

# Traceable Calibrations of Instruments Measuring Radon Activity Concentration

- EMPIR Project *Metrology for Radon* -

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| Verantwortung für Mensch und Umwelt |



## EMPIR Project *Metrology for Radon*

### Work Package 1.3 (extract)

- Emanation sources together with existing certified reference volumes will be installed in order to establish **constant and traceable  $^{222}\text{Rn}$  activity concentrations**.
- The **stability and the reproducibility** of atmospheres under environmental conditions (room climate) and for long-term operation will be evaluated.
- **Calibration procedures in the activity concentration range from 100 Bq/m<sup>3</sup> to 300 Bq/m<sup>3</sup> will be developed.**
- The **target relative uncertainty is  $\leq 5\%$  (k=1).**

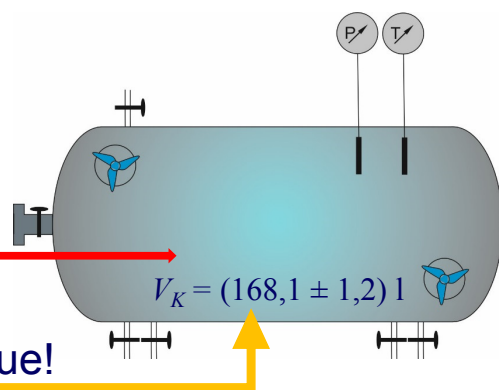
## Representation of the Radon Activity Concentration, $C_{Rn}$

Temperature  
Pressure  
Internal Ventilation



Chamber with Certified Volume

$$C_{Rn} = \frac{A_{Rn}}{V_K}$$



$A_{Rn}$  Activity of Radon: Gas Standard or Emanation Source

$V_K$  Volume: Traceable to PTB Volume Standard

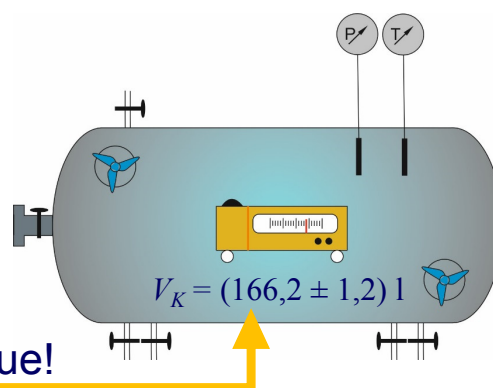
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## Representation of the Radon Activity Concentration, $C_{Rn}$

### Inventory & ALPHAGUARD

$$C_{Rn} = \frac{A_{Rn}}{V_K}$$

Mind the value!



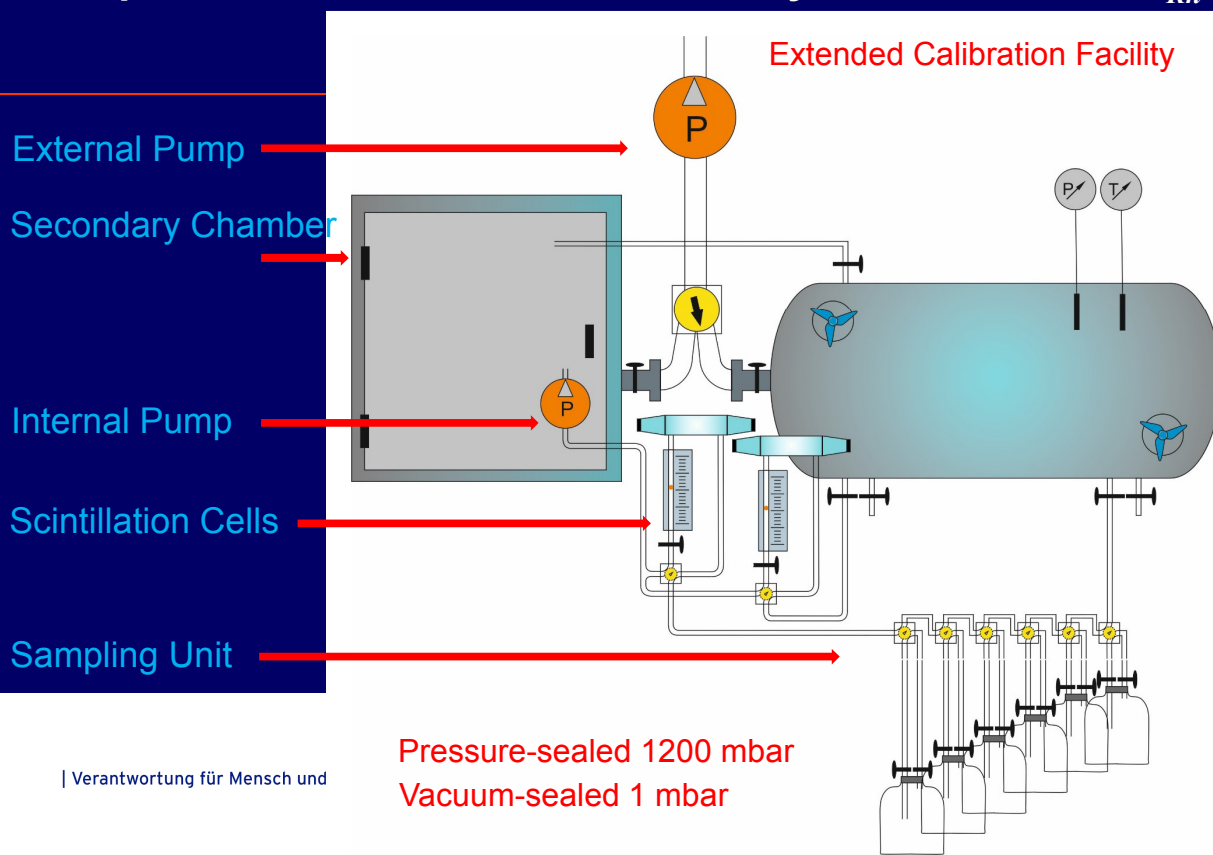
$V_K = (166,2 \pm 1,2) \text{ l}$

$A_{Rn}$  Activity of Radon: Gas Standard or Emanation Source

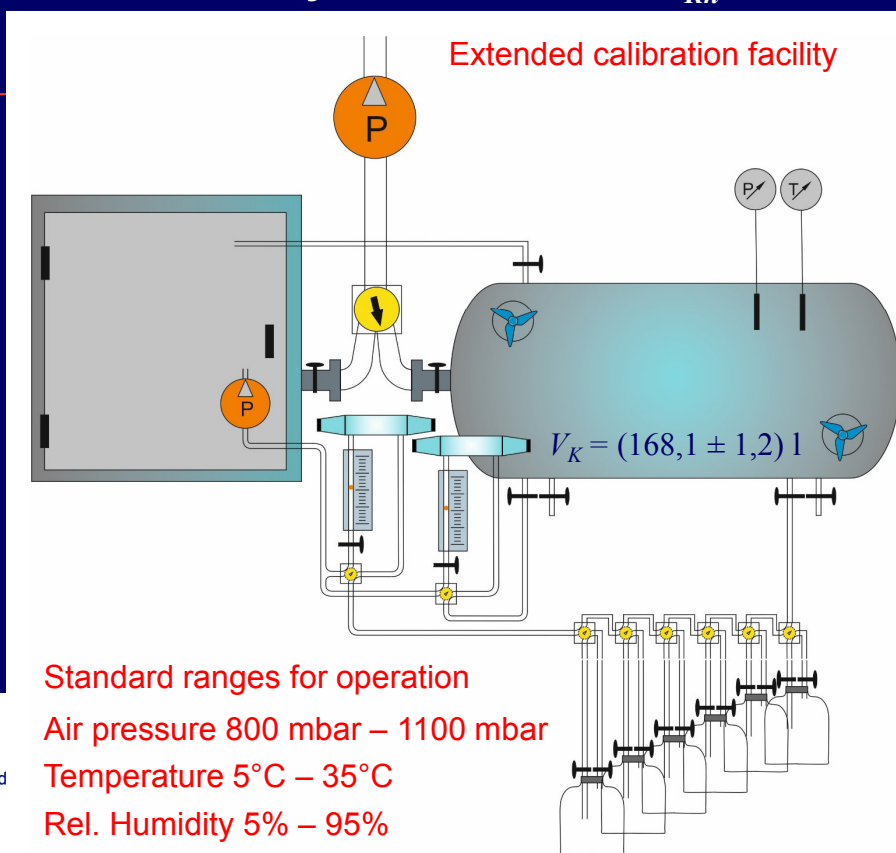
$V_K$  Volume: Traceable to PTB Volume Standard

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## Representation of the Radon Activity Concentration, $C_{Rn}$



## Realization of Radon Activity Concentration, $C_{Rn}$



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## Realization of Radon Activity Concentration, $C_{Rn}$



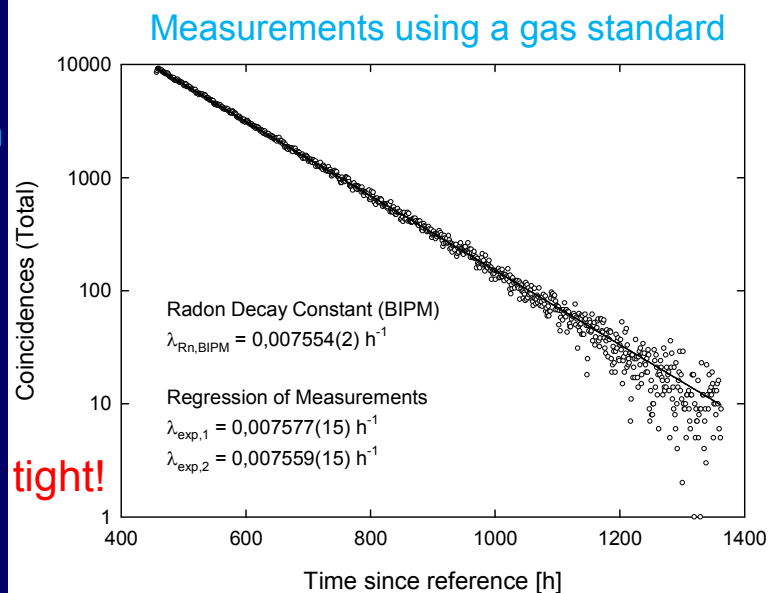
T.R. Beck: Traceable Calibrations of  
Instruments Measuring Radon Activity  
Concentration. III Internat. Conf. on Radon  
in the Environment. Krakow, Poland, May  
27- 31, 2019

## Realization of Radon Activity Concentration, $C_{Rn}$

Leakage test for radon

Decrease of radon not significantly different from its radioactive decay

➡ The facility is radon tight!

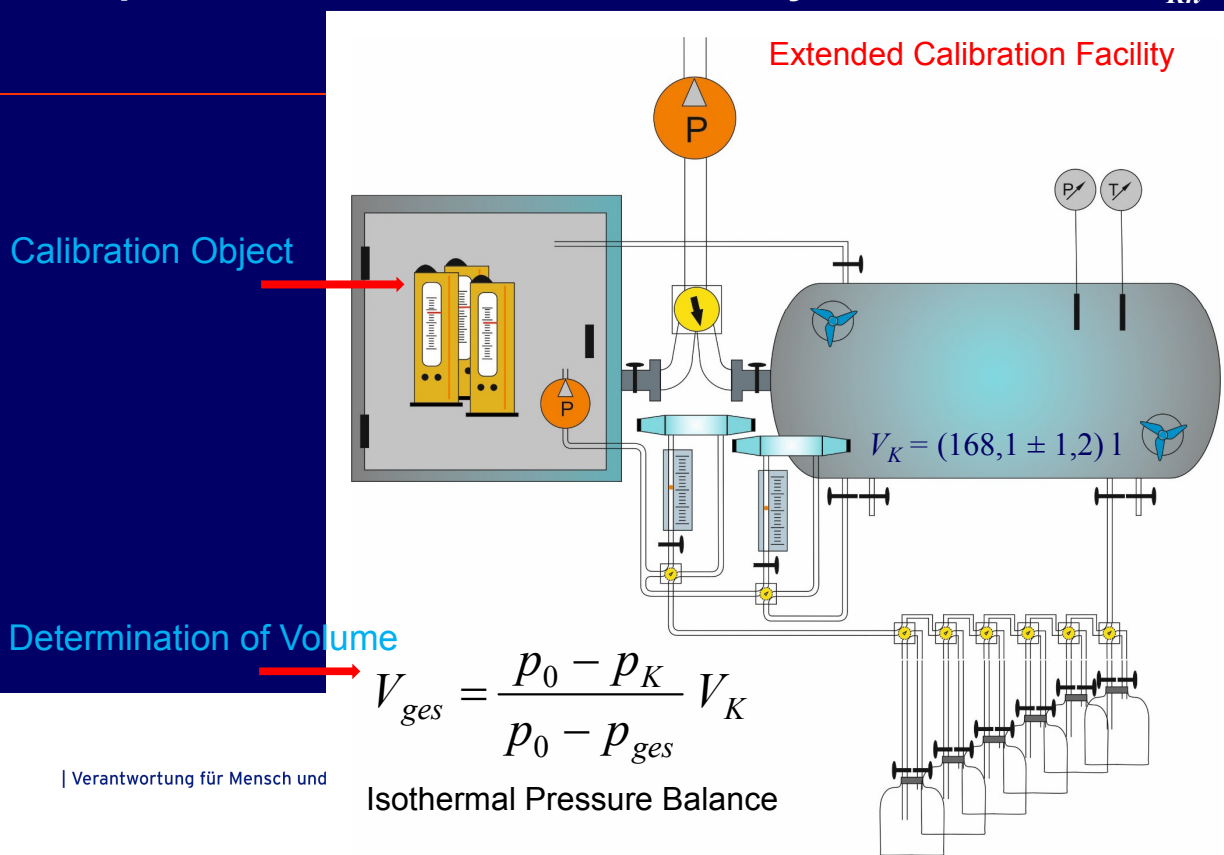


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Bundesamt für Strahlenschutz



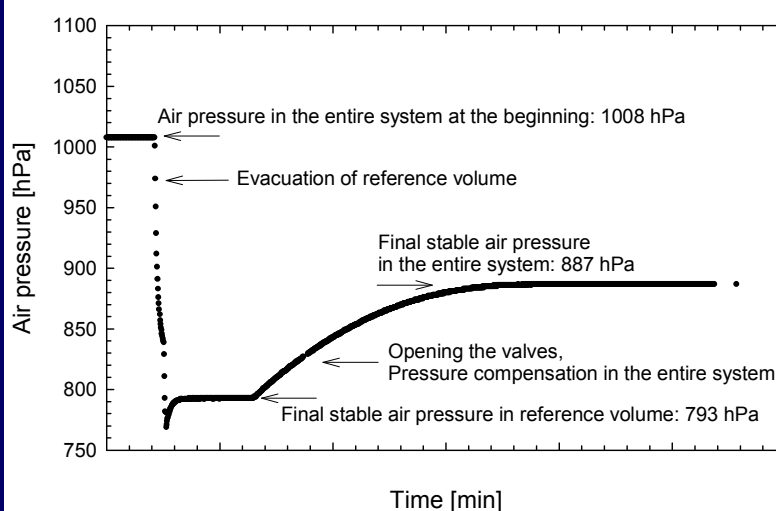
## Representation of the Radon Activity Concentration, $C_{Rn}$



## Representation of the Radon Activity Concentration, $C_{Rn}$

### Determination of Total Volume (Example)

$$V_{ges} = \frac{p_0 - p_K}{p_0 - p_{ges}} V_K$$



## Representation of the Radon Activity Concentration, $C_{Rn}$

### Determination of Total Volume (Example)

Calibration Object ALPHAGUARD included

Test	Total Volume [dm <sup>3</sup> , liter]	Uncertainty (K=2)	
		[dm <sup>3</sup> , liter]	%
1.	298,1	4,7	1,58
2.	297,4	5	1,68
3.	299,7	4,7	1,57
4.	299,5	4,6	1,54
<b>Average</b>	<b>299</b>	<b>5</b>	<b>1,7</b>

## Representation of the Radon Activity Concentration, $C_{Rn}$

Radon Supply

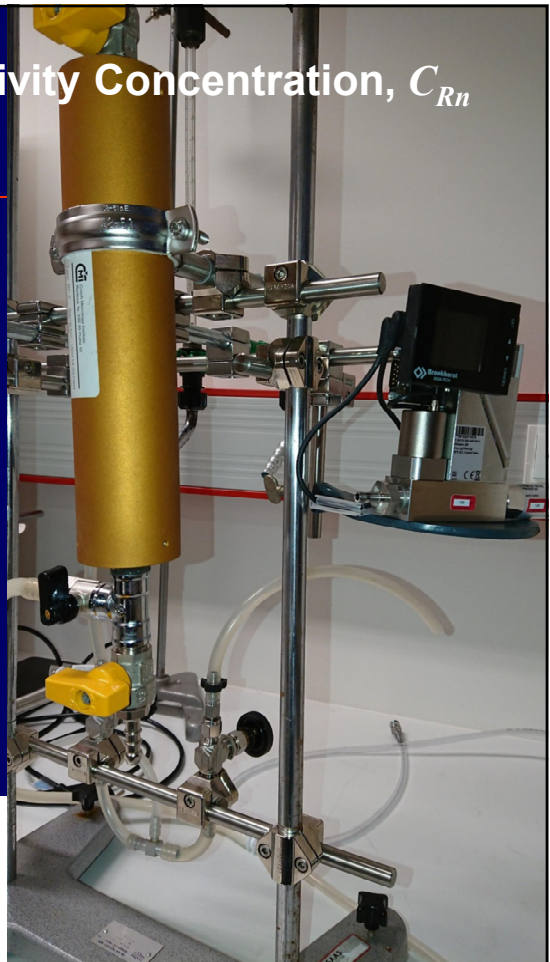
Emanation Source provided by CMI  
(Czech Metrological Institute)

Radium Activity: 5,058(51) kBq

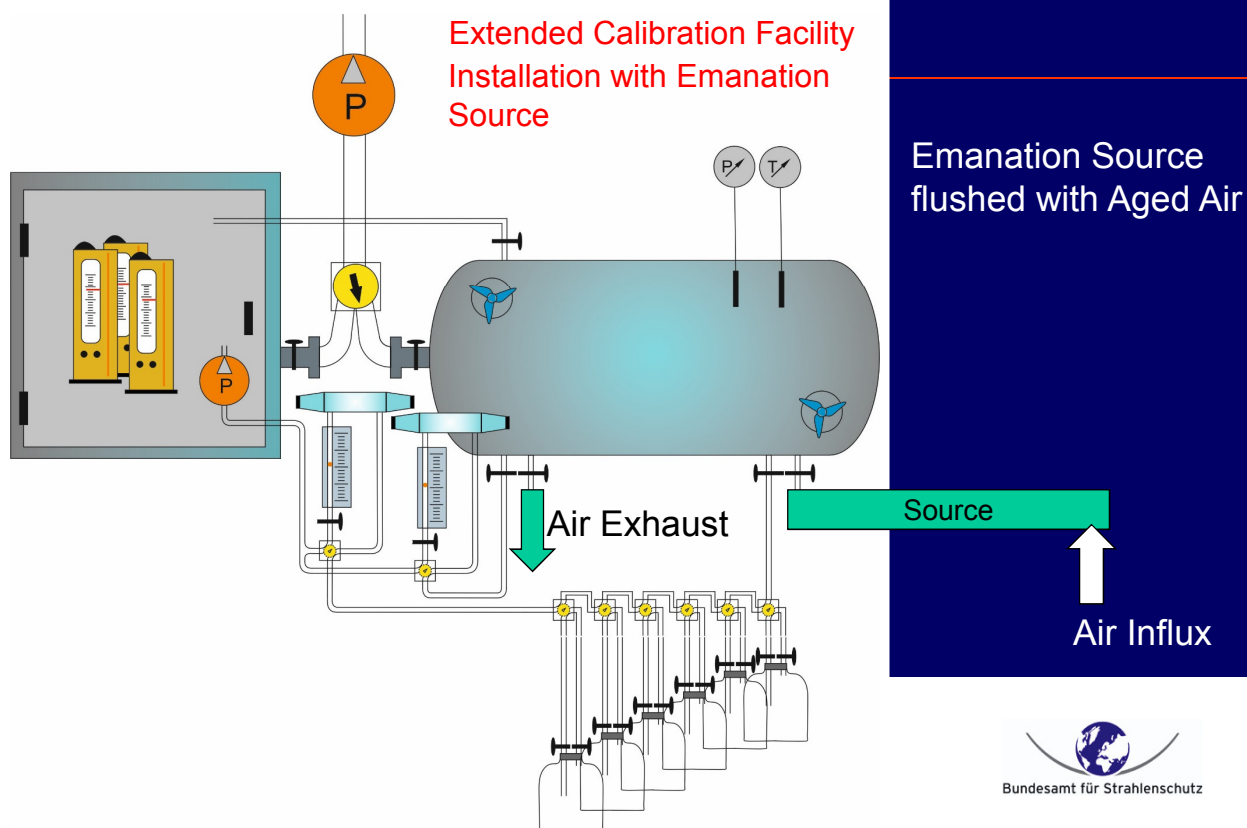
Emanation Rate:  
(Radon Output): 0,0106(1) Bq/s

Activity supply by controlled flow rate!

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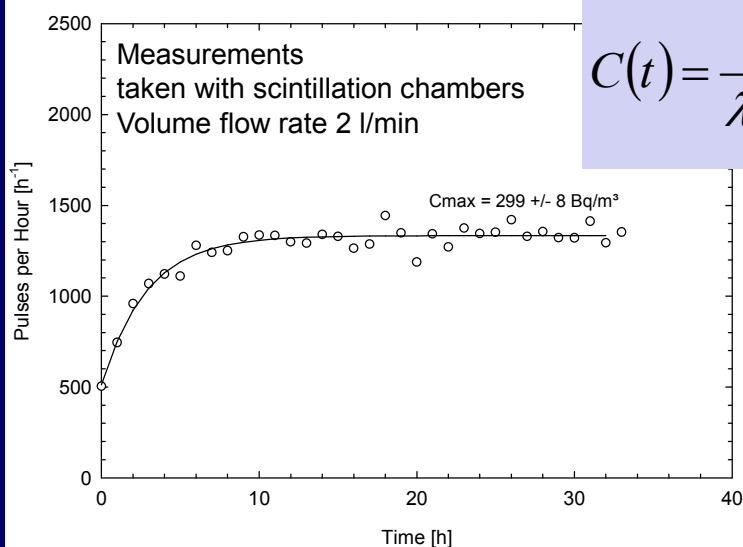


## Representation of the Radon Activity Concentration, $C_{Rn}$



## Measurements with Emanation Source

### Buildup of Activity Concentration



$$C(t) = \frac{\varepsilon}{\lambda V + \phi} \left( 1 - e^{-\left(\lambda + \frac{\phi}{V}\right)t} \right)$$

$$C_{\max} = \frac{\varepsilon}{\lambda V + \phi}$$

$\varepsilon$  Emanation Rate  
 $\lambda$  Decay Constant of Radon  
 $\phi$  Volume Flow Rate  
 $V$  Chamber Volume (Total)

## Representation of the Radon Activity Concentration, $C_{Rn}$

Budget of Uncertainty (provisional)

	Value	Unc (k=1)	Reference
Half-Life Rn-222	3,8232 d	0,0008 d	BIPM
Internal Flow Rate	2,96 l/min	0,06 l/min	Calibration Certificate + Reading & Setting Accuracy
External Flow Rate	variable	0,01 l/min	
Total Volume	299 liter	2,5 liter	Internal Calibration
Reference Volume	168,1 liter	0,6 liter	PTB Calibration Certificate
Emanation Rate	0,0106 Bq/s	0,0001 Bq/s	CMI Calibration Certificate

**Emanation rate is independent from temperature and humidity!**

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## Representation of the Radon Activity Concentration, $C_{Rn}$

Concentrations between 100 Bq/m<sup>3</sup> and 300 Bq/m<sup>3</sup>

Radon Activity Concentration in Secondary Chamber			
Flow rate through Emanation Source	$C_{Rn}$	Unc (k=2)	
	Bq/m <sup>3</sup>	Bq/m <sup>3</sup>	%
6 l/min	105	2	1,4
4 l/min	157	2	1,5
3 l/min	209	3	1,5
2 l/min	310	5	1,6

The uncertainty of the Radon Activity Concentration is 1,5 % (k=2).



## Conclusion

- Traceable **calibrations** in the range from 100 Bq/m<sup>3</sup> to 300 Bq/m<sup>3</sup>
- Calibration atmospheres are **precise & stable over a long time**
- Climatic variations do **not have a direct influence** on the calibrations
- **Limitations** for calibrations in the low range of activity concentration arise from
  - **background** of the calibration object,
  - **statistical variations** of measurements taken by the calibration object

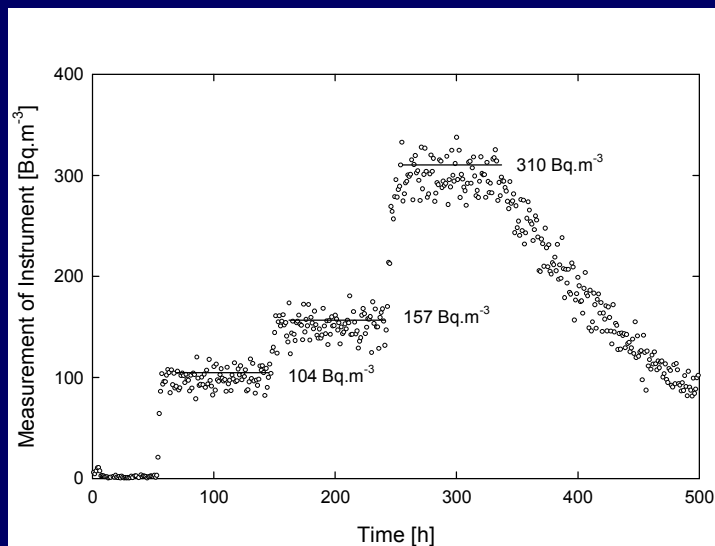


**For protracted exposures the target relative uncertainty of  $\leq 5\%$  ( $k=1$ ) will be achieved.**



## Calibration of ALPHAGUARD

Provisional Results, AG000102 DF2000



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