Manual

RTM-RPM22xx_EQF32xx

Version June 2024

Referenced documents:
Software manual dVision

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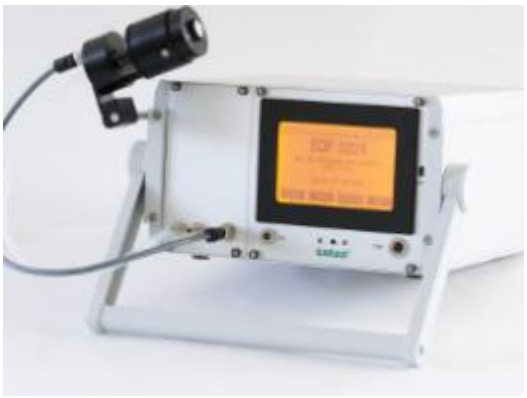
RTM 2200



RPM 2200



EQF 3200



EQF 3220

Introduction:

The instruments RTM 2200, RPM2200, EQF3200 and EQF3220 are based on SARAD's DACM (Data Acquisition and Control Module) technology.
The DACM technology offers a universal platform for instrumentation which can be fitted to any application without changes in the hardware or special knowledge in computer programming.
Compared with conventional data acquisition systems, the DACM is able to control complex sampling procedures in addition to the data logging and management.
Scalability and portability make the DACM architecture to a universal and future-oriented system. The system performance can be expanded or specialised in any order while the basic structure of system control and data flow is not touched.
All instruments covered by this manual contain the module DACM-01 which will be described in the document "DACM-01_Hardware-Reference". The user gets the possibility to modify afterwards all instrument functions with respect to the own requirements.

Applications:

RTM 2200 / RPM 2200:
• Environmental monitoring
• Geophysical analyzes (volcano monitoring, earthquake forecast)
• Radon in water analysis
• Automation & control
• gamma spectrographically applications (optional)
• Protection against radioactivity
• Building surveillance

EQF 3200 / EQF 3220:
• Use in mining as well as for geophysical investigations
• Long-term building air monitoring is possible
• Public radiological safety measurements
• Environmental monitoring
• Detection of toxic and explosive gases
• Gamma spectrography (optional)
• Radiological monitoring of nuclear facilities or locations with the use of ionizing radiation sources.

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Structure of this Manual

Chapters 1 and 2 describe the basic functionality of the instrument, derived from the DACM-01 hardware. This functionality is specifically extended for the various instrument types by sensors, detectors and required sampling equipment. These items will be descripted in the subsequent chapters. The table below gives an overview of the configuration of the different instrument types:

	RTM 2200	RPM 2200	EQF 3200	EQF 3220
Radon-Chamber (chapter 3)	X	-	X	X
Sampling head for aerosols and Radon daughters (chapter 4)		X	X	
Sampling head for attached und unattached Radon daughter products (chapter 5)	-	-	-	X
NaI Gamma-Detector-Modul (Chapter 7)	O	O	O	O
Detectors for combustible gases and Carbon Monoxide or Ammonia and Methane (chapter 8)	O	O	O	O

X = standard, O = option, - not available

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1. DACM Technology Overview

Each DACM based instrument contains a system core and a set of so-called components.
The system core includes the basic instrument properties like device control, data storage, interfacing, component management and the sampling control.
The components implemented in the DACM can be considered as a library of functional units which can be manipulated to fit them to own requirements:

- Each component can be configured specifically (e.g. transfer function, operation mode etc.)
- The state of a component can be changed during the sampling cycle
- components can generate, display and store measurement data
- components can generate alerts or react to alert states

You will find a detailed description of the DACM-01 functionality in the document “DACM-01 Hardware Reference”.

1. 1. Sampling control

To set and change the component status during the data acquisition process, at first a so-called sampling cycle has to be defined. The cycle can be also interpreted as the basic storage interval because each measurement series consists of a number of repetitions of this cycle. All acquired data are stored at the end of the cycle even if the physical sampling has been taken at any time within this cycle.
A cycle can be split into a maximum of 32 sequential subdivisions. The status of each component can be defined for each subdivision by the user. This is realised by a control bit or a control word. The time period of a subdivision can be set from one second up to the cycle interval period in one second steps.
The configuration software running on a PC allows editing the cycle definitions easily. All components are listed in a table and their status information is shown as a time chart. Only a simple mouse click into the time chart is necessary to change the status of any component within a subdivision. Several cycles may be stored on the DACM’s non-volatile memory and called for execution.

1. 2. Component configuration

Each implemented component can be separately configured by the user. Number and type of the configuration parameters are defined by the type of the component. A module can contain a maximum of 64 components. These components could be of the same or different types.

1. 3. Data flow

All generated data is stored in binary format as it has been generated by the component of origin. This ensures a 100% re-traceability of the acquired data resulting in a high level quality assurance. A component can generate one or more measurement values from the basic data. To display and transmit recent readings, all results are calculated by the module using these basic data. If the complete data is transferred to the PC, the packed basic data are transmitted together with all necessary module and configuration information.
That means, the calculation procedures are implemented in the DACM as well as in the PC software.
If the data will be stored on the replaceable card memory (SD card), a copy of the whole module and component configuration will be saved in parallel on the card. Thus, the results can be calculated correctly independent on the origin of the data.

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1. 4. Alert management

Several components are able to generate alerts (alert source). The type of alert is defined by component type and required alert conditions (alert level etc.). Both are elements of the component configuration. The alert check is carried out once per Second for all components which are enabled and activated during the recent cycle subdivision.
Other components are able to process alerts, meaning to act as an alert destination. If a component acts as alert source, a complete list of all available alert destinations is provided to select the component which shall react in case of an arising alert.
How the component responds to the alert situation is also defined by the component type and configuration of the alert destination.

1. 5. PC interfacing

Operation and configuration software are delivered as two separate programs. Thus, once configured, the instrument looks like an instrument designed only for that purpose. This simplifies the handling and operation of the unit if it is used by unskilled staff.

1. 5. 1. Configuration software (dCONFIG)

The configuration software allows to:

- transfer the configuration information and the cycle definitions from and to the module
- edit the common module information
- edit the configuration of the implemented components
- edit the cycle definitions
- save the configuration and cycle information on the hard disc

After loading the actual module and component configuration from the DACM or hard disk, a list of all components available in DACM will appear. Several tables show clearly arranged the settings of the configuration parameters for all components of the same type.
A simple mouse click into the table opens a dialog window to edit the parameter settings of the selected component. The changed parameters can be transferred to the DACM ore saved on the hard disk after finishing the configuration process.
The cycle definition is also very easily editable by a time chart (cycle subdivisions in X axis) which lists all components vertically. Subdivisions can be created or deleted and component states can be changed by a few mouse clicks clicking onto the desired chart position.

1. 5. 2. Operation software (dVISION)

The operation software allows to:

- set the DACM real time clock
- set the clock switch
- start and stop the cycles uploaded to the module
- display and transmit the recent measurement results
- transmit the complete measurement data
- save measurement data as set or as single tracks
- show the measurement data in configurable diagrams
- export the measurement data to Excel/GIS compatible test files

The data loaded from the module will be saved as binary data file with pre-defined filename and folder structure. This file contains all measurement data of the components, the configuration of the components and the module information.
For further data processing this file is split into several data tracks, one for each measurement value. These tracks can be saved and exported separately. Any combination of tracks can be loaded into the chart view later on. This allows the simultaneous displaying of data generated by several instruments or acquired during several time periods.

Graphic options:

- Selection of any time period for the chart view
- Combination of various data tracks, each with manually or automatically scaled Y-axis
- Selecting line width, line colour and line style of any data track
- Grid, cross line cursor and sliding result box for a selected track
- Scale definition for each track

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2. Operation of the instrument

2. 1. Turning ON/OFF, main switch and fuse, battery replacement

The RTM 2200 enters into a low power standby mode if the measurement has been finished. It is not necessary to disconnect the unit from the battery if it is frequently used. But if the instrument is not used over longer periods (several weeks), the battery should be completely charged and after that, the electronic circuits should be disconnected by removing the fuse at the instruments rear panel.

2. 2. Charging the battery, battery maintenance

The RTM 2200 is equipped with a 12V/7.6Ah rechargeable NiMH battery. The power consumption during the measurement (pump rate 0.25 l/min) is approximately 60mA. This enables an autonomous operation period of >100 hours.
To recharge the battery, connect the power adapter to the “DC” receptacle at the front panel. Any other voltage supply with a current rating of at least 2A at 18VDC (>38W) can be used instead (inner contact is the positive pole of the voltage).
The integrated charging circuit manages a fast re-charge process. It takes about 4 hours to recharge a complete discharged battery. During charging, the red LED indicator right below the display is on. It turns off as soon as the battery is completely charged.

Charge the battery only within the temperature range from 10°C to 30°C. If the ambient temperature rises above 40°C, the charging process will be interrupted automatically to protect the battery pack.

It is possible to operate the RTM 2200 continuously from mains power adapter. The charge circuit controls a cyclic discharge scheme to optimize the life time of the battery. Heat is generated during charging, resulting in a warm up of the whole instrument. In that case, the internal temperature sensor will show increased readings. To measure the ambient temperature correctly, an additional external sensor should be used.

If the instrument has switched to the standby mode, the total power consumption is reduced to a few hundred Microampere. Even of this small current, the battery can be discharged completely in case of longer periods without re-charging. To protect the battery against deep discharging, an electronic circuit switches off the power from the whole electronics if the voltage drops below 10.5V. After that, the instrument must be re-charged until the voltage reaches a level of 10.8V. During that period no operation is possible. If the battery voltage goes below 11.2V during a running sample, the instrument enters the standby mode automatically.

2. 3. Touch screen

The RTM 2200 is controlled by touch screen menus. The power consumption of the display as well as the backlight is very high compared with the other electronics. Therefore, the display will be switched off automatically after an adjustable period. The time span (max. 255 Seconds) can be set by the instrument set-up function of the operation software.
To activate the display, press the small push button below the display. All other required inputs are realized by dynamic touch buttons on the screen. The screen will show always the display page which has been selected before the display was switched off.

2. 4. Communication interfaces (RS232, USB)

The instrument offers a RS232 interface (COM, below display) as well as an USB port (right beside display) for communication. The RS232 enables the direct connection of a modem or wireless communication adapter (e.g. ZigBee) while the USB port serves for direct PC connection.
Note, that the RS232 signal lines will be disconnected automatically if an USB connection has been established. Both ports can be used only alternatively.
The transfer rate is set to 9600 bps to ensure proper function even if radio modems are used in noisy environment. As an option, the ZigBee interface can be integrated in the instrument. In that case, the RS232 interface is skipped.
If no measurement is running, the transfer speed can be increased significantly by the “Card Reader” function. This function can be activated by a touch button in the main menu (upper part). Please note that the function needs to be enabled in the PC software dVISION too. The function will work only for communication through the USB interface.

2. 5. Data storage (SD Card)

All acquired data will be stored on a replaceable memory card (SD standard). There is no restriction for card capacity. More than 2 Million records (RTM 2200) can be stored at a 2GB standard card even if all components are active.
Furthermore, a complete copy of the system configuration (module settings and components) will be saved (or refreshed) if a measurement has started. Therefore, data can be read from the card independent on the instrument (e.g. by an external reader).
If the configuration has been changed, the interpretation of the previous acquired data may become invalid. It is recommended to clear all data at the card before applying a new configuration.
The instrument is able to collect huge amounts of data over long periods which have to be transferred and handled later on. To minimize transfer periods, only activate the sensors really required for your sampling procedure. Choose the sampling interval not as short as possible but with respect to your timing requirements.
The SD card can be replaced. The slot is placed on the left hand side of the DACM-01 electronic module. The left partial front panel must be removed for access. Stop the running sample and remove the fuse at the rear of the instrument before replacing the card. Use the RESET + CLEAR functions of the operation software dVISION to initialize a new card after insertion. Starting a new sample is not possible if no card has been inserted.

2. 6. Menu navigation

2. 6. 1. Main page

If the display wakes up appears the main page on the screen. In standby mode, this page shows the instrument name, the name of the actual configuration (with the date of the last update) and the selected measurement cycle. Touch the **CYCLE** button to call a list containing all pre-defined cycles to select another cycle.
Now the measurement can be started by pressing the **START** button. It is necessary that a memory card is inserted and a valid cycle has been selected before. All information about the status of sampling is displayed during cycle execution:

- Date/time (with black background if the clock needs to be set after power interruption)
- Name of the processed cycle
- Time span from the start of the whole sampling period (total sample time)
- Time span from the begin of the running interval
- Number of the executed step and step count of the running cycle
- Remaining data memory (number of data records which can be stored)

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Several buttons are present at the main page to enable the access to various display pages. It is possible to show recent readings, data already stored on memory card, component configuration etc.
The cycle execution can be stopped by the button **STOP**.

2. 6. 2. Module information and options

These pages show the module information as well as the actual setting of the module options. The menu can be called from the main menu by touching the **INFO** button. Use the **TOGGLE** button to toggle between the several pages.
Module information:

- Software version
- Serial number
- Date of manufacturing
- Date of the last software update

Options:

- Pre-set start time if the option “Synchronized start” is enabled
- Operation mode and time scheduling of the clock switch

Use the **BACK** button to return to the main menu or the **CONFIG** button to show the actual configuration of the various components.

2. 6. 3. Component configuration

This menu shows the actual settings of the configuration parameters of each component. The user can check them for validity but it is not possible to make any changes. Components can be selected by the buttons **NEXT** and **LAST**. If not all parameters can be shown on one page, the others are accessible using the **TOGGLE** button.

2. 6. 4. Selecting the cycle

This menu allows the selection of the sampling cycles which have been transferred to the instrument before. A touch sensitive list with the names of all available cycles appears after calling from main menu by the button **CYCLE**. If more than five cycles have been stored, the list can be scrolled by the **TOGGLE** button. A touch at the desired cycle name will select the cycle for execution. Touch the **BACK** button to return to the main menu without a new selection.

2. 6. 5. Recent readings display

This page is only available if a cycle is in progress. Use the button **RECENT** to call the recent readings page from the main menu. The results are updated once per second to show the actual sampling results. The display shows only data of components which are used and activated within the executed cycle. To select the different components for display, the buttons **NEXT** and **PREVIOUS** must be used. The order of components is defined by the order of component indexes (see document “DACM-01_Hardware-Reference”). The name of the selected component appears in the headline of the screen. Some components calculate more than one result from the acquired basic data. In that case, the **TOGGLE** button toggles between the various results.
To return to the main page touch the **BACK** button.

2. 6. 6. Displaying the data stored at the memory card

If available, all data stored data at the memory card can be displayed. This page can be called from the main page by the **INTERVAL** button even if the sample execution has been finished. The selection of the components and results is implemented in the same kind like in the recent data menu. If a component generates more than one result, an additional page with all results in parallel has been implemented.
There is an additional navigation menu directly above the control buttons. These buttons are used to select any data record within the card memory for display. The button in the middle selects the last acquired record while the other buttons scroll the data memory forward and backward by a factor of 1 or 10. If the current cycle has been finished, the new data appear immediately on the screen.
The headline of the display shows the time stamp and if available the GPS coordinates of the selected data record.
To return to the main page touch the **BACK** button.

2. 7. How to use DACM components in own applications

The integrated DACM-01 offers the possibility to extent the instrument functionality by using of the available components. This could be done by connecting more sensors or external actuators like pumps, valves etc.
The document “DACM-01_Hardware-Reference” contains a list of components which are already used internally by the particular instrument type. These components are completely pre-configured by the manufacturer and can be used within pre-installed or user-created measurement cycles. All other components are free for use.
The module is placed directly behind the front panel which is split into two separate plates. The left plate can be replaced or removed for mechanical conditioning if connectors or other parts must be added. Remove the battery or disconnect at least the battery by the main power switch before removing the front panel.
All component inputs and outputs are available by screw terminals. For an easy handling, bottom and top of the enclosure can be removed (four screws).
ATTENTION: All manipulations must be carried out by skilled persons. These persons should have experience in the field of electronics and instrumentation. If there are difficulties or uncertainties, please contact the manufacturer for assistance. The manufacturer will not be liable for defects in case of faulty workmanship.
You will find a detailed description of the DACM functionality, usage of components as well as a configuration reference in the document “DACM-01 Hardware Reference”.

2. 8. Instrument set-up (clock switch, synchronized start, display sleep mode)

These options can be adjusted by the operation software dVISION.

2. 8. 1. Clock switch

The integrated clock switch can be used to supply external components (e.g. switches, valves, modems) for a defined time period by battery voltage. The maximum load current must not exceed 500mA. The clock switch is accessible by connecter X1 at the DACM-01 PCB behind the front panel. Note, that there is no short cut protection on-board. It needs to be added if necessary.
The clock switch offers two different modes of operation (selected by the drop down list “Clock Switch Mode” in dVISION).

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1. Clock switch
Time stamps (real time) for switching on and off can be defined. The switch will turn on daily during the covered period. Time base is the real time clock of the instrument.

2. Periodical timer („periodical“)
In this mode, the clock switch is triggered with the start of the measurement cycle. Beside an ON and an OFF period, a delay period can be defined. This allows shifting the trigger within the sampling cycle. Set the delay period to zero, if the ON period shall start in parallel with the sampling. The voltage is applied for the ON period and will be turned off during the OFF period. This cycle will be repeated as long the sampling cycle is running.

If the clock switch is not used, it should be deactivated.

2. 8. 2. Synchronized start of a measurement

Sometimes it is required to synchronize the sampling points of several instruments at different locations. This can be done easily by the synchronized start capability of the instrument. Select the cycle which shall executed from the cycle selection menu. Use dVISION to set the day time when the cycle shall start. Check out if all instruments which have to be synchronized are set to the same time base.

2. 8. 3. Display standby

The display is switched off after a certain period to save power. The period counts from the moment of the last touch to any of the soft buttons and may be set to a value between 1 and 255 Seconds.

2. 9. Transfer of recent readings

This feature can be used by costumer created software solutions to obtain the latest results from the DACM. The data transfer is based on a small protocol. All results are transferred as formatted text. This functionality is used by dVISION to get the recent readings from the module. For more information see document “DACM-01_Hardware-Reference”.

2. 10. The integrated GPS receiver

If the instrument is equipped by a GPS receiver, the coordinates (latitude, longitude), the altitude, and the deviation of the GPS fix are saved for each data record. This information is visible on the menu page for interval data as well as in the data management software dVISION. The exported text files will only contain longitude and latitude which appear directly beside the time stamp of the data record. It is possible to export the sampling data into a GIS compatible KML format. This file format can be opened directly by Google Earth ™. The software dVISION allows the map-based presentation of sampling results.
If the instrument will be moved during a sampling interval, the geographic average is stored. Each five seconds, the position will be fixed and averaged over the whole interval.
The shown deviation is only an indicator for the accuracy of the position depending on the signal quality. The real deviation for one point can be higher than shown.
The coordinates are presented on the display as decimal degrees with a resolution of six decimal places followed by a character for the geographic direction. The software dVISION uses positive or negative signed values instead of the characters:

- 0…90° northern hemisphere = 0…+90

- 0…90° southern hemisphere = 0…-90
- 0…90° eastern hemisphere = 0…+180
- 0…90° western hemisphere = 0…-180

If no GPS receiver is installed or the satellite signal is too poor, the text “GPS not available” appears on the screen instead of the coordinates. After starting a new sample, the receiver needs a few minutes to detect all available satellites.

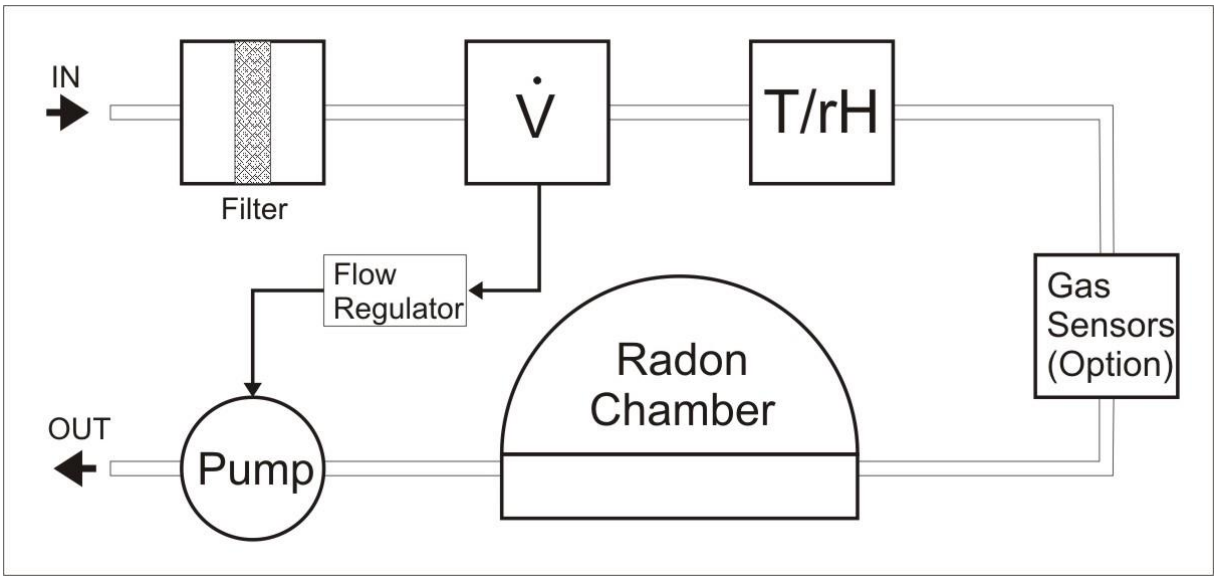
The antenna module is either integrated into the housing of the instrument or connected to the front panel by a removable cable. This version allows the user to place the antenna away from unit if necessary, for example when it is used in vehicles.

3. The Radon Chamber

RTM 2200 - EQF3200 - EQF3220

3. 1. Internal air loop

The measured air circulates through a sealed internal air loop. Beside the Radon chamber, sensors for humidity, temperature, flow rate and a filter system are included in the loop. Both input and output of the loop are available at the front panel by tube terminals. Thus, external sampling equipment can be connected easily. The air will be sucked through the loop by an internal pump. In aerosol and radon daughter product monitors, rotary-van pumps with a regulation range from 0.5 to 2.5 l/min are used. In Radon only monitors we use membrane pumps with a flow range from 0.25 to 0.75 l/min (pre-setting is 0.5 l/min). The flow rate is controlled by an internal regulator circuit. The total volume of the air loop (including all tubes and dead volumes) amounts approximately 250 ml. The whole air volume will be exchanged within approximately 2…3 minutes. The flow rates for the aerosol- and progeny monitors are set with respect to the used sampling head and must not be changed.



3. 2. Hints for operation

Especially if soil gas or water samples shall be analyzed, the user must take care to keep out water from the internal air loop. The pump power is high enough to draw water even from deeper boreholes. All sensors are directly in touch with the media in the air loop. We strictly recommend the use of the optionally available protection unit. The unit consists of a bottle with a floating switch which will be inserted between the sampling equipment (soil gas probe or water bubbler) and the air inlet of the instrument. The switch is connected by a cable to the front panel. If the pump sucks water, the bottle will be filled and the switch turns off the pump. Instruments without this protection unit can be upgraded by SARAD.
It is also important to avoid condensation inside the instrument. Condensation appears if the temperature of the instrument is significantly lower than the temperature of the measured air. In this case, the unit must be tempered before using. The instrument will not be damaged but the measurement can become invalid. If the instrument will be used stationary under such conditions, some dispositions must be applied. One solution could be to operate the instrument inside a heated box (not more than 30°C) or to use a cooler/condenser in front of the air inlet.

3. 3. Principal of operation

The Radon (Rn-222) gas concentration will be measured by the short living daughter products, generated by the Radon decay inside a measurement chamber. Daughter products which are already present in the atmosphere will be kept out by a filter system.
Directly after the decay, the remaining Po-218-nuclei will be charged positively for a short period, because some shell electrons are scattered away by the emitted alpha particle. Those ions are collected by the electrical field forces on the surface of a semiconductor detector. The number of collected Po-218 ions is proportional to the Radon gas concentration inside the chamber.
Po-218 itself decays with a half-life time of only 3.05 Minutes and about 50% (particles emitted towards the detector surface) of all decays will be registered by the detector.
The equilibrium between the Radon decay rate and Po-218 detector activity is given after about 5 half-life times, say 15 Minutes. This time span defines the minimum achievable response time to a Radon concentration step.
Now, the decay chain is continued by the both beta emitters Pb-214 and Bi-214 followed by another alpha emitter, Po-214. That means, each Po-218 decay causes one more detectable decay by the Po-214 which is delayed about 3 hours because of the superposed half-life times of the nuclides of the decay chain. The emission energies of Po-218 and Po-214 are different and therefore it is possible to separate both nuclides from each other by alpha spectroscopy.
Spectroscopic working monitors offer two calculation modes for the Radon concentration, one (Slow) includes both, Po-218 and Po-214 decays and the other one includes Po-218 only (Fast). The advantage of the “Fast” mode is the quick response to concentration changes while the “Slow” mode gives sensitivity twice as high compared with the fast mode. The higher sensitivity reduces the statistical error of a measurement which depends on the number of counted decay events only.
In case of Thoron (Rn-220), the direct daughter product Po-216 (which also underlies the ionisation process) is used to calculate the Thoron activity concentration. The half-life of Po-216 is less than 1s and therefore, the equilibrium state between gas concentration and collected activity on the detector is present immediately.
The half-life of the Po-216 decay products Pb-212 (beta) and Pb-212/Bi-212 (alpha) are too long to use them for Thoron measurement. The single nuclides of the Thoron decay chain will be also separated by alpha spectroscopy.

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4. Sampling head for Radon daughters and radioactive aerosols

RPM2200 - EQF3200 - A²M4000

4. 1. Principal of operation

Radon daughter products as well as aerosols will be collected by the internal pump on a filter. The detector, placed directly above the filter, detects the deposited activity simultaneously. The output signal is connected to a spectroscopy module which generates an alpha spectrum for each data record. All further result calculations are based on this spectrum. Calibration parameters which have been determined are related to the nominal air flow rate of 1.5 l/min. If the flow rate shall be changed, a re-calibration is required.

4. 2. Calculation of results

While the RPM/EQF devices calculate only the concentrations of the short-living Radon daughters, the A²M offers additionally readings for long-lived Alpha and Beta emitters. Furthermore, the instrument distinguishes between natural Uranium and other isotopes.

4. 2. 1. Radon progeny

The activity of Po-218, Po-214 and Po-212 are separated by spectroscopy which allows the determination of the Potential Alpha Energy Concentration (PAEC) for both Radon and Thoron. To obtain a reasonable response time for changes in Thoron daughter product concentration, the time distribution of Po-212 filter-activity will be differentiated. In that case, the measured activity of two sequential intervals must be used to determine the increase/decrease of activity. Both activity readings show statistical fluctuations resulting in wider statistical variation of the final result. Therefore, the sampling interval must be set long enough to reduce these variations. In practice, two or three hours are a good choice at non-negligible concentrations. Then, daily fluctuations will be shown and the results are in good time-correlation with the Radon (Rn-222) daughters.

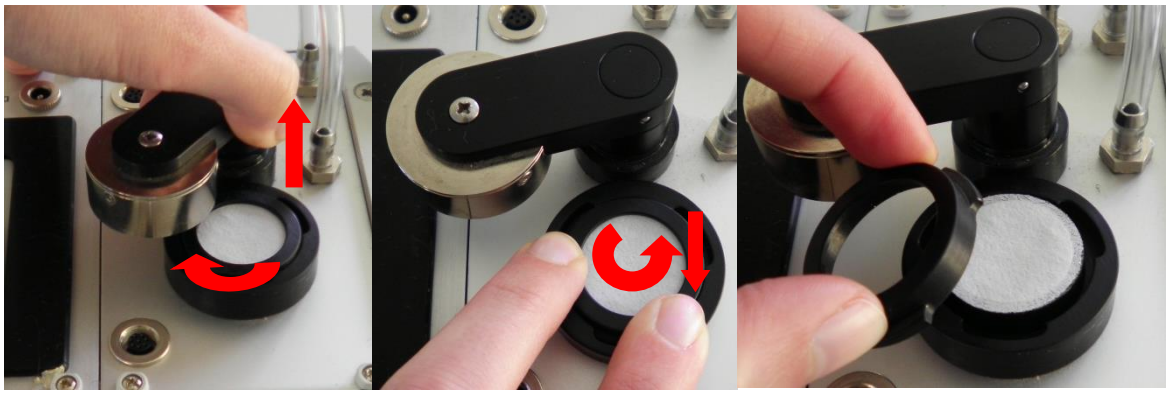
4. 3. Operation conditions

The instrument has been designed as a robust unit for portable use in nuclear facilities and mining facilities. Because of the sampling method, the detector head is directly exposed to the ambient conditions. Therefore, the user should mind a few limitations.

- The temperature range from 0°C to 50°C should not be exceeded. An extended range can be provided on request.
- Condensation of water must be avoided. After strong temperature changes (moving a cold unit in warm environment) the instrument should be tempered for a while before using.
- Avoid beats onto the enclosure or detector head. The microphonic (piezo-electric) effect generates electronic signals similar to decay events. The instrument is equipped with dynamic shock suppression (electronic pulse shape analyses). Frequently shocks or permanent vibration must still be avoided. The unit should be worn on the body using the holster. The holster and the position close to the breathing tract offer a perfect shock protection as well as a good sampling procedure.
- Do not use any strong source of electro-magnetic fields in the immediate surroundings of the instrument (e.g. mobile phones, Wi-Fi adapter/router).
- The internal battery warms up during charging process. Therefore, the instrument must not be covered or operated in a box while the power supply is connected.
- The instrument should never be operated without filter. Particles in the air loop resulting in an increased abrasion of the pump.

4. 4. Filter replacement

At first, the pivot mounted sampling head must be pulled out slightly and turned towards the display (pic. 1). After that, the filter cap (inner ring) must be pressed and turned to lose the bayonet-catch (pic. 2). Now, the old filter can be removed and replaced by a new one. The smooth side of the filter must show in direction of the sampling head. Only filters specified by SARAD should be used. This ensures a reliable sealing as well as the required spectroscopic performance.



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4. 5. EQF3200 filter bypass

To use the EQF3200 also for Radon analysis in soil gas and water, the air loop has been split between sampling head and Radon chamber. Both sides are connected to tube terminals at the front panel. This allows the user to connect the external water, and soil gas equipment directly to the inlet of the Radon chamber. In case of Radon daughter product measurements, the connection between sampling head and Radon chamber must be realized by a short piece of flexible tube as shown at the picture left. The connection of the sampling head is placed left beside the pivot axis while the inlet of the Radon chamber is placed straight beneath. Check the tube connections against leakages before starting a sample. We recommend silicon tube.

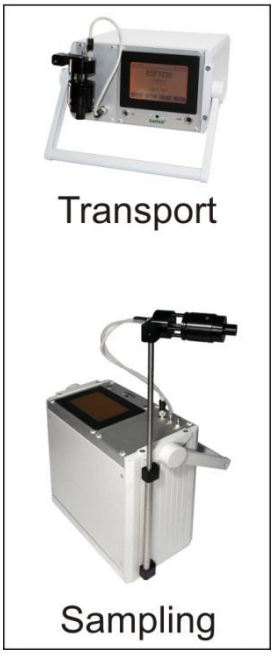


5. Sampling head for attached and unattached progeny

EQF3220

The EQF3220 is equipped with are movable sampling head to measure the activity concentration of unattached und attached Radon daughter products.
The sampling head is positioned by a telescopic holder which is mounted on the left side of the instrument enclosure. The EQF3220 can be also operated without the sampling head to use it as a standard Radon monitor. This can be helpful if exhalation bonnets, water samplers or soil gas kits shall be connected. In such cases it is recommended to reduce the air flow to a value of 0.75 l/min (cycle definition).
The sampling head has been designed for continuous monitoring. That means, air sampling and activity analysis are carried out simultaneously. This feature enables a gap-less measurement resulting in an accurate as possible exposure assessment.

5. 1. Connection and operation positions



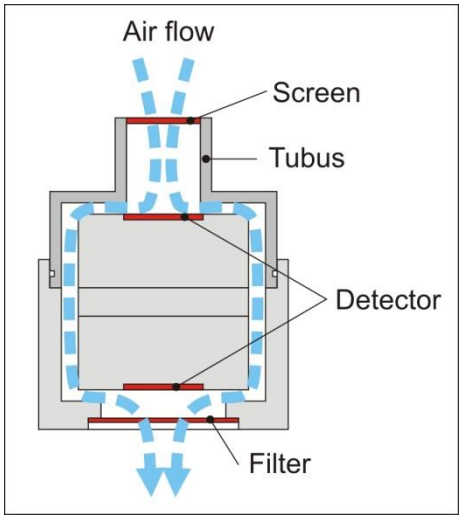
The electrical connection is realized by a single cable with a 7-pin connector (screw lock) on each side. The plugs must be connected to the sockets at the sampling head and at the small front panel (right beside the air terminals). A flexible tube, made of silicon rubber connects the head with the air inlet (left terminal) of the instrument.
Both, tube and cable can be extended up to a length of 5m, e.g. if the head shall be placed in the middle of a room.
Take care that the tube connection not avoids the planar alignment of the pressure plate. Use only silicon rubber tubes with thin walls.
To carry out a measurement, the sampling head must be pulled out until the telescope holder latches in the slide-way. Swivel the head simultaneously anti-clockwise until the air inlet (screen) points away from the instrument enclosure (see picture “sampling”).
In this position, the distance between air inlet and enclosure is big enough to keep out influences by depletion of unattached daughters. Take care for sufficient space between sampling head and other surrounding surfaces (> 20...30cm).
Slide in the sampling head for transportation and turn the head with the air inlet above the air terminals of the front panel. Only in this position is it possible to push the holder completely into the slide-way to lock the head against rotation. Disconnect the silicon tube if necessary.
Do not expose the head mechanical shocks and vibrations. Avoid direct light incidence (perpendicular to the screen).

5. 2. Theory of operation

At first, the sampled air passes the screen and the intake duct (tubus). A silicon detector is placed at the end of the duct. This detector is used to measure the unattached fraction of the Radon daughters. Nearly the complete unattached fraction (< 5nm) will be deposited on the screen while the attached fraction (> 100nm) can pass screen and duct. Another size fraction in the order of 10…20nm (further called “Cluster”) is present in case of burning processes. These particles are primary deposited on the surfaces of the duct and the detector. A small amount of this fraction will be also deposited on the back face of the screen and must be subtracted from the deposited unattached fraction.

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This is possible by the separate determination of the “unaffected” cluster fraction which has been deposited on the duct wall. Because of the higher distance between screen and detector compared with the duct, each nuclide appears twice in the alpha spectrum. The lower peak always represents the activity on the screen while the upper peak is generated by the particles attached to the duct (less air path). Therefore, the upper peak can be used to calculate the cluster concentration on the one hand and to estimate (and correct) the part of cluster fraction on the screen on the other hand.
The attached fraction is carried by the air stream through the sampling head and is collected on a filter which is placed vice versa the screen. A second silicon detector is used to determine the filter activity.



5. 3. Calculation of results

Both detectors are connected to two independent spectroscopy modules, which are providing one alpha spectrum per sample interval. These spectra act as the basic data for all further calculation procedures. Two different calculation algorithms have been implemented to take the specific physical particle collection in account.
Calibration parameters and design are based on a nominal flow rate of 1.65 l/min. Keep this value if new measurement cycles shall be defined. Otherwise, the deposition characteristic of the screen with respect to the particle size will be changed. This results in a wrong separation process of the various size fractions. The EQF3220 calculates following results:

Detector filter:
EEC and PAEC of the attached fraction of Rn-222 and Rn-220 (Thoron) daughters

Detector screen:
EEC and PAEC of the unattached and cluster fraction of Rn-222 daughters

A special algorithm has been added to obtain a reasonable time resolution for the Thoron daughter product concentration. This procedure is based on the differentiation of the Po-212 filter activity time distribution. Differentiation means the subtraction of the count sums of two sequential sampling intervals to get the relative activity increase. Because of the statistical fluctuations of both count sums, the result will show a much higher statistical variance as the count sums self. Especially if the increase is low, this problem becomes significant.
To reduce the statistical error of the calculated Thoron EEC/PAEC, the sample interval should be set to values between one and three hours. In practice, these intervals are short enough to record daily fluctuations and long enough to keep the statistical fluctuations low. Furthermore, it aligns with the response time of the Radon (Rn-222) daughter product measurement.

5. 4. Filter replacement

The EQF3220 uses PTFE filters with small pore sizes to achieve a high energy resolution of the acquired spectra. Only special filters with an additional Neoprene™ sealing can be used. Without this sealing a part of the air flow is bypassed because of the rough surface structure of the filter material (texture reinforcement). This part increases with the increasing filter pollution and cannot be calibrated.




To remove the old filter, disconnect the silicon tube from the air terminal. Then, the pressure plate can be pulled back against the spring. Use plastic tweezers to pick up the filter (catch it at the Neoprene sealing). Do not touch the surface of the detector which is located directly behind the filter.
To insert a new filter, set the sampling head in the position that the side without a guide bolt points upward. Pull the pressure plate back again and let the filter slide into the clamping arrangement. The sealing must show towards the pressure plate (see right picture).
The filter will be automatically positioned by the three guide bolts and the pressure plate can now set back to its original position.
Connect the tube to the air terminal and pull back once more the pressure plate. Thus, the silicon tube will slip completely over the air terminal. Check again the accurate alignment of the pressure plate after finishing the replacement procedure.

5. 5. Removing the screen arrangement

Screen and screen holder are joined by an adhesive and can be replaced only together. Normally, no replacement is required because the mesh size is too big for large particle deposition. Read the following hints if still a cleaning of the screen is required. The screen holder is fixed and sealed by an O-ring between holder and the sampling head and can be pulled out without tools. However, after longer operation, the O-ring can “glue” at the surfaces and the removal by hand becomes impossible. In that case you may use two multi grip pliers while placing suitable protective material (stable rubber mat) between pliers and the parts of the sampling head. Do not apply force and do not beat on the sampling head. The detector is directly located behind the screen holder. Do not touch the detector surface.
Check the O-ring seal before placing the screen holder back into the head. Take care for correct position of the screen holder (completely inserted, straight alignment).

6. Filter exhaustion indicator and pump protection

The instrument is equipped with red warn lamp (LED) left below the display. If the filter is heavily charged by particles and the pump cannot longer regulate the flow at the nominal rate, the LED begins to light (95% of the regulation limit). At least now the filter must be replaced. The LED is controlled by the alert function of the analogous input AIN1. To warn the user earlier, the alert level can be adjusted by the configuration of AIN1. It is recommended to cancel a measurement instead of optical alert when the instrument works unsupervised for longer periods. This avoids strongly increased abrasion of the pump. Choose “Stop Cycle” instead “DOUT2” as alert destination in the AIN1 configuration.

To protect the electronics in case of a faulty pump, the instrument observes the pump current continuously trough the analogous input AIN2. In case of a pump current higher than 300mA, the measurement cycle will be stopped.

IMPORTANT: Include always the components AIN1 and AIN2 if you create own sampling cycles. Otherwise there is no protection against pump overload and damage.

7. Gamma probe

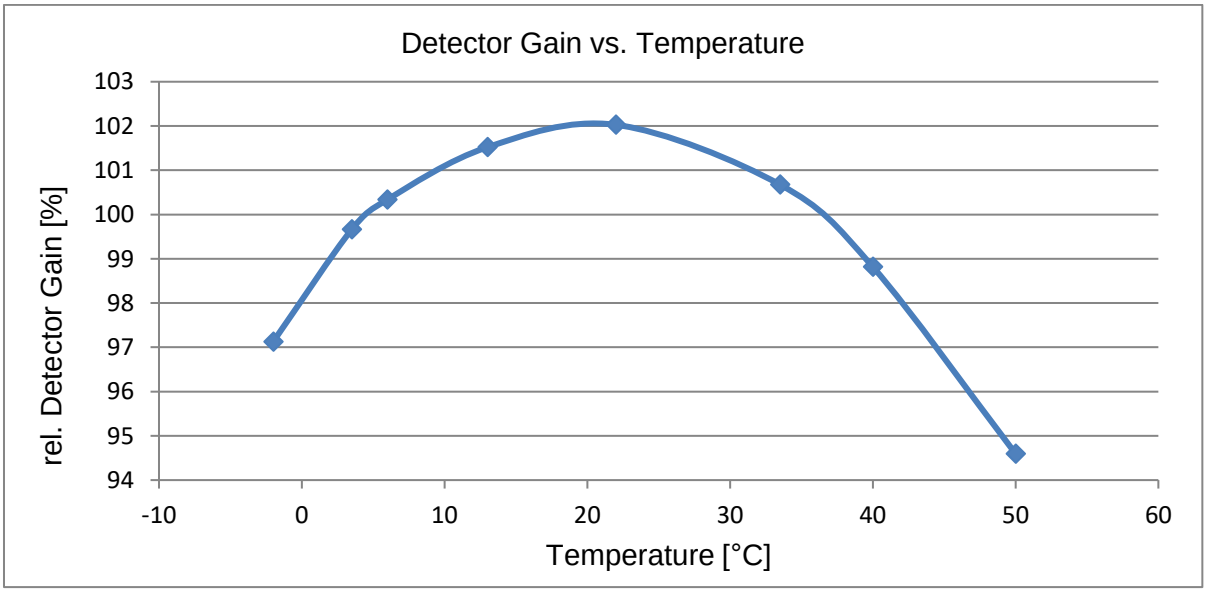
Option for RTM 2200, RPM2200, EQF3200, EQF3220

7. 1. General hints for operation

The gamma probe contains a 2” x 2” NaI(Tl) detector, a photo-multiplier, a high voltage supply and the electronic circuits for signal conditioning. The probe is shielded against magnetic fields and compensated against temperature variations. The electric connection between probe and instrument is realized by a single cable, connected to the electronic box. The pulses are processed by the subsequent spectroscopy module. The supply voltage for the probe is provided by the instrument.
Photo-multipliers are vacuum tubes with a high number of internal electrodes. Therefore, they are sensitive against mechanical shocks. Even the scintillator crystal must not be exposed to mechanical stress. Do not expose the probe to strong sun light.

7. 2. Temperature compensation

Sodium Iodide crystals as well as photo-multipliers show a significant temperature-dependency of efficiency and gain. Therefore, the signal gain must be regulated with respect to the ambient temperature. In case of the NucScout this is done by an electronic circuit, by the way the usage of test sources is not necessary. The electronic compensation stabilises the signal within a range of 0°C to 40°C with a maximum variation of ±2%. A peak will be detected reliably by the PSV nuclide identification within this range (see also chapter “Calculation of the measuring quantity and nuclide identification”). If the unit is used out of this temperature limits, a calibration under the expected conditions must be carried out. After rapid temperature changes, the probe should be tempered at least one hour before usage. The graphic below shows that the maximum of the detector signal will be reached at approximately 22°C. For higher and lower temperatures the signal will be lowered. The energy calibration is performed at 35°C resulting in a slight peak shift to right between 5°C and 35°C and a slight shift to left outside this range.



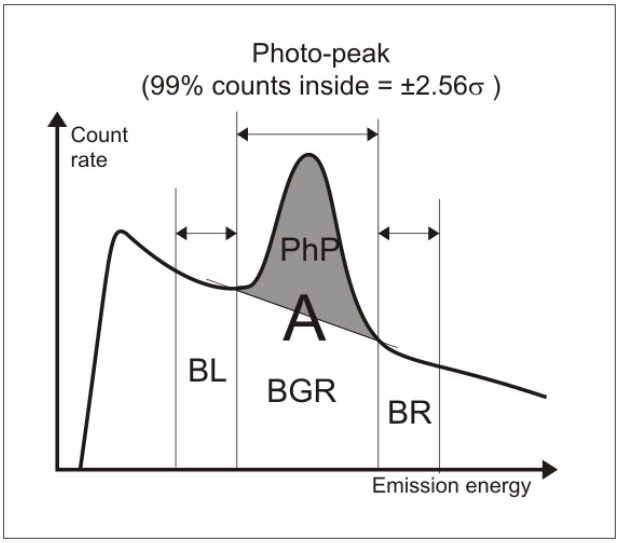
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7. 3. Calculation of the measuring quantity and nuclide identification

Based on the acquired spectra, the local dose rate as well as the activities of seven single nuclides (nuclide list) on user's choice will be determined. For the single nuclide analysis, two different procedures are at disposal (Trapezoid or Peak Shape Verification PSV) that can be also selected by the user. The PSV analysis is pre-set by the manufacturer.

7. 3. 1. Trapezoid Method

With the trapezoid method, the background to be subtracted will be determined by a linear interpolation of the assumed background left (BL) and right (BR) of the emission line. To obtain a minimum detection limit, the ranges used for background estimation are defined by the half of the full peak width. Thus, the estimated pulse number in the background (BGR) will be identical with the sum of the pulse numbers of BL and BR. So the net pulse number in the photo peak (PhP) will be a result from the difference of the total pulse (A) in the peak range and the estimated background:

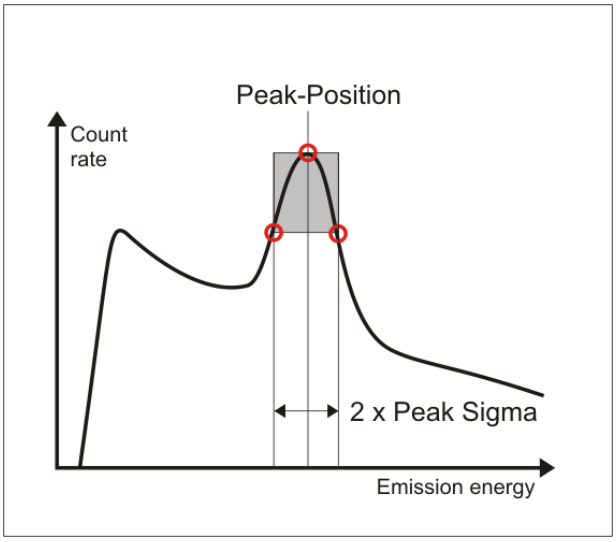


PhP = A – (BL + BR)

The Trapezoid Method will only deliver reliable results if the background within the peak range and the background ranges can be assumed to be linear.

7. 3. 2. PSV Method

A photo line (peak) appears within the scintillation spectrum as a Gaussian curve superimposed to the background.



This photo line is clearly defined by its characteristic parameters μ and σ. The parameter μ meets the position of the peak (peak position) within the spectrum while σ determines the width of the peak. The peak width is a function of emission energy and is a characteristic for each detector. The PSV analysis is based on the comparison of the peak shape (μ, σ) to be expected from the detector calibration with that real shape determined from a measurement.

For this purpose, the spectrum will be smoothed by means of a suitable filter in order to suppress the statistical fluctuations within the counting channels. In the range of each peak as defined in the peak list will be searched for a maximum (μ). If a maximum is present the accompanying turning points (σ) shall be determined. If the parameters will be in coincidence with the values of the detector calibration the area of the peak (net pulses) can be determined by means of shape parameters independently upon the background. The PSV analysis guarantees that only "real" photo line will be verified. Furthermore, just the real range of spectra of the peaks (c. double half-width)

is needed. So the peaks that are directly situated side by side can be clearly separated and calculated. Another advantages are given by compensating small spectrum shifts (e.g. by temperature fluctuations).
The following table refers to the advantages and disadvantages of both analysis methods and their preferred use.

	Advantages	Disadvantages	Use
Trapezoid	Lowest detection limit Highest accuracy	Requires a linear background in the peak range and left and right of it Calculates values for any convex spectrum course Sensitive for slight spectrum shifts	Lab works with known samples Efficiency calibration with specific calibration sources
Peak Shape Verification (PSV)	Allows slight spectrum shifts Verifies only „true“ photo peaks Also correctly calculates peaks being directly side by side	Higher detection limit Greater statistical error	All kinds of field measurements and „in situ“ analyses

7. 3. 3. Calculation of the nuclide-specific activity

In order to be able to determine the activity of a nuclide within a sample, in addition to the net pulse number (N) in the photo peak are required: the measuring time (T), the transition probability of the emission line selected (P) and the counting yield (efficiency η) of the detector. The transition probability is a constituent of the peak information of an entry in the peak list. The efficiency must be determined by a previous calibration. It contains both the energy-dependent response curve of the detector and the geometry effects and absorption effects of the sample or between detector and sample, resp. The activity of a nuclide can be calculated as follows:

$$A = \frac{N}{T * P * \eta}$$

7. 3. 4. Calculation of the dose rate

In order to calculate the local dose rate, at first, the energy-dependent photon-flow Φ(E) in the radiation field needs to be determined. Base for it is the measured energy spectrum of the detector as well as its efficiency characteristic with taking a homogeneous radiation field for granted.

$$\Phi(E) = \frac{R(E)}{\eta(E) * F}$$

R(E) counting rate of the detector at the photon energy E
η(E) efficiency of the detector for the photon energy E
F cross-sectional area of the detector

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The energy-dependent dose rate can be determined by using the energy-dependent mass energy – absorption- coefficient of air μ(E):

$$\frac{H(E)}{t} = \Phi(E) * E * \mu(E) = \frac{R(E)}{\eta(E) * F} * E * \mu(E)$$

H(E)/t dose rate (dose H / time t)
μ(E) mass energy-absorption-coefficient of air

Now, the dose rate for the whole energy range in the spectrum is given by the equation:

$$\frac{H}{t} = \int_0^{3MeV} \frac{R(E)}{\eta(E) * F} * E * \mu(E)\, dE$$

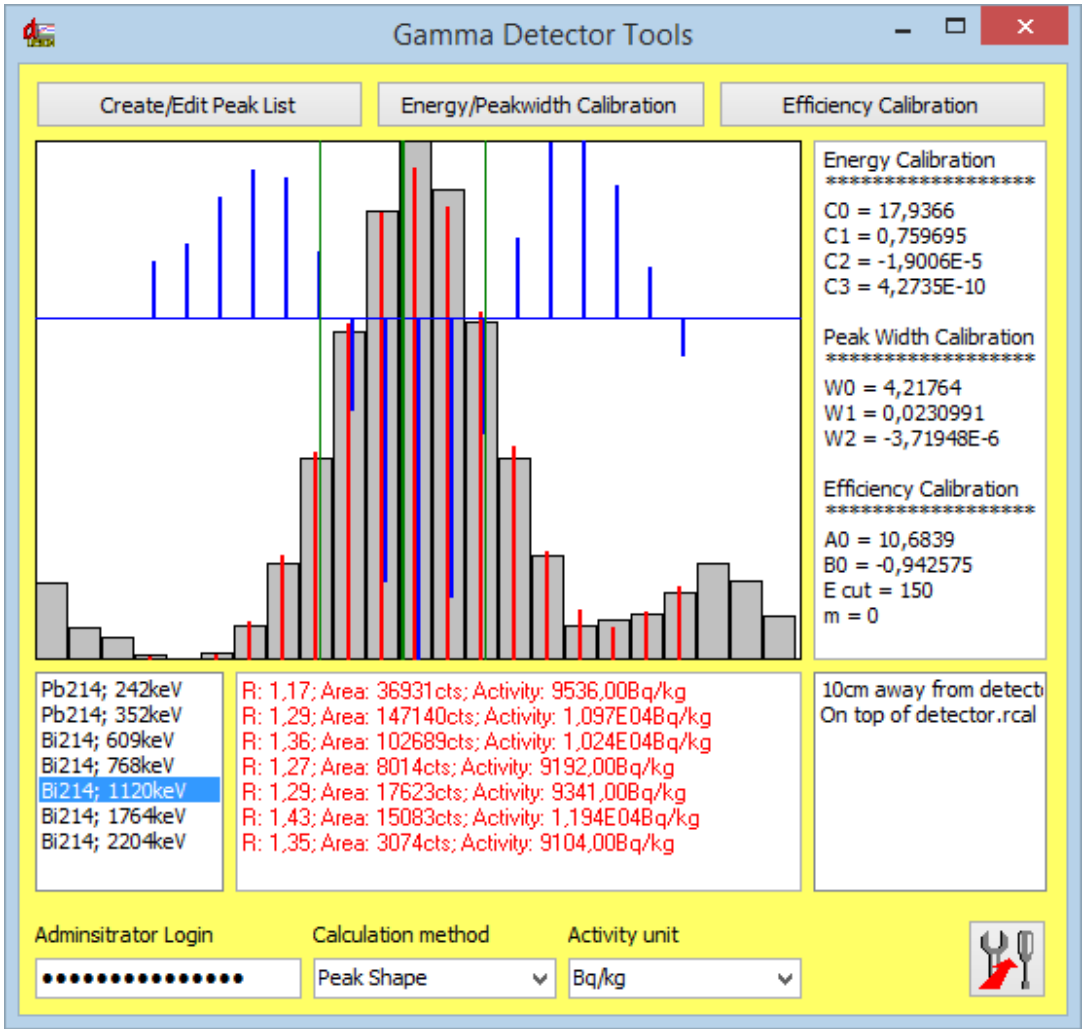
The integration is performed numerically, i.e. the partial dose contributions are being summed up. This procedure will secure a correct determination of the dose rate, independent on nuclide vector, by means of which the radiation field is generated. So a calibration of a Cs-137 reference source keeps its validity for natural radiation fields likewise.

7. 4. Tools for Gamma Detectors

The software dVISION as a part of the delivery volume offers a set of tools that are required for the configuration and the operation of gamma detectors. They are summarized in a window which has to be opened via the switch area “Tools”  in the spectrum view of dVISION. The following functions are implemented:

- Detector calibrations
- Editing of the nuclide list used for analysis
- Selection of the calculation method and the physical unit of the result
- Selection of predefined measuring geometries for the quantitative analysis
- Detailed analysis of the recently displayed spectrum

The calibration of the detector and the selection of the nuclide list will be explained in details in the sections “Detector calibration” or “Definition of the nuclide list”, resp.



The window contains a graphic area in which the spectrum range in the environment of the selected emission line is displayed. Beneath it, two list boxes are placed that contain the information of the emission lines in the nuclide list just selected. A click on a nuclide in the left box will select this nuclide for display in the graphic area. In the box next to it will appear the results of the analysis. It might be either a calculated activity or the reason why the verification went wrong (e.g. no maximum had been found or an invalid peak shape).

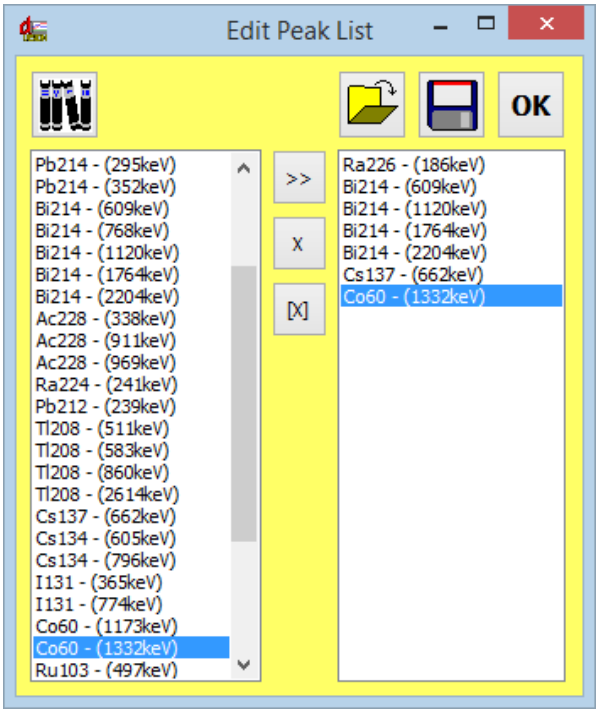
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The spectrum channels are displayed as grey bars in the graphic. They will be summarized in its type, thus, a constant peak width will result independent on the position in the spectrum. The red lines show the spectrum range after smoothing by means of filter while the blue line will display the second derivative of the filtered spectrum. Here a zero crossing means the position of the inflection. The green vertical lines display the position of the expected value deducted from detector calibration for the peak position and its width (Sigma). The meaning of these parameters will be explained in detail in the section “Calculation of the measuring quantities and nuclide identification”.
The right part of the window displays the polynomial coefficient of the used detector calibration. There is a list box by means of which you can select pre-defined measuring geometries. They meet an efficiency calibration carried out for this geometry. The calibrations are saved as binary files (extension „*.rcal“) in the subdirectory “CAL”. The list box displays the names of all the files available in this directory. More data whatever can be added by the user. This will be done within the framework of the efficiency calibration.
There are list fields in the lower window range for selecting the activity unit to be used and the calculation method to be used. The access to the calibration functions and the selection of the analysis method are protected by code. It must be entered in order to enable the relevant control elements.
All the changes done will have an immediate impact on the activity values calculated from the spectrum so that the result of the manipulation can be checked at once.

The switch area „Transfer“  will enter all the performed settings (incl. nuclide list and calibrations) into the instrument. As long as the analysed measuring data are still available in the instrument storage they can be loaded from the instrument under usage of the new settings. This will e.g. enable the analysis of a complete measuring series with different nuclide lists. In order to make the changes effective on the instrument you must start a new measurement but which can be again cancelled at once.

7. 5. Definition of the nuclide list

By means of the nuclide list (also called peak list) you will determine what emission lines shall be identified and quantified. The nuclide list contains a selection of seven emission lines at a maximum which will be displayed later as measured values and stored, respectively. Due to the flexible handling of the list the different peak lists can be used on an acquired spectrum. The selection of the emission lines will be performed by the help of a library which will be part of the delivery volume of the operating software dVISION the contents of which can be edited by the user.



Each line of the file contains the name of the nuclide the emission energy as well as the transition probability of the photo peak. These entries are separated by tab stops. By means of the Windows Editor you can add any nuclides. But note, that the names of the nuclides shall have only five characters at a maximum, the emission energy shall be entered as an integer value in the unit “keV” and the transition probability in percentage (here are floating point numbers allowed).
The tools for gamma detectors offer an easy possibility to edit the nuclide list. These can be called on from the spectrum view of dVISION. Clicking the switch area “Edit/ Create Peak list“ will open a dialog window that contains at the right side a list box for the nuclide library , and at the right side a further list box with selected emission lines.
First of all, by means of the switch area „Library“  a library must be loaded.
The **switch areas** between both lists perform the following manipulations:

[x] will delete all entries from the nuclide list
X will delete the selected entry from the nuclide list
>> will take over the entry into the nuclide list as selected in the library

At a maximum, seven nuclides can be can be assigned to the nuclide list. Therefore, possibly, you should remove that photo lines not needed any longer, before you will add new lines.

By means of the switch areas „Open“  and „Save“  you can store the nuclide lists made out or you can load them. By means of the switch area “OK” the new list will be taken over. The transfer to the instrument shall be done by clicking the switch area „Transfer“  in the tools for gamma detectors. Precondition for it is an opened connection to the instrument.

7. 6. Detector Calibration

Several calibrations are required for the identification and quantification of radiation sources.

<u>Definition of the energy range</u>
will fix the energetic upper limit of the spectrum to be analysed (adjustment of the detector signal to the ADC entry of the multi-channel analyser)

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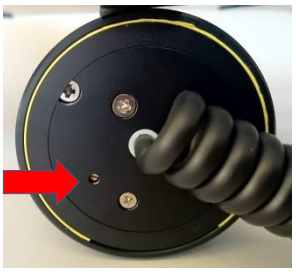
Energy calibration
is used for the positional determination of a peak within the spectrum (assignment of the ADC channels to the emission energy)

Peak-Width calibration
will fix for the **trapezoid method** the width of the peak ranges and the background ranges. For the PSV analysis, it delivers the anticipated comparison value to the actually measured peak width.

Efficiency calibration
compensates the energy-dependent response curve of the detector as well as the absorption in the probe or between probe and detector, resp.

The instrument will be delivered with being completely calibrated. There are, on your choice, different efficiency calibrations for common standard applications. But in case of special applications, a new calibration might be required.
While the setting of the energy range is being done from the hardware part by means of a potentiometer on the probe the required calibrations can be performed very easily and quickly per software. Preconditions for doing it are suitable calibrating standards.
The calibrating functions are accessible via the spectrum view in the operational software dVISION. There you will find - in the right side upper corner of the window – a button used to open the tools for gamma spectroscopy. The various functions will be explained in detail in the following paragraphs.

7. 6. 1. Definition of the Energy Range



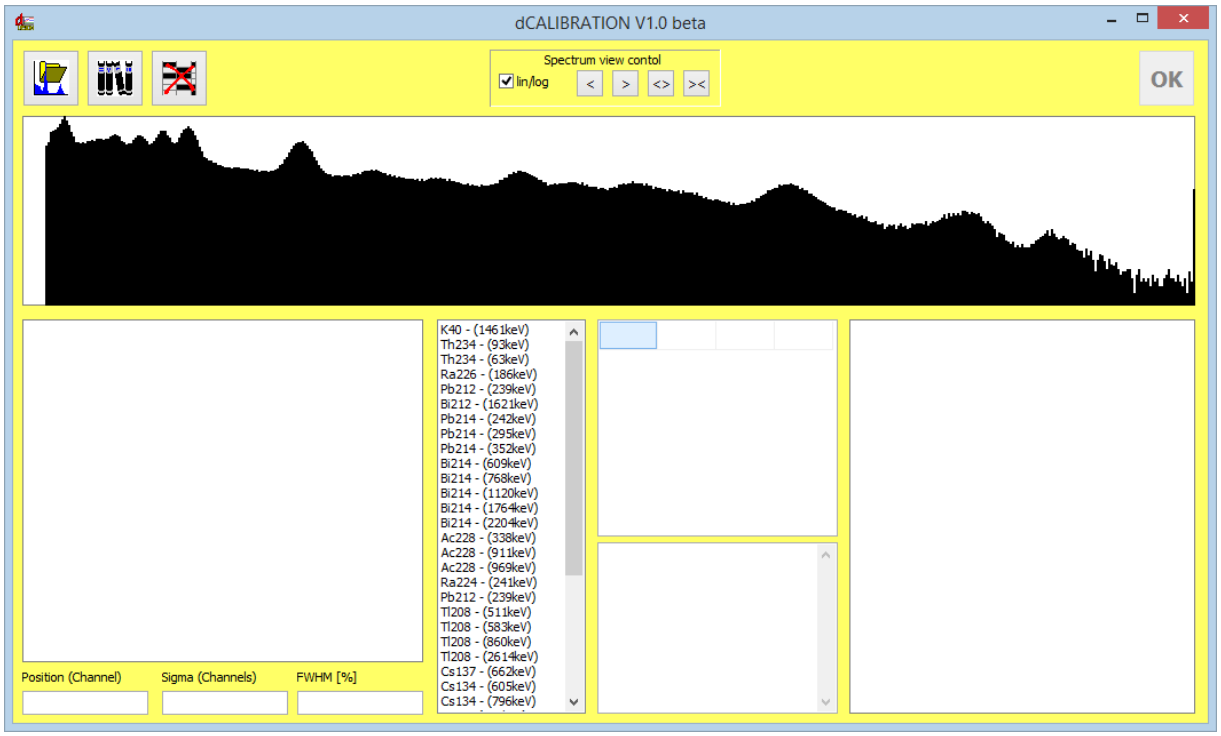
The energy range is fixed by the amplification as set on the probe. By means of a potentiometer at the rear of the gamma probe (photo) you can adjust the dynode voltage of the photo multiplier. If you turn in a clockwise direction, the amplification will be increased. Resulting from this the photo peaks will be shifted to the right, and in this way the measuring range will be limited. Vice versa, the measuring range will be extended by turning the potentiometer in a counter-clockwise direction. A greater amplification will result in a slight reduction of the peak width, the maximum counting rate will be reduced by the increased dynode current though. The instrument, when delivered, has a setting for a measuring range of c. 3 MeV, so Tl-208, likewise will be in the spectrum. The lower limit (threshold of pulse recognition) of the energy range can be adjusted by means of the configuration software (dCONFIG). With instrument delivery, it is approx. 25 keV. An increase of amplification might be purposeful, for example, if you want to make measurements in a range below 25 keV.
Please note: When setting the energy range, pay attention, that the peak to be analysed and being in the most right position shall not be directly at the spectrum boundary. Conditioned by the methods of analysis an additional distance from the right boundary will be required at an amount of the peak width.

7. 6. 2. Energy calibration and peak width calibration

The calibration of energy and peak width will be performed in one single step. At the beginning, a calibrating spectrum will be taken by means of the instrument that should contain photo lines as many as possible in the whole energy range. We recommend to use a solid radium or thorium test source. The measuring time shall be selected in such a manner that the statistical fluctuations of the single counting channels will not result in a falsification of the Gaussian profile of the peaks. Now, the acquired data can be loaded from the instrument by means of

dVISION, and the calibrating spectrum can be displayed. The button “CAL” in the upper right-side corner of the window will open the tools for gamma detectors. After having entered the administrator code the switch area “Energy/Peak width calibration” will be at your disposal. An interactive window will be opened that already will contain the calibrating spectrum. The following steps shall be carried out:

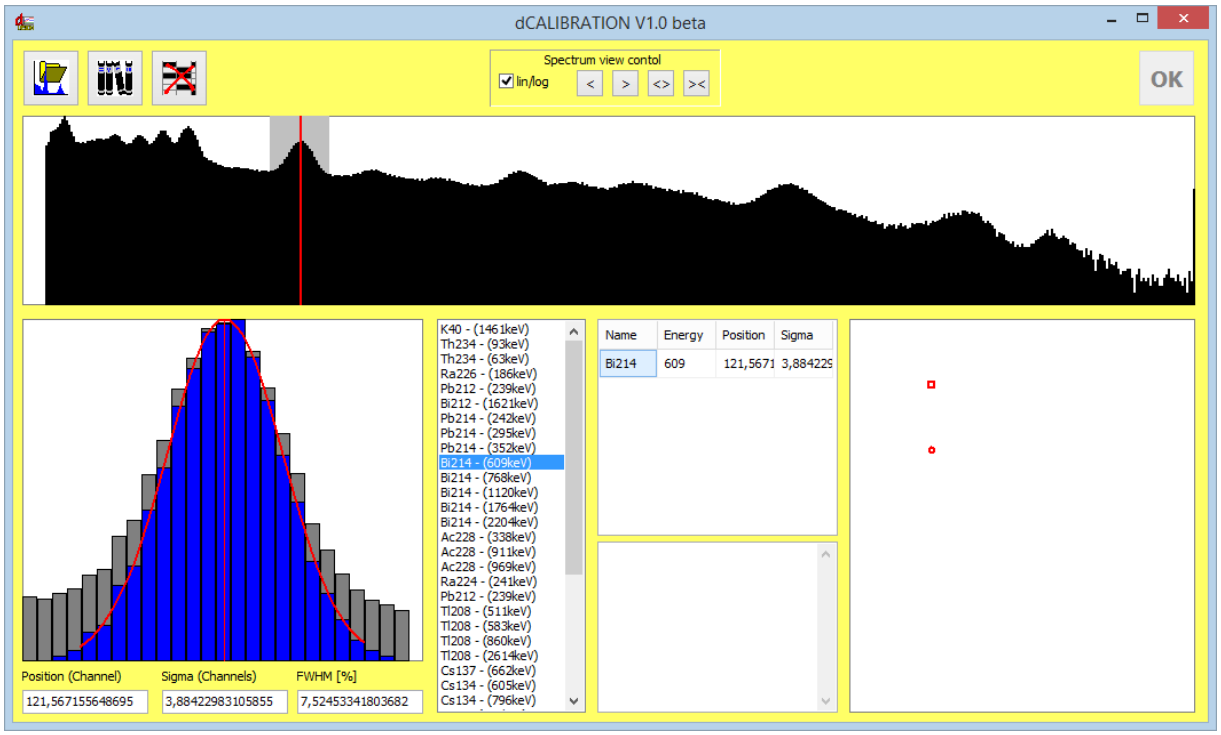
1. Open a nuclide library. This text file must contain that photo lines as used for calibration. The Installation of the software dVISION contains the standard library file “Gamma-Library.txt”.



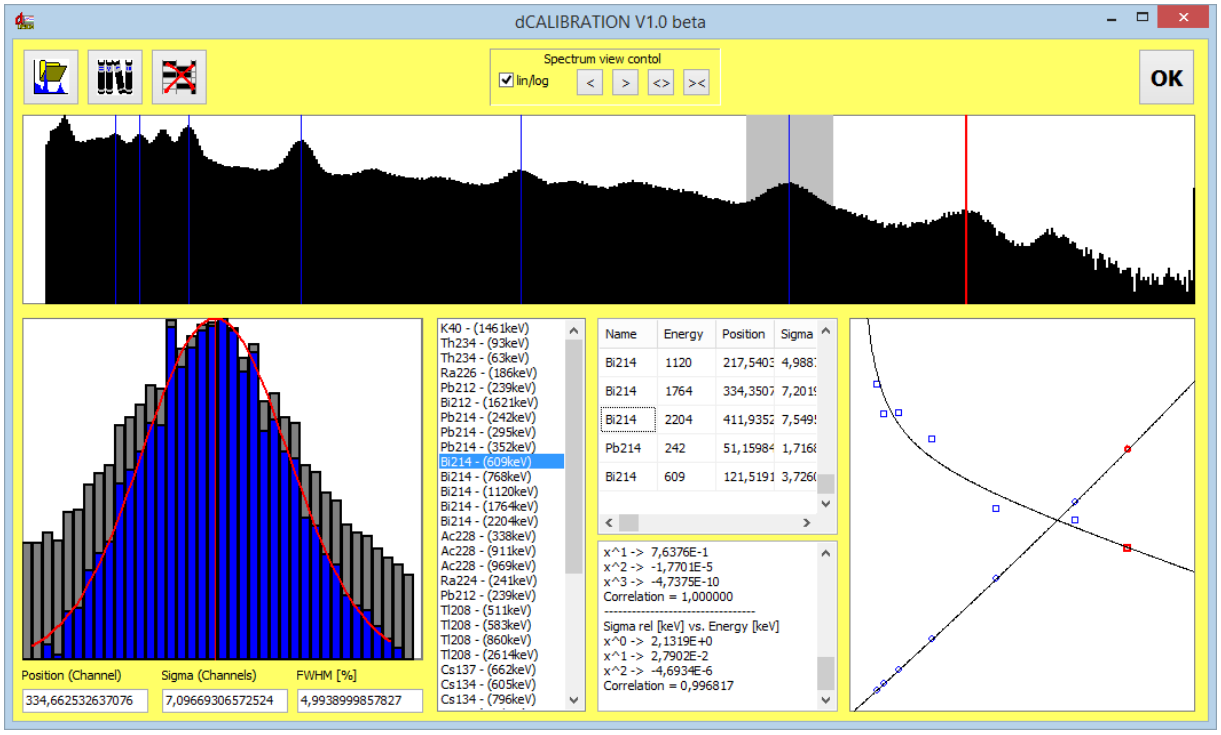
2. Mark the limits of the first peak that is intended to be used for calibration. In order to set the markings you should click – by means of the right mouse key at the right side, by means of the left mouse key at the left side – beside the peak. The peak range is highlighted in grey colour in the spectrum and appears separately in the graphic box under the spectrum. The limits shall be set in such a manner that the whole peak will be contained. The limiting channels will be used for a linear background subtraction. The blue bars show the net peak after this subtraction. With sufficient statistics and a correct range selection the net peak should appear symmetrically. A Gaussian curve (red line) that represents the modelled peak with mean and standard deviation is overlaid. These parameters and the peak width resulting from it (Sigma or FWHM, resp.) will be displayed in the text fields beneath it.

A double-click on to the nuclide in the library that corresponds with the selected peak will add its pieces of peak information to the list of calibrating points (right-hand side beside the nuclide library). The graphic box at the right down side will display the first data points for energy and FWHM.

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3. Repeat that steps as given under point 2 for the next peaks. Already with adding the second data point the calibrating curves will be calculated. But you should consider that a polynomial of third order will be expected as a calibrating curve. Therefore, four data points at a minimum should be used. At a maximum, nine data points can be used. At the same time, the peak width calibration will be performed by using the Sigma calculated of the single peaks. This will be described by a polynomial of second order.
In order to remove a peak from the list it will be sufficient to double-click in the corresponding line of the calibration point list. The text field beneath it contains the calculated coefficients of the polynomial for various instrument-specific definitions of the calibrating function.
If there might be the need for using more than one spectrum the spectra can be sequentially imported. The calibrating points which have been already entered remain existent.



The calculated coefficients will be taken over by means of the button „OK“. The calibrating parameters can be entered into the instrument by clicking the button “Transfer”  (precondition is an opened connection to the instrument).

7. 6. 3. Efficiency calibration

In order to correctly calculate the activity of a nuclide, in addition to the knowledge of the emission probability of the used photo peak, the energy-dependent counting yield of the detector must be taken in account. On the one hand, it is dependent on the detector sensitivity and, on the other hand, on the absorption in the sample or the shielding between sample and detector, resp. In case of nearly homogeneous samples and emission lines greater than 100 keV the efficiency can be described very well by means of a function of the following equation:

$$\eta(E) = \frac{R(E)}{Z} = A * E^B$$

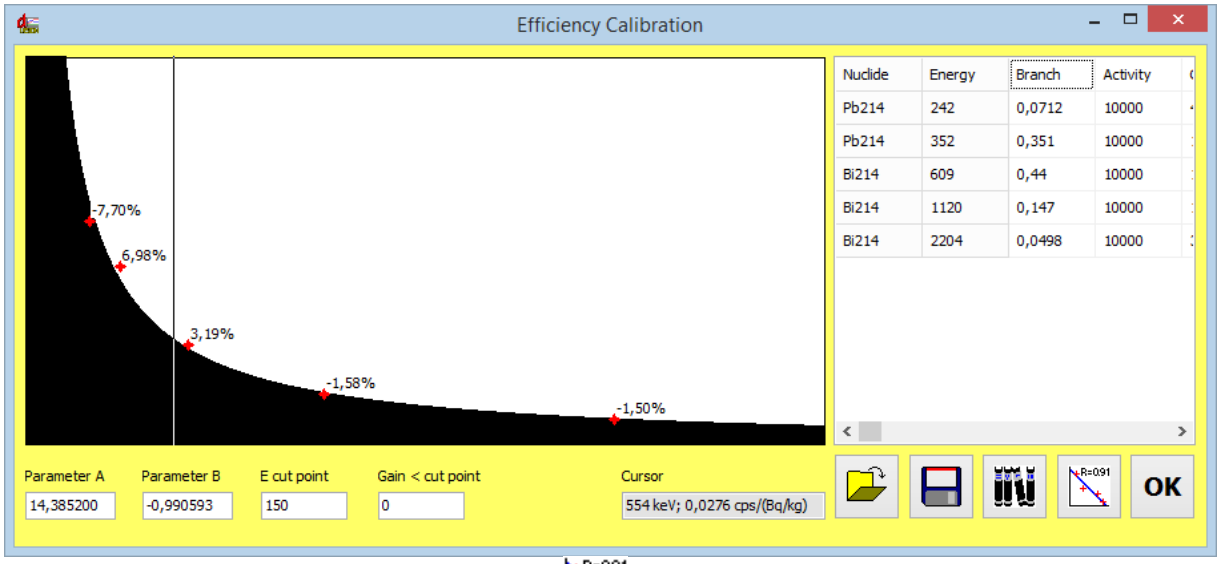
with:

η(E)	Detector efficiency for the photo peak with the emission energy E
R(E)	energy-dependent counting rate of the detector
Z	decay rate of the relevant photo line of the emission energy E
E	emission energy
A, B	equation parameters of the approximation function

From this, an easy and quick possibility is given for efficiency calibration by means of a reference sample. Geometry and density of the reference sample should correspond at a good approximation with those of the samples to be analysed. Generally, only two emission lines will be required. Due to the function course one line should be below 300 keV, another line above a 1,000 keV. The calibration will be very easy if all the required lines are existent in one spectrum.
Precondition for the efficiency calibration is an energy and peak width calibration of the instrument already performed. Firstly, a measurement of the reference sample shall be performed. The measuring time should be taken in such a manner that the expected statistical error of the achieved counting sums can be neglected in the photo peaks that are used for calibration.
After having loaded the measured values the tools for gamma detectors can be opened from the spectrum display. After entry of the administrator code the switch area “Efficiency Calibration” will be accessible. In order to simplify the calibration, first of all, the peak list should be adjusted in such a way that all the emission lines needed for calibration are contained. (Refer to section “Definition of the peak list”). With a correct energy calibration and sufficient counting statistics, corresponding net counting pulses (peak area) will appear for the selected peaks in the result box of the tool window. They will be taken over jointly with the parameters of the selected peaks for the efficiency calibration.
By clicking on the button “Efficiency calibration” the calibrating window will be opened. Before, an query to enter the activity of the reference sample will appear. This value is used as a pre-setting for all the peaks included in the calibration. If all the peaks of a nuclide or a decay series are in a radioactive equilibrium so there will be no need of more entries later. Here likewise, we recommend e.g. radium or thorium samples.
The calibrating window, at the left side, contains a graphic range to display the relevant efficiency calibration function. Below the graphic range, energy and efficiency will be given for the relevant cursor position. Small red crosses will mark the calibrating points determined from the available reference measurement and the activity pre-setting.
The table in the right window range contains all the emission lines needed for calibration. The fields for activity and counting rate can be edited. This allows entering the true values for all nuclides theirs activities do not fit with the previously input. Furthermore, the peak list can be

increased (or reduced) in order to include calibrating points from other samples (with manual input of activity and count rate).

A click on the button „Library“  will open the selection dialogue. Of course, for these emission lines both the counting rate and the reference activity shall be entered.



If you now click on the button „Calibration“  the program will calculate the approximation best possible of the afore- described function for all the calibrating points used. The resulting deviation of the single markings from the functional value should amount to some percentages at a maximum, otherwise the reference activities assigned to the lines shall be checked and possibly changed in the table right beside the graphic. If greater deviations remain existent in spite of correct entries, one or several lines might be unsuitable for calibration, e.g. by superimposing of another line or insufficient counting statistics.
Furthermore, switch areas to store and load of efficiency calibrations are at your disposal. More particulars for their management can be found in the section “Tools for gamma detection”.

8. Gas sensors

The DACM system offers the possibility to integrate a number of various gas sensors. In parallel to our own sensors also OEM modules can be integrated easily. With respect to the required signal processing, the sensors are connected either to a configured analogous port or through a transmitter board to the internal system bus. A transmitter board delivers an already calculated digital result including linearization and temperature compensation.

You should take care for the special characteristic of any used gas sensor because they have very individual properties regarding life time and calibration cycles. Semiconductor and electrochemical sensors underlie an aging process and needs to be replaced periodically.

There are less or more distinct interferences in presence of other gases. Semiconductor sensors may be damaged if they are exposed to silicon gases.

Gas sensors connected through transmitter boards have in most cases an own test procedures to detect sensor faults. They output negative sensor codes instead the gas concentration result.

Please read carefully our document “Info sheet for gas sensors” and the specific data sheets if your system contains gas sensors.

9. Disposal instructions

Batteries and accumulators must not be disposed of in the garbage, but you are legally obligated to return them to the appropriate waste collection centres.

The measuring instruments must be disposed of in the electronic waste or handed to the manufacturer at the end of their service life for proper disposal.
If necessary, they have to be decontaminated before.

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10. Technical Data

Equipment	RTM 2200 (item no 22040020)	RTM 2200 Soil Gas (item no 22040021)	EQF 3200 (item no 33077020)
Detector for Rn/Th gas: quantity, pcs x size, mm²	4 x 200, Si-detectors	4 x 200, Si-detectors	4 x 200, Si-detectors
HV-chamber total volume, ml /quantity, pcs	250 / 4	250 / 4	250 / 4
Detector for Rn/Th progeny: quantity, pcs x size, mm²	NO	NO	1 x 400 mm² Si-detector
Measurement of:	**Rn/Th gas**	**Rn/Th gas**	**Rn/Th gas & PROGENY**
Sensitivity, cpm/1000Bq/m3 (fast/slow)	3 / 6,5	3 / 6,5	3 / 6,5
Measurement range, Bq/m³	1-10 000 000	1-10 000 000	1-10 000 000
Measurement accuracy	<=5%	<=5%	<=5%
Measurement interval	1 sec up to weeks	1 sec up to weeks	1 sec up to weeks
Cycles at the instrument	up to 16, programmable	up to 16, programmable	up to 16, programmable
Pump	YES, built-in	YES, built-in	YES, built-in
Air flow rate, l/min	up to 5, regulated	up to 5, regulated	up to 5, regulated
Pump operation mode	continuous/interval, programmable	continuous/interval, programmable	continuous/interval, programmable
Display	touchscreen, 9 x 6 cm with back-light	touchscreen, 9 x 6 cm with back-light	touchscreen, 9 x 6 cm with back-light
Display backlight	YES	YES	YES
Units	SI/US	SI/US	SI/US
Clock (Date, Time)	YES	YES	YES
Memory, records (incl. spectrum)	2GB SD, >1 Mio	2GB SD, >1 Mio	2GB SD, >1 Mio
Power supply	Internal battery (14,6V)	Internal battery (14,6V)	Internal battery (14,6V)
Power supply adapter 230V AC	YES	YES	YES
Life-time between charging, hrs**	> 110	> 110	> 110
Battery voltage indication on Display	YES	YES	YES
Low battery indication	YES	YES	YES
Alert indication (red LED/sound)	YES	YES	YES
rel. Humidity on display	YES	YES	YES
bar. Pressure on display	YES	YES	YES
Temperature on display	YES	YES	YES
Additional analog/digital inputs / outputs	on request	on request	on request

Display language	DE, EN (RU on request)	DE, EN (RU on request)	DE, EN, (RU on request)
Alert threshold setting	manually, dConfig SW	manually, dConfig SW	manually, dConfig SW
Wireless interface (4G VPN-router)	on request, incl. SIM (500 Mb)	on request, incl. SIM (500 Mb)	on request, incl. SIM (500 Mb)
Communication interfece	RS 232, USB	RS 232, USB	RS 232, USB
Software for data reading and analysis	dVision/dConfig (SARAD) (Win)	dVision/dConfig (SARAD) (Win)	dVision/dConfig (SARAD) (Win)
Environmental conditions: **Temperature, ^{0}C** **rel. Humidity, %** **Bar. Pressure, hPa**	5 - 40 0 - 95%, non-condensing 800 - 1100	5 - 40 0 - 95%, non-condensing 800 - 1100	5 - 40 0 - 95%, non-condensing 800 - 1100
Instrument weight, kg (incl. batteries)	6	6	6
Dimensions, mm	235x140x255	235x140x255	235x140x255
Scope of delivery	Power supply adapter USB data cable RS-232 data cable Dust filter (1+1 pc) Fuse (1+1 pc) PVC tube (1,5 m) Transportation case User manual & SW (electronic version) Calibration certificate	Water inlet protection (built-in) GPS receiver (built-in) Power supply adapter USB data cable RS-232 data cable Dust filter (1+1 pc) Fuse (1+1 pc) PVC tube (1,5 m) Case for field applications (IP67) User manual & SW (electronic version) Calibration certificate	Power supply adapter USB data cable RS-232 data cable Dust filter (1+1 pc) Aerosol filter (1+10 pcs) Fuse (1+1 pc) PVC tube (1,5 m) Transportation case User manual & SW (electronic version) Calibration certificate
Accredited calibration DIN ISO/IEC 17025:2017	incl.	incl.	incl.

Equipment	RTM 2200	RTM 2200 Soil Gas	EQF 3200
0ptional accessories	**Case** for field applications (item no. 20050025); **Aqua Kit** (item no. 10010003); **Gas transfer membrane** (Rn-in-Water) (item no. 10010004); **Soil gas probes Kit** (simple) (item no. 10010007); **Sharp tips for soil gas probes** (item no. 10010017); **Simple retractor** for soil gas probes (item no. 80020005); **Special retractor** for soil gas probes (item no. 10010010); **Monopak borehole packer probe** (item no. 20040003); **Twinpak borehole double-pack packer probe** (up to 4,3m) (item no. 20040004); **Exhalation unit** (item no. 10010009); **Water intake protection** (item no. 90050027); **Dust filters for RTM 2200** (item no. 80020002); **4G VPN-Router** incl. power supply adapter (item no. 90010126); **Barrel** for Radon emanation test of bulk materials, 5 l. (item no. 50011012); **Peltier dryer** (item no. 20044009); **different gas sensors** like CO, CO2, H2S, CH4, etc.; **Radon flux module** (item no. 22030025); **GPS Module** (item no. 30070001); **TDR soil moisture probe** (20044047)	**Aqua Kit (**item no. 10010003); **Gas transfer membrane** (Rn-in-Water) (item no. 10010004); **Soil gas probes Kit** (simple) (item no. 10010007); **Sharp tips for soil gas probes** (item no. 10010017); **Simple retractor** for soil gas probes (item no. 80020005); **Special retractor** for soil gas probes (item no. 10010010); **Monopak borehole packer probe** (item no. 20040003); **Twinpak borehole double-pack packer** probe (up to 4,3m) (item no. 20040004); **Exhalation unit** (item no. 10010009); **Dust filters** for RTM 2200 (item no. 80020002); **4G VPN-Router** incl. power supply adapter (item no. 90010126); **Barrel** for Radon emanation test of bulk materials, 5 l. (item no. 50011012); **Peltier dryer** (item no. 20044009); different gas sensors like CO, CO2, H2S, CH4, etc.; **Radon flux module** (item no. 22030025); **TDR soil moisture probe** (20044047)	**Case** for field applications (item no. 20050025); **Aqua Kit** (item no. 10010003); **Gas transfer membrane** (Rn-in-Water) (item no. 10010004); **Soil gas probes Kit** (simple) (item no. 10010007); **Sharp tips for soil gas probes** (item no. 10010017); **Simple retractor** for soil gas probes (item no. 80020005); **Special retractor** for soil gas probes (item no. 10010010); **Monopak borehole packer probe** (item no. 20040003); **Twinpak borehole double-pack packer probe** (up to 4,3m) (item no. 20040004); **Exhalation unit** (item no. 10010009); **Water intake protection** (item no. 90050027); **Dust filters** for RTM 2200 (item no. 80020002); **4G VPN-Router** incl. power supply adapter (item no. 90010126); **Barrel** for Radon emanation test of bulk materials, 5 l. (item no. 50011012); **Peltier dryer** (item no. 20044009); **different gas sensors** like CO, CO2, H2S, CH4, etc.; **Radon flux module** (item no. 22030025); **GPS Module** (item no. 30070001); **Filters for EQFseries** (item no. 80010004); **TDR soil moisture probe** (20044047)