Manual

RTM 2300

Radon/Thoron monitor incl. versions “Soil Gas” and “ULTRA”

Version 04/2026

Reference documents:
Software manual dVISION

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Operational controls

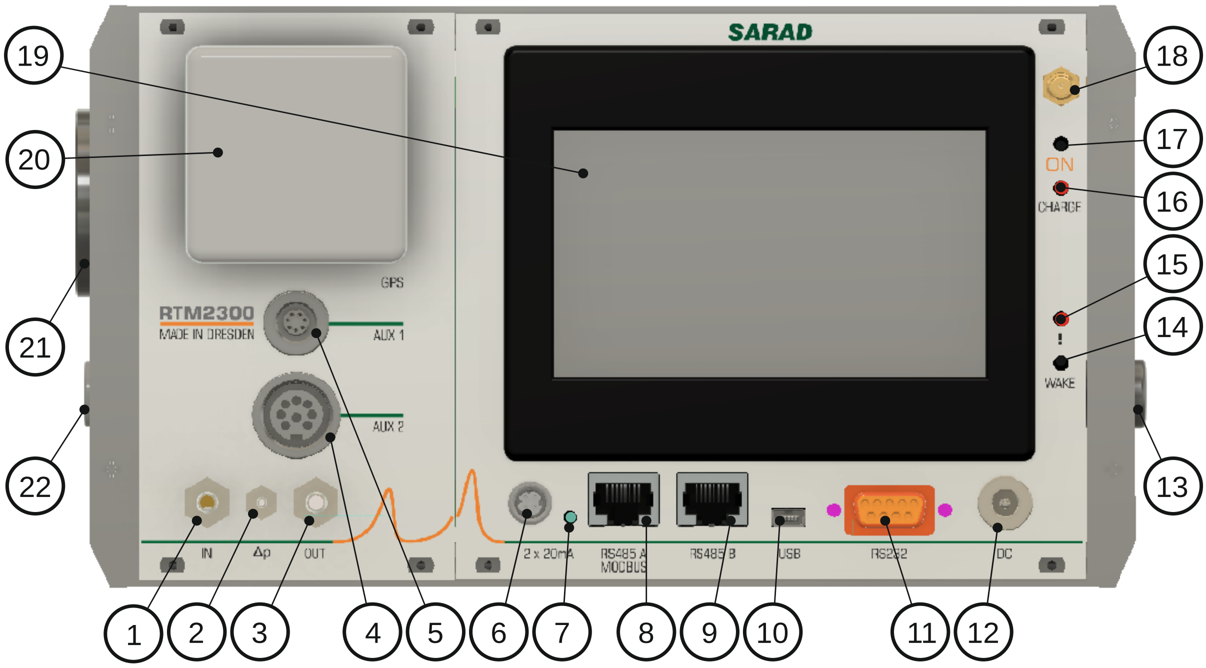


Figure 1 Basic monitor

1) Air circuit inlet
2) Connection for differential pressure measurement
3) Air circuit outlet
4) Accessory socket AUX2 for connecting signal lights
5) Accessory socket AUX1 for connecting the radon decay product sensor head
6) Connection socket for 20 mA current loop outputs
7) LED indicator for activated current loop outputs
8) RS-485 A interface (configurable for MODBUS RTU protocol)
9) RS-485 B interface
10) USB Type B Mini interface
11) RS-232 interface
12) Connection socket for power supply
13) Fuse
14) Button for activating the display
15) LED indicator for alarms/warnings
16) LED indicator for charging status
17) Power button
18) Socket for Wi-Fi antenna
19) Touchscreen display
20) GPS receiver
21) Accessory adapter
22) Connection socket for water ingress protection (optional)

1. Overview

1. 1. The DACM32 platform as basic equipment

The Radon/Thoron monitor RTM 2300 is based on the DACM32 measurement platform developed by SARAD. This platform is based on a microcontroller with proprietary firmware. Since no operating system is used and communication also takes place via proprietary protocols, maximum protection against tampering is guaranteed.

The DACM32 platform is based on hardware with a number of universal interfaces to which a wide variety of sensors and actuators can be connected. Simple examples are an analog input and a switching output. These interfaces are referred to as components in the DACM32, and the different types of interfaces are referred to as component types. Each component can be parameterized using configuration software to calculate the respective measured values in the desired physical unit from the sensor's electrical output signal. Each component is uniquely indexed in the DACM32 and has a unique name. This consists of an abbreviation for the component type followed by an index if multiple components of the same type are present (example: AIN2 refers to analog input no. 2). Each component is assigned an alias name via configuration that identifies the component in a user-friendly manner. Depending on requirements, the short names or alias names are used on the device display, in the configuration software, and in the operating software. The appendix contains a list of all component types with a brief functional description.

A specific measuring device is created by combining the DACM32 hardware with the required sensors and actuators, as well as the associated component and device configuration. Standard users do not need to worry about these aspects, as the devices are fully configured for the respective measurement task upon delivery. However, familiarity with the platform concept will help you better understand this manual. Furthermore, both device manufacturers and experienced users can implement customized modifications quickly and easily.

1. 2. Control of the measurement process—measuring cycles

A measurement cycle defines the time interval at the end of which the measured values acquired during this interval are stored in the data memory. Depending on the definition, the measurement cycle is repeated for a defined number of measurements or indefinitely, so that the measurement data is available as a time series. Up to 15 measurement cycles can be stored in the device, customized for the respective measurement task. The required measurement cycles for all standard applications are already included upon delivery. The measurement cycles are defined using configuration software, allowing experienced users to create their own cycles.

Within a measurement cycle, each component can be controlled individually. It is defined which components are included in a measurement – and when within a cycle a component should generate data or activate actuators.

1. 3. Alarm system

A maximum of 32 independent alarms can be freely defined. Any measurement value available in the device can be used as the data source for an alarm. A distinction is made between alarms for current sample values (measurement and verification every second) and interval alarms (verification of the integral values at the end of the interval). An alarm is acknowledged either via the touch panel, a communication interface, or (if provided in the device) via an input for connecting a button. The types of acknowledgements permitted can be determined via configuration. A on and off threshold can be defined for each alarm, allowing the implementation of a hysteresis. If the on threshold is greater than the off threshold, an alarm is generated when the measured value increases; otherwise, an alarm is generated when the measured value decreases. Each alarm can be assigned several actions that are executed by the corresponding components (e.g., activating a signal light via a switching output). The alarm settings configured in the device are described in the "Predefined Warnings and Alarms" section.

1. 4. Event memory

The last 100 important events affecting the device are stored in the event log with a time stamp. This log cannot be deleted by the user, so errors, alarm situations, and tampering with the device can be traced later. The following events are recorded:

- Turning the device on and off
- Setting the device clock
- Changes to the component or device configuration
- Selecting a measurement cycle
- Starting and stopping the measurement
- Occurred alarms
- Acknowledgment of alarms

1.5. Communication with the host system

All monitor settings, data transfer, and remote control of the RTM 2300 are performed independently of the communication channel using a proprietary protocol. This protocol is used by all SARAD software solutions. Additionally, current measurement data can be retrieved via the industry-standard MODBUS RTU protocol. Separate PC-software are available for configuration & settings (dCONFIG) and data analysis (dVISION).

2. Operation

2. 1. Switching ON/OFF, standby-mode, fuse

For safety reasons, the device is shipped with the removed fuse. Before switching the RTM 2300 on, please open the fuse holder on the right side of the housing, insert the fuse, and then close the fuse holder again. Press the ON power button and wait until the SARAD logo appears on the display. The monitor is switched off using the OFF-touch button in the main menu (top center).

After completing a measurement, the monitor goes into standby mode so that instrument is not completely disconnected from the internal battery. The display is deactivated after a configurable time interval. The display is activated by pressing the WAKE button.

If the monitor is not used for an extended period of time, the battery should be fully charged and disconnected from the power supply by switching it off using the OFF-touch button in the main menu on the display.

NOTE: The fuse must be removed for shipping or air transport.

2. 2. Power supply

The instrument contains a NiMH battery with a nominal voltage of 12 V and a capacity of 7.6 Ah. Power consumption during measurement depends on the configuration and the components/sensors used in the measurement cycle. To maximize battery operating time, use only the components/sensors actually required.

The battery is charged using the included plug-in power adapter (20 V/60 VA). The integrated charging circuit allows the battery to be fully charged within four hours. The DC connection socket for the power adapter is located at the bottom right of the front panel of the monitor. The red LED indicator to the right of the display lights up during charging. It switches off when the battery is fully charged.

The RTM 2300 can be operated continuously with the power supply. The charging control ensures cyclic charging to optimize battery life. During the charging process, heat is released, which causes the entire device to heat up. The integrated temperature sensor then displays significantly elevated values.

NOTE: To accurately measure the outside temperature, an additional external sensor should be used in the case of continuous mains operation.

If the battery voltage drops below 11.2 V during a measurement, the measurement is aborted. If the discharge continues below a threshold of 10.6 V, the deep discharge protection completely shuts down the device's electronics. The device can only be switched on again once the battery voltage has reached the threshold of 11.6 V during the charging process.

The battery should always be charged at temperatures between 10 °C and 30 °C. At ambient temperatures above 40 °C, charging is automatically interrupted to protect the battery. When not in use, the device should be turned off using the OFF-touch button in the main menu.

2. 3. Operation panel (Touch screen)

The RTM 2300 is operated via touchscreen. The display and backlight consume a relatively high amount of power, so they automatically shut off even during a measurement if no input is made. The time from the last touch to shutdown can be set to a maximum of 255 seconds via the setup.
The display is activated as soon as the black WAKE push button is pressed. The last displayed page is always activated afterward. All other operating functions are controlled via the dynamic touch buttons shown on the display.

2. 4. Interfaces

2. 4. 1. Interfaces for communication (COM1, COM2)

The RTM 2300 has two independent communication channels (COM1, COM2) that can be used to communicate with the monitor simultaneously. Different physical interfaces are assigned to each channel, which are automatically switched between according to a priority scheme.
The following interfaces are assigned to the COM1 communication channel:
USB: active as soon as a USB connection is established
RS232: active when an RS-232 signal is detected and no USB connection is present
RS485B: active when neither a USB nor an RS-232 connection is present
The COM1 communication channel cannot be configured using configuration software. This ensures constant access to the RTM 2300 monitor. The data transfer speed can be increased by pressing the COM1 button in the main menu.
The following interfaces are assigned to the COM2 communication channel:
WLAN: active when WLAN has been activated by the user and the instrument is logged in
RS485A: active when the instrument is not logged in to the WLAN
The COM2 communication channel is configured using the setup functions of the configuration software. The following modes are available:

- SARAD 9600 bps no parity
- SARAD 115200 bps no parity
- MODBUS 9600 bps even parity
- MODBUS 19200 bps even parity
- SARAD wireless

The modes marked with SARAD use the proprietary SARAD protocol. This includes data transfer and complete control of the instrument.
The industry standard MODBUS RTU is also supported. This protocol only supports querying current measured values. Information on using the MODBUS RTU protocol can be found in the document “AN-009-sarad_modbus_rtu_protocol”.
The *SARAD wireless* setting must be selected to activate the WLAN interface. If WLAN is not used, this mode should not be selected, as operating the wireless interface consumes a relatively high amount of power. Once this mode is enabled, the device will only switch to the WLAN connection once it is logged in. The WLAN access data (SSID, password, server, and port) must be entered in the setup function of the configuration software.

2. 4. 2. Analog output

The RTM 2300 has two freely configurable current loop outputs, which are available at the *2 x 20 mA* socket. The following output signal options are available:

- 0…20 mA
- 4…20 mA
- 0…24 mA

Each output can be assigned any measured value acquired in the monitor. The desired value range of the measured value must be assigned to the selected output range (e.g., for battery voltage: 4…20 mA corresponds to 0…15 V). All settings are made using the setup function within the configuration software dConfig.

2. 4. 3. Sockets for external accessories (AUX1, AUX2)

The two sockets provide additional components of the DACM32 platform. They can be used to control external accessories or integrate external sensors into the system. In addition to the standard configuration, instrument- and user-specific modifications are possible. The standard configuration is documented in section 3. 6. The connectors AUX1 and AUX2. Customer-specific configurations are described in a separate document.

2. 5. Data storage of measurements

The measurement data is stored on an internal SD card. Several million data records can be stored. The generated measurement data is always saved as raw data, i.e., in the binary format generated by the components. This ensures absolute traceability of the measurement data for quality assurance purposes. A component can generate one or more measured variables from the raw data. To display the measured values on the RTM 2300 or to retrieve current measured values via the communication interface, they are calculated based on the raw data using the component configuration. When transferring the complete measurement data to the host system, however, only the compressed raw data is transferred along with the component configurations. The host system then generates the actual measurement results from this.

NOTE: the RTM 2300 can collect very large amounts of measurement data, which later result in longer transmission times via the communication interfaces. Therefore, only activate the required sensors and select the length of the measurement intervals appropriate to your application.

The data of the memory card can be deleted using the corresponding function in the operating software.

2. 6. Menu navigation

2. 6. 1. Main page

After activating the display using the button below the display, the main navigation page appears.

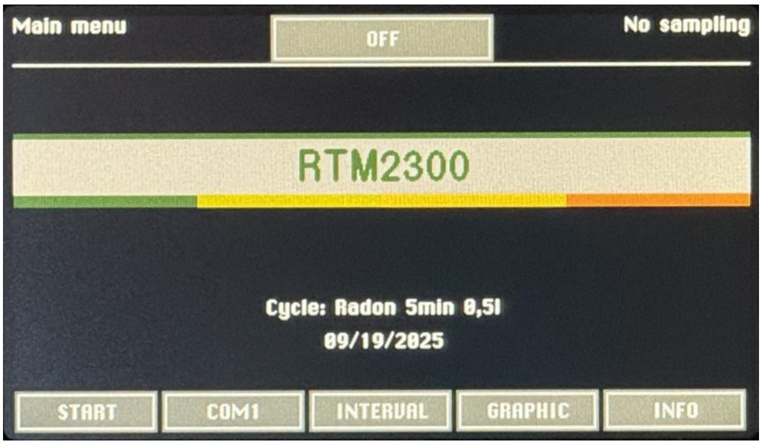


Figure 2 Main menu if measurement stopped

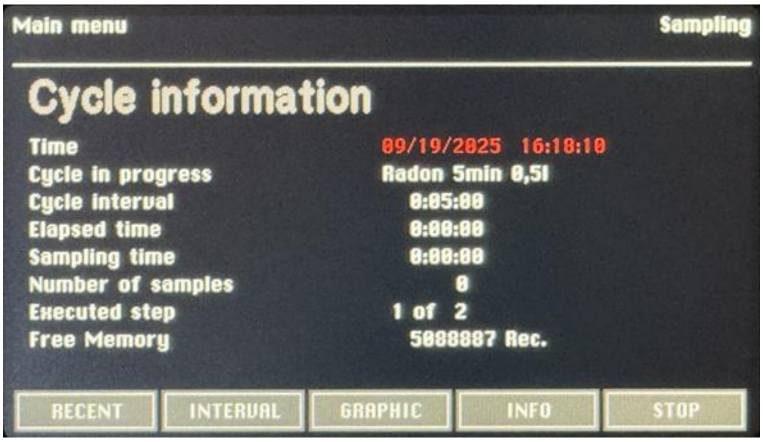


Figure 3 Main menu during measurement

In Standby mode, the instrument device name, the name of the current instrument configuration (including the date of the last change), and the selected measurement cycle are displayed. The measurement is started by touching the START button. While a measurement is running, the current cycle settings and system status are displayed:

- Time
- Name of the currently running measurement cycle
- Current measurement time of the current interval
- Total measurement time since the start of the measurement
- Number of the completed step and number of steps within the cycle
- Size of the free data memory (number of data records still available for storage)

From the main menu, you can also access the submenus for displaying the module and component configuration, the data stored on the memory card, and, if a measurement is running, the current measured values of the sensors.
To end a measurement in progress, touch the STOP button.

2. 6. 2. Display of module information and module settings

The display pages, accessible from the main menu via the “INFO” button, provide an overview of the module version and the current settings of various parameters of the RTM 2300. The display pages can be switched using the “TOGGLE” button.

Page 1 Module Information

- Software Version
- Serial Number
- Manufacturing Date
- Date of Last Firmware Update

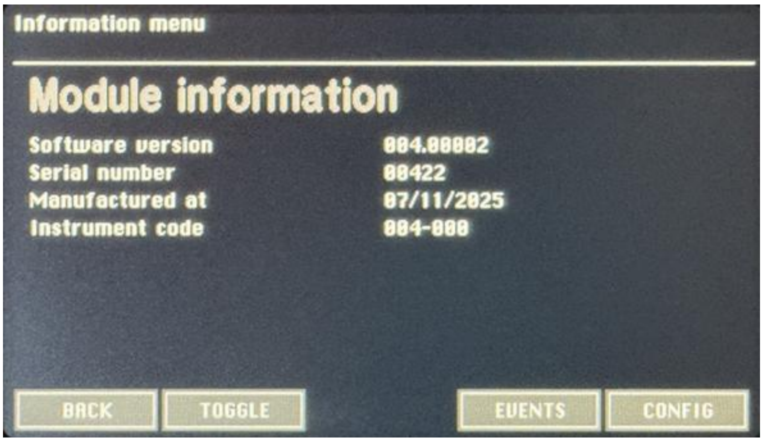


Figure 4 Module information

Page 2 Module Settings

- Time of automatic start, if this function has been enabled. Otherwise, the text "disabled" appears instead of the time.
- Protocol set for the COM2 communication interface
- Information about the Wi-Fi connection stored to the RTM 2300 (SSID and server/port)
- Current loop output settings (data source, output signal range, and assigned value range). (The name of the data source corresponds to the unique component name. The value range refers to the physical unit of the selected measured value.)

Page 3: Additional module settings

- Timer operating mode (timer or periodic timer synchronized with the measurement cycle)
- Time points for switching the timer on and off, either as real time (timer mode) or as on, off, and delay intervals (periodic timer mode)

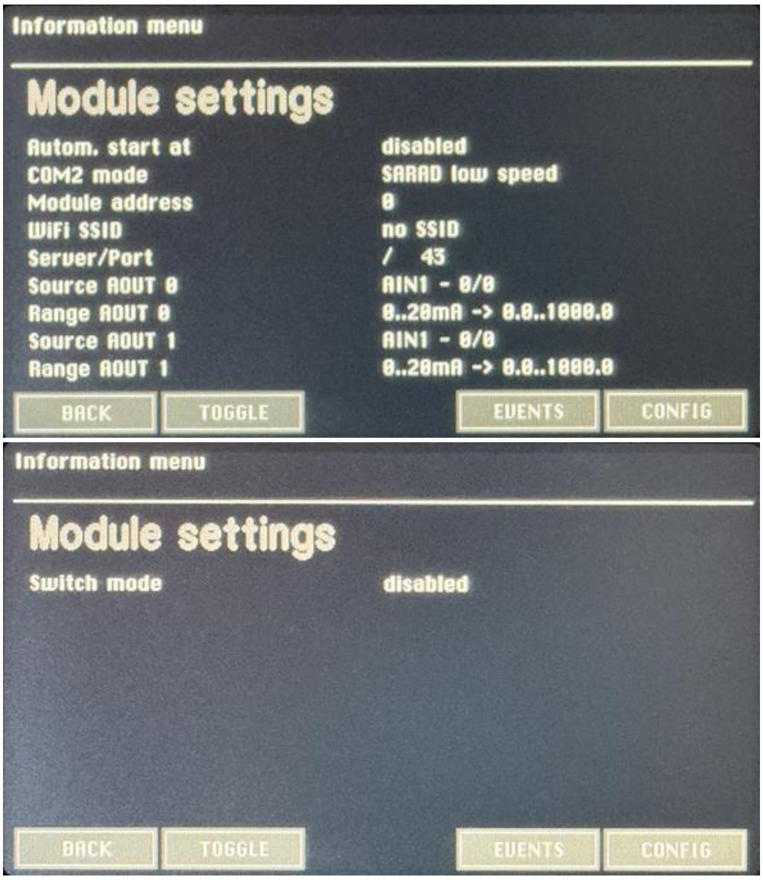


Figure 5 Module settings

The "BACK" button returns to the main page. The "CONFIG" button allows you to switch to the display pages for the configured component parameters.

2. 6. 3. Display of component configuration

The current configuration parameter settings for each component can be viewed for review. To do so, click the "CONFIG" button in the information menu. Parameter changes cannot be made. The "NEXT" and "LAST" buttons can be used to select individual components.

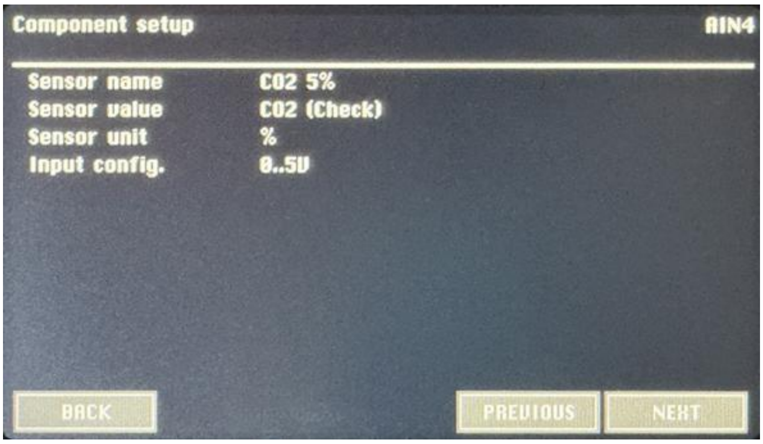


Figure 6 Configuration of components

If one page isn't sufficient to display all parameters, you can access additional pages using the "TOGGLE" button. You can return to the main page using the "BACK" button. The unique component name is displayed in the upper right corner.

2. 6. 4. Selection of measurement cycle

Touching the cycle name displayed in the main menu opens a list for selecting one of the predefined measurement cycles. A maximum of 16 different measurement cycles can be stored in the RTM 2300. If the number of stored cycles does not fit on one display page, the "MORE" button appears, which can be used to scroll through the list. The desired measurement cycle is selected by touching the list entry. In this case, the radon monitor automatically returns to the main page. If you do not want to select a new cycle, press the "BACK" button.

2. 6. 5. Display of actual measured values

This display page is only accessible when a measurement is in progress. You access this page by touching the "RECENT" button. The display is updated every second so that the current sample value of a component is always shown. This function corresponds to that of a direct reading measuring device. Only the data of those components that are actually included in the measurement cycle and are currently active are displayed. Switching between the available components is done using the "NEXT" and "LAST" buttons. The alias name of the component appears in the display header.
If a component delivers more than one result, the "TOGGLE" button for switching the measured values is activated. Return to the main page is done using the "BACK" button.

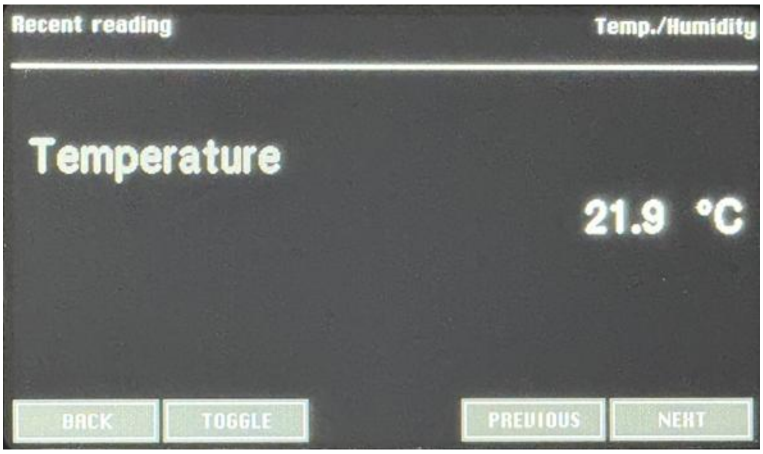


Figure 7 Display of actual measured values

2. 6. 6. Display of the stored measurement values

If available, all measurement data stored on the memory card can be displayed. This function is accessible via the "INTERVAL" button during or stopped measurement. Switching between the individual components whose data is contained in the data set and selecting the desired measurement value is carried out in the same way as displaying the current values. For components that calculate multiple measured values, an additional overview page has been implemented for viewing all measurement results simultaneously.

A bar with navigation buttons appears for selecting data points within the measurement series. The middle button can be used to retrieve the most recent data set chronologically. The other buttons scroll forward or backward by one or ten data sets, respectively.
The header of the display shows the alias name of the component and the time at which the data set was saved. If the geographical position could be determined using the integrated GPS receiver, the coordinates appear in the footer. Return to the main page is achieved by pressing the “BACK” button.
In addition to the highlighted mean value of the measurement for the current measurement interval, the minimum and maximum individual values within the interval are displayed below. For radiological measurements, these two values indicate the 1-sigma confidence interval determined from the counting statistics.

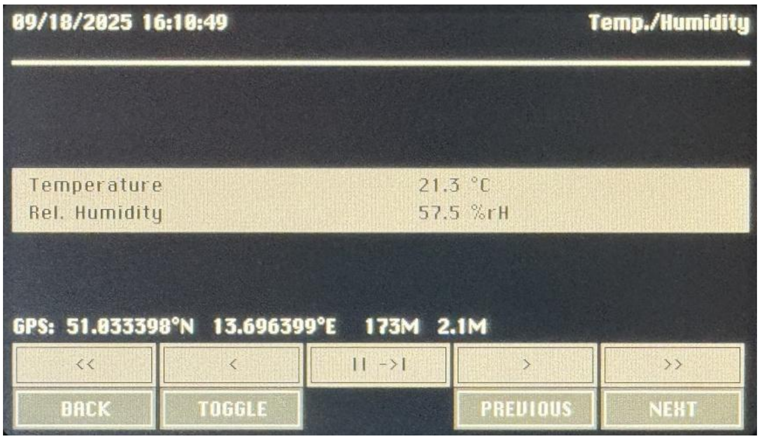


Figure 8 First display page for interval measurement data for components with multiple measured values

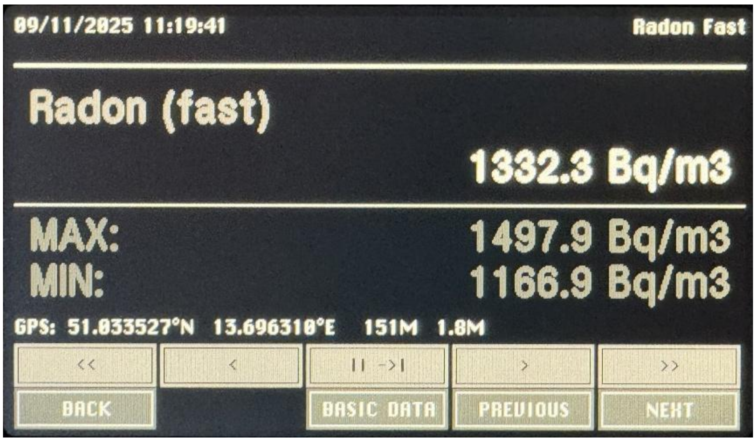


Figure 9 Display of interval measurement data

2. 6. 7. Graphical display of the measurement data as a time series

All measured values available on the RTM 2300 can be displayed as a time series in a diagram. To do this, touch the “GRAPH” button in the main menu. The display is limited to the last 50 values of the current or most recently executed measurement cycle. The time axis is scaled accordingly until the limit of 50 measuring points is reached; after that, the oldest data is moved out of view with each new measured value during the measurement. Two measured variables can be displayed simultaneously. The Y-axis is always scaled automatically. Below the diagram view there are four navigation buttons with which the red cursor line can be moved by one or ten measured values. The timestamps and measured values associated with the cursor position appear above the cursor line. The desired measured variable is selected using the Select Y button. A table with the alias names of all available components appears. Now the desired component to be assigned to the left Y-axis can be selected. Since some components can generate multiple measured values, a list appears for selecting the desired value. The procedure for selecting the measurement value for the right Y-axis is then repeated. The BACK button returns to the main menu.

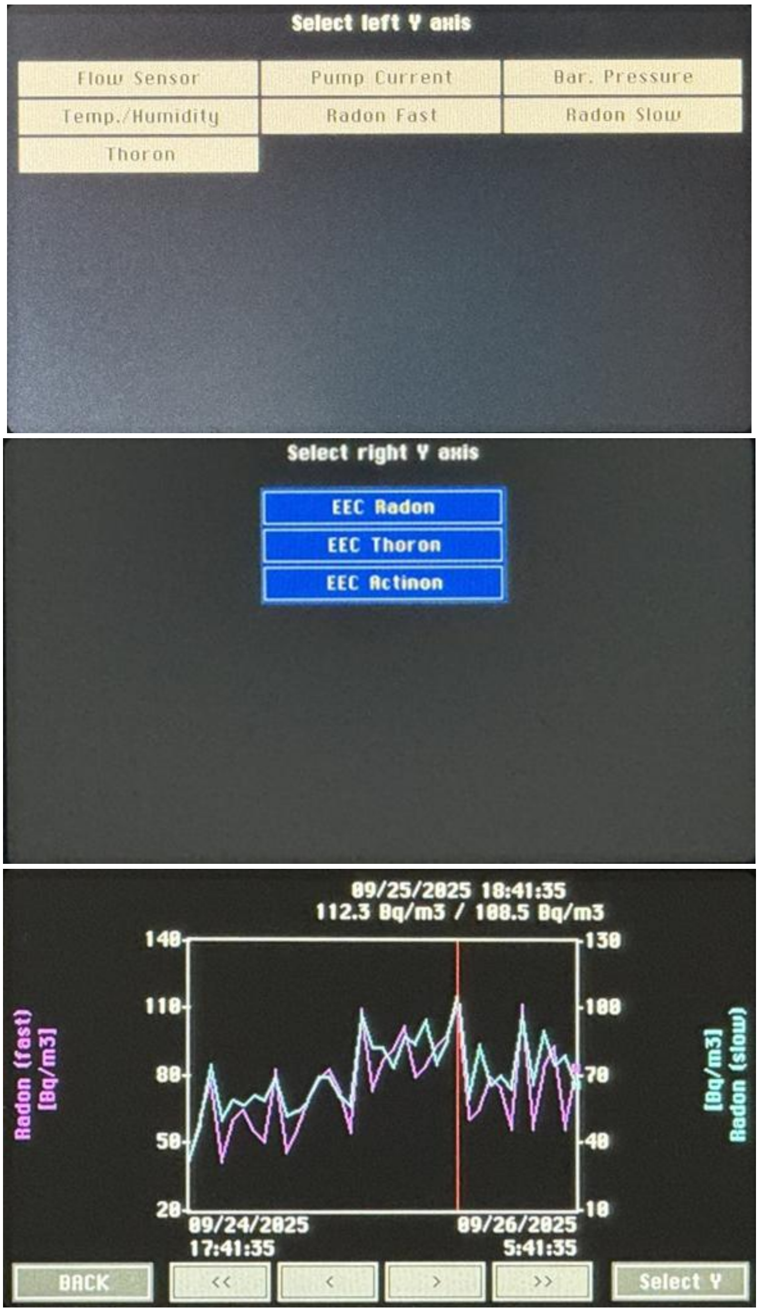


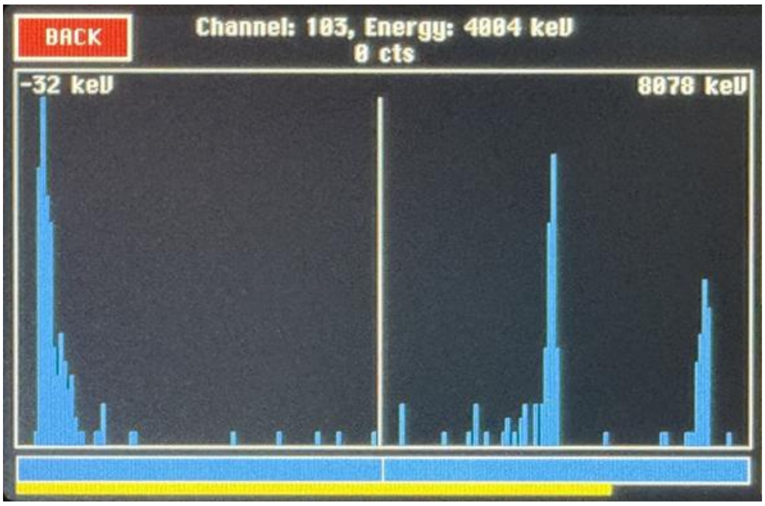
Figure 10 Selection and display of series of measurements

2. 6. 8. Display of basic data

Some components support the display of the acquired base data used to calculate the displayed measured values. For such components, an additional button labeled “BASE DATA” appears on the interval data display page, which takes you to the corresponding display page.

2. 6. 8. 1. Display of the acquired spectrum

A spectrum can be displayed for all measured values that were calculated based on an acquired energy spectrum. The spectrum is shown in the form of a diagram. A control panel appears to the right of the diagram. The light gray buttons are used for cursor navigation, while the dark gray buttons are used to control the display. The upper button switches between cursor and ROI navigation. The navigation buttons can then be used to either move the cursor or switch between the energy regions (ROI) required for calculating the measured values. The FIT Y button scales the diagram to the maximum value of the spectrum. The “/10” and “x10” buttons can be used to increase or decrease the scaling of the Y-axis by a factor of 10. The lower button is used to switch the spectrum view between linear and logarithmic scaling.
When cursor navigation is selected, the counting channel, the associated energy, and the number of counting pulses contained in the counting channel appear above the white cursor line. When ROI navigation is selected, the energy range of the ROI is highlighted in color. The energy range of the ROI and the counting pulses contained therein are displayed above it.
Depending on the number of counting channels in the energy spectrum, a correspondingly segmented bar appears below the diagram, allowing the spectrum to be scrolled left or right across the diagram area. The yellow bar below the scroll bar indicates the currently displayed spectrum range.



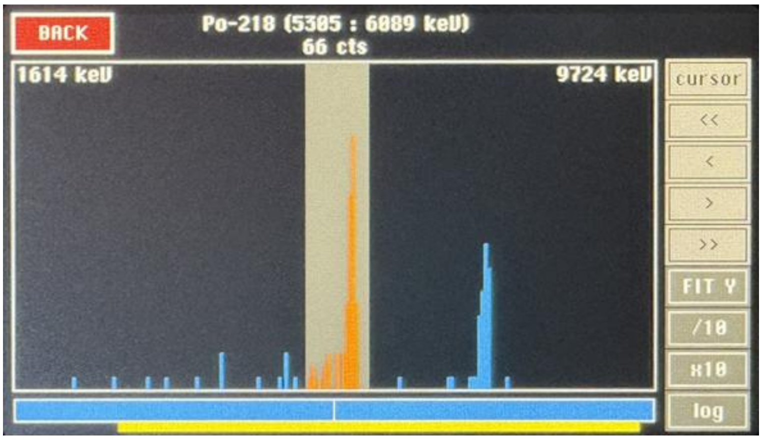


Figure 11 Display of spectra (cursor and ROI navigation)

2. 6. 9. Alarm-display

As soon as a new alarm occurs on the device, it automatically switches to the alarm display page. If the display was deactivated, it will be activated. The display contains a list of all existing alarms in the form of a text line. The current status of an alarm is indicated by the text color, which is assigned as follows:

Red: New alarms, only when the alarm menu is first accessed
Yellow: Alarm situation still exists; alarm confirmation has not yet been received
Green: Alarm situation still exists; alarm has already been confirmed
White: Alarm situation no longer exists; alarm confirmation has not yet been received
The alarm is confirmed using the “CONFIRM” button in the bottom right corner of the display. The “BACK” button returns to the main menu. As long as alarm situations exist or there are unconfirmed alarms, a red button labeled “ALARM” appears at the top center of the main menu. This button can be used to access the alarm display page at any time.

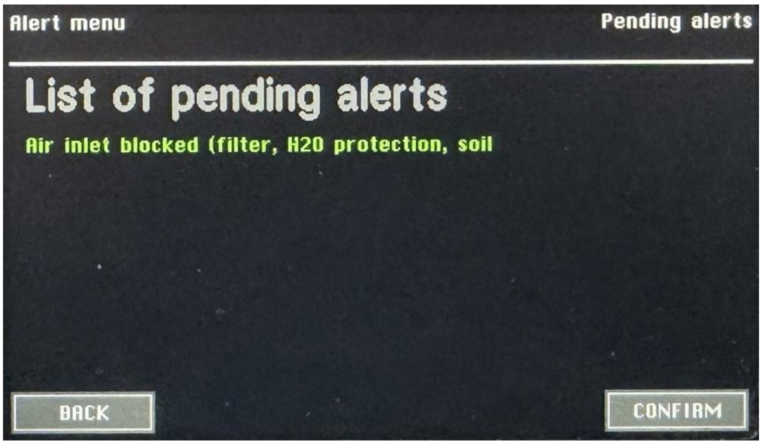


Figure 12 Display of alert

2. 6. 10. Display of event memory

The entries in the event log can be displayed from the main menu using the “EVENTS” button. The output is in reverse chronological order, i.e. the most recent event is at the top of the list. The

“MORE” button scrolls to the end of the event list. The events are output as text messages. For some event types, the text contains additional information regarding the origin of the event, e.g. whether the event was triggered via the touch screen or via one of the communication interfaces. When selecting a cycle, the index of the selected cycle is specified. If alarms have occurred, a bit mask is displayed. The index of a component corresponds to its position within the bit mask. A set bit (a "1" is displayed) signals the origin of the alarm(s) that have occurred. The “BACK” button takes you back to the main menu.

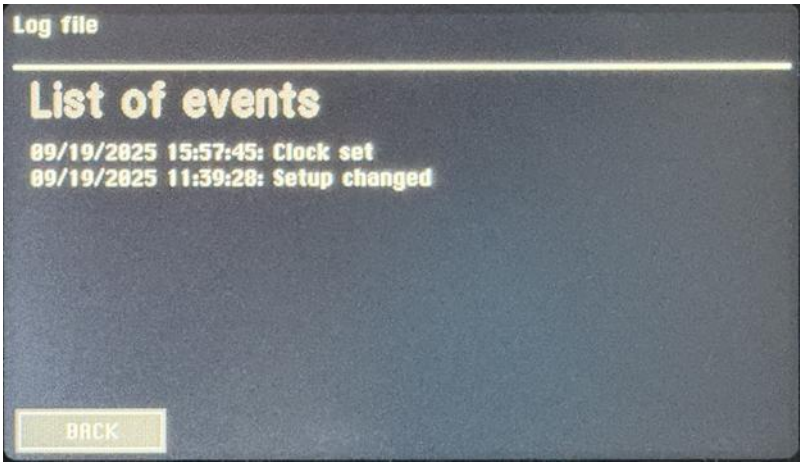


Figure 13 Display of events

2. 7. Setup (timer, synchronous start, display switch off)

2. 7. 1. Timer

Using the integrated timer, the 12 VDC system voltage can be switched to an external load (e.g., relay, solenoid valve, modem, etc.) for a specific period of time. The maximum current must not exceed 400 mA.
The switched voltage is available at the AUX2 jack. The timer can operate in two modes (Clock Switch Mode):
1. Timer
In this mode, two times of day are specified for switching on and off. The switching process then occurs daily at these times. The device's internal real-time clock serves as the time base.

2. Periodical timer
Here, a period for the on and off states, as well as an additional switch-on delay, can be defined. The timer function is synchronized with the start of a measurement. After the start, the device waits for the switch-on delay period (which can also be set to 0). The voltage is then switched on for the switch-on period and, after this period has elapsed, switched off for the switch-off period. This process is repeated periodically until the end of the measurement. If the timer is not to be used, it can be deactivated by selecting the operating modes.

2. 7. 2. Synchronous start at a set time of day

If multiple measuring devices at different locations need to be synchronized, we recommend using the synchronous start function. A time of day can be set at which the currently selected measurement cycle will automatically start. The device's internal real-time clock serves as the time reference. The clocks of all devices to be synchronized should be set to the same time beforehand.

2. 7. 3. Display shutdown interval

To reduce power consumption, the display is deactivated after a configurable period of time (starting from the last touchscreen operation). The time period can be set from 1 to 255 seconds.

2. 8. The integrated GPS receiver

The device is equipped with a GPS receiver. The coordinates (longitude, latitude), altitude, and the deviation underlying the positioning are saved for each data set. This information is shown on the device display (interval data menu).
If the device is moved within a measurement interval, the time-weighted geographic center is saved. The current position is determined every 5 seconds, and the average values for longitude, latitude, and altitude are calculated for the entire measurement interval.
The specified deviation is an indicator of the navigation accuracy (satellite signal) underlying the positioning. The actual deviation may be greater.
Coordinates are displayed on the device in decimal degrees (max. 6 decimal places), each with the compass direction indicated.
If the reception quality is too poor, the message “No signal” appears on the display instead of the coordinates. After starting a measurement, the module needs a few minutes to acquire all satellites available for navigation.

3. Sensors and actuators in the RTM 2300

The following describes the sensors available in the device, their assignment to the DACM32 components, and the measured values generated from the sensor signals. The configuration of the respective components is not explicitly discussed, as this was defined by the manufacturer for the device. The text provides the unique component names and, in parentheses, the alias names of the components. Both names are used as needed on the various display pages.

3. 1. Radon measurement, temperature and relative humidity

The device has an internal radon measurement chamber as part of a closed air circuit between the two hose nipples IN and OUT. The measuring air is pumped through the air circuit by a regulated pump with a constant flow rate.

3. 1. 1. Measuring principle

The radon activity concentration is determined based on the short-lived radon decay products formed in the device's measuring chamber. Decay products already present in the measuring air are retained by a filter system. Immediately after the decay of the radon (alpha emitter), the remaining Po-218 atom exists as a positive ion, as the emitted alpha particle tears electrons from the atomic shell. These ions are deposited on the surface of the semiconductor detector by an electrostatic field applied between the chamber wall and the detector. The number of Po-218 ions collected per unit time is proportional to the radon concentration in the measuring chamber.

Po-218, also an alpha emitter, decays with a half-life of 3.097 minutes on the surface of the detector, of which 50% of the decays (half-space) are recorded. Activity equilibrium between radon and Po-218 is reached after approximately 5 half-lives, or about 15 minutes. This determines the fastest possible response time of the device to a sudden change in radon concentration.

According to the decay sequence, the radioactive decay process continues with the two beta emitters Pb-214 and Bi-214, followed by the alpha decay of the resulting Po-214. Consequently, each Po-218 decay is detected again by the decay of Po-214 on the detector. However, this decay is delayed by the half-lives of the intervening nuclides, so that activity equilibrium between Po-218 and Po-214 is only reached after approximately two hours.

The emission energies of Po-218 and Po-214 are different, so both nuclides can be separated using alpha spectroscopy.

Spectroscopic monitors offer a choice between two methods for calculating radon concentration. In the so-called *slow mode*, both Po-218 and Po-214 are included in the calculation, while in *fast mode*, only the fast Po-218 is used.

The advantage of *fast mode* is the rapid response time to occurring concentration changes, while in *slow mode*, the sensitivity (detected decays per time and radon concentration) is doubled. This increased sensitivity reduces the statistical error of the measurement, which is directly determined by the number of decays recorded within the measurement.

In the case of thoron (Rn-220), the measurement is carried out exclusively using the direct progeny Po-216. The deposition process is identical to Po-218. Since the half-life of Po-216 is less than one second, the equilibrium between thoron and Po-216 activity concentration is virtually instantaneous, and thus the measured value is available immediately.

The half-life of the Po-216 progeny Pb-212, at more than ten hours, is too long for a reasonably timely measurement, so the resulting alpha emitters Po-212 and Bi-212 are detected but not used for concentration determination. The thoron progeny products are also separated using alpha spectroscopy.
There is temperature/humidity sensor located in the device's internal air circuit to determine the humidity in the measurement chamber. The sensor detects possible condensation inside the chamber. Due to the variable power consumption of the instrument the sensor readings do not represent the environmental conditions. Therefore, an external sensor which can connected to the “AUX2” socket is part of delivery.

3. 1. 2. DACM32 components for the radon measurement

The amplified signal from the semiconductor detector is connected to the input of the spectrometer component SPEC1 (radon). This component separately records the count rates of the individual radon decay products Po-218 (for *fast mode*), Po-218 + Po-214 (for *slow mode*), and Po-216 (for thoron). Humidity measurement is performed by component I2C1 (SHT21), which integrates a digital humidity/temperature sensor. The radon concentration is calculated from the count rate and the measured humidity using three calculator components: CALC1 (radon (fast)), CALC2 (radon (slow)), and CALC3 (thoron).

3. 1. 3. Display of measuring values for radon, temperature and humidity

To calculate a radon measurement value, an alpha spectrum is required, which is acquired over the period of the measurement interval and is only available at its end. The calculated radon measurement values (CALC1/2/3) are therefore only displayed on the interval data display page. To make the acquisition visible during an interval, the total counting pulses of the spectrometer component SPEC1 are shown on the current data display page. Temperature and humidity values are displayed both as current measured values and as average values. Note: Since temperature and humidity are measured in the air circuit, the measurement results are only of limited use for characterizing the ambient conditions. This is particularly the case if the measuring air is drawn in from another location or if the device is heated (e.g., by sunlight or during battery charging).

3. 2. Flow measurement, flow control and pump current

For reproducible measurements of radon decay products and other radioactive aerosols, a constant flow rate ensures both consistent sensitivity and consistent airflow conditions. The latter is necessary to avoid variable particle size-dependent collection losses. The air flow is generated by an internal pump.

3. 2. 1. Functional principle

The flow rate is measured using a calorimetric mass flow sensor. This also serves as the actual value transmitter for flow control. A mass flow sensor always measures the air volume that would occupy the displayed volume under standard conditions. For example, if the ambient pressure is 10 % lower, the flow rate must also be increased by 10 % to achieve the same air flow rate. The measuring air flows through the flow sensor as part of the internal air circuit. The control loop gradually increases or decreases the pump flow if the sensor's measured value deviates upwards or downwards from the nominal flow (setpoint). If the filter is too heavily contaminated, the pump reaches its maximum capacity, so that further contamination will prevent the nominal flow rate from being achieved. Therefore, the device's alarm system generates a warning signal at 80 % of the pump capacity. Every pump is a mechanical component subject to wear. At the end of its service life or in the event of a defect, the pump's operating current can increase significantly, even leading to a short circuit. To protect the electronics, the device monitors the pump current and the alarm system stops the measurement if a limit value is exceeded.

3. 2. 2. DACM32 components for internal air circuit

The flow sensor output is connected to analog input AIN6, and the pump current and pump voltage signals are connected to analog inputs AIN6 and AIN7. The pump power is controlled by the controller component REG1. The controller component generates a control voltage that can be used to vary the pump power.

3. 2. 3. Display of measuring values of the air circuit

The current flow rate measurement (AIN6) and the pump current (AIN7) are displayed in the corresponding physical unit. The pump voltage (AIN8) serves as an indicator of the required pump power and thus the condition of the filter. The maximum possible pump voltage determines the maximum pump power and thus the control limit for the flow. The control limit is equated with a filter occupancy of 100 %. A new filter would theoretically correspond to a filter occupancy of 0%. However, the lower value is factory-set to 15 %, as the required pump power can vary within certain limits depending on the ambient conditions and filter. Instead of the pump voltage, the device displays the filter occupancy in percent. Each measured value of the air circuit has its own display page.

3. 3. Barometric pressure, differential pressure (option for Standard version)

The device is equipped with a barometric pressure sensor as standard, and an optional differential pressure sensor for small differential pressures. In the standard RTM 2300, the pressure sensor terminal is connected to the monitor's center hose nipple labeled “p”. If a differential pressure sensor is present, the vacuum sensor terminal is connected to the hose nipple. The unconnected terminals are open, i.e., they are subjected to ambient pressure. Note: The pressures applied to the “p” hose nipple must not exceed the maximum permissible pressure values specified in the data sheet.
The I2C2 component is used for the barometric pressure sensor; for the optional differential pressure sensor, the analog input AIN5 or the I2C3 component is used, depending on the configuration. The pressure values are displayed on a separate display page.

3. 4. Soil gas measurements (only versions Soil Gas and ULTRA)

Soil gas measurements determine not only the radon concentration in the soil air but also the gas permeability (permeability) of the soil. From these two parameters, the existing radon potential can be derived. Soil gas measurements can be performed either continuously or as individual measurements according to a defined schedule. Appropriate measurement cycles are available for both options. In addition to measuring radon concentration and permeability, the individual measurement also includes the necessary fresh air purge of the measuring chamber and a parallel measurement of the CO2 concentration in the soil gas for quality assurance.

3. 4. 1. Measuring soil permeability - operating principle

The determination of the soil permeability is based on the measurement of the pressure difference generated by a volume flow between a sample volume (soil probe) and the free atmosphere. During a permeability measurement, the device generates a defined (controlled) volume flow and simultaneously measures the differential pressure. To cover the widest possible measuring range for permeability, two differential pressure sensors were implemented. The first sensor has a measuring range of 1000 hPa and is suitable for measuring low permeability. The second sensor, with a measuring range of 10 hPa, enables the precise measurement of a low differential pressure, which can be expected at high permeability. The device defines measurement cycles for high and low permeability, which can be used alternatively. In addition to the choice of differential pressure sensor, these differ in the generated volume flow, which is higher in the cycle for higher permeability.
In addition to the measured values for volume flow and differential pressure, the device constant of the soil probe used, specified by the respective manufacturer, is included in the permeability calculation.

3. 4. 2. DACM32 components for the soil gas measurement

Radon measurement and volume flow control have already been described in the previous sections. Caution: For individual measurements, the measured value “Radon (almost)” must always be used as the result! The 10 hPa differential pressure sensor is integrated via component I2C3, and the 1000 hPa sensor via component I2C4. The pressure terminals of both sensors are connected internally via a hose to the hose nipple labeled “p” on the front panel of the device. The CO2 sensor is permanently installed in the device and is part of the internal air circuit. It receives its power supply via the switching output DOUT3, and the output signal is connected to the analog inputs AIN5 and AIN6. The two analog inputs are activated at different times during the special soil gas measurement cycle, so that a measured value is available for each soil gas measurement at the beginning and end of the cycle. The measuring chamber is flushed by internal valves. Instead of the soil gas being drawn in via the hose nipple IN, radon-poor air is drawn in from inside the device. The valves are controlled via the switching output DOUT5. The components CALC4 (calculation with a 10 hPa sensor) or CALC5 (1000 hPa sensor) are used to calculate the permeability.

3. 4. 3. Display of soil air measurements

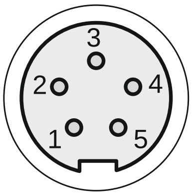
In addition to the radon measured values, the measured value display also shows the differential pressure, the measured permeability, and the CO2 concentration on various pages. Two values are provided for permeability, as this is calculated for the results of both differential pressure sensors. The suffix LO is used for the result using the 1000 hPa sensor and "HI" for the result using the 10 hPa sensor. When displaying the differential pressure measured values, the respective measuring range of the sensor (10 hPa or 1000 hPa) is also displayed.

3. 5. Warning and alarm lights

The basic unit has a signal LED labeled "!" directly above the WAKE button. This LED illuminates both in the event of warnings and alarms. The signal LED is connected to the DOUT8 switching output. Two additional signal lights can be connected to the AUX2 socket. A signal tower (yellow/red combination) is included upon request, or two separate signal lights (yellow and red) can be mounted on the lid of the measuring case. The yellow light indicates warnings regarding the operating status of the device (DOUT1), while the red light (DOUT2) is assigned to radiometric alarms.

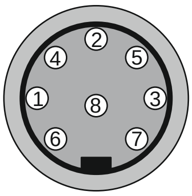
3. 6. The connectors AUX1 and AUX2

The two accessory connectors allow the connection of external sensors and actuators, as well as accessories for special measurement tasks. Caution: Only components supplied by SARAD may be connected to these two sockets. Improper use may damage the device's electronics.
The AUX1 socket is primarily intended for connecting radiation sensors, while the AUX2 socket provides external connections for various DACM32 components. The following tables show the socket assignments and signal usage in the RTM 2300.



Socket AUX1 (Binder Series 712, 5-pin), front view of the socket

Pin	Signal	Use
1	CMP1/CNT1	Comparator/counter combination, for optional accessories
2	V+	4.7 V supply voltage for beam detectors
3	CMP2/CNT2	Comparator/counter combination, for optional accessories
4	BIAS	Bias voltage
5	GND	Reference potential



Socket AUX2 (Binder Series 680 – DIN 8-pin), front view of the socket

Pin	Signal	Use
1	DOUT1	Switching output for optional accessories, controlled by the alarm system. A voltage of +12 VDC is applied when activated.
2	AIN1	Analog input for optional accessories
3	AGND	Reference potential for AIN1, AIN2, and DIN1
4	DOUT2	Switching output for optional accessories, controlled by the alarm system. A voltage of +12 VDC is applied when activated.
5	AIN2	Analog input for optional accessories
6	Clock-Switch	Switching output of the timer. A voltage of +12 VDC is applied when

		activated.
7	PGND	Reference potential for +12 VDC
8	DIN1	Digital status input for optional accessories

3. 7. Radon measurement chamber with Lucas cell (ULTRA version only)

The "ULTRA" version is equipped with a second, independent radon measuring chamber based on a Lucas cell. This combines the advantages of the two most advanced radon measurement methods in a single device:

HV measuring chamber

- Spectroscopic separation of radon (Rn-222) and thoron (Rn-220)
- No influence of long-lived Po-210 background
- Detection of the lowest concentrations
- Fastest possible response time

Lucas cell

- High sensitivity
- High immunity against any kind of external influences

3. 7. 1. Measurement principle

There are openings at the base of the device through which the air enters the measuring chamber by diffusion. Radon decay products already present in the air are prevented from entering by a filter. The diffusion time is designed so that any thoron present in the air can decay during diffusion. Almost 100% of the alpha particles emitted during the decay of radon and its short-lived decay products, Po-218 and Po-214, reach the wall of the measuring chamber. On the walls their energy is converted into flashes of light by a scintillation coating. The light is converted by a photo-detector into electrical pulses, which are counted by the device. The count rate is therefore directly linearly proportional to the radon concentration.

3. 1. 2. DACM32 components for radon measurement using a Lucas cell

The supply voltage for the Lucas cell is provided via the digital output DOUT5. When using the Lucas cell, this switch must always be enabled during the measurement cycle. The pulse output of the Lucas cell is connected to the input of the counter component CNT3. This component provides the count rate as the basis for calculating the radon concentration using the CALC6 calculator component. A further calculator component (CALC7) is used to combine the measurements from the Lucas cell and the high-voltage measuring chamber.

3. 1. 3. Display of measured values

The radon concentration measured by the Lucas cell is displayed as "Radon LC" on the display page of the CALC6 component. By configuring the CNT3 counter, the count rate is determined for the period from the start of the current measurement interval. This provides an immediate measurement value, the statistical fluctuations of which decrease progressively over the course of the interval. The measurement value for combined operation (display page of CALC7) is only available as an interval value named “Radon combined”, as the measurement value from the high-voltage measuring chamber is only available at that point.

4. RTM 2300 configuration

4. 1. Predefined measuring cycles

The following measuring cycles are stored in the delivered device:

Name of cycle	Description
Radon 15 min	Continuous radon measurement with 15-minute measurement intervals
Radon 30 min	Continuous radon measurement with 30-minute measurement intervals
Radon 1 h	Continuous radon measurement with 1-hour measurement intervals
Radon 2 h	Continuous radon measurement with 2-hour measurement intervals
Soil gas single *	Single soil gas measurement
Soil gas 15 min *	Continuous soil gas measurement with 15-minute measurement intervals
Soil gas 1 h *	Continuous soil gas measurement with 1-hour measurement intervals
Radon 60min LC **	Continuous radon measurement with 1-hour measurement intervals with Lucas cell and High voltage chamber
Signal Test	Test the "!" signal LED and, if present, the external signal lights (flashing)

*) only version Soil Gas

**) only version "ULTRA"

Additional measurement cycles are predefined at the factory if the corresponding accessories were ordered with the device. If the accessories are ordered later, the required cycle and configuration files are included.

4. 2. Predefined warnings and alarms

The DACM32 platform offers a highly flexible alarm system that allows any user-specific alarms and warnings to be generated. The following alarms are configured by default:

Measuring value (Alarm-source)	Hint	Signal	Alarm message
Pump controller (AIN8)	Pump capacity >80 %	LED front plate, ext. Yellow lamp	"Air inlet blocked or water inlet protection!"
Battery voltage (BATT)	Battery voltage less than 11.6 V	LED front plate, ext. Yellow lamp	"Battery discharged, please charge!"
Pump current (AIN7)	Pump current >300 mA	Measurement will be stopped immediately	"Measurement is stopped immediately, alarm can be read in the event log."
Differential pressure (I2C4)	Differential pressure higher than the sensor's measuring range	LED front plat, ext. Yellow lamp	"10 hPa measuring range exceeded!"
Radon concentration (SPEC1)	Control at the end of measurement cycle	LED front plate, ext. red lamp	"radon limit exceed"

Humidity Sensor (I2C2)	Humidity in internal air circuit >96 %	LED front plate, ext. red lamp	"danger of condensation"

Hint: The alarm check only is possible if the component that provides the measured value is activated in the measurement cycle. When defining custom measurement cycles, ensure that all components listed in the table are activated.
The battery voltage is monitored independently of the alarm system. At a voltage of 11.2 V, the measurement is automatically stopped without additional signaling. A corresponding entry is made in the event log.
The alarm signaling with yellow and red external lights is only activated if the device is supplied with a measuring case or a light column (accessory).

5. Important hints on operating the device

5. 1. Vibrations and strong electromagnetic fields

Continuous strong mechanical shocks and vibrations can affect the detector signal due to the piezoelectric effect and must be avoided. The device should not be operated in close proximity to strong and high-frequency electromagnetic fields (e.g., placing the device on high-voltage switchgear or placing mobile phones on the device).

5. 2. Aggressive Gases

Due to the operating principle, all sensors, semiconductor detectors, and mechanical components come into contact with the measuring air. Aggressive gases can damage or destroy the sensitive surfaces of the sensors/detectors or contact systems. This can lead to measurement errors or malfunction. Avoid using the device in the presence of aggressive gases.

5. 3. Environmental conditions

The ambient conditions specified in the data sheet must be observed. Operating outside the specified limits may result in incorrect measured values or limit the functionality of the device. If the device must be used under such conditions, please consult the manufacturer.

5. 4. Control of the alpha spectra

Recording and displaying alpha spectra is the most powerful tool for quality assurance of radon and progeny measurements. Both the radon measurement chamber and the progeny sensor head provide characteristic energy spectra that the user can reliably evaluate after a short period of time. All radon and thoron progeny generate characteristic peaks in the spectrum, the shape and position of which indicate the proper functioning of the device. Less experienced users should save the initial measurement results after delivery of the device so that reference spectra are available for later comparison. A quick look at the acquired alpha spectra should always be part of good measurement practice.

5. 5. Avoiding condensation

The formation of condensation in the device must be avoided. Condensation can occur if the device temperature is below the temperature of the measuring air and the dew point is exceeded upon cooling. Typical scenarios are soil air measurements in winter or immediate measurements in humid, warm rooms after transport at low temperatures. In such cases, the device must be sufficiently warmed before use. Damage to the device is not expected, but it may impair the measurement. If, for example, constant temperature changes are expected in a stationary installation under humid ambient conditions, a cooling and condensation device must be installed upstream or the device must be placed in a heated measuring cabinet. Depending on the device type, rotary vane pumps are used to generate the airflow. The surfaces of the compressors can corrode if surface moisture is present, which can lead to reduced pumping performance or even inoperability. After measurements under humid conditions, a fifteen-minute measurement should be performed in a dry environment to remove any moisture present from the internal air circuit.

5. 6. Water ingress protection

Especially when measuring soil gas or water samples, it is important to ensure that no water can enter the internal air circuit. The pump's power is sufficient to suck water even from deeper sample boreholes. In this case, all sensors come into direct contact with water. For this reason, the water inlet protection must always be used. This is included with the Soil Gas and ULTRA versions of the device and is available as an accessory for the standard device. This consists of a container with a float switch that is inserted between the sampling device and the air inlet of the device. If water enters, the float switch switches off the pump via an additional socket on the device. Note: The container must always be used vertically, i.e. with the connections pointing upwards (for devices with a retaining clamp for the water inlet protection, the device must be operated in the appropriate position). It is recommended that a functional test be carried out before each use. To do this, start a test measurement and then turn the empty container with the connections facing downwards. The pump must stop immediately.

If water is accidentally sucked in, first disconnect the hose connecting the container to the air inlet. Then, disconnect the second hose from the container and the connecting cable from the device. The container can now be removed from the holder, unscrewed (turn the lid counterclockwise), and emptied. The surfaces should be dried with a cloth. Any water contained in the hoses should also be removed. When closing the container lid, ensure that the rubber seal is correctly seated. The container should be checked for leaks.

5. 7. Filter at the air inlet of the device

The internal gas circuit contains a multi-stage filter to prevent radon decay products already present in the sample air from entering the radon measurement chamber. This filter is not accessible from the outside and is normally maintenance-free. This requires that dust and other particles are removed from the sample air beforehand. If the decay product measuring head is not used, the supplied syringe filter should be connected to the device's air inlet instead. This filter should be replaced if significant contamination is visible or if the required pumping capacity is significantly increased.

5. 8. Rechargeable battery

The lifespan of the built-in battery is reduced if it is deeply discharged or stored in a discharged state for extended periods. Even a fully charged battery will reduce its lifespan. For this reason, the battery should be subjected to a charge and discharge cycle every three months. This also applies if the device is not used for an extended period of time (the battery is subject to slight self-discharge, i.e., it loses capacity even when no power is drawn). Before the device is not used for an extended period of time, the battery should be charged to approximately 13V, the device turned off, and the fuse removed. Note: Deep discharge of the battery usually leads to a defect. This is detected by the charger, so the charging process will not begin.

5. 9. Hints for soil gas measurements (Version Soil Gas)

Soil gas measurements are primarily used to estimate potential radon exposure in newly constructed buildings. Based on the results of such measurements, decisions about necessary radon protection measures can be made even before construction begins.

5. 9. 1. Radon-Potential and Radon-Index

Radon potential is the product of soil permeability and radon soil air concentration. The higher these two values, the greater the probability that a large amount of radon is present in the area of a structure in contact with the ground. The uncertainty of a permeability measurement is primarily determined by the inhomogeneity of the soil and deviations from the defined geometry of the sample volume. With an in-situ method, the user has no information about this. For radon measurements, relatively large uncertainties also arise due to the sampling and varying ambient conditions during the measurement. A soil air measurement can therefore only serve to estimate the existing radon potential.

To simplify matters, Neznal [1][2] conducted extensive studies and, taking the uncertainties mentioned above into account, introduced a so-called radon index. The radon index can only assume the values *low*, *medium*, and *high*, which relatively reliably assess the radon risk for a planned building.

For this purpose, three defined permeability ranges are assigned to three radon concentration ranges in a table. To determine the radon index, select the corresponding column based on the permeability measurement and find the row whose radon concentration range contains the measured radon concentration. The radon index can now be read off in the last column of the determined row.

Permeability k [m²]	< 4E-13 (low)	4E-13 … 4E-12 (middle)	> 4E-12 (high)	Radon Index
Radon concentration [kBq/m³]	< 30	< 20	< 10	low
	30 … 100	20 … 70	10 … 30	middle
	> 100	> 70	> 30	high

5. 9. 2. Measurement results and their interpretation

An in-situ measurement of soil permeability is performed by measuring the pressure drop in the soil and the air flow rate through the soil according to Darcy's law. Combining all equipment-specific parameters and natural constants, the equation can be written as follows:

$$k = C \cdot \frac{Q}{\Delta p}$$

C Device constant of the soil air probe

Q Volume flow generated in the soil

Δp Pressure drop in the soil between the probe and the ambient air

According to this equation, the theoretical value range of permeability extends from zero (completely impermeable soil) to infinity (permeability similar to a free airway). With reasonable technical effort, only a value range limited by the maximum pump output and the minimum measurable pressure difference can be determined. In order to achieve high measurement accuracy even at high

permeability, an additional sensor for very small differential pressures was implemented. For this reason, two values for permeability appear on the display and in the measurement data, calculated using the measured values of the two differential pressure sensors. Permeability HI stands for the calculation using the measured value of the sensor for small differential pressures, and Permeability LO stands for the calculation using the sensor for large differential pressures. If the differential pressure exceeds the respective measuring ranges of the sensors, an alarm message is shown on the display. If no message appears, the measured value Permeability HI should be used. If the message “Permeability HI outside measuring range” appears, Permeability LO should be used as the measurement result. If “Permeability LO out of range” is displayed, the permeability cannot be accurately determined. The actual permeability will be lower than the displayed value.
Note: Since the differential pressure is the denominator of the permeability calculation formula, measurements without a measurable differential pressure may be divided by zero. In this case, “NaN” (Not a Number) is displayed instead of the measured value.
The measured value “Radon (fast)” is always used as the measured value for the radon soil air concentration.

5. 9. 3. Process of an individual measurement and quality assurance

A special measurement cycle with a measurement duration of 20 minutes is available for a single measurement. At the end of the measurement, the measurement data is saved, and the results can be viewed in the interval data menu. Sensors and actuators are active at different times during the measurement, so current sample values are not always available.

Phase	Duration	Actions
1	5 min	Nominal flow rate 0.5 l/min; measurement with CO2 sensor for quality assurance - CO2 (TEST)
2	12 min	Wait for the response time for Radon Fast Mode
3	3 min	Begin radon measurement; measure CO2 concentration - CO2
4	1 min	Switch to maximum flow rate
5	1 min	Determine permeability
6	2 min	End of radon measurement; purge chamber

A significant source of error in soil gas measurements is insufficient sealing of the soil gas probe from the surrounding soil. This creates the risk of a greater or lesser amount of fresh air being drawn in. The CO2 sensor can be used as an indicator of insufficient sealing, as soil gas typically contains elevated CO2 concentrations. With adequate sealing, the CO2 concentration should remain at a relatively constant value above the fresh air concentration throughout the entire measurement period. At the beginning of the sampling process, the CO2 concentration is measured, and both the minimum and maximum values are determined. These are available at the end of the measurement as the measured value “CO2 (TEST)”. The minimum value should be within the range of the fresh air concentration (previous purge). The maximum value corresponds to the soil gas concentration before significant amounts of soil gas were extracted. At the end of the measurement cycle, the CO2 concentration is measured again and displayed as the measured value “CO2”. If the soil gas probe is properly sealed, this measured value should approximately correspond to the maximum value of “CO2 (TEST)”.

5. 9. 4. Continuous soil air measurement

The device can be used to conduct continuous soil gas measurements, with measurement cycles with various measurement intervals available. All sensors are then permanently active. When measuring soil gas over extended periods, changes in ambient parameters must always be expected. There is a risk of water being sucked in after rainfall. Condensation is to be expected if the device cools down while the soil is still moist and warm. For this reason, additional precautions must be taken. Since these must be individually adapted to the local situation, our staff should be consulted in advance.

5. 9. 5. Connection of the soil gas probe (only versions Soil Gas)

When measuring Radon in soil gas, the water inlet protection RTM 2300 must always be used. Its air outlet is connected directly to the IN hose nipple on the front panel of the radon monitor. The filter supplied with the soil probe must be connected to the air inlet of the water inlet protector (note the marked flow direction). This filter has lower air resistance than the syringe filter normally used. A F-piece is located on the soil gas probe, from which two tubes are fed to the air inlet of the water intake protector and to the “p” hose nipple on the instrument. To ensure that the differential pressure measurement is independent of the air supply, the F-piece must be placed directly on the air outlet of the soil gas probe.

5. 9. 6. Use of the simple soil gas probe

Impact probes have become established as the standard method for in-situ soil gas measurements. When used correctly, they enable the quick and reliable sampling of soil gas. An impact probe consists of a one-meter-long tube with a so-called *lost tip* attached to the lower end. Using a hammer, the tube is driven tip-first into the soil. A percussion sleeve is placed over the end of the tube to protect it during the drive-in process. The probe has reached the correct position when the upper end still protrudes approximately 15 cm from the soil. To achieve maximum sealing of the probe from the surrounding soil, the tube must be driven in straight and without pendulum motion. The drive rod is then inserted into the tube, and the lost tip is driven out of the tube with a few hammer blows (using the percussion sleeve). The process is complete when the upper end of the drive rod still protrudes approximately 1 cm from the tube. This creates a sample volume in the soil with a defined geometry, which is a prerequisite for the permeability measurement. The drive rod can now be pulled out and the connecting tube to the radon monitor can be plugged onto the upper end of the pipe. The hose connection must be checked for leaks before each measurement. A silicone hose with an inner diameter of 8 mm should always be used to connect the probe. Always use the water inlet protector between the probe and the instrument’s air inlet. Now start the soil gas measurement cycle on the RTM 2300 to measure radon in soil gas concentration and soil permeability simultaneously.

5. 10. Use of the Lucas cell (ULTRA version only)

5. 10. 1. Background compensation

Unlike spectroscopic measurements using the high-voltage measuring chamber, the Lucas cell also detects the long-lived radon decay product Po-210. The Po-210 activity produces a background signal with increasing exposure. This is negligible over long periods if radon concentrations are mostly measured in the same order of magnitude. However, if very high concentrations have been measured over long periods, the accumulated background can significantly increase the measurement result at very low concentrations. Even in the absence of Po-210, a few spontaneous pulses may occur via the light detector. For this reason, the background should be determined periodically and, if necessary, compensated for via the instrument configuration. To do this, the device can be exposed for at least 12 hours in an atmosphere with a radon concentration below 10 Bq/m³. To determine the background, the reading from the high-voltage measuring chamber is subtracted from that of the Lucas cell, and the result is entered into the instrument configuration. Due to the background signal, measurement results at concentrations below 10 Bq/m³ are subject to high statistical uncertainty; therefore, in this range, the reading from the high-voltage measuring chamber should be used.

Due to background subtraction and the counting statistics, negative radon readings may be calculated when measuring very low concentrations. Negative values are physically impossible and indicate that the radon concentration is below the detection limit. Nevertheless, it is useful to report these values when calculating the average over several measurement intervals. Treating negative values as zero values would distort the count statistics and thus lead to an overestimation of the calculated mean value.

5. 10. 2. Combined measurement

Combining both measuring chambers allows the statistical uncertainty to be minimised by maximising the count statistics, as the count pulses from both chambers are added together. This requires that both chambers measure the same air sample; in other words, no hose should be connected to the air inlet of the device. The base of the device, where the Lucas cell's air inlet is located, should not rest on a surface that may emit radon. The combined measurement value is available exclusively as an interval value. As the time response of the Lucas cell is similar to that of the 'Slow' mode of the high-voltage measuring chamber, the 'Radon (slow)' measurement value always serves as the basis for the calculation, thereby determining the response time of the measurement. The time response of both channels is not exactly identical, so that slightly differing measurement results may occur during strong and sudden changes in concentration. As negative values may occur at very low concentrations due to background compensation in the Lucas cell, this is also possible and useful in combined mode (see previous section).

6. Use of accessory

6. 1. Accessory adapter

For some accessories (e.g. water ingress protection) it is necessary or advisable to permanently connect them to the RTM 2300. For this purpose, there is an accessory adapter on the left side panel of the housing. This has a central threaded M6 hole for fastening and a series of opposite holes for positioning the accessories. The attachment is made using the counterpart that matches the respective accessory, which has two tabs for the positioning holes and a central hole for fastening with an M6 screw. The positioning holes are arranged in such a way that vertical positioning is guaranteed when the instrument is lying down (rack), standing up (case) and when using the stand bracket (table). The user must make the appropriate adjustment depending on the position of the RTM 2300.

6. 2. Measuring case for harsh environmental conditions

If the RTM 2300 is to be used in harsh environmental conditions, we recommend using the optionally available measuring case (included with the Soil Gas version). This is dust- and waterproof and has hose connections for transporting the measuring air to and from the radon monitor. The power supply socket on the case allows continuous operation of the RTM 2300 with the case closed (the cable extension in the case must be plugged into the DC socket). Depending on the model, one or two signal lights are mounted on the top of the case lid to indicate warnings and alarms. The connection cable for the signal lights is connected to the AUX2 socket on the front of the monitor. When closing the case lid, care must be taken to ensure that no hoses or cables are kinked.
Depending on the instrument's configuration and ordered accessories, the measuring case may have additional functions.

6. 3. Determination of the radon concentration in water samples

6. 3. 1. Measuring principle and accessory

The determination of radon concentration in water samples is based on the solubility equilibrium of radon between water and air. This is highly dependent on the temperature of the media and must be taken into account in the calculation. The physical and mathematical principles can be found in the application note "Radon Measurement in Water".
The radon concentration in water samples can be determined using the RTM 2300 and the Aqua Kit for Radon-in-water measurement available as an accessory. The Aqua Kit consists of a gas washing bottle and a base with an integrated optical temperature sensor. The sensor cable is connected to the AUX2 accessory socket on the front panel of the radon monitor, into which a defined amount of the water sample is poured.
The Aqua Kit is available as an accessory for determining radon activity concentration. The scope of delivery includes the following components:

- 500 ml gas wash bottle with hose adapters
- Plastic bottle holder with integrated temperature sensor
- Water ingress protection (if not purchased earlier with the radon monitor)

- Connecting hoses
- Measurement cycle as a configuration file for uploading to the RTM 2300

Note: the RTM 2300 configuration is designed for a sample volume of 500 ml. This determines the remaining air volume in the closed air circuit. Both volumes are included in the calculation, so the fill level must always be maintained and only the supplied gas wash bottle may be used.

6. 3. 2. Precautions against condensation and water ingress

To avoid condensation in the closed air circuit, the temperature of the water sample should not exceed the ambient temperature of the device (allow the sample to cool down before measuring if necessary). The relative humidity in the air circuit will then rise to a maximum of 95%. If the relative humidity in the air circuit approaches the dew point (RH > 95 %) due to samples that are too warm, a warning message is issued. The measurement must then be stopped immediately and the device purged with fresh air. Condensation in the high-voltage measurement chambers can lead to leakage currents that impair the detector signal and thus make a correct measurement impossible. If condensation occurs in the device, it must be dried immediately by purging it with dry air for an extended period. Afterwards, a test measurement should be performed to verify the proper functioning of the device (assessing the shape of the alpha spectrum).

When measuring water samples, it is essential to use the water inlet protection device between the gas washing bottle and the device's air inlet. This prevents water from entering if, for example, the gas washing bottle connections have been reversed. The float switch immediately interrupts the pump's power supply, preventing water from entering the device. Ensure that the stainless-steel vessel is always positioned vertically. Depending on the device's positioning, the vessel's position can be adjusted using the accessory adapter. If water is accidentally sucked in, proceed as follows:

- Remove the hose connection to the device's air inlet on the side of the device
- Stop the measurement (if it hasn't already stopped automatically)
- Remove the hose connection to the gas washing bottle
- Disconnect the float switch plug connection
- Remove the vessel from the clamp and unscrew the lid
- Completely remove water and moisture from the vessel and all hoses
- Reinstall the water inlet protection device. When screwing the lid back on, ensure the rubber seal is properly seated.

6. 3. 3. Carrying out the measurement

First, prepare the device for measurement by connecting the temperature sensor cable to the AUX2 socket on the device and making all tube connections:

- Water inlet protection → device air inlet
- Device air outlet → gas wash bottle (dip tube)
- Gas wash bottle (bottle neck) → water inlet protection

Note: The hose connections of the water ingress protection device are interchangeable. Only the supplied hoses may be used. Other materials (e.g., silicone) are permeable and will cause radon to escape during the measurement.

Before each measurement, the device must be purged with fresh air for at least five minutes. To do this, disconnect the hose connections on the gas scrubber bottle and start any measurement cycle.

The purging should be carried out for approximately five minutes in a location with very low radon concentration so that the device's internal air circuit is free of radon.
The gas scrubber bottle can now be filled with the specified water volume of 500 ml. Care must be taken to ensure that as little radon as possible escapes during sampling and filling (fill quickly, avoiding large contact surfaces with the ambient air). Then, screw on the cap with the immersion tube tightly. Ensure that all seals are correctly seated. The bottle is now inserted into the bottle holder and the “Radon in Water” measurement cycle is started on the device. After the end of the measurement cycle, the calculated radon activity concentration is saved and is available on the display as the measured value “Radon in water”.

6. 3. 4. Measuring cycle and components used

A flow rate of 1 l/min is selected for the measurement to ensure the fastest possible transfer of radon from the water to the air. Concentration equilibrium between water and air is reached after approximately 20 minutes. Since the transfer time constant is slightly longer than the response time of the device in radon "fast mode," the actual radon measurement can begin at the 21st minute. From this point on, the temperature is also recorded, as the temperatures of the air and water in the bottle have equalized. The radon measurement lasts 10 minutes, resulting in a total cycle time of 30 minutes.

The temperature sensor's signal output is connected to the analog input AIN2. The sensor's supply voltage (+12 V) is supplied via the switching output DOUT2. Since the sensor requires approximately 10 minutes to warm up, the voltage is switched on at the start of the measurement cycle, simultaneously with the pump. Temperature (AIN2) and radon measurements are only active from minute 21 to minute 30. To monitor relative humidity for condensation from the start of the measurement cycle, an additional I2C component (I2C3) is used, which provides the measured temperature and humidity values for the first 20 minutes. An alarm is set for both components at 95% relative humidity. Exceeding this limit is signaled by default only by the alarm light on the front panel. However, for water measurement, the alarm for the additional humidity measurement (I2C3) is configured so that the measurement is automatically aborted in the event of an alarm.6. Use of accessories

6. 4. Signal tower

The signal tower is used to signal warning and alarm conditions. The bright 360° signal lights ensure good visibility even from greater distances. The signal tower is connected to the device's AUX2 socket. It is controlled via the switching outputs DOUT1 (yellow) and DOUT2 (red). The signal tower can be freely positioned in the room using either a mounting bracket on the instrument’s accessory adapter or a suitable cable extension.

6. 5. External temperature and humidity sensor

The ambient temperature and humidity must be measured outside the device, as its power consumption distorts the readings of the internal sensor. The sensor is connected to the ‘AUX2’ sockets on the device. The required components and measurement cycles are already configured for this sensor when the device is delivered.

Attachment

A) DACM32 components

A1 – Type of components of DACM32

Type	Name	Description
Analog input	AIN	Connects sensors with analog output signals (0...1 V, 0...2 V, 0...5 V, 0...10 V, 0/4...20 mA). The sampling interval is 1 second; the average, minimum, and maximum values are recorded within a measurement interval.
Status input	DIN	Detects states (e.g., switch contacts), recording the on and off duration and the number of changes.
Comparator-input	CMP	Detects pulse signals that are greater than an adjustable threshold; used in conjunction with a counter input.
Counter input	CNT	Detects a total number of pulses, a pulse rate, or an average pulse rate. Use with sensors with a pulse output.
Spectrometer	SPEC	Spectrometer module for recording pulse height spectra.
Universal digital sensor interface	I2C	Connects sensors with a digital interface according to the I2C standard.
Controller	REG	Provides a PID control loop. All available measurement results from existing sensors serve as the setpoint, and a control voltage is output at the controller output.
Switching output	DOUT	Potential-free switching contacts (opto-MOS switch or relay changeover switch)
Frequency generator	PWM	Applies a square-wave signal with variable pulse width to the output.
Calculator	CALC	Calculates complex measurement results from the measured values of the available sensors using functional prototypes.

A2 – Overview of the used components in RTM 2300

Name	Alias-Name	Function
AIN1	AUX2-Pin2	Signal at AUX2 socket Temperature of external temperature/humidity sensor Soil temperature with soil moisture probe (accessory) Water temperature with water measuring system (accessory))
AIN2	AUX2-Pin5 Soil humidity	Signal at AUX2 jack Rel. humidity of external temperature/humidity sensor Soil moisture with soil moisture probe (accessory)
AIN3	CO2	Internal CO2 sensor (only versions Soil Gas and ULTRA)
AIN4	CO2 (Perm.)	Internal CO2 sensor (only versions Soil Gas and ULTRA) in the radon soil air cycle, measurement of the initial CO2

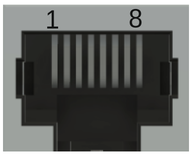
		concentration
AIN5	Flow (Perm.)	Flow measurement for permeability determination (only Soil Gas and ULTRA versions)
AIN6	Air-flow	Flow measurement and setpoint for flow control
AIN7	Pump current	Measurement of the internal pump current
AIN8	Filter assignment	Measurement of filter occupancy based on the pump voltage
DIN1	AUX2-Pin8	Signal at AUX2 socket, unused
CMP1	AUX1-Pin1 FP-measuring head	Unused, Signal at AUX1 socket, internal connection to CNT1 Impulse input for decay product measuring head (accessory)
CMP2	AUX1-Pin3 Gamma-Probe	Unused, signal at AUX1 socket, internal connection to CNT2 Pulse input for dose rate probe (accessory)
CNT1	Comparator 1 PAEC Radon	Internally connected to the output of CMP1, unused Measurement of radon PAEC (Rn-222) using the Markov algorithm
CNT2	Comparator 2 Dose rate	Internally connected to the output of CMP2, unused Measurement of the dose rate
SPEC1	Radon chamber	Connected to the detector signal of the radon measurement chamber, it generates an alpha spectrum and determines the count rates of the individual nuclides. Display: R Po-218, R Po-218/214, R Po-216
I2C1	Bar. pressure	Sensor for barometric air pressure
I2C2	Temp./humidity	Combined temperature and humidity measurement in the internal air circuit. Display: Temperature, Relative Humidity
I2C3	Delta p 10hPa	Differential pressure measurement with 10 hPa sensor (only versions Soil Gas and ULTRA)
I2C4	Delta-p 1000hPa	Differential pressure measurement with 1000 hPa sensor (only versions “Soil Gas” and ULTRA)
REG1	Pump controller	Controls the flow via the pump power, AIN6 serves as the actual value input
DOUT1	AUX2-Pin1 or Signal yellow	Signal to socket AUX2, either unused or: Power supply for external temperature/humidity sensor Connection of the yellow signal light on the measuring case
DOUT2	AUX2-Pin1 or Signal red	Signal to socket AUX2, either unused or connection of the red signal light on the measuring case
DOUT3	PWR CO2	Switches on the supply voltage for the CO2 sensor (only versions Soil Gas and ULTRA)
DOUT4	Valve 1/Valve 2	Switching internal air circuit (only version Soil Gas)
DOUT5	PWR Lucas cell	Power supply for the Lucas cell (only version ULTRA)
DOUT6	PWR HV	Switches on the high voltage for the radon measuring chamber
DOUT7	PWR Pump	Switches on the supply voltage for the pump and pump control
DOUT8	LED front plate	Red Signal LED “!” at the front plate
CALC1	Radon (fast)	Calculates the radon concentration (Fast-Mode) from Po218-

		count rate
CALC2	Radon (slow)	Calculates the radon concentration (Slow-Mode) from the sum of the count rates of Po218 and Po214
CALC3	Thoron	Calculates the Thoron concentration from Po216-count rate
CALC4	Permeability LO	Calculates soil permeability from flow (AIN6) and differential pressure (I2C4), determination of low permeability with 1000 hPa sensor
CALC5	Permeability HI	Calculates soil permeability from flow (AIN6) and differential pressure (I2C3), determination of high permeability with 10 hPa sensor
CALC6	Radon LC	Calculates the Radon concentration from the Lucas cell (only version "ULTRA")
CALC7	Radon combined	Calculates the Radon concentration from the count sums of Lucas cell and high voltage measurement chamber (only version "ULTRA")
CALC8	Radon in water	Calculates the radon activity concentration in a water sample (water measurement system required – accessory)

B) Connector pin assignment

2 x 4-20mA

Pin	Signal	Description
1	AOUT1+	Current Loop 1 Output
2	GND	Common reference potential (-) for AOUT1 and AOUT2
3	AOUT2+	Current Loop 2 Output
4	GND	Common reference potential (-) for AOUT1 and AOUT2



RS485A/RS485B (RJ45 socket, 8-pin)

Pin	Signal	Description
4	B/B'	Transceiver terminal 1, V1 voltage (V1 > V0 for binary 1 [OFF] state)
5	A/A'	Transceiver terminal 0, V0 voltage (V0 > V1 for binary 0 [ON] state)
8	GND	Reference potential

1, 2, 3, 6, 7	N.C.	Not used

RS232 (SUB-D female, 9-pin)

Pin	Signal	Description
2	TX	Device's transmit line (output)
3	RX	Device's receive line (input)
5	GND	Reference potential
1, 4, 6, 7, 8, 9	N.C.	Not used

DC (2.5 mm jack socket)

Pin	Signal	Description
Inside	20VDC	Power supply and charging voltage
Housing	GND	Reference potential

C) Disposal instructions

Batteries and accumulators must not be disposed of in the trash, but must be disposed of at local collection points!

At the end of their service life, the measuring devices must be disposed of as electronic waste or returned to the manufacturer for proper disposal! If necessary, decontamination must be carried out before disposal.

