# A PASSIVE DUAL-FILM ALPHA-TRACK DETECTOR FOR MEASURING IN TWO POSITIONS

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**Abstract**

A passive alpha-track detector, which offers the possibility to measure in two positions, has been developed. The detector has two CR-39 films and is possible to turn so that just one of the films is exposed in each position. With this detector, it is possible to measure during both working and non-working hours in workplaces and schools, or to measure personal exposure both at work and at home. The detector and its technical specifications are presented. Some countries have measurement protocols for attempting to evaluate the differences between radon concentrations during working and non-working time. How this detector could be used in relation with these measurement protocols is discussed.

## Introduction

The two-position radon detector Duotrak (patent application SE1550891-4) is a detector which can have two alpha-track films inside, as shown in Figure (1). The detector can be turned so that only one of the films is exposed at a time. Inside the top part of the detector, a cover shield with an opening of 1.5x1.5 cm is mounted (Figure (2)). This shield will cover the shielded film from most of alpha-decay inside the detector. When the detector is turned $180^{o}$ between the ON and OFF positions as shown in Figure (3), the film which is exposed to alpha-decay will change.

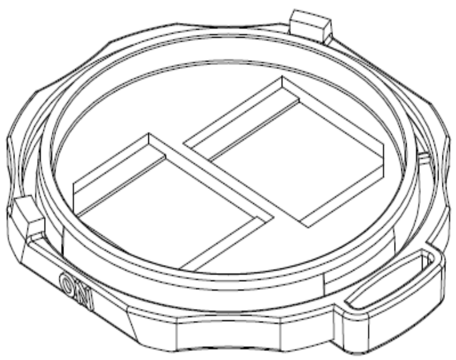

Figure (1): Bottom part of the detector which has two alpha-track film location areas.
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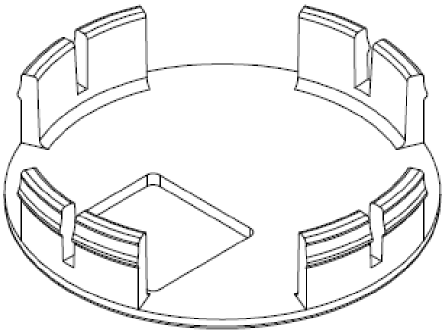

Figure (2): Cover shield with opening in the top of the detector.

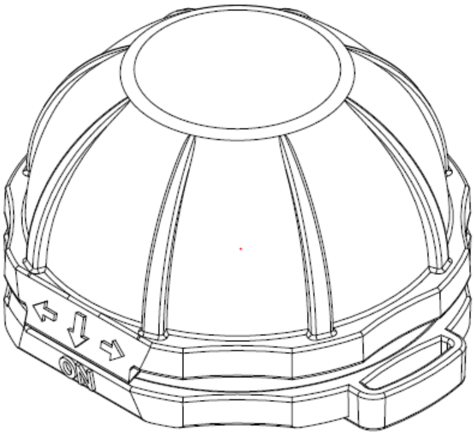


Figure (3): The detector can be turned 180$^{o}$ between the ON and OFF positions. The ON position exposes one CR-39 (e.g., time period of interest) and the OFF position exposes the other CR-39 film (e.g., secondary time period of interest).

The detector can be used as a normal standard detector. In this application, alpha-decay exposure to a single CR-39 film can be turned on or off, in particular to stop post-measurement exposure in cases when the detectors cannot be returned to the analysis laboratory at once.

The detector can also be used to measure in two position which could be used for measuring radon concentration in two different situations where the radon exposure can differ significantly. This could be a situation in a school or a workplace where the radon concentration can differ significantly between working and non-working hours. In this application, detector exposure to alpha decay that is different for each CR-39 film can be analyzed to achieve a measurement of each different condition and combined to achieve a measurement of the entire test duration. For this usage, a factor between ON-level and total-level is also calculated with a corresponding uncertainty.

## Methods

*Technical specifications and calculations*

Technical specifications of the Duotrak detector are:
Height: 4.0 cm, Diameter: 6.5 cm
Measurement range: 10-30,000 pCi*days/l
Detector sensitivity ((tracks/cm$^2$)/(pCi*days/l)): 3.7
Typical background: 5 pCi*days/l, Standard deviation in background: 2 pCi*days/l

Lowest Level of Detection (LLD): 10 pCi*days/l
Holder antistatic measures: Conducting holder

The Lowest Level of Detection (LLD) should according to the U.S. Environmental Protection Agency EPA (EPA, 1997) be calculated as LLD = $4.65*\sigma_b$ , where $\sigma_b$ is the standard deviation in the background. From the background measurement of about 100 film sheets, the observed LLDs were 8.0 ± 2.8 pCi*days/l. In situations where there is a large difference between the exposure in the OFF and ON positions, the additional exposure from the decay within the small gap between the cover shield and the alpha-track film will increase the LLD. 50 detectors set in the ON position and 50 detectors set in the OFF position were exposed with 680 pCi*days/l in the radon chamber of the Swedish Radiation Safety Authority (SSM). From this calibration exposure, it was found that on average 1.7% of the given exposure was shown as an additional exposure on the covered film. The uncertainty in this number which mainly is due to variation in film thickness has been estimated to be 30%.

When the detector is used as a two position detector, the factor (ON/Total) between the average radon concentration in the ON position and the average radon concentration during total measurement period (ON+OFF) can also be calculated.

## Results

*Detector performance test*

A test of the detector was performed in a typical location, such in schools and workplaces where a mechanical ventilation system is turned on and off. In such situations, the radon concentration can differ significantly depending on when the ventilation system is on or off. The detectors were tested by Radonor[1] in Norway in a room where the ventilation could be turned on and off similar to normal working hours conditions (ventilation on 8 hours during week days). The radon concentrations were monitored with an Alphaguard instrument. For each of the five different exposures eight Duotrak detectors were used. The main purpose of the exposure was to evaluate the ON/Total factor measured with the Duotrak detector. The result from the test is shown in the table of results in Figure (4). The spreading of the results from the Duotrak detectors in the table is shown with one standard deviation. As can be seen in result table, the difference between exposure when the ventilation was on or off was very large. The radon concentration when the ventilation was on was usually about 3 pCi/l and when it was off about 20 pCi/l.

In the second exposure, the detectors where left in the OFF exposure a little bit longer than planned giving an OFF exposure which was 28 times higher than the ON exposure. In such a situation, the subtraction of the addition exposure on the ON-film during the OFF-exposure will have significance. For this actual exposure, this contribution will be 0.017*271 pCi*days/l = 4.6 pCi*days/l, where the 1.7% contribution factor was determined in the previously described calibration. This contribution is subtracted but the uncertainty in this estimation will increase the uncertainty in calculated ON/Total factor which also can be seen in the results. The ON-exposure in the first exposure is below the LLD of the detectors. For the other exposures, the measured ON/Total factor agrees very well with the results from the Alphaguard instrument.

*(1) RadonorAS, Postboks 2, NO-2712 BRANDBU, Norway*

| Exposure ON - Alphaguard (pCi*days/l) | Exposure OFF Alphaguard (pCi*days/l) | ON/Total-factor Alphaguard | Exposure ON Duotrak (pCi*days/l) | ON/Total-factor Duotrak |
|---|---|---|---|---|
| 5.7 (<LLD) | 146 | 0.16 | 2.7 ± 3.8 | 0.08 ± 0.11 |
| 9.8 | 271 | 0.20 | 10.6 ± 3.8 | 0.21 ± 0.07 |
| 16.7 | 355 | 0.17 | 19.1 ± 1.8 | 0.18 ± 0.02 |
| 22.3 | 465 | 0.17 | 23.5 ± 4.4 | 0.18 ± 0.03 |
| 32.1 | 851 | 0.13 | 32.7 ± 4.0 | 0.14 ± 0.02 |

Figure (4): Result table from a test of the Duotrak detector

*Usage of the detector*

In cold climates, buildings are often configured with mechanical ventilation systems. In order to save energy, the ventilation is often turned off when the building is unoccupied which can often increase radon concentrations in the building. Therefore, a measured long-term average radon concentration could overestimate the radon concentrations when the building is occupied.

In the guide (Health Canada, 2008) for radon measurements in public buildings in Canada, it is stated that the radon concentrations during school hours can be estimated by multiplying the long-term average with an ON/Total factor measured in a short-term measurement with a continuous radon monitor (CRM). A similar measurement protocol is used in Norway for measurement in schools and kindergartens (Statens strålevern, 2015). In cases where CRMs could not be used, the Duotrak detector could be an alternative for measuring the ON/Total factor. However, the measurement time must at least be long enough to give an exposure in both the ON and OFF positions which are above the LLD. Figure (5) show the minimum measurement time needed to reach the LLD for an exposure of 10 pCi*days/l. With about 40 working hours per week, at least 2-3 weeks of measurement is needed to give a result that clearly estimates concentrations below common reference levels.

| LLD (pCi/l) | Measured hours needed to reach the LLD for exposure | Measured weeks needed assuming 40 hours in ON-position per week |
|---|---|---|
| 1.0 | 240 | 6 |
| 2.7 (100 Bq/m$^3$) | 89 | 2.2 |
| 4.0 | 60 | 1.5 |

Figure (5): Needed measurement time to reach the LLD

The detector could also be good alternative for passive short-term measurement in schools and workplaces by measuring for two work-week duration with the detector turned off only during the weekend between the work-weeks.

Personal radon monitoring is usually performed by storing the personal radon detectors in a controlled low-radon concentration environment. However, for workers who do not have an obvious storage room, the detector could be a good alternative as a personal radon monitor where the personal exposure during working hours is measured with the detector in the ON position.

## Conclusions

With a passive alpha-track detector, which offers the possibility to measure in two positions with two different CR-39 films, it is possible to measure during both working and non-working hours in workplaces and schools, or to measure personal exposure both at work and at home. The preformed tests show good agreement between the results from CRMs when the exposures are above the LLD in both positions of the dual-film detector.

## References

EPA 1997, Guidance on Quality Assurance, EPA 402-R-95-012

Health Canada, 2008, Guide for Radon Measurements in Public Building, ISBN: 978-1-100-10183-5.

Statens strålevern (Norwegian Radiation Protection Authority), 2015, Måleprosedyre for radon i skoler og barnehager (Measurement procedure for radon in schools and kindergartens)