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RECOMMENDATION

State System of Ensuring the
Uniformity of Measurements
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PROCEDURE MANUAL FOR FAST MEASUREMENT
OF ^{222}Rn CONCENTRATION IN THE SOIL AIR
USING THE RRA-TYPE RADON RADIOMETERS

Moscow, 2004

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This Procedure Manual defines the procedure for measurement of radon concentration in the air in the range of 30 ... 30000 Bq·m⁻³.

1. Limits for the measurement uncertainty

1.1. This Procedure Manual ensures the measurement of radon concentration in the soil air with the uncertainty no more than ±40%.

2. Measurement instrumentation and accessories

2.1. 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, Fig.3;

- air sampler (hereafter – sampler) with volume 1.05±0.01 litres – Appendix 1, Fig. 1;

- connecting tubes with the diameter 4 mm and total length 2 m.

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

3. Method of measurement

3.1. Measurement of radon concentration in the air is based on the sampling air into the sampler followed by mixing the sample with the air inside the radon radiometer RRA measuring chamber, measurement of radon concentration of this air mixture and calculation of the radon concentration in the initial air sample. 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 radon concentration in the soil air 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 sampling device POU;
- air sampling.

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

6.2. Air sampling

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

- remove rubber caps from the air outlets of air sampler, of the air-blowing unit and from the air inlet of the RRA;
- connect one of the air outlets of air sampler to the "OUT" (“ВЫХОД”)outlet of the air-blowing unit POU, using tubes included in the sampling device
- Set the duration of sampling to five minutes by pressing the button “2” on the air-blowing unit and then start sampling using the button "RUN" (“ПУСК”).

- After the automatic stop of sampling, hermetically seal the air sampler using the rubber caps. Write the time when sampling was complete (t_1) and the number of air sampler in the record sheet (see Appendix 4).

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 Q_b , $Bq \cdot m^{-3}$:

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

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.

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

Assemble a circuit using accessories included in the sampling device as shown in Figure 3 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" (“ВХОД”) inlet of the air-blowing unit POU;
- connect the outlet "OUT" (“ВЫХОД”) 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" (“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.

7.3. Measurement of radon concentration. Perform at least 5 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.

8. Analysis of measurement results

8.1. Calculate radon concentration in air by the following formula:

$$Q_{Rn} = \left(Q \cdot \left(1 + \frac{V_2}{V_1} \right) - Q_b \cdot \frac{V_2}{V_1} \right) \cdot \exp(\lambda \cdot t), \quad (3)$$

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 liter;

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

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 , $\lambda=1.26 \cdot 10^{-4} \text{ min}^{-1}$;

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

$$\delta Q_{Rn} = \pm 40\% \text{ in the range of } Q_{Rn} \text{ from } 30 \text{ to } 150 \text{ Bq} \cdot \text{m}^{-3};$$

$$\delta Q_{Rn} = \pm 30\% \text{ in the range of } Q_{Rn} \text{ from } 150 \text{ to } 30000 \text{ Bq} \cdot \text{m}^{-3};$$

9. Presentation of measurement results

Use the recommended form for presentation of the measurement results (Appendix 4).

APPENDICIES

Appendix 1

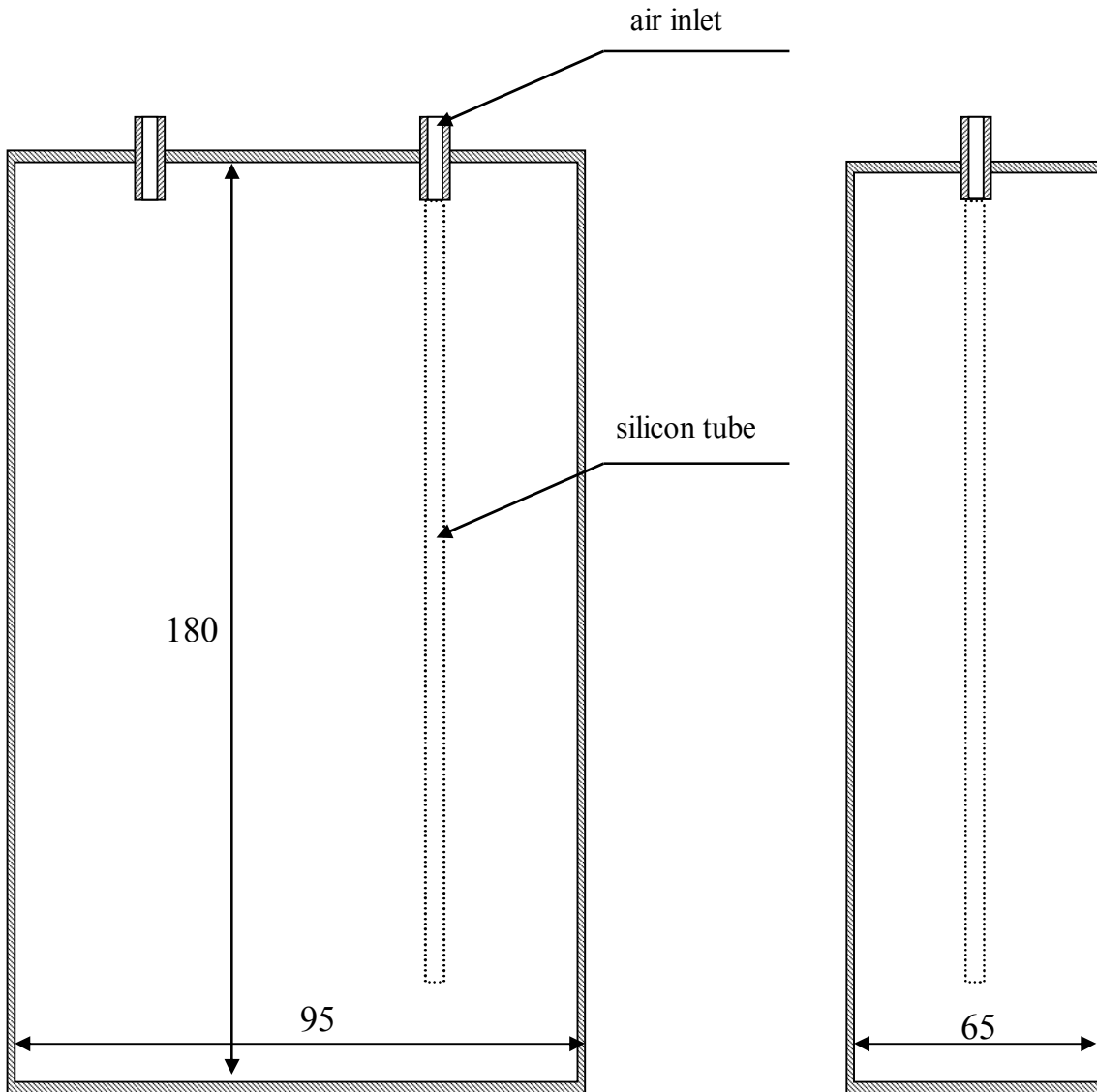


Figure 1. Air sampler

Appendix 1

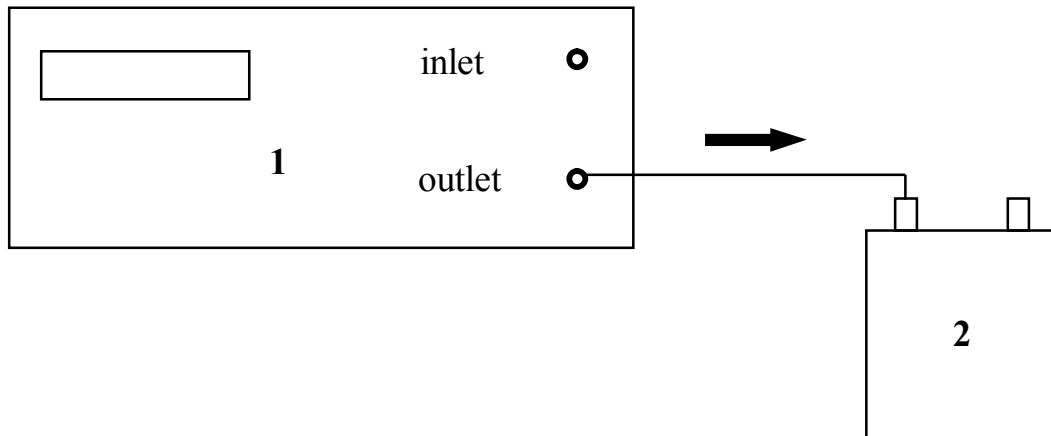


Figure 2. Scheme for air sampling

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

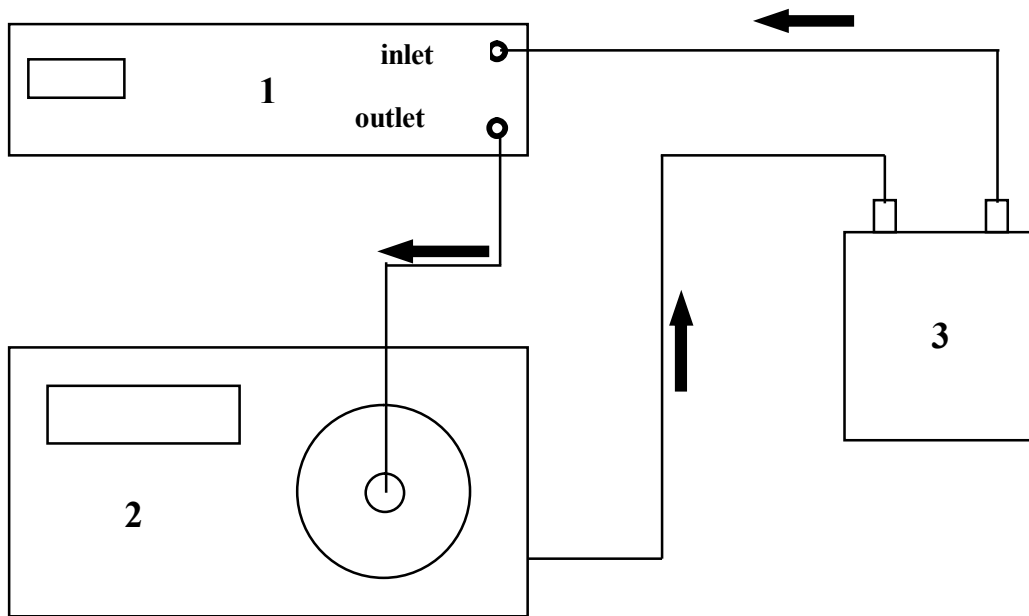


Figure 3. Scheme for measuring the sample

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

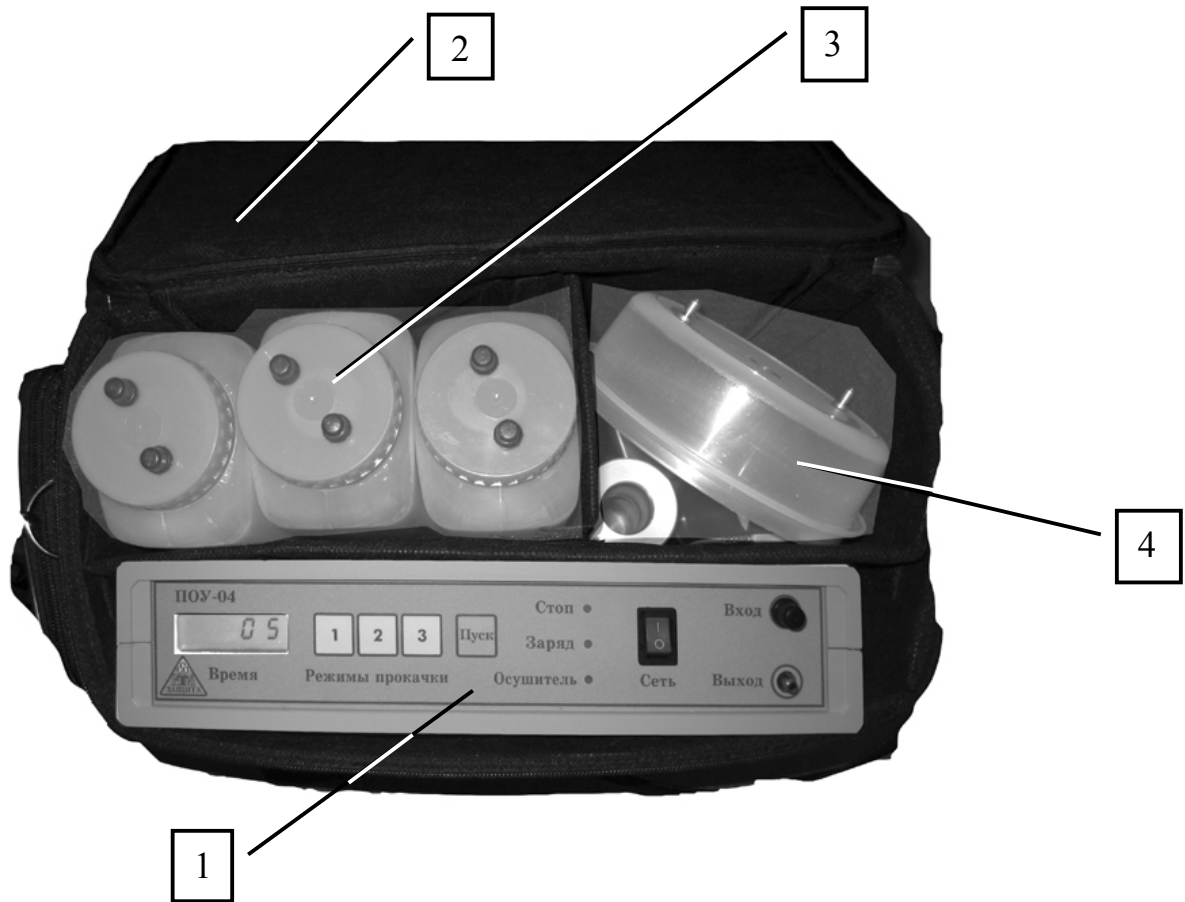


Figure 4. Overview of the sampling device (view from above)

- 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 “**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**".

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 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 AIR

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 |
| $Q_b, \text{Bq}\cdot\text{m}^{-3}$ | | | | | |

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

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

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

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

8. Radon-222 concentration in air, $\text{Bq}\cdot\text{m}^{-3}$ \pm

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

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

Appendix 6. Controls Designations of Sampling Device POU-04

