ISSN 2348 – 8034
Impact Factor3.155

GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

PERFORMANCE EVALUATION OFION CHAMBER-TYPE RADON COUNTERS

Gyu-Sik Kim[*1] ,Tae-Gue Oh[1], Jae-Hak Kim[1], and Ki-Nam Kim[1]
[*1]Department of Electrical Engineering, The Univ. of Seoul, Seoul, Korea

ABSTRACT

Radon is a natural, inert, invisible, odorless and chemically inactive radioactive gas emitted from the earth. It is produced by the decay of uranium ore, such as radium, actinium, or thorium.Because inhaling radon and its radioactive decay products causes irradiation of lung tissue, prolonged exposure to high concentrations of radon significantly increases the risk of developing cancer. Various types of equipment and components have been proposed to date for radon detection.In this paper, in order to investigate the performance of the ion chamber-type radon counter : RD200, the radon measurement system : RAD7 was used. Through some experimental studies, we found that the radon data of two RD200s tracked those of RAD7 very closely and RD200 had some advantages over PIN photodiode-type radon counter : Siren PRO3 for excellent sensitivity and prompt display of the radon concentration.

Keywords: *radon, radon counter, ion chamber-type, RAD7, RD200, radon concentration*

I. INTRODUCTION

Radon is a natural, inert, invisible, odorless and chemically inactive radioactive gas emitted from the earth. It is produced by the decay of uranium ore, such as radium, actinium, or thorium. Because it is inert and does not chemically bond to elements, it is released from soil into the atmosphere. Radon is emitted almost everywhere on earth, but some geographical regions have higher concentrations than others. When radon decays, it released alpha particles with energy of 5.5 MeV. Because inhaling radon and its radioactive decay products causes irradiation of lung tissue, prolonged exposure to high concentrations of radon significantly increases the risk of developing cancer. It has been reported that the US. Environmental Protection Agency estimates exposure to naturally occurring radon leads to 21,000 lung cancer deaths nationwide each year, making radon the nation's primary environmental health threat and second only to cigarette smoking as a cause of fatal lung cancer.

Various types of equipment and components have been proposed to date for radon detection. In [1], highly sensitive, electrostatic collection chambers have been developed for low-level radon measurements using CR-39 plastic track detectors. In [2], a radon detector employs an electrically charged pressed, porous metal filter that allows radon gas diffusion, while blocking ambient light, so that it readily traps both attached and unattached Po-214 and Po-2l8 ions, that may be present in gas passing through the filter, the filter being charged positively relative to an unbiased PN junction of a photo diode detector within a detection chamber. In [3], a passive direct-reading radon monitor utilizing a custom α particle detecting MOS integrated circuit and electrostatic radon progeny concentrator has been designed. In [4], a silicon PIN photodiode was designed and fabricated in consideration of low-leakage-current and high-bias-voltage application. In [5], a fast-responding passive radon detector using electrostatic concentration and enhanced readout electronics has been designed. In [6], it is shown that BJT detectors can be efficiently used for a-particle detectionand consequently for radon detection. Moreover, analysis of theperformance of detectors under different temperatures has shownthat the detector can be efficiently used in a rather wide rangeof temperaturesconfirming that the detector can beused both in indoor and outdoor applications.In [7], the system is developed which monitors the radon level, using a PIN diode for detecting the radon particles and a data processing module with Wi-Fi communication capabilities for the transmission and management of measurement results. In [8], an electrostatic concentrator constructed by metalizing a plastic funnel is used to focus charged radon progeny onto the exposed surface of an optical image sensor from a webcam. Alpha particles emitted by the collected progeny strike the image sensor, generating sufficient charge to completely saturate one or more pixels.

In this paper, in order to investigate the performance of the ion chamber-type radon counter : RD200, the radon measurement system : RAD7 was used. Through some experimental studies, we found that the radon data of two

RD200s tracked those of RAD7 very closely and RD200 had some advantages over PIN photodiode-type radon counter : Siren PRO3 for excellent sensitivity and prompt display of the radon concentration.

II. ION CHAMBER-TYPE RADON COUNTER : RD200

The RD200M is the new innovative fastest radon sensor, which has the highest sensitivity, 30 cph/pCi/l on the market today. This sensor is optimized for the IAQ monitor, air purifier, radon detector and auto ventilation system. A breakthrough in FTLAB's patent technology which received a New ExcellentTechnology certification in 2015, the RD200M uses a dual probe structured pulsed ionization chamber and a special high impedance differential amplifier circuit to offer the highest signal to noise ratio. It effectively detects the secondary charges which were generated from collisions with air and **α**-particle caused by radon or radon's progeny. The accuracy and precision of the RD200M are±10% at 10pCi/l, which has been tested by the international standard Radon Testing Laboratory in KTL. Each sensor has been individually calibrated by equipments which are already calibrated to traceable international standards. Fig. 1 shows the ion chamber-type radon counter : RD200, made by FTLAB, Korea. Table 1 shows the specifications of RD200.

Figure:

Figure 1.Ion chamber-type radon counter : RD200

Table:

Table 1.Specs.of RD200

Descriptions	RD200 is a real time smart radon detector for home owner wh ich has the high sensitivity 0.5cpm/pCi/L, about 20~30 times more than conve ntional radon detector by FTLAB's high stable circuit technol ogy
Type	pulsed ion chamber 200cc
First reliable data ou t	< 60min
Data interval	10min update (60min moving average)
Sensitivity	0.5cpm/pCi/L at 10pCi/L (30cph/pCi/L)
Operating range	10~40℃, RH<90%
Range	0.1~99.99pCi/L
Precision	<10% at 10pCi/L
Accuracy	<10% (min. error <0.5pCi/L
Power	DC 12 0.1V, 65mA (12V DC adapter)
Size	Φ80(mm) x 120(mm), 240g
Data coomunication	Bluetooth LE (Android/iOS)
Data log	max 1year(1h step)

Display	0.96 inch OLED

III. RADON MEASUREMENT SYSTEM : RAD7

The RAD7 is a highly versatile instrument that can form the basis of a comprehensive radon measurementsystem. It may be used in many different modes for different purposes.In this paper, the performance of an ion chamber-type radon counter is evaluated using the accurate and expensive measurementsystem :RAD7, anelectronic radon detector manufacturedby Durridge Company, USA. The RAD7 radonmonitor apparatus uses an air pump and a solidstate alpha detector which consists of a semiconductormaterial that convertsalpha radiation directly to an electrical signal.It has desiccant ($CaSO_4$) tubes and inlet filters(pore size 1 μm) that block fine dust particles andradon daughters from entering the radon testchamber. The RAD7's internal sample cell is a 0.7litter hemisphere, coated on the inside with an electricalconductor. The center of the hemisphere isoccupied by a silicon alpha detector. One importantbenefit of solid state devices is ruggedness.Another advantage is the ability to immediatelydifferentiate radon from thoron by the energy ofthe alpha particle released. The RAD7 has alsothe ability to tell the difference between the newradon daughters and the old radon daughters leftfrom previous tests. The equipment is portableand battery operated, and the measurementis fast.Fig. 2 shows the radon measurement system : RAD7. Table 2and Table 3show the specifications of RAD7.

Figure:

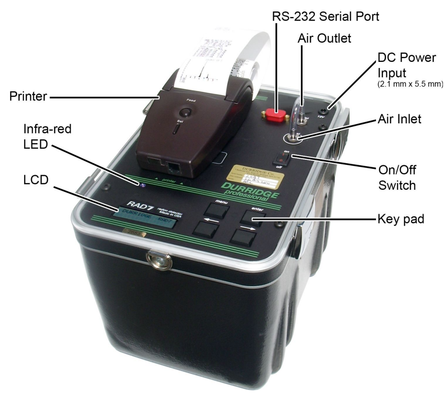

Figure 2. Radon measurement system : RAD7

Table:

Table 2.Functional specs. of RAD7

Modes of Operation	SNIFF Rapid response and rapid recovery radon measurement THORON Radon and thoron measured simultaneously and independently NORMAL High sensitivity AUTO Automatic switch from SNIFF to NORMAL after three hours run GRAB Analysis of grab samples WAT Automatic analysis of water samples with RAD H2O accessory
Measurements	Radon in air with Sniff protocol for quick, spot reading Thoron protocol for searching for radon entry points Radon in air 1-day, 2-day or weeks protocol for long term measurement Radon in water batch samples with RAD H2O and Big Bottle RAD H2O Continuous radon in water with RAD AQUA and Radon-in-Water Probe Radon in soil gas with Soil Gas Probe and Active DRYSTIK Radon emission from soil and hard surfaces with surface emission chamber

	Bulk radon emission from bulk materials and objects
Data Storage	1,000 records, each with 23 fields of data Log of printer output also stored
Sample Pumping	Built-in pump draws sample from chosen sampling point Flow rate typically 800mL/min
Print Output	Short, medium or long format data printed after each cycle Run summary printed at end of run, including averages and spectrum
PC Connectivity	RS232 serial port, full remote control implemented in CAPTURE Software
Audio Output	GEIGER Tone beeps for radon and thoron counts CHIME Chime only at the end of each cycle, otherwise silent OFF No sound
Tamper Resistance	TEST LOCK command locks keypad to secure against tampering

Table:

Table 3.Technical specs.of RAD7

Principle of Operation	Electrostatic collection of alpha-emitters with spectral analysis Passivated Ion-implanted Planar Silicon detector SNIFF mode counts polonium-218 decays NORMAL mode counts both polonium 218 and polonium 214 decays
Built-In Air Pump	Nominal 1 liter/minute flow rate Inlet and outlet Luer connectors
Connectivity	RS-232 port up to 19,200 baud rate USB adaptor is included with every RAD7
Measurement Accuracy	5% absolute accuracy, 0% - 100% RH
Nominal Sensitivity	SNIFF mode, 0.25 cpm/(pCi/L), 0.0067 cpm/(Bq/m^3) NORMAL mode, 0.5 cpm/(pCi/L), 0.013 cpm/(Bq/m^3)
Radon Concentration Range	0.1 - 20,000 pCi/L (4.0 - 750,000 Bq/m^3)
Intrinsic Background	0.005 pCi/L (0.2 Bq/m^3) or less, for the life of the instrument
Recovery Time	Residual activity in Sniff mode drops by factor of 1,000 in 30 minutes
Operating Ranges	Temperature: 32° - 113˚F(0° - 45℃) Humidity: 0% - 100%, non-condensing
Cycle Range	User controllable number of cycles, from 1 to 99 to unlimited, per run User controllable cycle time, from 2 minutes to 24 hours
CAPTURE Software	Compatible with Microsoft Windows XP and 7, and Mac OS X Automatic RAD7 location, connection and data download Graphs radon, thoron, temperature and humidity over time Automatic humidity correction Statistical analysis tools track concentration averages and uncertainties Chart Recorder mode provides real-time RAD7 status monitoring Control RAD7 operations from computer via direct or remote connection Automatic calculation and display of radon in water for RAD AQUA Automatic combination of multiple RAD7 data

IV. EXPERIMENTAL RESULTS AND DISCUSSION

In order to investigate the performance of the ion chamber-type radon counter : RD200, the radon measurement system : RAD7was used. The methyl methacrylate box was made for these experiments as shown in Fig. 3. Fig. 4 shows the experimental results of RAD7 and two RD200s for 5days.

 ISSN 2348 – 8034
Impact Factor3.155

Figure:

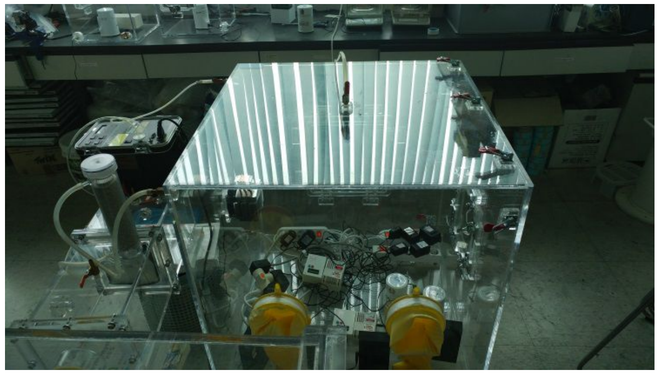

Figure 3.Experimental set-up for performance test

Figure:

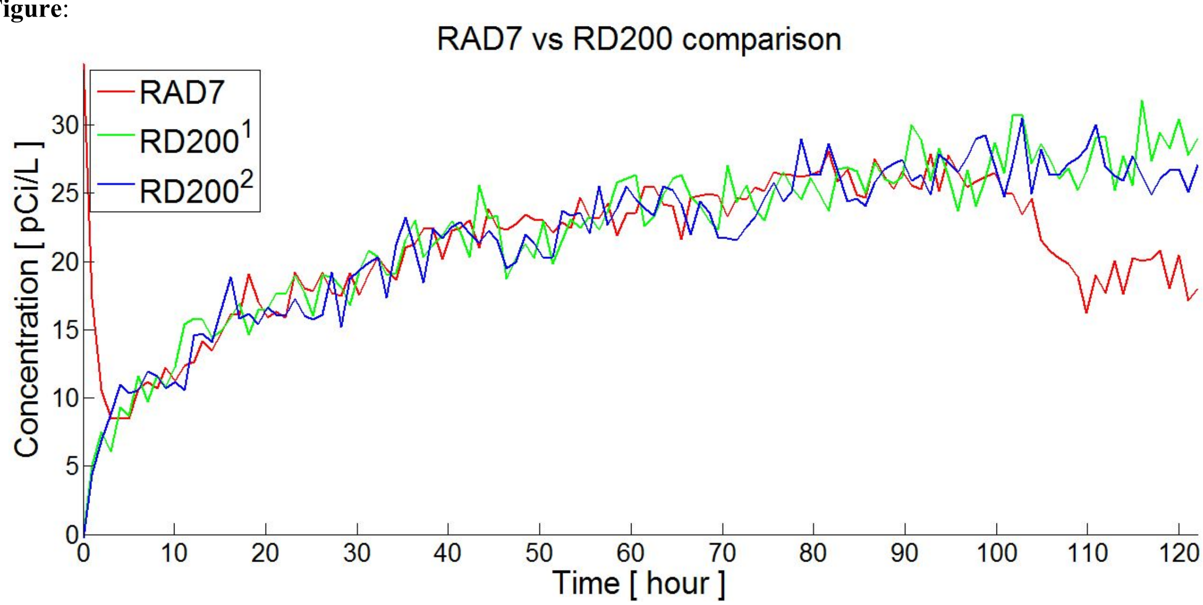

Figure 4.Experimental results of RAD7 and RD200

As shown in Fig. 4, the radon data of two RD200s track those of RAD7 very closely except for initial 3hours and final 15hours. We found that RD200 has some advantages over PIN photodiode-type radon counter : Siren PRO3 such that its sensitivity is 0.5cpm/pCi/L at 10pCi/L, which is very excellent comparing with Siren PRO3. In addition, it displays the concentration of radon as soon as it is turned on. On the other hand, for Siren PRO3, it displays the concentration of radon in 48hours.

V. CONCLUSION

Because inhaling radon and its radioactive decay products causes irradiation of lung tissue, prolonged exposure to high concentrations of radon significantly increases the risk of developing cancer. Various types of equipment and components have been proposed to date for radon detection. In order to investigate the performance of the ion chamber-type radon counter : RD200, the radon measurement system : RAD7 was used. Through some experimental studies, we found that the radon data of two RD200s tracked those of RAD7 very closely and RD200 had some advantages over PIN photodiode-type radon counter : Siren PRO3 for excellent sensitivity and prompt display of the radon concentration. As for further studies, more performance evaluations for RD200 might be needed.

VI. ACKNOWLEDGEMENTS

This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea govern ment(MSIP) (No. 2016011249).

REFERENCES

1. *Hiroshi Miyake, KeijiOda and Masami Michijima, "Portable and High-Sensitive Apparatus for Measurement of Environmental Radon Using CR-39 Track Detector," Japanese Journal of Applied Physics, vol.26, No.4, pp.607-610, April, 1987*
2. *Peter J. Diamondis, "Radon gas measurement apparatus having alpha particle-detecting photovoltaic photodiode surrounded by porous pressed metal daughter filer electrically charged as PO-219 Ion accelerator," US patent, P.N. 5489780, Feb. 1996*
3. *R. H. Griffin, H. Le, D.T. Jack, A. Kochermin and N.G. Tarr, "Radon Monitor using Custom α-detecting MOS IC," in Proceedings of IEEE Sensors 2008, Lecce, Italy, pp.906-909, Oct. 2008.*
4. *Han Soo Kim, Se Hwan Park, Jang Ho-Ha, Dong-Hoon Lee, and SeungYeon Cho, "Characteristics of a Fabricated PIN Photodiode for a Matching With a CsI(TI) Scintillator," IEEE Trans. Nucl. Sci., vol.57, NO.3, pp. 1382-1385, June, 2010*
5. *R.H. Griffin, A. Kochermin, N.G. Tarr, H.McIntosh, H.Ding, J.Weber and R.Falcomer, "A sensitive, fast-responding passive electrostatic radon monitor," in Proceedings of IEEE Sensors 2011, Limerick, Ireland, Oct., 2011*
6. *V. Tyzhnevyi, G.-F. DallaBetta, G. Verzellesi, L. Bosisio, G. Batignani, G. Giacomini, A. Picciotto, "BJT detector for a-particle and Radon detectionand monitoring," 2011 IEEE Nuclear Science Symposium Conference Record N39-1, pp.1941-1945, 2011.*
7. *S. Folea, M. Hulea, G.Mois, V. Cosma, "Wi-Fi portable solution for distributed radon measurements," Rom. Journ. Phys., vol.58, pp.S126-s139, 2013.*
8. *Ryan H. Griffin and N. Garry Tarr, "Optical image sensors and their application in radon detection," in Proceedings of SPIE, vol.8915, pp.8915C-1~7, Oct., 2013.*
9. *Gyu-Sik Kim, Tae-Gue Oh and Jae-Hak Kim, "Implementation of a PIN photodiode radon counter," Global Journal of Engineering Science and Researches, vol. 3, no.1, pp.58-63, Jan., 2016.*