels 40 to 500.

The push-button [ENTER] stores the modified parameters into the memory.

The push-button [ESC] returns the instrument control to the setup menu.

5.5   Defining of Profile Number, Position and Step

This procedure defines the number of the profile – line, position of the next station to be measured, i.e. position of measurement on the profile, and step of measurement on the profile, i.e. a difference in numbering, expressing the separation, of two regular adjoining stations on the profile. The sign +/- defines the direction of measurement on the profile. Positive (+) sign means that the defined step on line value will be added to the actual position

on the profile, negative (-) sign means, that the defined step on line value will be subtracted from the actual position on the profile.

Cursor is set by means of push-buttons [∨], [∧] or [2] on the item 2: POSITION in the main menu, and the function is activated by the push-button [ENTER].

```
          18:57:34          S  .

          SET POSITION


       Line: +0089
       Pos:  +0001
       Step: +001
```
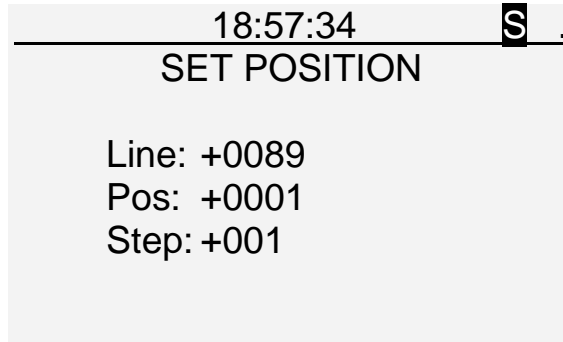
Cursor is shifted by push-buttons [<], [>] and [NEXT].

[∨], [∧], [0], [1], [2], ...,[9] are used to set or modify the line, position and step.

Sign +/- is changed by the push-button [∨] or [∧]. Pressing the push-button [ENTER], the set line, position and step are confirmed and stored into the memory, and the instrument control is switched to the main menu.

Push-button [ESC] returns the instrument control to the main menu without saving the modified parameters.

Line and position on a profile can be set in the range -9999 to +9999.

Step can be set in the range -999 to +999.

If the sum of position and step values exceeds the permitted range -9999 to +9999, an error message is displayed: "Position out of range!"

On pressing the push-button [ESC], the instrument control is switched to the main menu and the operator can introduce a new line and position.

If there is a need to break a regular advancement of measurements on the profile, i.e. leaving out one or several stations or by the change of the step or line, the above described procedure must be used to specify the next measured station.

6.   MEASUREMENT

The spectrometer is switched on by means of push-button [ON/OFF], and initial logo is displayed (see chap. 4.2). Pressing of any further push-button activates the display of the main menu (see chap. 3.4.1).

Cursor position is on the item 1. MEASURE – START. Pressing the push-button [ENTER] initiates the measurement with current parameters.

For measuring, the probe must be connected to the console by the supplied cable. Otherwise a message is displayed: "No signal! Check the probe."
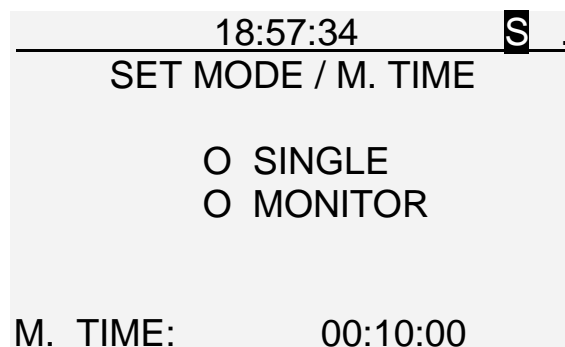
Measurement can be performed in one of the two modes:

SINGLE – s ingle measurement, measurement on profiles.

MONITOR – a automatically repeated measurements in pre-selected time and time intervals.

Measurement modes are selected in the item 3: MODE of the main menu.

Shift the cursor on the item 3: MODE and press the push-button [ENTER]. The cursor is moved on to the mode identifier.

```
        18:57:34          S  .
        SET MODE / M. TIME

          O  SINGLE
          O  MONITOR


   M.  TIME:          00:10:00
```

Measurement mode can be selected by means of keyboard push-buttons

Selection of required measurement mode can be confirmed by means of the push-button [ENTER].

The push-button [ESC] returns the instrument control to the main menu with no change of the measurement mode.

6.1   Measurement Mode SINGLE

Measurement mode SINGLE is a basic mode for single and profile radiometric measurements. The cursor is on the item 1. MEASURE – START and the measurement is initiated by pressing the push-button [ENTER]. Information is displayed: "Starting..."

Detection of energy gamma ray spectrum of the reference source and its reference peak in a pre-selected channel enables the automatic spectrum stabilization. Gamma ray spectrum

is accumulated in pre-selected time interval (e.g. 20s), the reference peak position is evaluated with respect to pre-selected reference channel (e.g. channel 110.0), and if necessary, gain of the shaping amplifier is adjusted. The reference peak position is sequentially evaluated in pre-selected time intervals independently on selected time of measurement. If the system identifies at the beginning of the test that the reference peak position (and accordingly the gain) is outside the precision range, the system corrects the gain and starts a new measurement.

If the system identifies that the gain is outside the tolerance range +/-25%, a message is displayed: "Cannot stabilize!" This case occurs, when pre-selected reference peak position does not correspond to the used reference source. A spectrum, measured with an incorrect instrument setting, is lost.

If the reference source does not give a good peak for stabilization, the following message is displayed: "Reference peak not present!"

If the reference source is too strong, messages may appear: "DC overflow!" or "DC stabilization failed!"

Measurements can be done without spectrum stabilization if the user selects the option in the stabilization menu.

Measurement runs in time pre-selected in the item 3. MODE / M. TIME of the main menu (e.g. 00:10:00). Termination of measurement can be carried out anytime by pressing the push-button [ESC].

In the course of measurement, the measured gamma ray spectrum and the alphanumerical information on measurement is displayed. Both the spectrum and information data are updated every second.
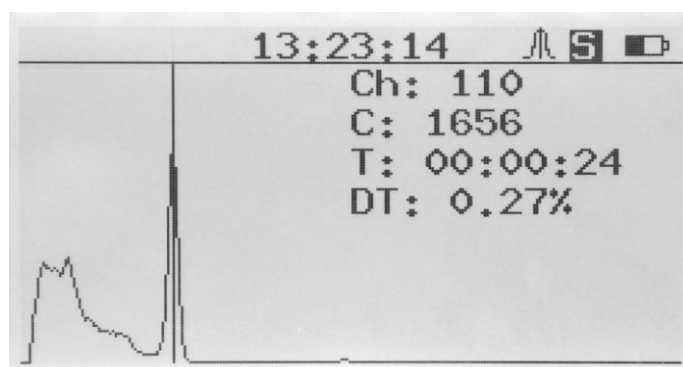
Cursor is marked in the displayed spectrum by a vertical line and can be shifted horizontally by push-buttons [<] and [>]. If the push-buttons [<] or [>] are kept pressed, the cursor movement is accelerated. The last cursor position is retained in the memory and will be applied in the next measurement.

The vertical scale of the spectrum graph (counts) is set and updated automatically or by push-buttons [∨], [∧]. Push-button [NEXT] switches between linear and logarithmic scale.

Horizontal scale can be changed by pressing the push-button [SPECT].

Symbols used in the alphanumeric information on the display:

Ch: 145 is the cursor position, expressed by a channel number.

C: 28 is the number of counts recorded in the cursor channel.

T: 00:03:25 is the actual elapsed time of measurement.

DT: 2.0% is the measurement dead time.

After the measurement has been terminated, information is displayed: "Finishing..." for three seconds and the following message appears:

```
        18:57:34          S   .
              INFO

        End of measurement.
             Save?

```
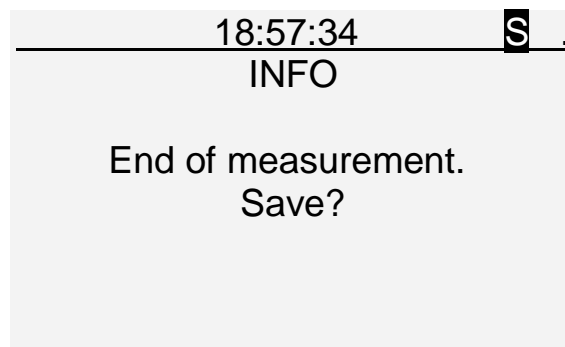
The data are saved by pressing the push-button [ENTER] or not saved by pressing the push-button [ESC], and the control returns to the main menu.

The energy resolution is calculated from the reference peak in measured spectrum after the measurement has been terminated.

Performing the measurement without spectrum stabilization, the energy resolution stored data are 0.0, and the reference peak position 0.00.

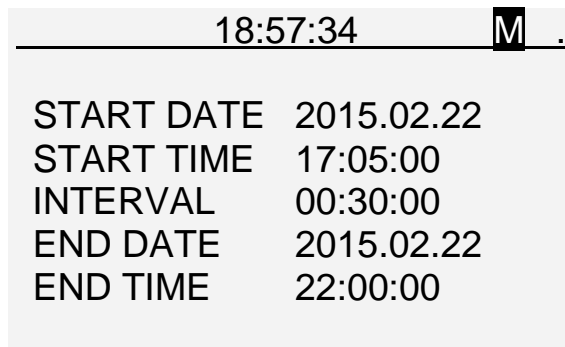Cosmic counts are registered by the energy exceeding the channel 512.

The last measured measurement can always be displayed by the push-button [DATA] or [SPECTRUM].

6.3   Measurement mode MONITOR

Measurement mode MONITOR enables automatic measurement without the presence of an operator. Measurement of full spectra can be pre-set for automatically repeated measurements in determined intervals and cycles with pre-selected starting time and end of monitoring in the MONITOR mode. Every measurement is run with a sample time set in the item 3. MODE / M. TIME and is automatically stored into the memory.

The item 3. MODE / M. TIME is selected in the main menu and the function is activated by the push-button [ENTER]. Push-buttons [∨] and [∧] switch between the measurement modes, and the selected mode MONITOR is confirmed by the push-button [ENTER].
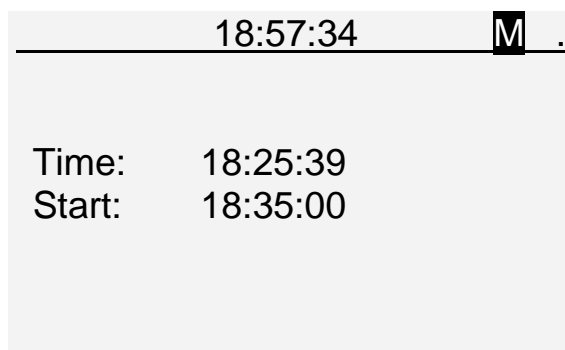
The item 1. MEASURE – START is selected in the main menu (i.e. by the push-button [1])
and the function is activated by the push-button [ENTER]. The display shows:

```
              18:57:34        M   .

 START DATE  2015.02.22
 START TIME  17:05:00
 INTERVAL    00:30:00
 END DATE    2015.02.22
 END TIME    22:00:00
```

Dates and times can be set by means of push-buttons [0],[1],[2],...[9], [∧], [<], [>], [<] and
[NEXT]. For example a measurement in MONITOR mode should be carried out each 30
minutes from 5 p.m. to 10 p.m., February 22, 2015.
Between two measurements, information is displayed:

```
              18:57:34        M   .



 Time:       18:25:39
 Start:      18:35:00
```

An ongoing measurement in the mode MONITOR can be terminated anytime by the push-
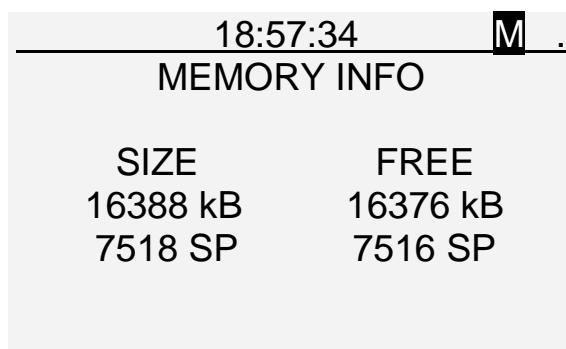button [ESC].

7.   DATA MEMORY

GS-512i gamma ray spectrometer is equipped by an internal data memory, into which the measured data can be stored. Stored data can be displayed on the instrument display, or transferred through the USB interface (or Bluetooth, which is slower) to an external computer.

The 16 MB digital memory enables to store up to 7500 measured spectra. The stored data are kept in the memory after instrument switch off or after removal of power supply batteries.

The cursor in the main menu is set on the item 4. MEMORY, and the function is activated by the push-button [ENTER]. A submenu is displayed:

```
          18:57:34          S   .
             MEMORY MENU
1. LIST
2. ERASE
3. INFO


```
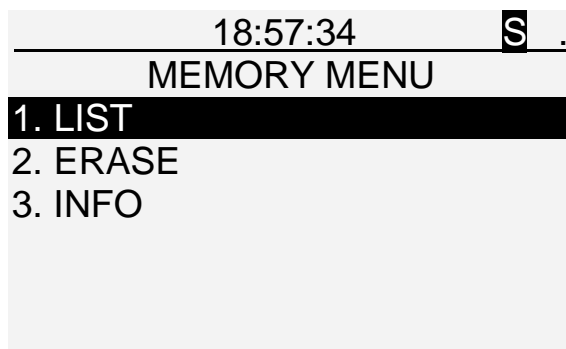
The free capacity of the data memory is displayed under the item 3. INFO

```
          18:57:34          M   .
             MEMORY INFO

       SIZE              FREE
     16388 kB          16376 kB
      7518 SP           7516 SP

```

7.1   Recording of Measured Data

After termination of a single measurement, data can be stored into the data memory. All important information on measurement, as date, real time, time of measurement, line and position and dead time are stored into the memory with the measured data.

7.1.1 Data Memory Erase

Before the data memory is being used, it is suitable to erase it. Of course, to use the current data, it is necessary to transfer them to an external computer in advance. Erasing of the data memory sets its capacity to maximum.

The cursor in the memory menu is set on the item 2. ERASE, and the function is activated by the push-button [ENTER]. An inquiry is displayed:

```
     18:57:34          S  .
          INFO

       This will erase all
      data. Are you sure?


```
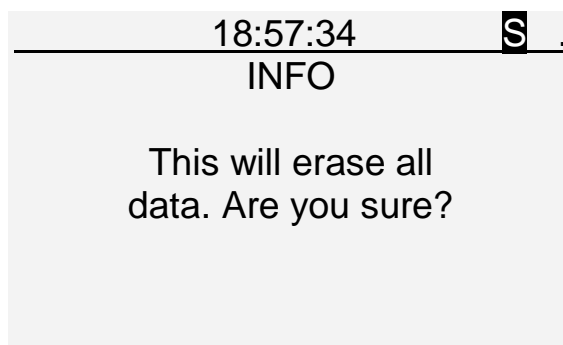
In affirmative case, on pressing the push-button [ENTER], the data memory is erased.

7.1.2 Data Storage into the Memory

After the measurement has been terminated, the push-button [ENTER] activates the procedure of data storage.

```
     18:57:34          S  .
          INFO

      End of measurement.
            Save?


```
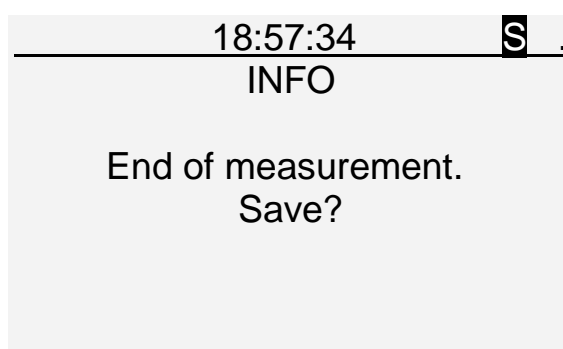
On pressing the push-button [ENTER], the measured data are stored into the memory and the number of position is increased by the specified value of step on line. Instrument control is returned to the main menu and updated location parameters are retained in the memory.

The push-button [ESC] (or any other) returns the instrument control to the main menu without data saving.

Until a new measurement is initiated, the measured spectrum remains in the operation memory, can be displayed by function [SPECT], and additionally, stored into the data memory by function [ENTER].

At the attempt of saving the measurement in a full data memory, a message is displayed: "Data memory full!" The user needs to transfer measured data to a PC and erase the data memory.

7.2 Retrieval of the Measured Data

Data stored in the data memory can be displayed or transferred through the USB interface (or Bluetooth) to an external computer.

7.2.1 Display of Data Stored in the Data Memory

Manipulation with data is commenced in the main menu by shifting the cursor, by means of push-buttons [∨], [∧] on the item 4. MEMORY, and by pressing the push-button [ENTER]. The display shows:

```
              18:57:33          S   .
              MEMORY MENU
1. LIST
2. ERASE
3. INFO


```
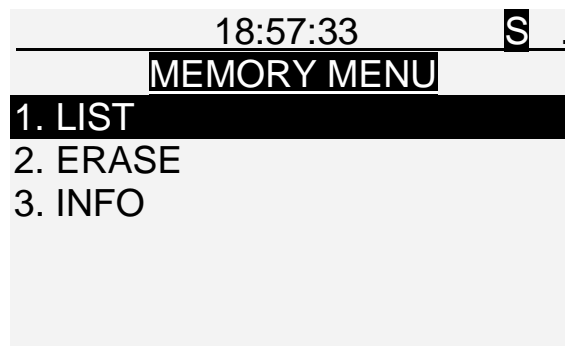
Shift the cursor to 1: LIST and press [ENTER]. The display shows various types of data:

```
              18:57:34          S   .
              MEMORY LIST
1: SINGLE
2: MONITOR
3: LATEST
4: CALIBRATION


```

After selecting an item and pressing [ENTER] the display shows information: "No single measurement." (e. g.) if there are no data of the desired type, and a list of measurements if there are any in the memory.

```
                18:57:34          S  .
 3  03. 02. 2015   11:23:15
 2  03. 02. 2015   11:20:45
 1  03. 02. 2015   11:16:22
 0  02. 02. 2015   09:06:39
```

The push-buttons [∨], [∧] shift the cursor down or up to the next item, the push-button [NEXT] moves the cursor to the next page, by 8 items down.

A detailed information on five screens on the selected measurement can be activated by push-button [DATA]:

```
                18:57:34          S  .
 L:   0010            P: 0015
 FWHM:   6.9%
 COSM:   112
 MT:        00:04:00
 DT:        0.24%
 PEAK:    110.01
```

```
                18:57:34          S  .
 CONCENTRATIONS
 TC:         19.50 Ueq
 K:          2.58 %
 U:          4.28 ppm
 Th:         10.60 ppm
```

MT indicates time of measurement.

DT indicates the relative value of the dead time of measurement.

COSM indicates counts of cosmic radiation, detected in an energy region exceeding channel 512. At usual conditions, using ^{137}Cs reference source, and position of the reference peak in the channel 110.0, cosmic count corresponds to energy exceeding 3 MeV.

FWHM is the energy resolution of the instrument.

PEAK is the actual reference peak position for the selected measurement.

Measurements without spectrum stabilization display zeroes on FWHM and PEAK.

Push-buttons [<] and [>] switch between the five screens.

```
                    18:57:34            S   .
DOSE RATES
K:            33.74 nGy/h
U:            24.30 nGy/h
Th:           26.45 nGy/h
SUM:          84.49 nGy/h
```

Dose rates are determined according to guidelines IAEA-TECDOC-1363.

Radioelement concentration is multiplied by the respective constant:

1% K corresponds to dose rate 13.078 nGy/h, 1 ppm U gives 5.675 nGy/h, 1 ppm Th   gives 2.494 nGy/h. Total dose rate from the natural radioelements in given in the SUM.

The forth and fifths screens are:

```
                    18:57:34          S   .
ROIS  (CPM)
ROI1:  2530.75
ROI2:   644.50
ROI3:   119.50
ROI4:    92.25
```

```
                    18:57:34          S   .
ROIS  (CPM)
ROI5:  0
ROI6:  0
ROI7:  0
ROI8:  0
```

ROIs are energy intervals.

CPM means counts per minute.

Push-button [ESC] returns the instrument control to preceding display of the data list.

If GPS receiver is used, the coordinates and other information are added to the appropriate measurement and can be displayed on the sixth screen of the [DATA] function, see chap. 10.

7.2.2 Transfer of Data from the Spectrometer to a Computer

The spectrometer GS-512i and the computer are connected by a cable of USB interface. Communication between these two units is made possible by means of the program SgData.EXE supplied by the producer. The USB icon is displayed in the upper left corner of the screen indicating the communication.

GS-512i can be connected to a PC via Bluetooth, but the data transfer is slower than by USB. To start the connection, Bluetooth must be enabled and the two devices paired, see chap. 10.

8. GAMMA RAY SPECTRA OPERATION

The spectrometer makes the use of LCD display for running spectrum graphical display of ongoing measurement, and for a display of spectra stored in data memory.

8.1 Measured Spectrum Display

Once the measurement is initiated, the gamma ray spectrum is displayed on the display. Numbers of channels 1 to 511 (i.e. energy) are displayed on the horizontal axis, recorded counts in separate channels are displayed on the vertical axis. Scale of the vertical axis is linear or logarithmic, switched by push-button [NEXT]. The vertical scale on the LCD display is set automatically, relative to the highest peak in the spectrum. Usually, the reference peak of the reference radiation source is the highest one.

Spectrum on the display is periodically updated every second.

After the measurement has been terminated, the spectrum can be displayed by [SPECT] with graphically marked energy windows (ROIs).
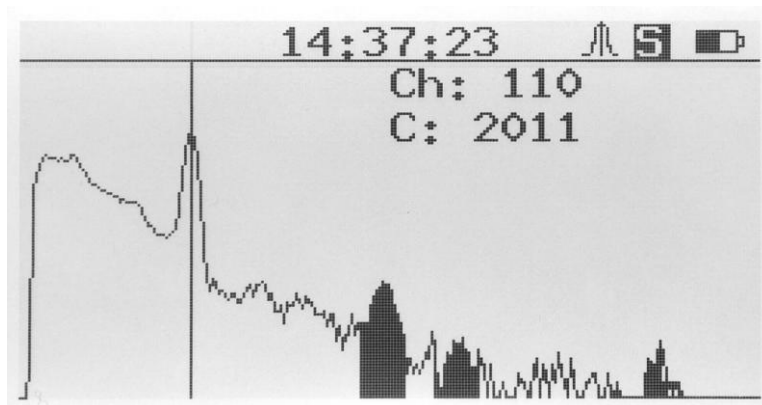
Identification and analysis of small peaks can be performed by the change of the vertical scale by means of push-buttons [∧] and [∨] multiplying or dividing the scale by a factor of 2. This can be repeated several times. Contents of channels, whose value exceed the vertical scale, do not change and remain of its value, surpass the upper limit of counts of displayed spectrum, and do not disturb the graph of small peaks.

Horizontal scale can be changed by pressing the push-button [SPECT].

Pressing of the push-button [DATA] displays information of the measured data.

The push-button [ENTER] offers another possibility to save the measured data if the reading has not been saved yet.

The push-button [ESC] returns the control to the main menu.

8.2   Memory Stored Spectra Display

The spectrum of the latest measurement, or the spectrum selected from the data memory, can be displayed by [SPECT]. See chap. 7.2.1 how to select the spectrum from the data memory.

Pressing of the push-button [DATA] displays information of the measured data.

Pressing [ENTER] offers saving the data if the measurement had not been saved yet.

The push-button [ESC] returns the control to the main menu.

9.   CALIBRATION

Determination of a total gamma ray activity and concentrations of K, U, Th in rocks can be performed with a calibrated gamma ray spectrometer. GS-512i gamma ray spectrometer has been quantitatively calibrated by the producer, i.e. the limits of energy windows ROI1 to ROI4 have been set and 14 calibration constants have been determined and stored into the instrument. Calibration facility for portable gamma-ray spectrometers Straz pod Ralskem, Czech Republic was used, see http://gammastandard.com.

Calibration of a portable gamma ray spectrometer means measurement at 4 calibration standards (calibration pads) of a calibration facility. The calibration pads must be large enough to emulate a half space.

It is recommended to use cylinders 0.5 m thick and 2 m in diameter. They are: potassium standard (K - pad), uranium standard (U - pad), thorium standard (Th - pad) and a blank standard (Zero - pad). Contents of the given elements at its standards must be significant in comparison with other standards.

Calibration of the spectrometer GS-512i can be carried out by means of built-in function 4. CALIBRATION in the setup menu.

The validity of calibration should be checked once a year by the measurement at a calibration facility.

9.1   Determination of instrument radiation

Instrument internal signal is caused by radio-elements trace concentration in the instrument construction material and by the electric noise. It is measured in a lead box and processed in the factory. The result is the first four calibration constants C1, C2, C3, C4, that are stored in the GS-512i memory.

9.2   Measurement at the Calibration Facility

Calibration facility consists of four large-scale three-dimensional standards (calibration pads).

K standard

U standard

Th standard

Zero standard

Calibration constants C5 to C14 are being determined by the measurement on calibration standards.

9.2.1 Basic Spectrometer Setting for Calibration Measurement

Measurement time is set for 10 min as minimum. The setting of measurement time is carried out in item 3. MODE / M.TIME (e.g. 00:10:00, see chap. 5.2).

Calibration of the spectrometer is carried out with the spectrometer setting for an automatic spectrum stabilization by means of radiation reference source (e. g. ^{137}Cs or ^{133}Ba – see chap. 5.4). The same source must be used for field measurements.

Measurements of calibration gamma ray spectra is performed under function selected by item 4. CALIBRATION of the setup menu. The cursor is set on the item 4. CALIBRATION, and the function is activated by pressing the push-button [ENTER]. The display shows the calibration menu:

```
            18:57:23        S   .
          CALIBRATION MENU
1. MEASURE PADS
2. PAD PARAMETERS
3. PROCESS
4. DEFAULT

```
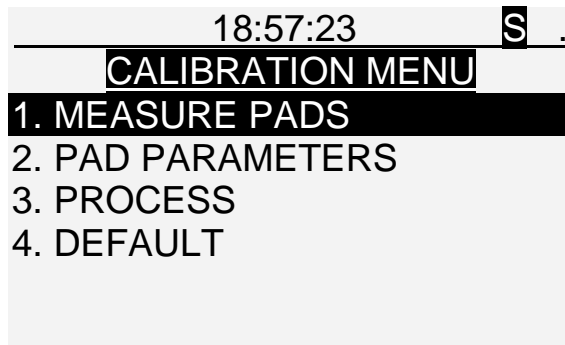
The selected item is marked by a cursor.

The item is initiated by pressing the push-button [ENTER].

9.2.2 Measurement of Calibration Spectra

Calibration spectra can be measured in an arbitrary sequence. Calibration measurement is performed with the detection probe positioned directly on standards (calibration pads) in the centre of their upper surface.

Item 1. MEASURE PADS is activated by [ENTER]. The display shows:

```
            18:57:23        S   .
         MEASURE CALIBRATION
1. PAD K
2. PAD U
3. PAD Th
4. PAD ZERO
```
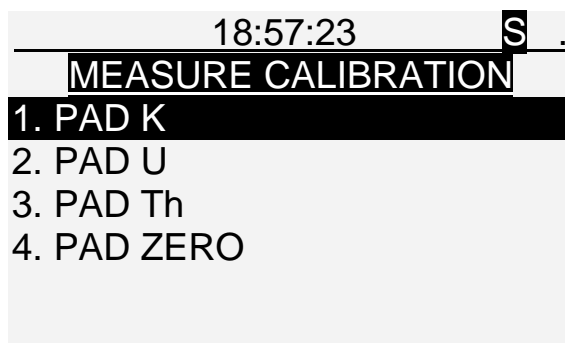
The selection of the standard, that will be measured, is carried out by push-buttons [∧], [∨].

The measurement is initiated by pressing the push-button [ENTER].

The measured calibration spectrum is displayed (see chap.6.1).

When the measurement has been terminated, the measured spectrum is automatically stored into the memory and information displayed: "End of measurement. Measurement saved."

After pressing [ESC] or [ENTER], the offer of four standards measurement is displayed again. All four standards are sequentially measured.

The measured calibration spectra can be replaced anytime by a new measurement. A question is displayed: "Calibration spectrum U exists. Continue?"

The instrument control is returned to the offer of four standards by the push-button [ESC], and other standard can be selected.

The actual standard selection is confirmed by the push-button [ENTER], and the repeated calibration spectrum measurement is initiated.

Measurement of a calibration spectrum can be terminated by the push-button [ESC]. A question is displayed: "Measurement cancelled. Save?" The measurement is saved after pressing the push-button [ENTER].
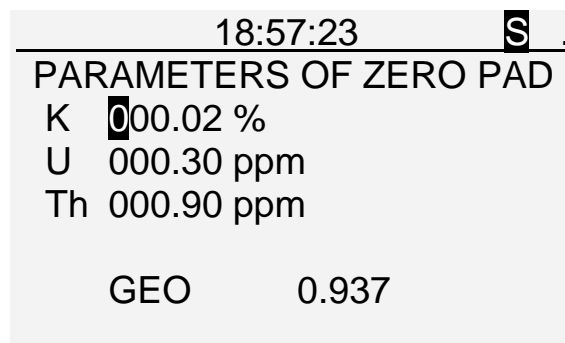
9.2.3 Editing Parameters of Test Pads

The parameters: tpK(K,U,Th), tpU(K,U,Th), tpTh(K,U,Th), tp0(K,U,Th) are K, U, Th concentrations of test pads and GEO is a geometry factor G depending on the size and shape of the test pads. For a cylindrical pad (all of equal radius) is:

$G = 1 - h/r$

where r [m] is the radius of the pad and h [m] is the height of the crystal centre above the surface of pad. For GSP-3 is h=0.073m (for GSP-4 is h=0.095m).

Test pads parameters can be displayed in four screens and modified by means of the function 2. PAD PARAMETERS in the Calibration menu.

An example of the last screen:

```
                18:57:23        S  .
         PARAMETERS OF ZERO PAD
          K   000.02 %
          U   000.30 ppm
          Th  000.90 ppm

          GEO          0.937
```

Push-buttons [<], [>], [NEXT] shift the cursor over parameters without changing the numerical values.

Push-buttons [∨], [∧], [0], [1], [2], ...,[9] introduce the new value, the point is fixed.

Push-button [ENTER] confirms the displayed modified numerical values, stores them into the instrument memory and the instrument control returns to the calibration menu.

Push-button [ESC] interrupts editing, and the instrument control returns to the calibration menu without any change of parameters.

9.2.4 Calculation of Calibration Constants & ROIs

From measurements on a calibration pad, the K, U and Th window count rates are linearly related to the K, U and Th concentrations of the pad. By subtracting the count rates and concentrations of the zero pad from those of the K, U and Th pad, a set of three equations with three unknowns is received, for each of the three windows.

The 3 x 3 concentration matrix [Q] (calculated from the parameters, chap. 9.2.3) is related to the 3 x 3 count rate matrix [n] (calculated from the measurements, chap. 9.2.2) and the 3 x 3 calibration matrix [C] (composed of the calibration constants C6 - C14) by the matrix equation

$$[Q]=[C] \times [n]$$

from which the calibration matrix may be evaluated using

$$[C]=[Q] \times [n]^{-1}$$

The constant C5 is

$C5 = s^{-1} \times 10^{5}$,

where s is the sensitivity to U in the Total count window (ROI1).

Before you start the calculation, be sure that the parameters of test pads set in spectrometer are correct (see chap.9.2.3).

Calculation of calibration constants in the spectrometer can be performed by means of the function 3. PROCESS in the calibration menu (chap.9.2.1).

Shift the cursor to the item. Press the push-button [ENTER].

K, U and Th peak positions are evaluated, the optimal limits of ROI2, ROI3 and ROI4 are set and calibration constants C5 - C14 are calculated from the calibration spectra. The limits of energy windows ROIs and calibration constants are stored in the inner memory of the spectrometer. A message is displayed: "Processing..." and afterwards: "Done."

Calibration constants can be examined in function 4: CONSTANTS of the setup menu.

ROI1 and ROI5 - ROI8 are taken from the user's setting.

Calibration constants C1 – C4 describe radiation of the instrument itself and are set by the producer.

The limits of energy windows and calibration constants are stored in the inner memory of the spectrometer.

For the processing, calibration spectra must be stored in the data memory, otherwise a message is displayed, e. g.: "K, Zero calibration spectra not found!"

9.3   Calculation of Constants by PC

Calculation of calibration constants can also be performed by means of a program SgData.EXE by the computer. The program SgData.EXE is supplied with the instrument. The result is determination of optimal limits of energy windows ROI2, ROI3, ROI4 and calibration constants C5 to C14. These constants can be loaded into the spectrometer by means of the program SgData.EXE.
Please notice the limits of ROI1 remain untouched after processing the calibration and ROI5 – ROI8 are not set – zeroes.

9.4   Default ROIs and constants

Default values (set by the producer) of ROIs and calibration constants can be restored in the calibration menu by the function 4. DEFAULT. After pressing the push-button [ENTER] a message is displayed: "Default calibration restored."

9.5   Display of Calibration Constants

By the cursor setting on the item 3. CONSTANTS in the setup menu, and pressing the push-button [ENTER], fourteen calibration constants C1 to C14 are displayed in two screens. Push-button [NEXT] switches between them.

```
              18:57:34          S   .
                CONSTANTS
C1    +000024
C2    +000006
C3    +000005
C4    +000149



```

```
              18:57:34          S   .
                CONSTANTS
C5    +000801   C6    +00506
C7    -000530   C8    -000064
```

```
C9   +000024   C10  +005954
C11  -003151   C12  -000002
C13  -000380   C14  +012631
```

Calibration constants are results of the last calibration. They cannot be edited.

The default calibration – original results from the factory can be restored in the calibration menu.

The first four calibration constants express radiation of the instrument itself:

C1 – count rate [min^{-1}] in the total count energy window ROI1.

C2 – count rate [min^{-1}] in the potassium energy window ROI2.

C3 – count rate [min^{-1}] in the uranium energy window ROI3.

C4 – count rate [min^{-1}] in the thorium energy window ROI4.

The calibration constant C5 is used for calculation of the total count value Q_{TC} [ppm Ueq], using the equation

$$Q_{TC} = 10^{-5} \cdot C5 \cdot n_1$$

where n_1 [min^{-1}] is the registered count rate in ROI1 with background correction.

Calibration constants C6 to C14 are used for computing the concentrations Q_K, Q_U and Q_{Th}, applying

$$\begin{bmatrix} Q_K \\ Q_U \\ Q_{Th} \end{bmatrix} = 10^{-5} \times \begin{bmatrix} C6 & C7 & C8 \\ C9 & C10 & C11 \\ C12 & C13 & C14 \end{bmatrix} \times \begin{bmatrix} n_2 \\ n_3 \\ n_4 \end{bmatrix}$$

where n_2, n_3, n_4 are registered count rates [min^{-1}] in ROI2, ROI3, ROI4 with instrument correction.

10. GPS COORDINATES

Spectrometer GS-512i can be connected to an external GPS receiver via Bluetooth. Data from the GPS receiver are stored together with the measured data and can be displayed by pressing push-button [DATA] and pressing [>] four times, as the fifth screen. The GPS data are transferred to a PC together with the measured data.

```
                 18:57:23           S   .
GPS DATA
FIX:  3D
LAT: 49.241475°
LON: 16.578266°
ELV: 284.2 m
PDOP:  1.2
```
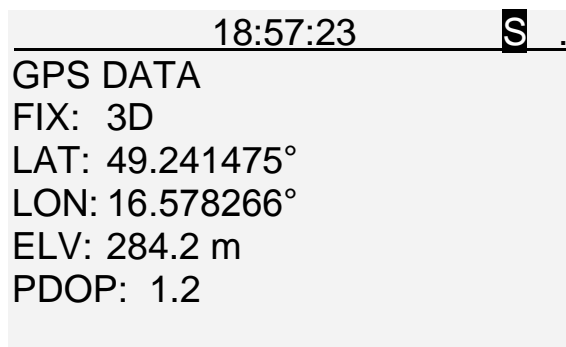
Before actual using the Bluetooth communication, it must be enabled. Item 5. SETUP of the main menu offers item 5. SYSTEM. Item 1. BLUETOOTH of the system menu handles various functions of the Bluetooth communication.

```
                 18:57:23           S   .
             BLUETOOTH MENU
1. BT MODE
2. SEARCH
3. GPS DATA
4. TIME SYNC
```
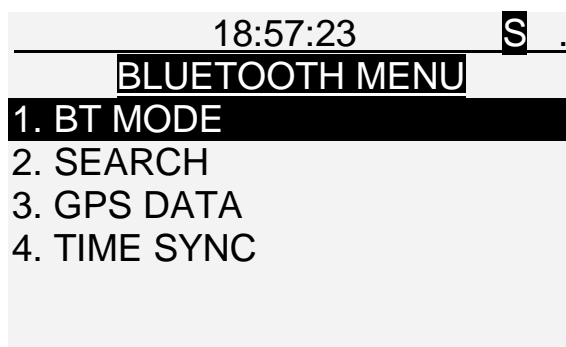
Activating item 1. BT MODE displays radio buttons to select the BT mode. Default value (after switching the instrument on) is OFF.

```
                 18:57:23           S   .
             SET BT MODE

   O OFF
   O GPS
   O PC
```
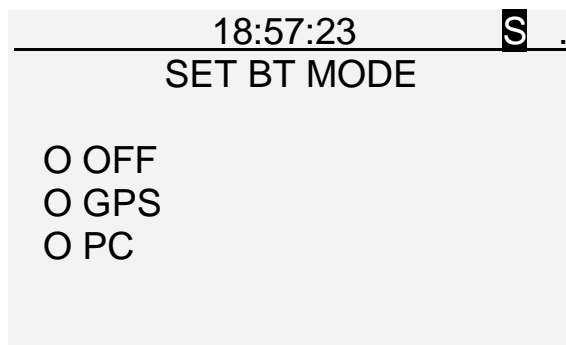
The instrument can communicate with the GSP receiver or with a PC. However data transfer to a PC via Bluetooth is much slower than via USB and usually is not used.

If Bluetooth communication is enabled, the Bluetooth icon appears in the upper left corner of the screen.

The other device (GPS or PC) must be found using the item 2. SEARCH and paired as usual for a Bluetooth communication. In case the searching fails, a message may be displayed: "No device found."

Item 3. GPS DATA of the Bluetooth menu allows to display current coordinates. BT mode must be set to GPS, otherwise a message is displayed: "GPS not enabled. Please enable GPS first." If the GPS receiver has no signal and does not give valid data, zeroes are displayed:

```
              18:57:23              S   .
                   GPS DATA
       LAT:        0.000000°
       LON:        0.000000°
       ELV:        0 m
       HDOP:       0
       VDOP:       0
       PDOP:       0.0
```

Latitude and longitude are given in degrees, elevation in meters. The remaining three values describe accuracy of the position.

Item 4. TIME SYNC of Bluetooth menu serves for time synchronization of the spectrometer with GPS. Date, minutes and seconds are taken from GPS, hours are to set by an operator. If GPS information is not available, a message is displayed: "No GPS connection."

See the following Declaration of conformity regarding the Bluetooth module built in the console of spectrometer.

Declaration of Conformity

$C \in 0678$

We, **connectBlue AB**, of **Norra Vallgatan 64 3V**
SE-211 22 Malmö, Sweden

declare under our sole responsibility that our products:

cB-OBS410 (cB-0925-01), OEM Module Adapter III (cB-0068).

to which this declaration relates, conforms to the following product specifications:

R&TTE Directive 1999/5/EC:

Effective use of frequency spectrum:
  EN 300 328 V1.7.1 (2006-10)

EMC:
  EN 301 489-1 V1.9.2 (2011-09)
  EN 301 489-17 V2.2.1 (2012-09)
  EN 61000-6-2 (2005)

Health and safety:
  EN 62479:2010
  EN 60950-1:2006 + A11:2009 + A1:2010 + A12:2011
  IEC 60950-1:2005 + A1:2009

Medical Electrical Equipment

  IEC 60601-1-2 (2007)

2014-04-09 Malmö, Sweden

Mats Andersson

CTO of connectBlue AB

11. SUPPLEMENTARY INFORMATION

11.1 GS-512i Gamma Ray Spectrometer Connections

Description of the detection probe: An output signal from the photomultiplier (PMT) is fed to a charge sensitive preamplifier and then to a variable gain amplifier. Due to the variable photomultiplier function, the gain adjustment serves for end unification of pulse amplitudes originating from identical energy of gamma quanta. Manual gain adjustment is made only when the scintiblock is changed, otherwise the gain need not be changed. The photomultiplier is powered from a stabilised HV supply, which is adjusted by the producer.

Description of the spectrometer console: The analog chain of measured signals processing comprises at the input a „pole - zero" compensation circuit, a semi-Gaussian shaping amplifier with time constant $\tau = 1$ μs, a diode base line restoration circuit and an analog - digital converter (ADC). The converter is connected to the microcomputer, which processes the data and introduces the dead time correction.

The heart of the processing unit is the microcomputer which controls the measurement and simultaneously corrects the gain of the shaping amplifier, thus performing spectrum stabilization function. In the course of a measurement, the accumulated spectrum is displayed. The microcomputer also controls the data memory and the input/output circuits.

11.2 Gain Adjustment of Detection Probe

If the detector is damaged, or the scintiblock has to be changed, the amplitude of the output pulses must be adjusted to the required level (see chap. 2.1). The following procedure is to be used:

Disconnect the probe cable and dismount the probe cover with the handle by removing four screws.

Carefully loose the probe cover by pulling on 10 - 15 cm, paying attention on internal cables.

Pull the scintiblock with the probe electronics by means of an internal textile band from the detection probe housing.

Connect the cable to the spectrometer console, turn on the spectrometer and initiate a measurement with STABILIZATION OFF.

By turning the trimmer (P1,50k) on the preamplifier PCB in the detection probe, adjust the required gain so that the Cesium peak is placed on 110. channel on the display (position of the channel 110 is marked by a cursor).

Switch STABILIZATION ON (see chap. 5.4) i.e. set stabilization to channel 110.0 and carry out a measurement. Read the actual gain value [%] on the display (see chap. 5.4).

Set the gain value [%] to 0.0 ± 5.0 % by the trimmer fine (P1,50k) adjustment at several repeated measurements.

Turn off the measurement, disconnect the detection probe and re-assemble it.

11.3 Maintenance and Repairs

Under normal operational conditions, the spectrometer requires no special maintenance. It should only be kept clean, both the detection probe and the spectrometer console. Heat and mechanical shocks, which can damage the scintiblock, should be avoided. It is recommended to check the contacts in the battery compartment periodically, and remove the batteries from the compartment, if the instrument is not being used. The leaking electrolyte from flat batteries may damage the battery holder contacts in the battery compartment, or it may be impossible to remove a swollen battery from the battery compartment.

Due to the complexity of the instrument, the producer strictly warns against non qualified manipulation with the instrument electronics. Apart from setting the gain in the detection probe (see chap. 11.2), no circuit in the spectrometer need to be adjusted.

If the instrument fails or is functioning improperly, the producer or his distributor should be contacted.

A high level service for spectrometers at the producer is guaranteed and will be carried out with an overall check of all main parameters in a very short time.

11.4 Storage and Transportation

The packed instrument can be stored and transported at temperatures of -20 to +70 °C and relative humidity up to 90 %.

The detector is fragile, it needs to be transported in the case supplied with the instrument.

11.5 Warranty

All instruments are warranted against defective materials and workmanship for one year. Any questions with respect to the warranty should be taken up with your distributor.

All requests for repairs and replacement parts should be directed to the manufacturer. This will assure you the fastest possible service. Please include the instrument Type Number and Serial Number with all request for parts or service.

Specifications and price change privileges reserved.

Information relating to warranty is also given in the Warranty Certificate.

11.6 Connectors Wiring

Connector for connection the detector to the spectrometer:

GS-512i Pin No	Explanation	GSP Pin No
A	+3.3V	A
B	+5V	B
C	-3.3V	C
D	not connected	D
E	GND	E
F	signal from probe	F

Connector for external power supply connection:

Pin No.	Explanation
A	(+) positive pole of external power supply
B	(-) negative pole of external power supply or charger

11.7 Communication Program SgData.EXE

Description:

runs under Windows 7 and later

imports the measured data from the instrument memory to a PC

saves the data in a file (gzipxml), reads data from the file

exports data in a text file *.txt

provides information of a selected spectrum

calculates calibration constants and limits of ROIs

Installation:

Insert the installation disk

Run Setup.exe (select optional documentation or example of data)

Instructions for data transfer:

Connect GS-512i with a PC by USB cable.

Start the program SgData.EXE.

Follow the program instructions.

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