The track technique in radon measurements (*)(**)

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Summary. — The review considers constructions of the passive track devices for measurements of concentrations of radon, thoron and short-lived radon daughters in air and soil.

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1. – Introduction

The possibility of radon measurements by a track method was noted already in 1965 [1]. The present short (1) review considers constructions of the passive track devices for measurements of concentrations of radon-222, radon-220 and short-lived radon daughters (RD) in air and soil. The review is based mainly on the materials of conferences on nuclear tracks in solids from 1976 to 1996.

2. – Design of measuring devices

In fig. 1 various passive devices for measurements of concentrations of radon isotopes and RD are schematically shown. They are divided into 8 groups.

2.1. *Open ("bare") detectors.* – The variant using an open ("bare") detector for radon measurements (fig. 1, Ia) attracted the attention of many researchers due to its simplicity and cheapness. Numerous attempts were made to apply for this purpose LR-115 and CR-39. However, the response instability caused by the plate-out effect and the uncertainty of the equilibrium factor F under natural conditions make the application of a single open detector CR-39 practically impossible [2]. The effect of

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(**) The authors of this paper have agreed to not receive the proofs for correction.
(1) There were 75 references in the Conference poster but only 27 stayed here because of space limitation.

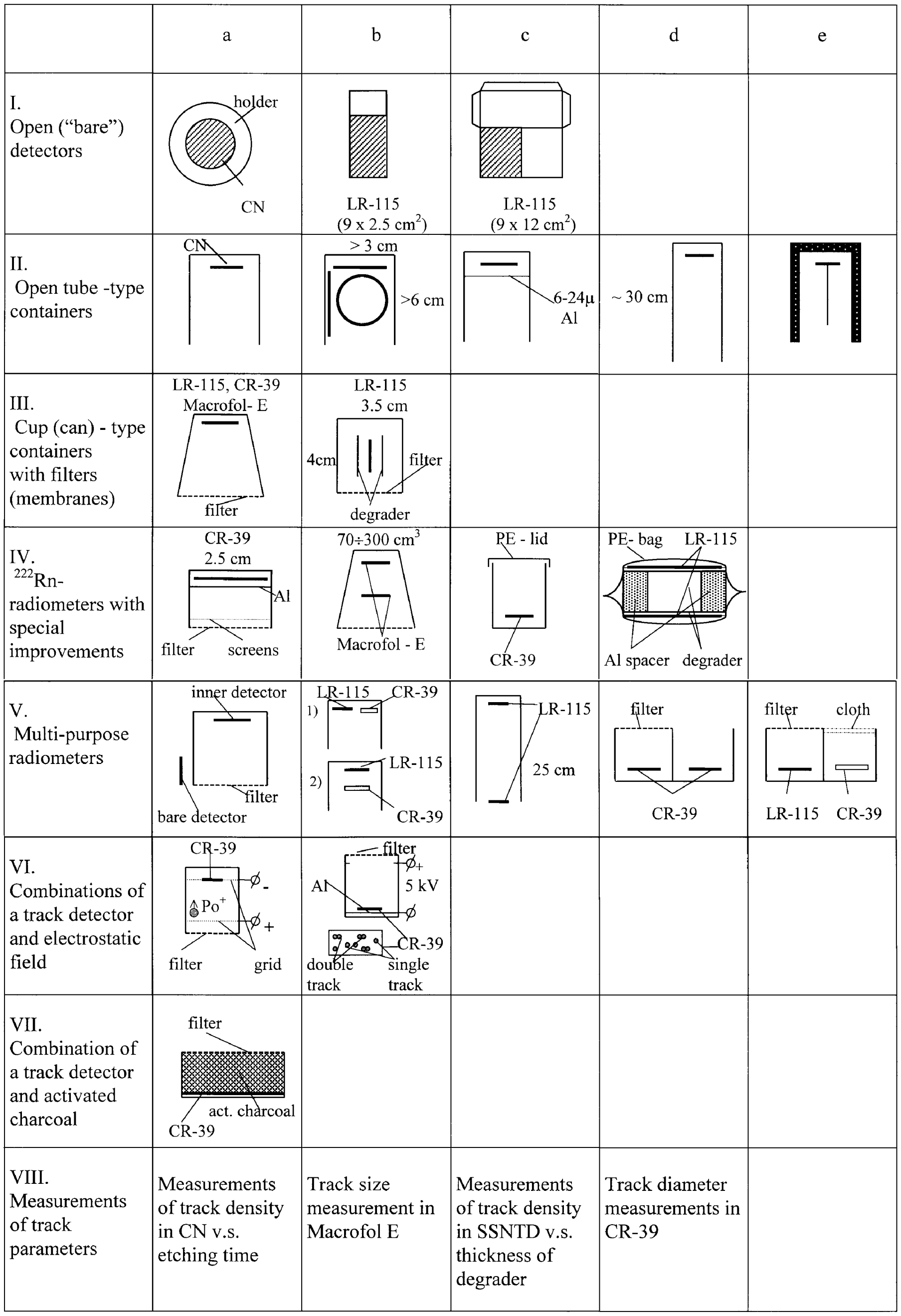

Fig. 1. – Range of devices for radon measurement based on utilization of track detectors.

plate-out is not essential for a NC (nitrate of cellulose)-detector since the RD deposited on the surface of the detector are not registered. Therefore a “bare” detector based on LR-115 can be used as a monitor of radon-222 assuming a certain value of F.

Unfortunately, the existing NC-materials sometimes have significant deviations of the background. In this connection in work [3] a device (fig. 1, Ib) is applied, in which a part of the detector is closed during the exposure time for checking the background. In paper [4] for increasing the sensitivity of the detector it is proposed to use open detectors of large area (fig. 1, Ic) with their subsequent processing by a spark-over method. Thus, despite the rather broad application of open detectors, many researchers note the instability of their response and difficulties in calibration.

2·2. *Open chambers.* – First open cups for selection of a certain volume of air and protection from alpha-radiation of the environment (fig. 1, IIa) were described or patented for the purposes of uranium exploration [5] and dosimetry [6]. The optimisation of the volume and the exposure geometry (fig. 1, IIb) essentially increase the precision of measurements [7]. First such devices had a diameter ∼5–7 cm. However it is possible to reduce the size of the chambers up to 2–3 cm applying absorbers imposed on the NC-detector (fig. 1, IIc) [8]. Choosing the length of the tube enough large (fig. 1 IId), it is possible to decrease by ten-hundred times the registration efficiency of radon-220 which decays during the diffusion along the tube because of its small half-life (55 s) [9]. A chamber with thermostatic walls (fig. 1, IIe) is proposed to decrease the effect of condensation of water vapours [10].

2·3. *Radiometers of radon-*222 *with an inlet filter.* – The filter (membrane) closing the inlet into the chamber protects the detector from exterior aerosols, thoron and moisture, as well as preventing the movement of air inside the chamber [11]. Therefore the chambers are easily calibrated by radon-222, allow the use of CR-39, can be applied for measurements both in the air of premises and in soil. For the past 20 years they became the most popular type of the passive radiometer (fig. 1, IIIa). When LR-115-II is used as a detector in these chambers an absorber before the detector is frequently applied [12] (fig. 1, IIIb).

2·4. *Radiometers of radon-*222 *with improved parameters.* – The construction of a small chamber with conducting walls and a CR-39 detector covered with a conducting grid was proposed [13] to eliminate the electrization effects and to reduce the plate-out effect (fig. 1, IVa). To increase the reliability of measurements, many researchers began to mount 2 identical detectors in the same chamber (fig. 1, IVb). A chamber has been designed [14], in which a polyethylene lid played the role of an inlet filter (fig. 1, IVc). The authors of the paper [15] used in the construction the advantages of a small chamber, two detectors and conducting walls. Moreover, they used a plastic bag as a filter for the whole detecting device (fig. 1, IVd), due to the large area of which it was possible to reach fast penetration of radon inside the chamber.

2·5. *Multipurpose radiometers.* – A CR-39 detector can register isotopes of radon and RD deposited on the surface of the detector. In paper [16] it was proposed to use this property in the 2-detector devices, where one detector was open, and another was placed in the chamber closed with an inlet filter (fig. 1, Va) (it is known as MCB method). By means of the MCB method it is possible to determine the equilibrium factor F. It should be noted, however, that applying a bare detector in the MCB method has a number of disadvantages, inherent in bare detectors (see sect. **1**). It is proposed in [17] to use for the same purpose LR-115 and CR-39 placed in one chamber (fig. 1, VbI). There were developed a 2-detector device [18] for measurement of radon and thoron in soils (fig. 1, Vc) on the basis of a long tube and LR-115 and also a similar 2-detector device for measurement of thoron and a 3-detector device for measurement of radon and RD [10]. Two-chamber devices (fig. 1, Vd, Ve) are also proposed for measurement of F and thoron [19, 20]. The twin chamber (fig. 1, Ve), containing in one of its part a LR-115 detector, is closed with a filter of silicone rubber for only radon registration, while the second part, containing the same detector or CR-39, is protected from aerosols with a cloth filter and registers the sum of radon and thoron. The small size of the chamber ($r = 1.5$ cm) causes identical response both for radon and for thoron [10], which allows to take advantage of calibration of the chamber by radon-222.

2·6. *Combinations of a track detector and electrostatic field.* – A few constructions of radiometers are proposed, in which charged RD are deposited on the surface of the detector by means of an electric field. It is reported that the sensitivity of such devices (fig. 1, VIa) is by one order higher than that of usual ones [21]. In paper [22] a method of determination of the absolute radon concentration by means of electrostatic collection of RD at the surface of a track detector, followed by counting of single and paired (arising from genealogically correlated α-decays of the same nuclei) tracks is described (fig. 1, VIb). A mathematic model for the determination of the radon concentration by an absolute method (without calibration) based on the measured data is developed.

2·7. *Combination of track detector and activated charcoal.* – It was proposed [23] to increase the sensitivity of measuring the concentration of radon by about two orders by a combination of the method of activated charcoal with registration of alpha-radiation of sorbed radon and RD by means of SSNTD (fig. 1, VIIa).

2·8. *Methods and devices for identification of isotopes of radon and radon daughters by means of measurements of track parameters.* – A lot of identification methods were proposed based on measurements of track parameters, depending on the energy of alpha-particles by using the difference in: the development of tracks and properties of annealing [24] (fig. 1, VIIIa); track sizes [25, 26] (fig. 1, VIIIb, d); a number of tracks of alpha-particles passed through absorbers before registration [27] (fig. 1, VIIIc).

3. – Conclusion

In the last 20 years a number of various designs of passive radiometers for the determination of concentration of isotopes of radon and RD have been proposed. Some of them (the open detector, the chamber with an inlet filter) have a lot of modifications and are applied very widely both in geophysical researches, and in dosimetric surveys of premises for radon hazard. At the same time, some developments exist only as proposals. In recent years the number of the reports devoted to multipurpose radiometers, theoretical developments and investigations of the permeability of various filters to radon has increased.

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