

"СОГЛАСОВАНО"



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RECOMMENDATION

State System of Ensuring the
Uniformity of Measurements
of the Russian Federation

PROCEDURE MANUAL FOR FAST MEASUREMENT OF ^{222}Rn FLUX FROM THE SOIL SURFACE USING THE RRA-TYPE RADON RADIOMETERS

Moscow, 2004

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This Procedure Manual defines the procedure for measurement of radon-222 flux from the soil surface in the range of 20 ... 1000 mBq/(s×m²).

1. Limits for the measurement uncertainty

1.1. This Procedure Manual ensures the measurement of radon-222 flux with the uncertainty no more than ±40%.

2. Measurement instrumentation and accessories

For the purpose of measurements according to this Procedure Manual, the following measurement instrumentation and accessories are used:

- radiometer RRA-01M-01 or RRA-01M-03 (hereafter RRA),
measurement range of radon concentration in the air: 20÷20000 Bq·m⁻³,
Maximum permissible intrinsic relative error:
 - in the range of radon concentration 20÷100 Bq·m⁻³ 30%;
 - in the range of radon concentration 100÷20000 Bq·m⁻³ 20%.
- sampling device (POU) including air-blowing unit with timer, volume throughput 1.0±0.3 litres per minute – Appendix 1, Figure 3;
- air sampler with volume 1.05 litre – Appendix 1, Figure 5;
- connecting tubes with the diameter 4 mm and total length 2 m;
- accumulation chamber 1 (hereafter “chamber-1”) with net volume 0.563 litre and area of sampling 0.0163 m² – Appendix 1, Figure 4a;
- accumulation chamber 2 (hereafter “chamber-2”) with net volume 0.093 litre and area of sampling 0.0016 m² – Appendix 1, Figure 4b;

A valid certificate of verification (calibration) must be provided with the RRA. The use of other types of measurement instrumentation is allowed provided that their metrological characteristics are not worse than that of RRA and certificate of verification is present.

3. Method of measurement

3.1. Measurement of the radon flux is based on the determination of the amount of radon accumulated in the air sampler (or in the measuring chamber of radon radiometer RRA) during predetermined period of time due to its exhalation from the soil surface of known area limited by the accumulation chamber. Measurement principle of the RRA implies the measurement of alpha particles emitted by radon decay product RaA (²¹⁸Po) collected on the surface of the semiconductor detector due to electrostatic potential.

4. Safety requirements

4.1. When performing measurement of the radon flux personnel must abide the terms set by related legislation for the electrical and radiation safety (in the Russian Federation – “Norms of radiation safety NRB-99”, “Basic rules for ensuring radiation safety OSPORB-99”, “Rules for exploitation of the user’s electrical installations and safety code for exploitation of the user’s electrical installations”).

4.2. Before performing measurements, personnel should read this Procedure Manual, the Operation Manual of the RRA and obtain permission for work with radiation sources.

5. Conditions for sampling and measurement

5.1. The conditions during measurements should comply with the following terms:

- temperature of the ambient air from + 5°C to + 40°C;
- relative humidity up to 85% at + 25°C;
- atmospheric pressure from 84 to 106.7 kPa (630÷800 mmHg).

5.2. The conditions during air sampling should comply with the following terms:

- temperature of the ambient air from minus 2°C to + 50°C;
- relative humidity up to 100% at + 25°C;
- atmospheric pressure from 84 to 106.7 kPa (630÷800 mmHg).
- sampling should not be performed in case the soil is frozen or flooded with

water.

6. Preparation for measurements

Preparation for measurements includes:

- preparation of the sampling device;
- selection and preparation of the site for radon flux measurements.

6.1. Preparation of the sampling device should be performed according to Appendix 2 of this Procedure Manual.

6.2. Selection and preparation of the site for radon flux measurements.

6.2.1. The number and location of test points within the site, where radon flux measurements are to be performed, are determined according to the local legislation for construction industry.

6.2.2. For each selected test point, a spot on the ground should be prepared with the area 0.2×0.2 m. The preparation includes cleaning the surface of the snow, garbage, vegetation and large stones and also loosening of the soil down to 3÷5 centimeters and leveling of the surface.

6.2.3. Allow at least 20 minutes after preparation of a spot before start of the measurement.

7. Performing measurements

This Recommendation offers two modes of radon flux measurement:

- sampling air from the accumulation chamber into the air sampler on site followed by measurement of radon concentration in the sample on site or in the laboratory;
- sampling air directly to the RRA measuring chamber and measurement of radon concentration on site.

The first mode is suitable for fast measurements in the range of radon flux from 20 to 80 mBq/(s×m²) and is recommended for the initial survey of the site.

The second mode is suitable for measurements in the range of radon flux from 80 to 1000 mBq/(s×m²) and is recommended for the detailed survey of the test points, where the value of radon flux is higher than reference level equal to 80 mBq/(s×m²).

7.1. Procedure for measurement of radon flux (mode 1).

7.1.1. Assemble a circuit using accessories included in the sampling device as shown in Figure 1a of the Appendix 1. Follow these steps: using tubes connect one of the air outlets of accumulation chamber-1 to the "IN" ("ВХОД") inlet of the air-blowing unit POU, the outlet "OUT" ("ВЫХОД") – with one of the air outlets of the air sampler. Connect the other outlet of the air sampler to the vacant outlet of the chamber-1.

7.1.2. Set the duration of sampling to 5 minutes by pressing the button "2" on the air-blowing unit and then start sampling using the button "RUN" ("ПУСК"). **Within 15 seconds** after that, place the accumulation chamber-1 on the prepared soil surface and bury it in the soil by pressing downward until the limiter of the chamber-1 reaches the ground level.

7.1.3. After the automatic stop of sampling, hermetically seal the air sampler using the rubber caps included in the sampling device POU. Write the time when sampling was complete (t₁) and the number of air sampler in the record sheet (see Appendix 4).

7.1.4. Pull out the chamber-1 from the soil and blow the ambient air through POU and chamber-1 for 2 minutes. To do that, press the button "3" and then the button "RUN" ("ПУСК"). Secure the chamber-1 higher than 50 centimeters above the ground level for the period of blowing.

7.1.5. Measurement of radon concentration in the sample includes the following steps:

- measurement of background radon concentration in the measuring chamber of the RRA;
- mixing the air sample between air sampler and chamber of the RRA;
- measurement of radon concentration in the measuring chamber of the RRA.

7.1.5.1. Measurement of background radon concentration in the chamber of the RRA.

Following the Operation Manual of the RRA, switch on the air blower build in the RRA for 5 minutes for filling the measuring chamber with ambient (outdoor) air.

Perform at least five successive measurements of radon concentration as described in the Operation Manual of the RRA.

Calculate mean value Q_b, Bq·m⁻³:

$$Q_b = \frac{1}{N} \sum_{i=1}^N Q_{b_i}, \quad (1)$$

where Q_{b_i} – “i” measurement result (readout), $Bq \cdot m^{-3}$;

N – number of measurements.

Q_b should not exceed the background value stated in the passport of the RRA.

Write the results in the record sheet.

7.1.5.2. Mixing air sample between the air sampler and the RRA chamber.

Assemble a circuit using accessories included in the sampling device as shown in Figure 2 of the Appendix 1. Follow these steps:

- using tubes included in the sampling device, connect the air outlet of the air sampler (that is without an attached silicon tube) to the "IN" inlet of the air-blowing unit POU;

- connect the outlet "OUT" of POU to inlet of the RRA (situated on the front panel of the RRA);

- connect the outlet of the RRA (outlet 1 on the rear side of the RRA; the outlet 2 should be sealed with cap) to the vacant outlet of the air sampler;

- switch on the air-blowing unit pressing the button “2” and then "RUN". The unit will blow air for 5 minutes.

After the mixing of the air is complete, write the start time of the first measurement in series t_2 in the record sheet.

7.1.5.3. Measurement of radon concentration.

Perform at least five successive measurements of radon concentration as described in the RRA Operation Manual.

Calculate mean value Q , $Bq \cdot m^{-3}$:

$$Q = \frac{1}{N} \sum_{i=1}^N Q_i, \quad (2)$$

where Q_i – measurement result (readout) i, $Bq \cdot m^{-3}$;

N – number of measurements.

Write the results in the record sheet.

7.2. Procedure for measurement of radon flux (mode 2).

7.2.1. Perform measurement of the background radon concentration in the chamber of the RRA (see 7.1.5.1).

7.2.1.1. Assemble a circuit using accessories included in the sampling device as shown in Figure 1b of the Appendix 1. Follow these steps: using tubes connect one of the air outlets of accumulation chamber-2 to the "IN" inlet of the air-blowing unit POU, the outlet "OUT" – with the inlet of the RRA. Connect the outlet of the RRA to the vacant outlet of the chamber-2.

7.2.1.2. Securing the chamber-2 higher than 50 centimeters above ground, blow the air through the system for 5 minutes by pressing the button “2” and then "RUN" on the air-blowing unit.

7.2.1.3. After the sample stops, perform at least five successive measurements of radon concentration as described in the RRA Operation Manual. Calculate mean value Q_b , $Bq \cdot m^{-3}$ by formula (1). Write the result in the record sheet and use it for radon flux calculations for all test points at this site.

7.2.2. Measurement of the radon flux.

7.2.2.1. Switch on the air-blower for 5 minutes by pressing the button "2" and then "RUN". **Within 15 seconds** after that, place the accumulation chamber-2 on the prepared soil surface and bury it in the soil by pressing downward until the limiter of the chamber-2 reaches the ground level.

7.2.2.2. After the automatic stop of sampling, perform at least five measurements of radon concentration as described in the Operation Manual of the RRA. Calculate mean value Q , $Bq \cdot m^{-3}$ by formula (2). Write the results in the record sheet (see Appendix 4).

7.2.2.3. Pull out the chamber-2 from the soil and blow the ambient air through POU and chamber-1 for 5 minutes. To do that press, the button "2" and then the button "ПЫСК". When blowing, secure the chamber-2 higher than 50 centimeters above the ground level.

8. Analysis of measurement results

8.1. In case of using mode 1, calculate radon flux by the following formula:

$$F_{Rn} = \left(Q \cdot \left(1 + \frac{V_2}{V_1} \right) - Q_b \cdot \frac{V_2}{V_1} \right) \cdot \exp(\lambda \cdot t) \cdot \frac{V_1 + V_3}{T \cdot S_1},$$

where:

Q – radon concentration calculated by the formula (2), $Bq \cdot m^{-3}$;

Q_b – background radon concentration, calculated by the formula (1), $Bq \cdot m^{-3}$;

V_2 – volume of the measuring chamber of the RRA, 1.6 litres;

V_1 – volume of sample in the air sampler, $V_1=1.05$ litre;

t – time elapsed after the end of exposition before the start of measurement, min, $t=t_2-t_1$;

λ – decay constant of ^{222}Rn , $\lambda=1.26 \cdot 10^{-4} \text{ min}^{-1}$;

V_3 – net volume of the chamber-1 and connecting tubes, $V_3=0.563$ litre;

T – period of sampling, $T = 300$ s;

S_1 – the area of contact with the soil (area of radon collection) of the chamber-1, $S_1=0.0163 \text{ m}^2$.

The uncertainty of calculated radon flux value, in case that all terms of this Procedure Manual are met, is no more than:

$$\delta F_{Rn} = \pm 40\% \text{ in the range of } F_{Rn} \text{ from } 20 \text{ to } 80 \text{ mBq}/(s \cdot m^2).$$

8.2. In case of using mode 2, calculate radon flux by the following formula:

$$F_{Rn} = (Q - Q_b) \cdot \frac{V_2 + V_3}{T \cdot S_2}$$

where:

Q – radon concentration calculated by the formula (2), Bq·m⁻³;

Q_b – background radon concentration, calculated by the formula (1), Bq·m⁻³;

V₂ – volume of the measuring chamber of the RRA, 1.6 litres;

V₃ – volume of the chamber-2 and connecting tubes, V₃=0.093 litre;

T – period of sampling, T = 300 s;

S₂ – the area of contact with the soil (area of radon collection) of the chamber-2,

S₂= 0.0016 m².

The uncertainty of calculated radon flux value, provided that the terms of this Procedure Manual are met, is no more than:

$$\delta F_{Rn} = \pm 30\% \text{ in the range of } F_{Rn} \text{ from } 500 \text{ to } 1000 \text{ mBq}/(\text{s} \cdot \text{m}^2)$$

$$\delta F_{Rn} = \pm 40\% \text{ in the range of } F_{Rn} \text{ from } 20 \text{ to } 500 \text{ mBq}/(\text{s} \cdot \text{m}^2)$$

8.3 Write the calculated measurement results in the record sheet (Appendix 4).

9. Presentation of measurement results

Use the recommended form for presentation of the measurement results (Appendix 4). The form should be accompanied by the site plan with depicted test points.

APPENDICIES

Appendix 1.

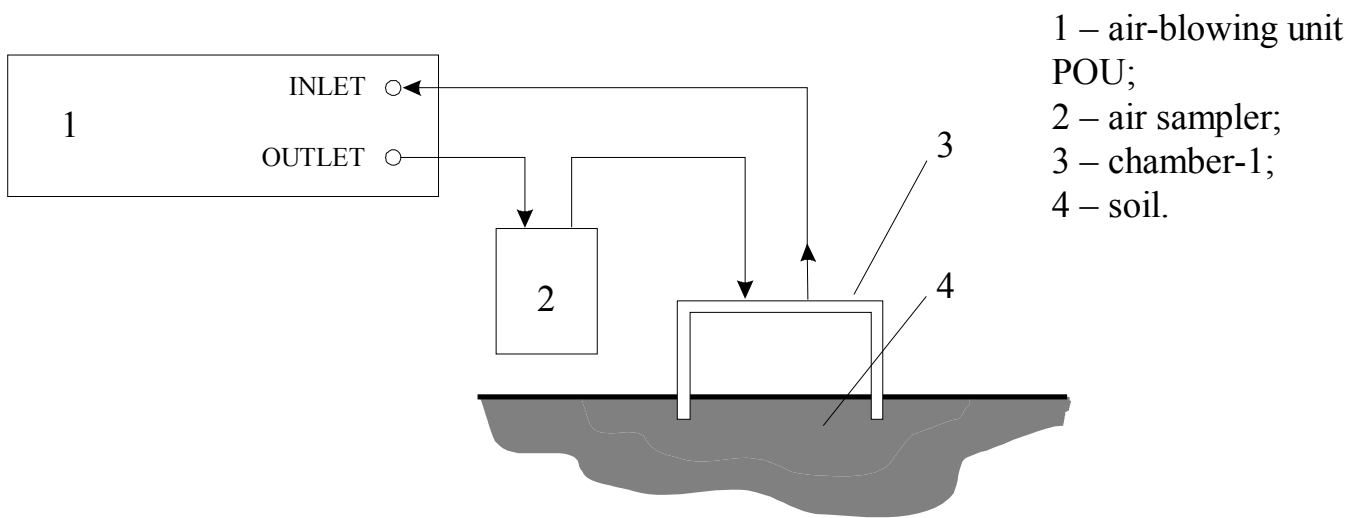


Figure 1a. The first air sampling scheme for determination of radon flux.

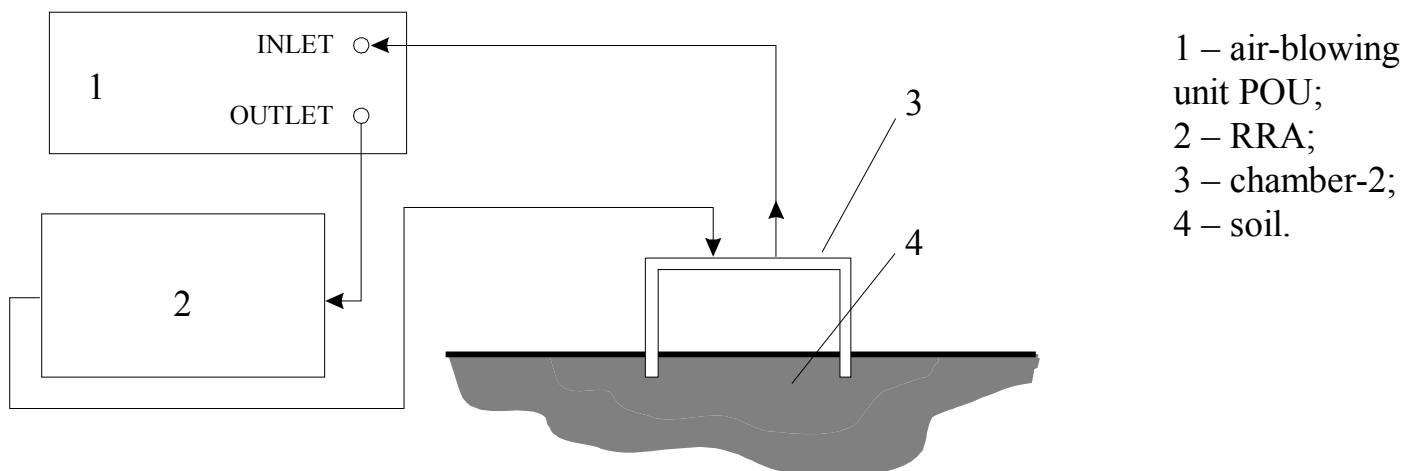


Figure 1b. The second air sampling scheme for determination of radon flux.

Appendix 1.

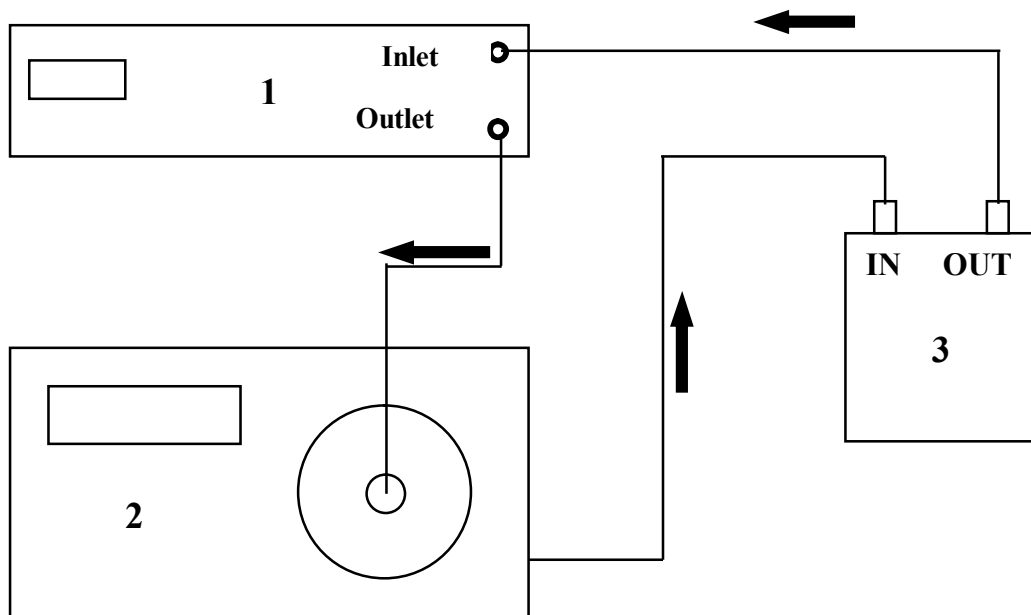


Figure 2. Scheme for radon measurement in the air sample.

- 1 – air-blowing unit POU;
- 2 – RRA;
- 3 – air sampler.

Appendix 1.

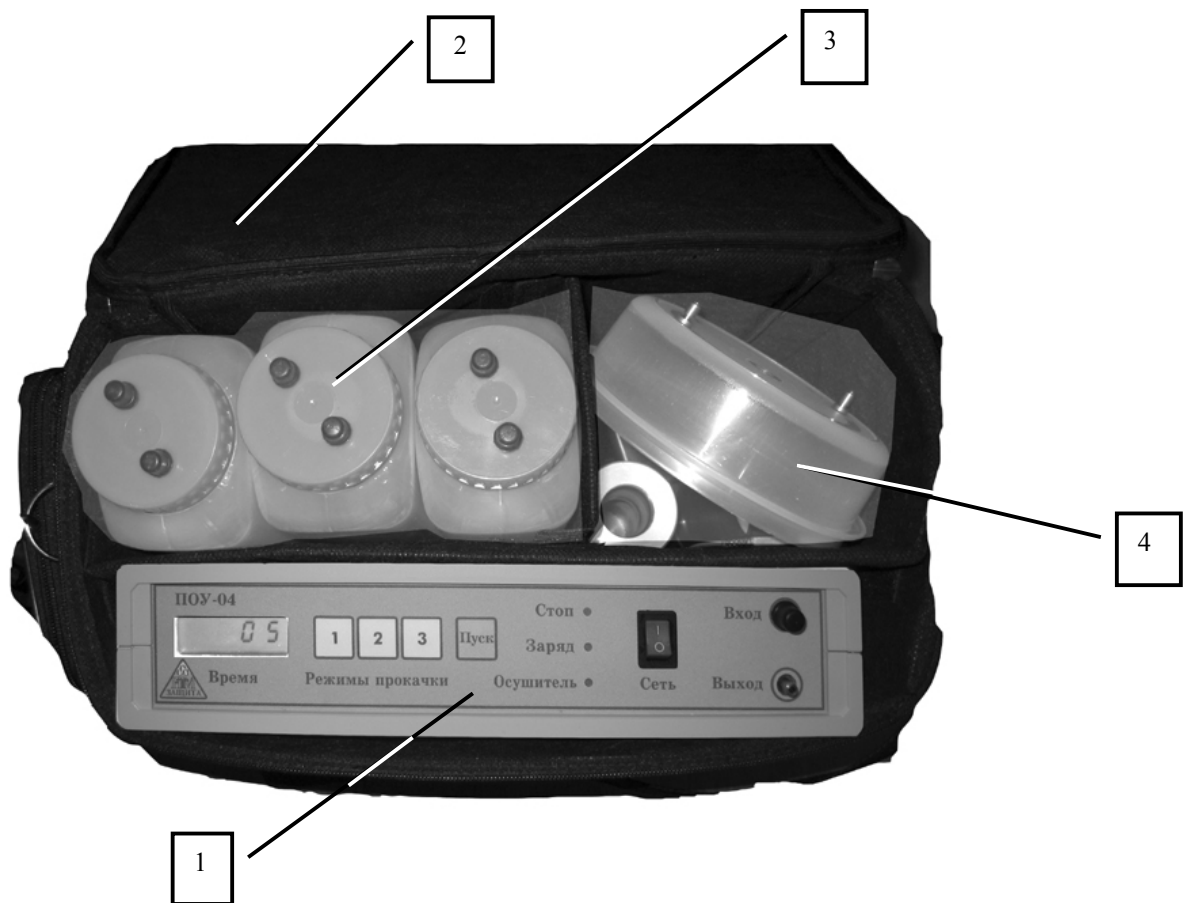


Figure 3. Overview of the sampling device (view from above).

- 1 – air-blowing unit with timer POU-04;
- 2 – handbag for transportation;
- 3 – air samplers;
- 4 – accumulation chambers and additional samplers.

Appendix 1

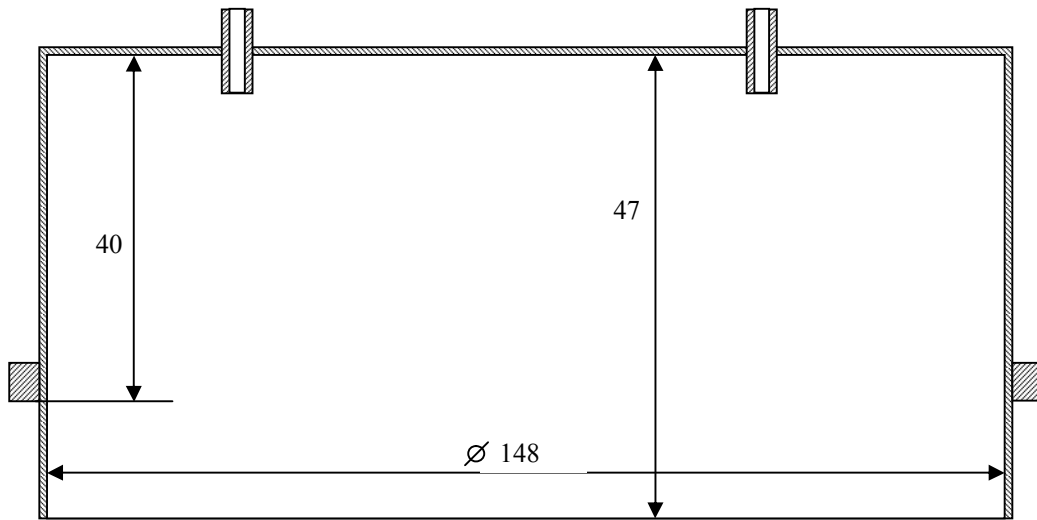


Figure 4a. Accumulation chamber-1

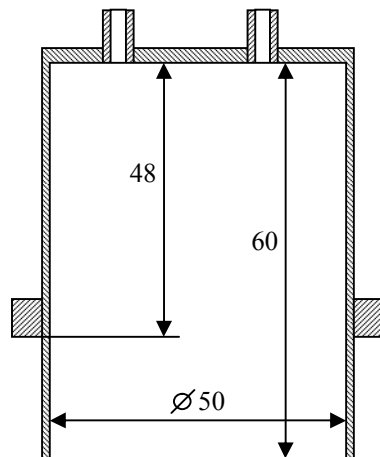


Figure 4b. Accumulation chamber-2

Appendix 1

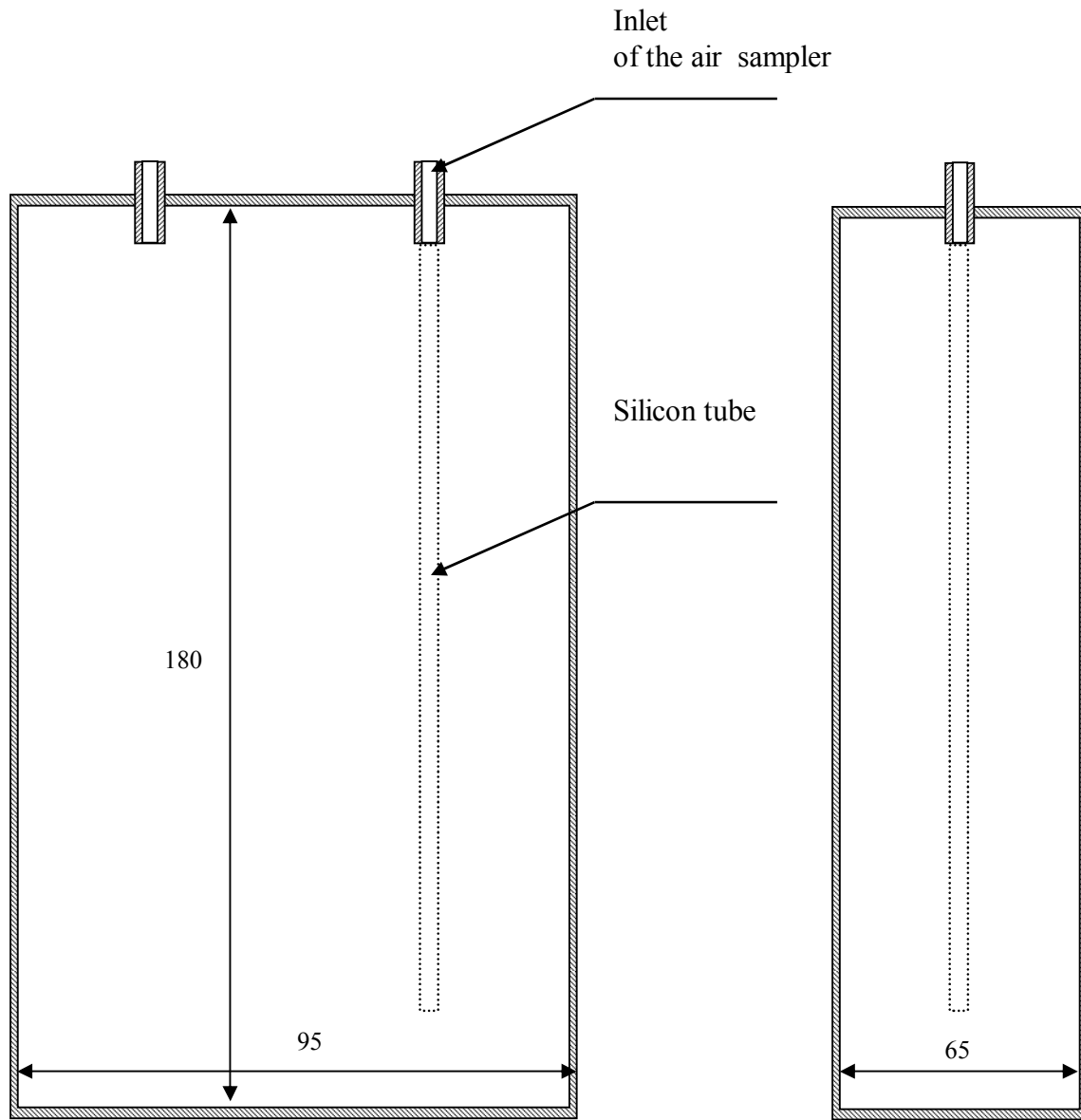


Figure 5. Air sampler.

Appendix 2

Preparation and instructions for use of the POU

1. Preparation.

1.1. Open the handbag with the POU.

1.2. Check operation of the air-blowing unit POU following these steps:

- switch on the air-blowing unit by pressing the button “**POWER**” (“**СЕТЬ**”);
- check the presence of indication “00” on the LCD;
- check dehumidifier: in case the LED “**Dehumidifier**” (“**Осушитель**”) on the front panel of the POU is ON, replace the reagent in the dehumidifier according to clause 4 of this appendix.
- check the battery: in case the symbol “**II**” is blinking on the display (LCD), charge the battery according to clause 2.9 of this appendix.

2. Instructions for use of the air-blowing unit POU.

2.1. Switch on the air-blowing unit using tumbler switch “**POWER**” situated on the front panel. The “00” indication will appear on the LCD.

2.2. Select the blowing period: press one of the buttons “**1**”, “**2**” or “**3**”. The selected period will appear on the LCD (accordingly, 20, 5 and 2 minutes).

2.3. To start blowing, press the button “**RUN**” (“**ПУСК**”).

2.4. To interrupt blowing at any time before it stops automatically, press one of the buttons “**1**”, “**2**” or “**3**”.

2.5. At the end of the selected period, blowing stops automatically; it is accompanied by the beep signal and blinking of the LED “**STOP**” (“**СТОП**”).

2.6. To switch these audible and visual signals off, press one of the buttons “**1**”, “**2**” or “**3**”.

2.7. When the battery is low, you will see the blinking symbol “**II**” on the LCD.

2.8. To charge the battery, use the mains adapter included in the sampling device.

2.9. Insert the plug of the mains adapter into the wall outlet 220 V. The charging will start automatically, the LED “**CHARGE**” (“**ЗАРЯД**”) will be lit until the process is finished.

2.10. The charging current is 150 mA. Period necessary for full charge of the battery is 8 – 10 hours.

2.11. When charging is on the way, the air-blowing unit POU is fully operational, powered from the mains adapter.

3. Switching the air-blowing unit OFF.

3.1. After use of air-blowing unit POU is finished:

- switch the unit off using the tumbler switch “**POWER**”;
- unplug the mains adapter if it is in use;
- put connecting tubes, samplers and other accessories into compartments of the handbag;
- close the handbag.

4. Replacement of the reagent in the dehumidifier.

4.1. The air-blowing unit POU includes the dehumidifier (air drying tube) with CaCl_2 reagent (granules 2÷5 mm). The dehumidifier life is no less than 200 samples. When the LED “**Dehumidifier**” is lit, you need to replace the reagent inside the dehumidifier.

4.2. To replace the reagent, follow these steps:

- unscrew 4 screws on the rear panel of POU;
- remove the rear panel with attached dehumidifier;
- release dehumidifier from tubes and sensor wires;
- withdraw and disassemble the dehumidifier, remove exhaust reagent, cleanse and dry parts, fill the dehumidifier with fresh reagent;
- install the dehumidifier into the air-blowing unit POU in the reverse sequence.

Appendix 3. Delivery packaging of the sampling device

Table 1

Basic hardware of POU-04

№	Item (document)	Designation	Q-ty ¹
1.	Air- blowing unit	POU-04	1
2.	Bubbler	κM1.181196.71	1
3.	Air sampler	κM1.181196.74	3
4.	Soil air sampler	κM1.181196.76	1
5.	Water sampler	κM1.181196.75	5
6.	Accumulation chamber-1, Ø148 mm	κM1.181196.77	1
7.	Accumulation chamber-2, Ø50 mm	κM1.181196.78	1
8.	Sampling funnel		1
9.	Connecting tube, 80 centimeters	TY 64-2-286-79	2
10.	Connecting tube, 40 centimeters	TY 64-2-286-79	2
11.	Pipe for connecting POU to RRA	κM1.181196.72	1
12.	Spare cap for bubbler		1
13.	Spare cap for sampler		1
14.	Handbag for transportation of sampling device	OCT 17.839.80	1
15.	Passport		1
16.	Procedure Manuals		1
17.	Mains adapter		1
18.	Battery Cable (+ 12 V)		1

¹ NOTE: The user can request different quantity of samplers.

Appendix 4. Record sheet for registration of the measurement data

MEASUREMENT OF RADON FLUX IN THE TEST POINT

1. Place of sampling
2. Serial number of test point
2. Date of sampling and measurement:.....
3. Serial number of air sampler:.....
4. Sampling finished at, t_1 (hh:mm):
5. Measurement started at, t_2 (hh:mm):
6. Area of the accumulation chamber, m^2 :.....($S_1=0.0163 m^2$, $S_2=0.0016 m^2$)
7. Results of measurement of background radon concentration in the RRA chamber:

№	1	2	3	4	5
$Q_b, Bq \cdot m^{-3}$					

Background radon concentration $Q_b, Bq \cdot m^{-3}$,

8. Results of measurement of radon concentration, $Q, Bq \cdot m^{-3}$,

№	1	2	3	4	5
$Q, Bq \cdot m^{-3}$					

Radon concentration, $Q, Bq \cdot m^{-3}$,

9. Radon-222 flux in the test point, $mBq/(s \times m^2)$ \pm

Measurements were performed with the use of radon radiometer RRA-01M-.....
serial number

Certificate of verification:

Responsible personnel: (Name, Signature) _____ / _____
 _____ / _____

Appendix 5. Form for presentation of the measurement results

THE RESULTS OF RADON FLUX MEASUREMENTS ON THE SITE

Test point number	Radon-222 flux and its uncertainty, mBq/(s×m ²)	
	Value (F _{Rn})	Uncertainty (δF _{Rn})

Measurements were performed with the use of radon radiometer RRA-01M-.....
 serial number; Certificate of verification:

Appendix: Location of test point on the site

Responsible person: (Name, Signature) _____ / _____

Appendix 6. Controls Designations of Sampling Device POU-04

