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# Technical Procedure Determination of Thoron Indoor Concentration by LR-115 Type II

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**Abstract:** Thoron (Rn-220) is an invisible, odorless radioactive gas and nine times heavier than air. Purpose of project is to set up procedure to determine Rn-220 concentration which has been carried out in laboratory using Solid State Nuclear Track Detector (SSNTD) based passive detector technique. In this study, technical procedure has been applied in Karlsruhe diffusion chamber and LR-115, Type II strippable (Kodak Pathe, France) detector. The results have investigated how LR-115 work for Rn-220 by using Monazite ore to simultaneously measure Rn-222 and Rn-220. To carry out experiment, Karlsruhe diffusion chamber is used to with and without Poly-Ethylene (PE) membrane. Karlsruhe diffusion chamber with PE membrane only detect Rn-222, without PE membrane detect total Rn-222 and Rn-220. Precision evaluation by duplicate measure at 8 cm detector-source distance with relative standard deviation is less than 2.54%. Testing technical procedure, detectors have been sent to National Institute of Radiological Science (NIRS) for Rn-220 calibration exposure. After detectors have been calibration exposure at NIRS, it carried out all the following steps of procedure which set up at laboratory in INST, Vietnam. Finally, calibration factor calculated is 0.21 (tracks·cm$^{-2}$/Bq·m$^{-3}$·h) and constructed curve between integrated Tn-220 concentration and tracks density with factor $R^2 = 0.975$.

**Key words:** LR-115, type-II (SSNTDs), Rn-220, spark counter.

## 1. Introduction

In earlier studies, scientists could be negligible of Rn-220 measurements because Rn-220 has a short half-life and not high exhalation rate. Although a lot of studies on radon have been done for a long time, there are few reports on Rn-220. It was considered that the presence of Rn-220 could be negligible because of its own quantity compared to that of radon. This may be not true from the recent studies resulted in the observation of high Rn-220 in the living environments in various countries and it is now increasingly felt that it may be necessary to have information on Rn-220 levels in the environment for obtaining a complete picture of inhalation dose [1-3]. However, recent studies have shown high Rn-220 levels in living environment. The alpha track method is one of the most common methods employed for long-term measurements of Rn-222 or Rn-220 gas concentrations. Long term profile studies outdoors have shown that the Rn-220 levels vary about 3 orders of magnitude within a range of 3 m [4]. In particular, high Rn-220 concentrations were occasionally observed in some areas of Japan. This fact made it clear that some of passive radon detectors were sensitive to the presence of Rn-220. Tokonami, S. [5] has pointed out that some of alpha track detectors are sensitive to Rn-220. Simultaneous measurements of radon and Rn-220 gas concentrations can then be made using the so-called "twin diffusion chamber method" with one diffusion chamber covered with filter paper (to record signals from Rn-222 and Rn-220) and the other covered with PE membrane (to mainly record the signals from radon) [6-8]. On the other hand, recent surveys have revealed that the exposure to Rn-220 and its progeny can equal or even exceed that of Rn-222 and its progeny in some areas. Therefore, measurements of Rn-220 are indispensable

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for more precise assessment of public exposure to Rn-222 and Rn-220. For long-term measurements of Rn-220, it is still difficult to measure only Rn-220 itself. However, Rn-220 can be evaluated by discriminating it from Rn-222 through the simultaneous measurements of both Rn-220 and Rn-222. At present, several types of Rn-222 and Rn-220 discriminative monitors have been developed.

## 2. Material and Methods

### *2.1 Detector*

In this study, LR-115 type II, strippable plastic track detector films of size (3 cm × 3 cm) are used. The LR-115 detectors described here were manufactured by DOSIRAD, France (LR-115 film, type II, strippable). The detectors consist of an active layer of red cellulose nitrate on a 100 μm clear polyester base substrate (Fig. 1).

### *2.2 Diffusion Chamber*

The diffusion chambers used in the present study, commonly named as the "Karlsruhe" diffusion chambers are conical, with inner base radius of 2.35 cm, top radius of 2.35 cm and height of 4.8 cm. There are holes in the brim of the chamber which allow air to flow in and out of the chamber. Twin diffusion chambers consist of two diffusion chambers. One is covered by a filter paper which allows both radon and thoron gas to diffuse inside the chamber and the other is covered by PE membranes which can exclude most of the thoron gas due to the long diffusion time needed to go through the PE membranes and the short half-life of thoron gas (55 s). Since radon progeny are particles in nature, they cannot pass through the filter paper or PE, while radon, being a gas, is free to diffuse into the chambers. An LR-115 detector is placed on the inner bottom of each chamber. Radon gas, thoron gas and their progeny formed by decays inside the chambers irradiate the LR-115 detectors and form damaged trails (Fig. 2).

### *2.3 Spark Counter*

The Spark Counter technique is applicable to plastic track detectors, which provide a convenient, economical and fast method for track counting. Spark Counter system consists of two electrodes made of brass, each has 1 $cm^2$ area and an electrical circuit as shown in Fig. 3. This technique was developed by Cross W. G., and Tommasino, L. [9], and is discussed in detail by several researchers. The etched sensitive layer of LR-115 detector acts as an insulating material is placed between two electrodes of the Spark Counter forming a capacitor and covered with an aluminized plastic foil (a thin layer of aluminum evaporated onto mylar backing). The aluminized side of the plastic foil is in contact with the thin detector. High voltage is applied which takes place an electrical discharge through a track hole. The voltage pulse produced can easily counted electronically by a scalar. The pre-spark voltage is 900 V and spark voltage is 500 V in this experiment. The measured track density was converted into Rn-220 concentrations using calibration factor.

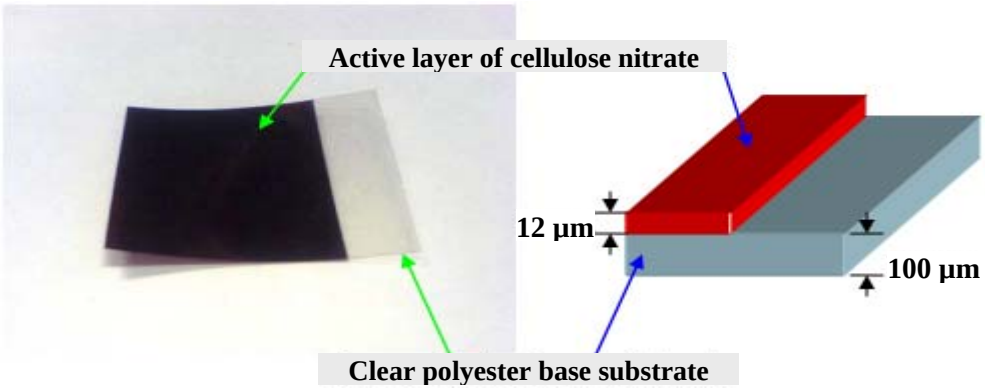


**Fig. 1 Photo of the LR-115 detector (3 cm × 3 cm).**

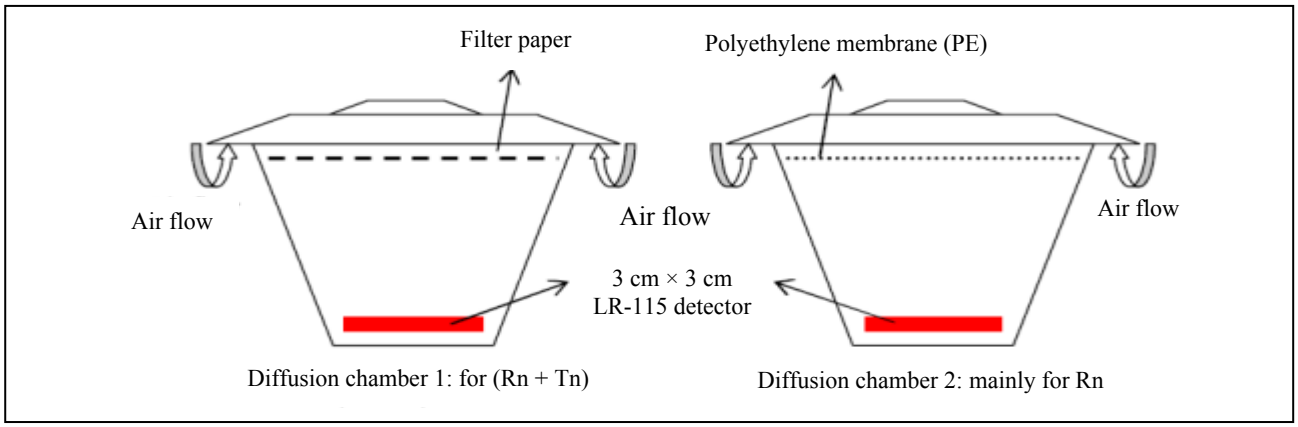


**Fig. 2 The twins diffusion chamber method for measuring Rn-222 and Rn-220 gas concentrations.**


**Fig. 3 Spark Counter system.**

*2.4 Procedures*

2.4.1 Preparation before Measurements

1. The LR-115 detectors were normally stored in a preserved condition, like protected by the plastic bag and kept in a refrigerator in order to prevent exposure to radon gas or progeny and high temperatures;

2. Forceps were always used to handle the detectors such as scissors, nylon bags, filter paper, PE, etc.;

3. A small slab of the LR-115 SSNTD, with a size of 3 cm × 3 cm stored in the plastic bags;

2.4.2 For Irradiation

4. At the selected site for monitoring, used two diffusion chambers and two 3 cm × 3 cm chambers. Detectors was placed onto the bottom of the diffusion chamber by the forceps;

5. The alpha track material was irradiated by the emissions from the radon and the progeny produced inside the diffusion chamber, leaving sub microscopic damages along the track of each alpha particle;

6. The initial time was recorded immediately;

7. After exposure, the SSNTDs were removed from the diffusion chambers and were carefully stored in plastic bags;

8. The final time of the actual exposure were recorded accurately;

9. The detectors were brought back to the laboratory and kept in the refrigerator;

2.4.3 For Etching

10. The slab was etched in 2.5 mol aqueous solution of NaOH (prepared by adding 300 mL distilled water to 30 g of NaOH);

11. The solution was maintained at 60 °C by a water bath. The water bath was sheltered by a plastic cover to reduce water loss. The solution was kept stirring for 1.5 hours;

12. The region of damage around each track was

extended by the etchant so that the tracks became visible as small holes on the surface of the detector;

13. After 1.5 hours, chemical etching the films are rinsed in running cold water for 30 minutes and dried and put back into a plastic bag for protection;

2.4.4 For Track Density Counting

14. The number of tracks was determined by counting them with spark counter with the number of tracks per unit area (minus the background) being proportional to the number of alpha particles striking the detector surface during exposure;

15. Determine average thoron concentration follow Eq. (1):

$$C_T = \frac{24*(\rho_T - \rho_B)}{C_f * H} \quad (1)$$

Where, $C_T$ is concentration of the Rn-220 indoor gas (Bq/m$^3$), $C_f$ is Calibration factor ($C_f$) Rn-220 gas (tracks·cm$^{-2}$/Bq·m$^{-3}$·h), $\rho_T$ is density tracks per unit area of exposed SSNTD (tracks·cm$^{-2}$), $\rho_B$ is density tracks per unit area of background SSNTD (tracks·cm$^{-2}$) and H is exposure time (hours).

## 3. Results and Discussion

### *3.1 Precision Evaluation*

Three exposed detectors and three background detectors were analyzed with same preparation, exposure, etching and counter processing. The results shown that average density value obtained was 31.66 ± 2.22 tracks·cm$^{-2}$ with relative standard deviation less than 2.54%.

### *3.2 Etching Time Evaluation*

Five exposed detectors and two background detectors were analyzed with same preparation, exposure and counter processing but different etching time. Region of plateau etching time ranges from 85 minutes to 100 minutes. Finally, etching time was selected 90 minutes. Fig. 4 shows relationship between tracks density (tracks·cm$^{-2}$) and etching time (minutes).

### *3.3 Testing Technical Procedure*

The authors have sent detectors to NIRS, Japan to Rn-220 calibration exposure as shown in Fig. 5. After detectors have been calibration exposure at NIRS, it carried out all the following steps of procedure which set up at laboratory in INST, Vietnam. Finally, standard curve constructed show that relationship between integrated Tn-220 concentration and tracks density is with factor being $R^2 = 0.975$ (Fig. 6).

### *3.4 Calculate Calibration Factor*

Calibration factor is the quantity, which was used

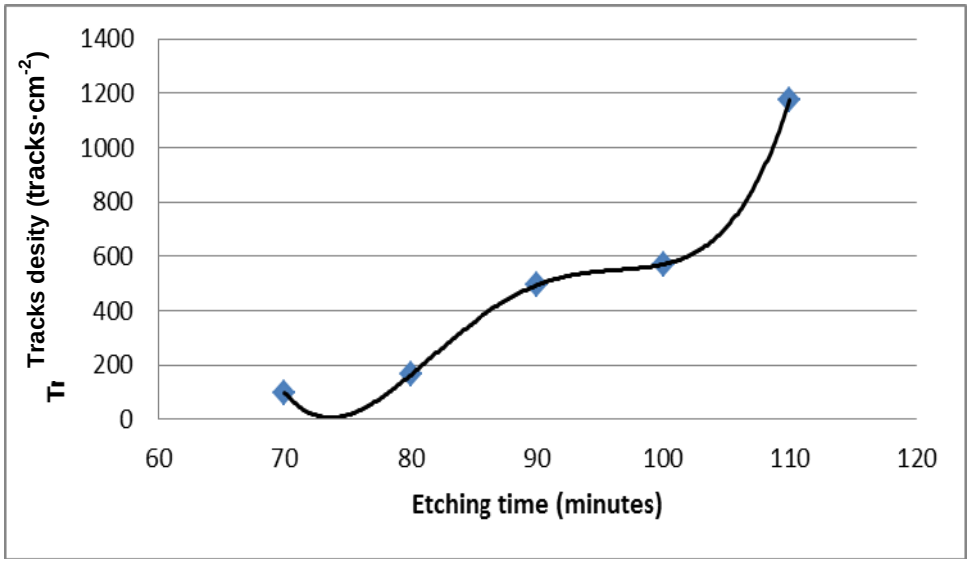


**Fig. 4 Relationship between tracks density (tracks·cm$^{-2}$) and etching time (minutes).**

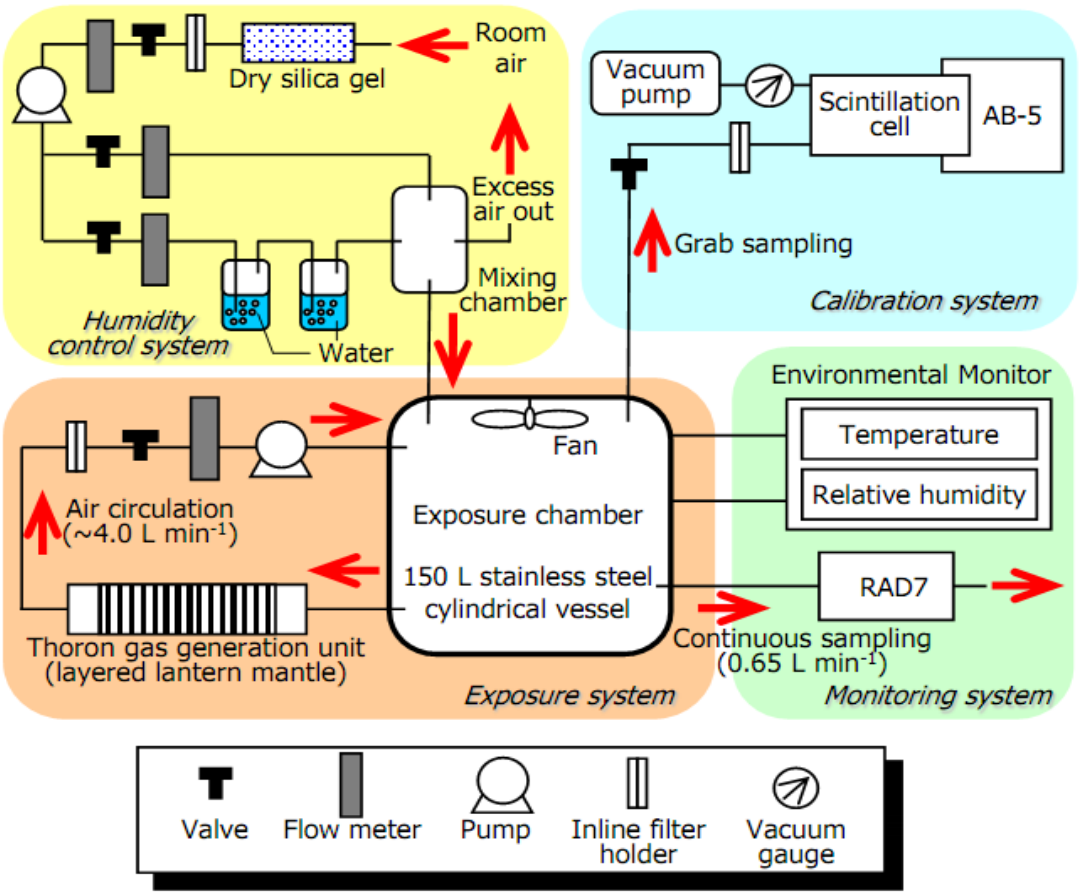


**Fig. 5 Thoron calibration chamber system in NIRS, Japan.**

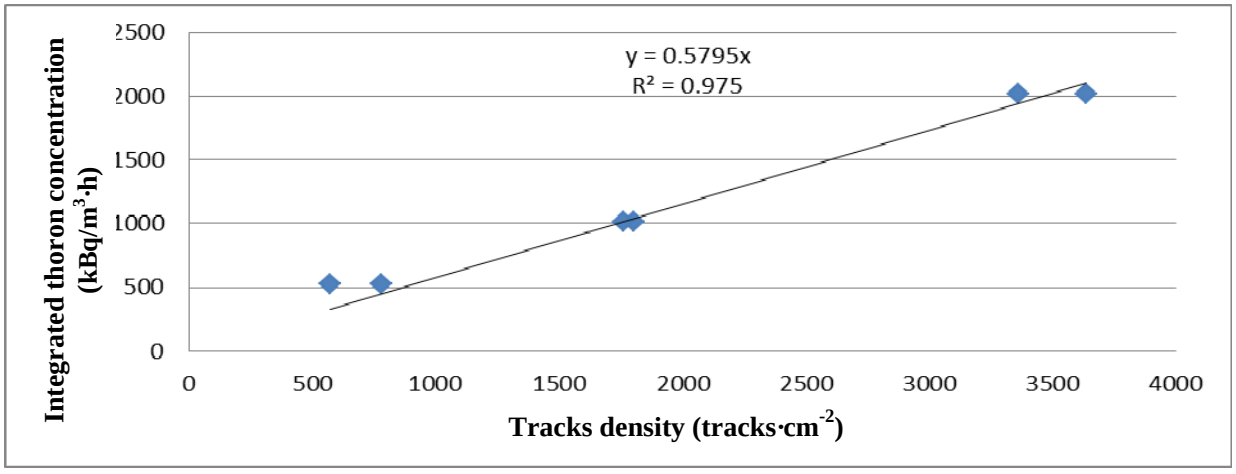


**Fig. 6 Relationship between integrated thoron concentration (kBq/m$^3$·h) and tracks density (tracks·cm$^{-2}$).**

for converting the observed track density rates to the activity concentration of the species of interest. If D (tracks·cm$^{-2}$) is taken as track density observed on a detector due to exposure in a given mode to a concentration C (Bq/m$^3$) of a given species for a time t(h) and $D_b$ (tracks·cm$^{-2}$) is taken as track density observed on a detector without exposure, then in general, the authors take K = (D-Db)/C × t (1), where K defined as calibration factor. Detectors have been sent to NIRS, Japan for Rn-220 calibration exposure. After detectors have been calibration exposure at NIRS, it carried out all the following steps of

procedure which set up at laboratory in INST, Vietnam. Finally, calibration factor K calculated is 0.21 tracks·cm$^{-2}$/Bq·m$^{-3}$·h.

## 4. Conclusion

Set up procedure to determine Rn-220 concentration has been carried out in laboratory using Solid State Nuclear Track Detector based passive detector technique. Precision evaluation with relative standard deviation is less than 2.54%. Calibration factor calculated is 0.21 tracks·cm$^{-2}$/Bq·m$^{-3}$·h from detectors which were Rn-220 calibration exposed in NIRS and constructed curve show that relationship between integrated thoron concentration (kBq/m$^3$·h) and tracks density (tracks·cm$^{-2}$) with $R^2$ equal to 0.975.

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