"СОГЛАСОВАНО"

Директор ГЦМИИ ГП "ВНИИФТРИ"

_____ В.Л.Ярына

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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 CONCENTRATION IN THE WATER USING THE RRA-TYPE RADON RADIOMETERS

Moscow, 2004

CONTENT

This Procedure Manual defines the procedure for measurement of radon-222 concentration in water in the range of 6000 … 800000 Bq×m^{-3}.

1. Limits for the measurement uncertainty

1.1. This Procedure Manual ensures the measurement of radon-222 concentration in water 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;
- water sampler with volume 0.046±0.001 litre – Appendix 1, Figure 1;
- connecting tubes with the diameter 4 mm and total length 2 m.
- bubbler.

A valid certificate of verification (calibration) must be provided with the RRA.

3. Method of measurement

3.1. Measurement of the radon concentration in water is based on the transfer of radon along with circulating air from the water sample to the measuring chamber of radon radiometer RRA by means of bubbling process. Measurement principle of the RRA implies the measurement of alpha particles emitted by radon decay product RaA (^{218}Po) 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).

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. Taking water sample

6.2.1. Pull the water sampler out of the transportation bag. You can use one of two sampling procedures, both ensuring correct measurements. The bubbler should be filled with water in full irrespective of sampling procedure used.

6.2.2. To sample water from the water reservoir or from the vessel with open water surface, perform the following steps. Remove the rubber caps from both outlets of the water sampler. Connect a connecting tube with a funnel (included in the delivery package

of the sampling device) to the outlet opposite to the sampler's lid (marked "**UP**"). Submerge the sampler into water along with part of the connecting tube as shown in the Figure 1a of the Appendix 1. Sample the water until its levels in the tube and in the reservoir (vessel) become equal to ensure the filling of the sampler in full. Close the funnel using your finger. Pull the sampler out of water, seal the vacant outlet with a cap, disconnect the tube and seal the second outlet with another cap. The sampling is finished. Record the time t_1 of sampling in the record sheet.

6.2.3. To sample water from the discharge jet (water well, tap water), perform the following steps. Remove the rubber caps from both outlets of the water sampler. Connect a connecting tube with a funnel (included in the delivery package of the sampling device) to the outlet on the sampler's lid (marked "**UP**"). Place a funnel under discharge jet as shown in the Figure 1b of the Appendix 1. When a steady flow appears from the opposite outlet of the sampler, seal it with a cap, disconnect the tube and seal the second outlet with another cap. The sampling is complete. Record the time t_1 of sampling in the record sheet.

7. Performing measurements

Measurement of radon concentration in the sample includes the following steps:
- measurement of background radon concentration in the RRA measuring chamber;
- mixing the air sample between air sampler and chamber of the RRA;
- measurement of radon concentration in the chamber of the RRA.

7.1. 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 five minutes for filling the measuring chamber with ambient (outdoor) air.

Perform at least 5 successive measurements of radon concentration as described in the Operation Manual of the RRA.

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

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

where Q_{bi} – "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.

7.2. Transfer of radon from water sample into 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 bubbler to the "**IN**" ("**ВХОД**") inlet of the air-blowing unit POU;
- remove the cap from the transparent part of the sampler ("TOP"), connect a tube with the sparger aerator, insert the sampler with connected tube into the bubbler's opening and seal it by turning the captive nut;
- remove another cap from the sampler and connect the this outlet to the outlet of the RRA (outlet 1 on the rear side of the RRA; the outlet 2 should be sealed with cap)
- connect the outlet "**OUT**" ("**ВЫХОД**") of POU to inlet of the RRA (situated on the front panel of the RRA);
- switch on the air-blowing unit pressing the button "2" and then "**RUN**" ("**ПУСК"**). The unit will blow air for five 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 (Appendix 4).

NOTE: INCORRECT CONNECTION OF TUBES CAUSES THE WATER INFLOW INTO THE MEASURING CHAMBER AND DAMAGE TO THE RADIOMETER.

7.3. Measurement of radon concentration.

Perform at least 5 successive measurements of radon concentration according as described in the Operation Manual of the RRA.

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

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

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

N – number of measurements.

Write the results in the record sheet.

8. Analysis of measurement results

8.1. Calculate the radon concentration in water Q, $Bq \cdot m^{-3}$:

$$Q_n = \left(Q \cdot \left(\alpha + \frac{V_2}{V_1} \right) - Q_{\phi} \cdot \frac{V_2}{V_1} \right) \cdot \exp(\lambda \cdot t), \quad (3)$$

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 litre;

V_1 – volume of water sample, V_1=0.046 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, $\lambda=1.26 \cdot 10^{-4}$ min^{-1};

α – radon solubility in water, α=0.25

The temperature dependence of the radon solubility in water in the temperature range as stated in section 5, modifies the calculation result within 0.5%.

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

$\delta Q_{water} = \pm 40\%$ in the range of Q_{water} from 6000 to 30000 Bq/m^3,

$\delta Q_{water} = \pm 30\%$ in the range of Q_{water} from 30000 to 800000 Bq/m^3.

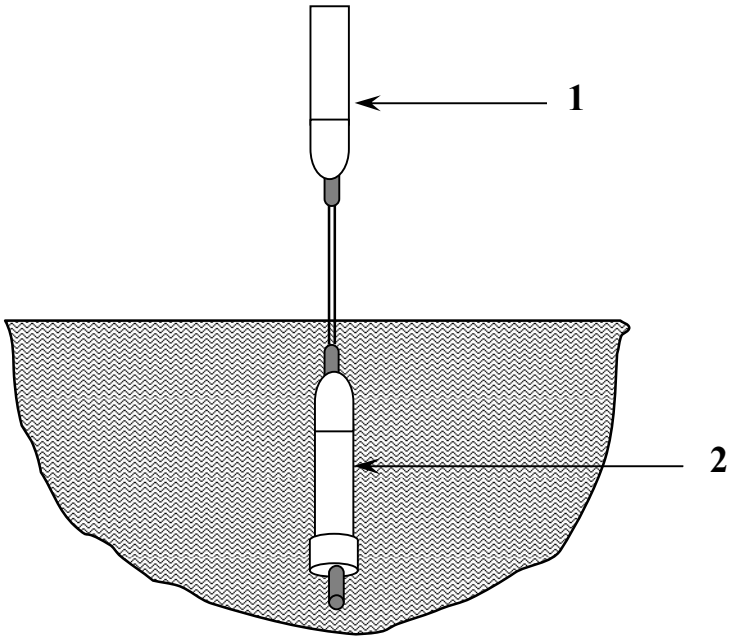
8.2. Write the calculated measurement results in the record sheet (Appendix 4).

9. Presentation of measurement results

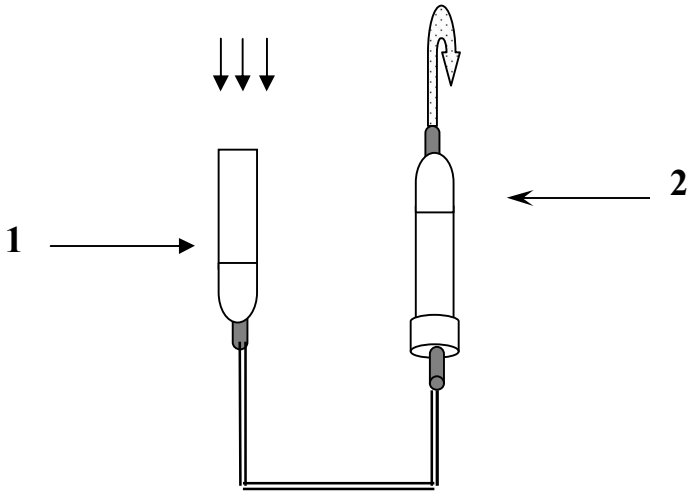
Prepare appropriate (approved) test report for presentation of the measurement results.

APPENDICIES

Appendix 1



а) Water sampling from the reservoir or vessel



б) Water sampling from discharge jet

Figure 1. Scheme for water sampling
1 – sampling funnel;
2 – sampler.

Appendix 1

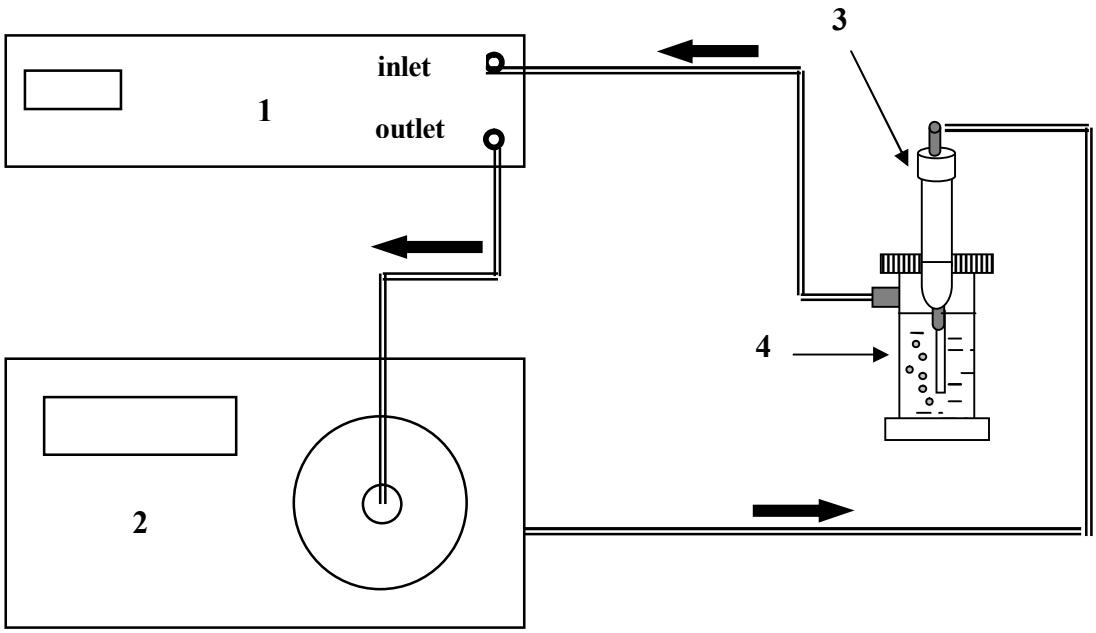


Figure 2. Scheme for measuring the sample

1 – air-blowing unit POU;
2 – RRA;
3 – water sampler;
4 – bubbler with sparger aerator.

Appendix 1

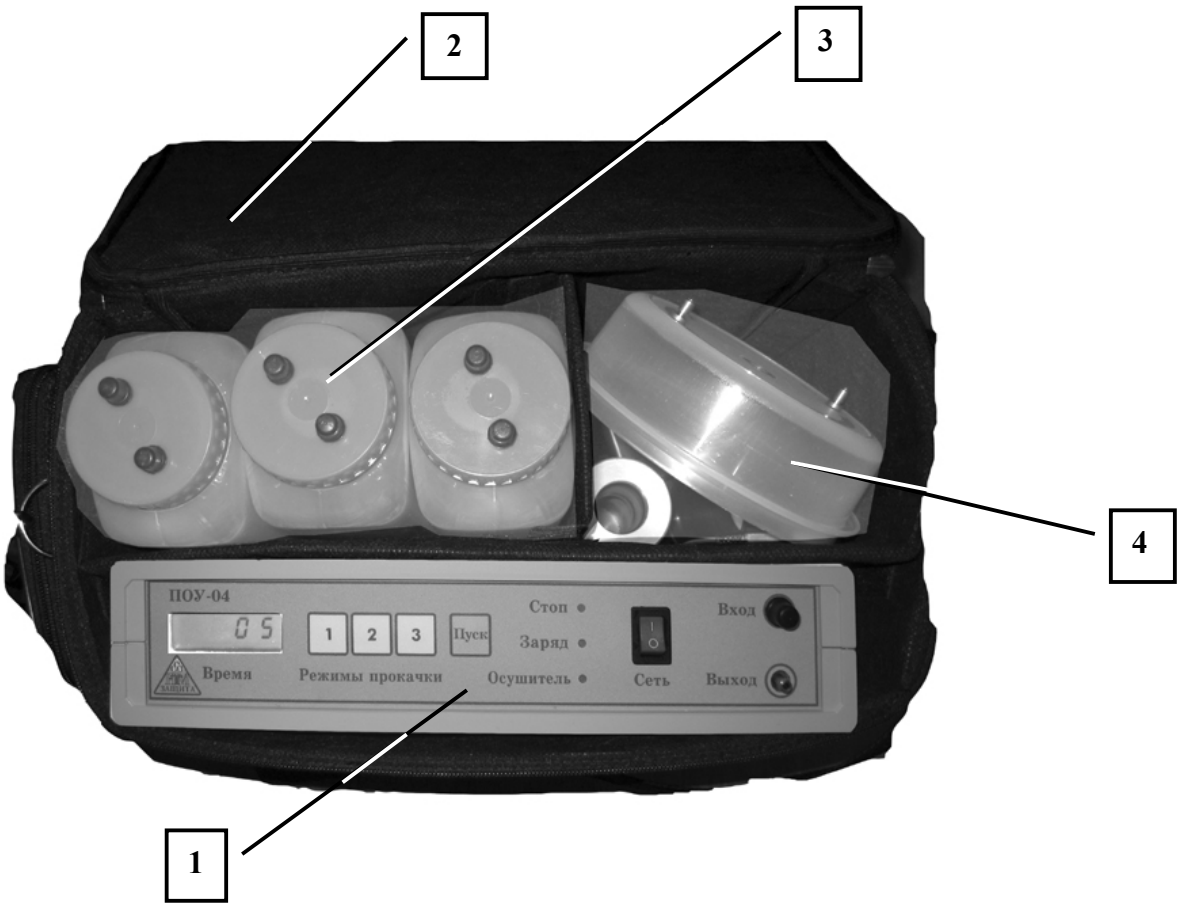


Figure 3. Overview of the sampling device (view from above).

1 – Air-blowing unit with timer POU-04;
2 – Handbag for transportation;
3 – Air samplers;
4 – Accumulation chambers and additional samplers.

Appendix 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 “**П**” 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 “**П**” 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	кМ1.181196.71	1
3.	Air sampler	кМ1.181196.74	3
4.	Soil air sampler	кМ1.181196.76	1
5.	Water sampler	кМ1.181196.75	5
6.	Accumulation chamber-1, ∅148 mm	кМ1.181196.77	1
7.	Accumulation chamber-2, ∅50 mm	кМ1.181196.78	1
8.	Sampling funnel		1
9.	Connecting tube, 80 centimeters	ТУ 64-2-286-79	2
10.	Connecting tube, 40 centimeters	ТУ 64-2-286-79	2
11.	Pipe for connecting POU to RRA	кМ1.181196.72	1
12.	Spare cap for bubbler		1
13.	Spare cap for sampler		1
14.	Handbag for transportation of sampling device	ОСТ 17.839.80	1
15.	Passport POU		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-222 CONCENTRATION IN WATER

1. Place of sampling: …….
2. Date of sampling and measurement: ……
3. Serial number of sampler: ……
4. Sampling complete at, t_1 (hh:mm): .....
5. Measurement started at, t_2 (hh:mm): .....
6. Results of measurement of background radon concentration in the RRA chamber:

№	1	2	3	4	5
Q_b, Bq·m^{-3}					

Background radon concentration Q_b, Bq·m^{-3},.....

7. Results of measurement of radon concentration, Q, Bq·m^{-3},……

№	1	2	3	4	5
Q, Bq·m^{-3}					

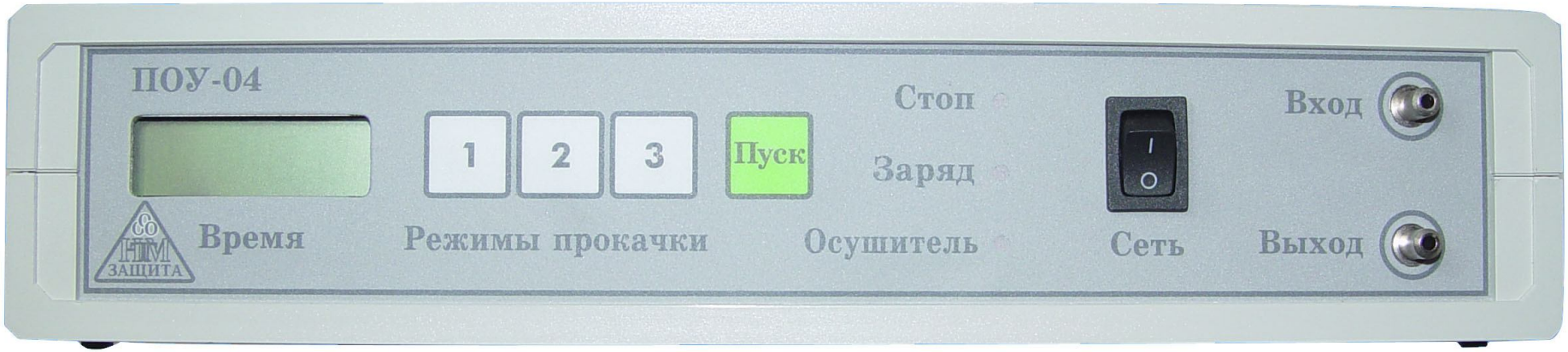
Radon concentration, Q, Bq·m^{-3}, ...

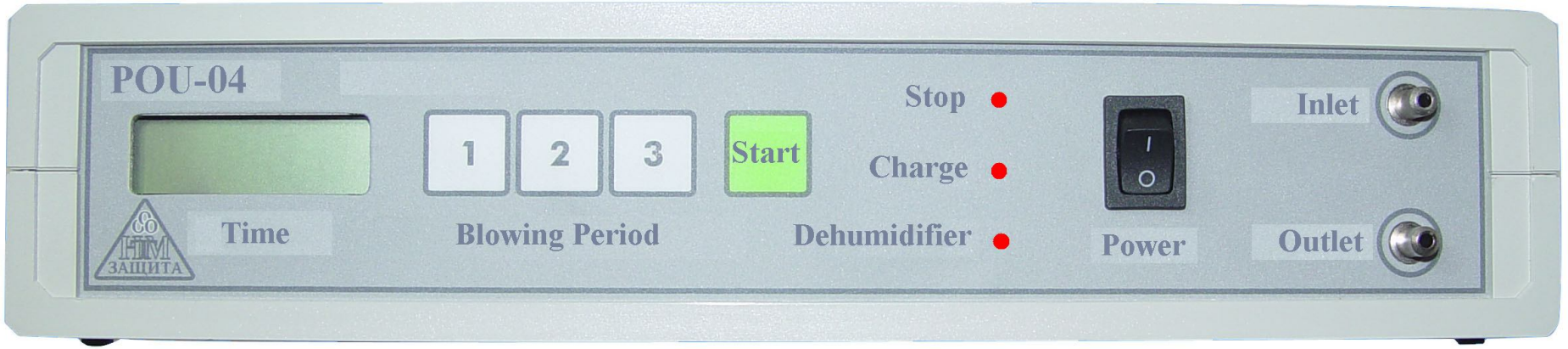
8. Radon-222 concentration in the water sample, Q_s = ...……..±.....…….. Bq·m^{-3}
9. Radon-222 concentration in water, Bq/l ....…..... ± ..……...

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

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

Appendix 5. Controls Designations of Sampling Device POU-04





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