Instrument performance test according to ANSI/AARST MS-PC 2022

Test report by

Veikko Oeser, Dipl.-Ing.
SARAD GmbH
Wiesbadener Straße 10
01159 Dresden/Germany
oeser@sarad.de
++49 351 6580712

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The tests conducted are intended to verify the conformity with ANSI/AARST MS-PC 2022 standard for the instrument types “RTM 1688-2” and “Smart Radon Sensor”.

All tests were carried out in November 2022 in the Radon calibration laboratory of SARAD GmbH in Dresden/Germany. The Radon calibration laboratory is accredited according DIN/EN/ISO/IEC 17025 by the German DAkkS under the label D-K-21847-01-00 for calibrations of the measurand radon activity concentration. Tests 7.1 and 7.2 are not within the scope of accreditation but performed with respect to the traceability requirements of the DIN/EN/ISO/IEC 17025.

Responsible person for the test campaign was Christian Bartzsch, head of the calibration laboratory.

Test campaign

Following instruments were available for the test:

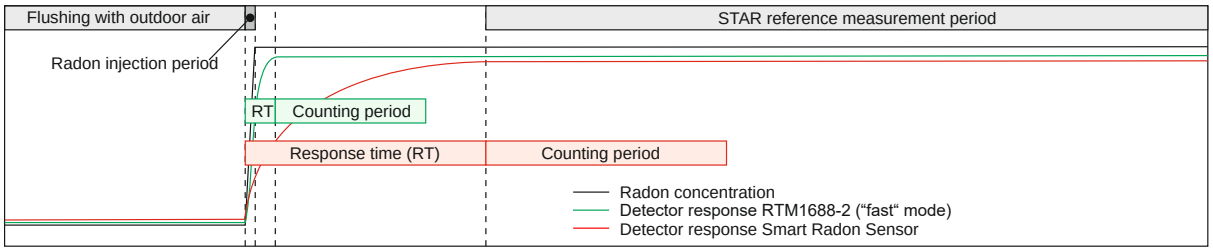
Type	#1	#2	#3	#4	#5	#6
RTM 1688-2	S/N 499	S/N 500	S/N 502	S/N 503	S/N 504	S/N 505
Smart Radon Sensor	S/N 91	S/N 92	S/N 93	S/N 94	S/N 95	-

All instruments have been calibrated together in the same chamber at a Radon level of 3000 Bq/m³ before the test. The gamma background during the tests was approximately 100 nSv/h. The elevation of the STAR chambers is approximately 150 meter above the sea level.

Accuracy & precision test (7.1)

The stated recommended minimum measurement time contains both, the response time (to obtain the equilibrium between Radon concentration and measurable activity) as well as the subsequent counting period for the activity determination. The results are based on the counting period only, otherwise a systematic underestimation of the true value would be the result. The test was conducted in a sealed calibration chamber and with a radon source that allows to generate a STAR of 300 Bq/m³ inside this chamber within approximately 5 minutes. Before injecting the Radon, the

chamber was flushed with outdoor air (C_{Rn} < 10 Bq/m³) for two hours to ensure zero readings as start conditions. The Radon injection was synchronised with the counting intervals of the instruments under test to get the exact start point for the counting interval. The conventionally true value is measured by a traceable reference instrument over a period of 6 hours, starting from 2 hours after Radon injection. It is supposed that Radon lost by decay and chamber leakage are negligible over a period of 6 hours. The following graphic illustrates the applied procedure.



Due to the spectroscopic measurement with separation of Po-218 (“fast” mode), the RTM 1688-2 offers a response time of just 15 minutes while the response time of the Smart Radon Sensor is about two hours.

To achieve the shortest possible measurement time, the sampling interval of the instruments was set to 15 minutes. The result represents the average of all 15 minutes results during the counting period. In practice, the sampling interval could be set equal to the counting period and the user should run a dummy measurement which is cancelled after the required response time directly followed by the real measurement.

The required counting interval (to meet the 25% criterion) was derived from the sensitivity of the instruments with respect to the required counting statistics.

Test for minimum detectable concentration (7.2.)

Test 7.2 was performed in a small chamber (50 l) which has been flushed with Nitrogen after inserting the instruments. We used Nitrogen (N_2) 5.0 from a pressured bottle and adjusted the gas stream to about 25 l/min for 16 minutes to ensure an eight times volume exchange.

This test has been performed for Smart Radon Sensor only. The SARAD Radon calibration laboratory has no containment large enough to expose five instruments of type RTM 1688-2 together in a Nitrogen atmosphere. From physical point of view this is not required due to the operational principle of alpha spectroscopy. Limiting factor is the background count rate of the used semiconductor detector. The evaluation of the very low MDC of the RTM 1688-2 was part of the accreditation process of our laboratory because the instrument is used as background reference. The background count rate is less than 0.22 cph which correspondents with a Radon activity concentration of less than 0.5 Bq/m³.

The Smart Radon Sensors were exposed over a period of 24 hours whereas the first three hours have been skipped from background calculation to make sure that all Po-214 is decayed. The pre-set sampling interval was one hour. The LLD in counts per minute (cpm) was calculated by the formula (2) given in chapter 4 of the MS-PC 2022 standard. The MDC is obtained by applying the calibration factor of the Smart Radon Sensor.

Test for proportionality, temperature and humidity (7.3/7.4/7.5)

For each of the tests according chapter 7.3, 7.4 and 7.5 a complete standard calibration campaign was carried out. That means all instruments were taken out of the chamber after each campaign.

Conditioning of the atmosphere did start from nearly standard conditions (20°C/50%rH). Each standard campaign starts with a 24-hour period with low Radon concentration (< 50 Bq/m³) inside the chamber. The exposure period at target concentration was 24 hours (3000 Bq/m³) or 60 hours (300 Bq/m³). A sampling interval of one hour was set for all instruments under test.

Deviating from the MS-PC 2022 standard, the high-level Radon concentration of the proportionality test (chapter 7.3) was 3000 Bq/m³ instead of 1100…2200 Bq/m³. This setup was necessary due to the accreditation limits of the calibration laboratory.

Tests at 3000 Bq/m³ and 300 Bq/m³ (low concentration in 7.3) were performed in different chambers with different reference instruments. These reference instruments are traced to the national standard in separate calibration chains.

Instrument information

	RTM 1688-2	Smart Radon Sensor
Picture		
Manufacturer	SARAD GmbH	SARAD GmbH
Monitor type	Continuous Radon Monitor	Continuous Radon Monitor
Principle of operation	Solid state detector and alpha spectroscopy	Scintillation detector (Lucas cell)
Sensitivity	0,4 cph / (Bq/m³)	0,2 cph/(Bq/m³)
Range of measurement	0…10 MBq/m³	0…1 MBq/m³
Min. measurement duration	1 hour	1 hour
Suggested method of calibration	Exposure in a STAR	Exposure in a STAR
Response to external radiation	non up to 1 mSv/h	non
Effect of temperature and humidity	Compensated by internal sensors for Temperature and Humidity	Non for operational conditions stated in the manual
Effect of pressure	non	Negligible from 950 to 1050 mbar
Effect of shocks/vibration	Strong shocks can cause electronic noise on detector signal	non
Effect of electromagnetic interference	According CE directive	According CE directive

Test results

Uncertainties for measured Radon concentrations are expressed as ± concentrations related to the stated result with a confidence interval of 95% (k = 2). Uncertainties of the device results are related only to the statistics of the calibration campaign while the uncertainty of the STAR contains also the traceability to the German national standard hold be the "Bundesamt für Strahlenschutz (BfS)" (Federal Office for radiation protection) in Berlin. The statistical uncertainty (k = 2) of the STAR reference measurements (Tests 7.3/7.4/7.5) is less than 1 % at 3000 Bq/m³ and less than 3 % at 300 Bq/m³. Uncertainties are derived according DIN/EN/ISO/IEC 17025 described in the document "EA 04/02 M: 2013". For Test 7.1 uncertainties have not been calculated – it is just a comparison of measured values of both reference instrument and instruments under test.

7.1. Accuracy and precision (2022-12-01 17:50; Kammer C)

Results RTM 1688-2

Response time: 15 min Counting period: 75 min

Test start: 2022-11-30 20:54 Test End: 2022-11-30 22:09

S/N	Temperature [°C]	Rel. Humidity [%]	STAR Rn conc. [Bq/m³]	Device result [Bq/m³]	IPE [%]	CV [%]
499	19	31	329	345	4.9	10.2
500				320	-2.7	
502				328	-0.3	
503				411	24.9	
504				326	-0.9	
505				322	-2.1	

Results Smart Radon Sensor

Response time: 120 min Counting period: 120 min

Test start: 2022-11-30 22:09 Test End: 2022-12-01 00:09

S/N	Temp. [°C]	Rel. Hum. [%]	STAR Rn conc. [Bq/m³]	Device result counting period [Bq/m³]	IPE [%]	CV [%]
91	19	31	329	280	-14,8	10.1
92				250	-24.0	
93				258	-21.6	
94				258	-21.6	
95				318	-3.3	

7.2. Lower limit of detection (LLD)

Results Smart Radon Sensor

Sampling interval (Counting interval): 60 min

Test start: 2022-12-01 20:15 Test End: 2022-12-02 17:15

S/N	Intervals with zero counts	Intervals with one or more counts	Total counts	LLD [cpm]	MDC [Bq/m³]
91	22	2	2	0.062	1.8
92	22	0	0	0.045	1.4
93	22	0	0	0.045	1.4
94	22	1	1	0.057	1.7
95	22	3	3	0.066	2.0

7.3. Proportionality test

Low concentration (2022-11-24_Kammer B_300Bq_98h)

Conditions: C_{Rn} 222 – 555 Bq/m³ Temp. 18 – 24 °C rel. Hum. 10 – 55%
Test start: 2022-11-26 21:36
Test End: 2022-11-29 09:36

Results RTM 1688-2

S/N	Temperature [°C]	Rel. Humidity [%]	STAR Rn conc. [Bq/m³]	Device result [Bq/m³]	IPE [%]	CV [%]
499	21	51	315 ± 50	315 ± 13	0	2.2
500				301 ± 14	-4.4	
502				311 ± 12	-1.3	
503				300 ± 14	-4.8	
504				303 ± 14	-3.8	
505				299 ± 13	-5.1	

Results Smart Radon Sensor

S/N	Temperature [°C]	Rel. Humidity [%]	STAR Rn conc. [Bq/m³]	Device result [Bq/m³]	IPE [%]	CV [%]
91	51	51	315 ± 50	293 ± 18	-7.0	2,4
92				311 ± 18	-1,3	
93				298 ± 19	-5,4	
94				308 ± 20	-2,2	
95				302 ± 18	-4,1	

High concentration (2022-11-01_Kammer A_3kBq_62h)

Conditions: C_{Rn} 1110 – 2220 Bq/m³ Temp. 18 – 24 °C rel. Hum. 10 – 55%
Test start: 2022-11-03 06:44
Test End: 2022-11-04 06:44

Results RTM 1688-2

S/N	Temperature [°C]	Rel. Humidity [%]	STAR Rn conc. [Bq/m³]	Device result [Bq/m³]	IPE [%]	CV [%]
499	19	54	3076 ± 186	3037 ± 41	-1.3	0,8
500				3057 ± 36	-0.6	
502				3026 ± 39	-1,6	
503				2998 ± 36	-2,5	
504				3026 ± 38	-1,6	
505				2991 ± 29	-2,7	

Results Smart Radon Sensor

S/N	Temperature [°C]	Rel. Humidity [%]	STAR Rn conc. [Bq/m³]	Device result [Bq/m³]	IPE [%]	CV [%]
91	19	54	3076 ±186	2939 ± 71	-4.4	2.6
92				3135 ±66	1.9	
93				2966 ±72	-3.6	
94				2982 ± 88	-3.0	
95				3042 ± 67	-1.1	

7.4. Temperature test

Temperature low (2022-11-14_Kammer A_3kBq_62h)

Range: C_{Rn} >370 Bq/m³ Temp. 13 – 19 °C rel. Hum. 10 – 25%
Test start: 2022-11-16 06:58
Test End: 2022-11-17 06:58

Results RTM 1688-2

S/N	Temperature [°C]	Rel. Humidity [%]	STAR Rn conc. [Bq/m³]	Device result [Bq/m³]	IPE [%]	CV [%]
499	18	16	2944 ± 180	2860 ± 32	-2.8	0.8
500				2888 ± 41	-1.9	
502				2892 ± 38	-1.8	
503				2842 ± 38	-3.5	
504				2856 ± 30	-3.0	
505				2842 ± 30	-3.5	

Results Smart Radon Sensor

S/N	Temperature [°C]	Rel. Humidity [%]	STAR Rn conc. [Bq/m³]	Device result [Bq/m³]	IPE [%]	CV [%]
91	18	16	2944 ± 180	2944 ± 71	0	0.8
92				2963 ± 66	0.6	
93				2900 ± 64	-1.5	
94				2930 ± 56	-0.5	
95				2944 ± 77	0	

Temperature high (2022-11-18_Kammer A_3kBq_62h)

Conditions: C_{Rn} >370 Bq/m³ Temp. 24 – 30 °C rel. Hum. 10 – 25%
Test start: 2022-11-19 23:21
Test End: 2022-11-20 23:21

Results RTM 1688-2

S/N	Temperature [°C]	Rel. Humidity [%]	STAR Rn conc. [Bq/m³]	Device result [Bq/m³]	IPE [%]	CV [%]
499	30	14	2956 ± 179	2833 ± 47	-4.2	2.3
500				2797 ± 25	-5.4	
502				2872 ± 35	-2.8	
503				2839 ± 36	-3.9	
504				2832 ± 33	-4.2	
505				2798 ± 39	-5.3	

Results Smart Radon Sensor

S/N	Temperature [°C]	Rel. Humidity [%]	STAR Rn conc. [Bq/m³]	Device result [Bq/m³]	IPE [%]	CV [%]
91	30	14	2956 ± 179	2909 ± 68	-1.6	1.4
92				3007 ±71	1.7	
93				2938 ± 68	-0.6	
94				2919 ± 78	-1.2	
95				2975 ± 51	0.6	

7.5. Humidity test

Humidity low (2022-11-11_Kammer A_3kBq_62h)

Conditions: C_{Rn} >370 Bq/m³ Temp. 18 – 24 °C rel. Hum. 15 – 25%
Test start: 2022-11-12 20:50
Test End: 2022-11-13 20:50

Results RTM 1688-2

S/N	Temperature [°C]	Rel. Humidity [%]	STAR Rn conc. [Bq/m³]	Device result [Bq/m³]	IPE [%]	CV [%]
499	18	26	3008 ± 184	2948 ± 32	-2.0	1.1
500				2957 ± 39	-1.7	
502				3000 ± 28	-0.3	
503				2960 ± 43	-1.6	
504				2955 ± 34	-1.8	
505				2896 ± 39	-3.7	

Results Smart Radon Sensor

S/N	Temperature [°C]	Rel. Humidity [%]	STAR Rn conc. [Bq/m³]	Device result [Bq/m³]	IPE [%]	CV [%]
91	18	26	3008 ± 184	2924 ± 95	-2.7	2.0
92				3084 ± 53	2.5	
93				2962 ± 69	-1.5	
94				3015 ± 70	0.2	
95				3006 ± 52	-0.06	

Humidity high (2022-11-07_Kammer A_3kBq_62h)

Conditions: C_{Rn} >370 Bq/m³ Temp. 18 – 24 °C rel. Hum. 70 – 80%
Test start: 2022-11-09 06:48
Test End: : 2022-11-10 06:48

Results RTM 1688-2

S/N	Temperature [°C]	Rel. Humidity [%]	STAR Rn conc. [Bq/m³]	Device result [Bq/m³]	IPE [%]	CV [%]
499	20	73	3628 ± 219	3703 ± 37	2.1	1.0
500				3697 ±50	1.9	
502				3716 ± 53	2.4	
503				3624 ± 49	2.4	
504				3671 ± 48	-0.1	
505				3640 ± 49	0.3	

Results Smart Radon Sensor

S/N	Temperature [°C]	Rel. Humidity [%]	STAR Rn conc. [Bq/m³]	Device result [Bq/m³]	IPE [%]	CV [%]
91	20	73	3628 ± 219	3491 ± 72	-3.7	2.0
92				3641 ±74	0.3	
93				3543 ± 80	-2.3	
94				3667 ± 82	1.1	
95				3552 ± 80	-2.1	

Additional test in very humid conditions (2022-11-21_Kammer A_3kBq_62h)

Test start: 2022-11-23 07:08
Test End: 2022-11-24 07:08

Results RTM 1688-2

S/N	Temperature [°C]	Rel. Humidity [%]	STAR Rn conc. [Bq/m³]	Device result [Bq/m³]	IPE [%]	CV [%]
499	31	76	6808 ± 466	6745 ± 236	-0.9	2.4
500				6747 ± 235	-0.09	
502				6906 ± 220	1.4	
503				6482 ± 224	-4.8	
504				6628 ± 241	-2.6	
505				6507 ± 208	-4.4	

Results Smart Radon Sensor

S/N	Temperature [°C]	Rel. Humidity [%]	STAR Rn conc. [Bq/m³]	Device result [Bq/m³]	IPE [%]	CV [%]
91	31	76	6806 ± 466	6580 ± 200	-3.3	1.5
92				6807 ± 151	0	
93				6670 ± 196	-1.9	
94				6818 ± 243	0.2	
95				6686 ± 170	-0.2	

Summary

The standard defines a maximum IPE (individual percentage error) smaller than 25% and a CV (coefficient of variation) less than 15% for the tests 7.1, 7.3, 7.4 and 7.5. All instruments have passed the test successfully. The IPE and CV results of tests 7.3 to 7.5 with variation of parameters are much lower while the measurements in test 7.1 are partly close to the limits. This behaviour is expected because the shortest measurement period was selected with respect to these limits.

Mr. Crhistian Bartzsch, Dipl.-Ing.
Head of Calibration Laboratory

Mr. Veikko Oeser, Dipl.-Ing.
Head of R&D, Procurist