Australian Government

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Sources of uncertainty for ANSTO radon monitors and scope for improvement

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Overview

For ANSTO monitors the C_{Rn} is calculated for every time interval (t) according to:

$$C_{Rn} = \frac{G_\alpha - B}{t \cdot F_{cal}} \cdot C_P C_T$$

where: C_{Rn} is the radon concentration
G_α is the gross alpha count
B is the instrumental background
F_{cal} is the calibration factor
$C_P.C_T$ is the STP correction (P_0=1000 hPa, T_0=293.15° K)

Additional considerations include:

- Uncertainty in humidity observations if dry air values are to be calculated
- Uncertainty associated with the detector's internal flow rate (see RTC)
- Uncertainty associated with the detector's external (sampling) flow rate (see RTC)
- Uncertainty associated with the high voltage supplied to the measurement head

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Uncertainty in gross alpha counts (G_α)

- For raw observations, usually just consider the counting uncertainty: $u(G_\alpha) = \sqrt{G_\alpha}/\text{net}$ (k=1)
- For deconvolved data the software assigns (assumed) uncertainty for:

  counting uncertainty, external flow (2%), internal flow (20%), screen efficiency (5%), plate-out (2%) and delay time (1%) -- total 30%
- **Note regarding sampling flow rate of direct radon monitors:**

  - the external flow rate does NOT impact sensitivity

  - the external flow rate DOES impact response time
- **Regarding the Internal Flow Rate of ANSTO monitors**: there are competing issues

  - the higher the internal flow rate, the lower the head's capture efficiency

  - the lower the internal flow rate, the greater the loss of ^{218}Po (half-life 3.1 min)

  - Consequently, the internal flow rate of the 200L detector needs to be optimised

  (it is currently very high compared with 1500L detectors)

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Uncertainty in Background

- For the 200 L detector, if the instrumental background is measured inside the PTB climate chamber, the uncertainty is very low: e.g., $B = (0.0317 \pm 0.00015)\ s^{-1}$

- For the 200 L detector where instrumental background is checked in the field using zero air, the background value is lower, but uncertainty higher: e.g., $B = (0.01709 \pm 0.0023)\ s^{-1}$

- For ANSTO detectors in the field where background is estimated simply by shutting down the blowers, this does not account for self-generation of radon (slight dependence on ambient radon). Background estimates are usually low, but uncertainty is higher (look at σ of 30-min BG count over 19 hours).

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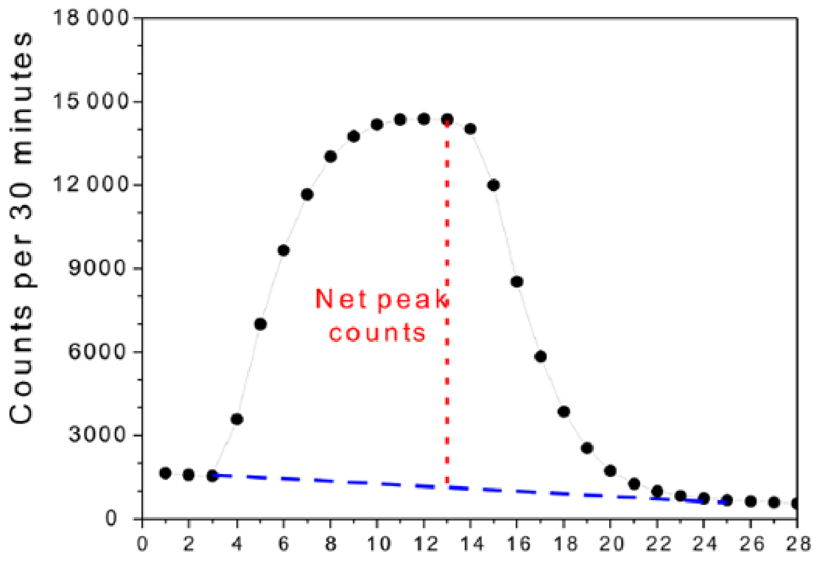
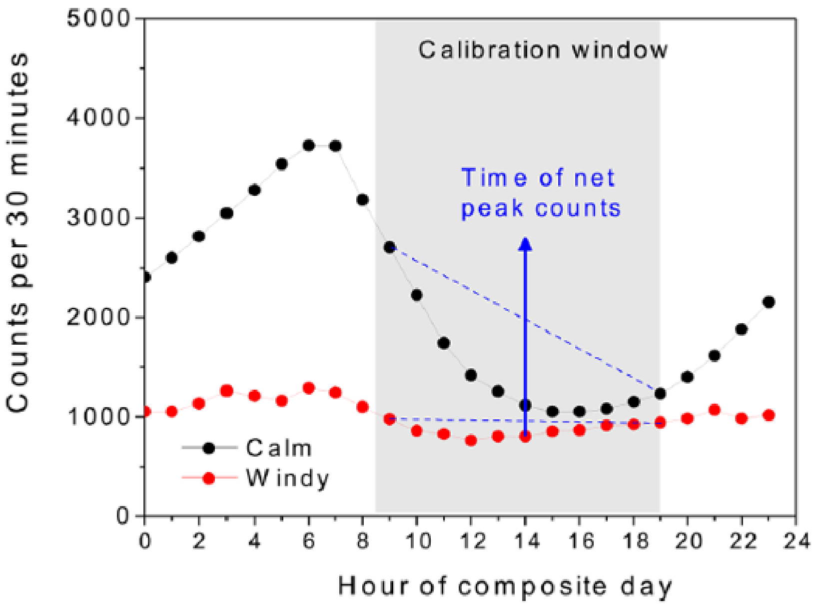
Uncertainty in Calibration

- 200L detector, calibrated in PTB climate chamber, uncertainty is low: (0.038460 ± 0.0013) s^{-1} $(Bq \cdot m^{-3})^{-1}$ 3%
- 200L detector, calibrated in the field using zero air, uncertainty <10%, even for C_{Rn} ~ 5 Bq m^{-3}
- Large ANSTO detectors: field calibrations **on top of ambient flow** have high and variable uncertainty (due to changing ambient radon, inconsistent performance of pump, humidity issues if desiccant not maintained, small contributions of ambient radon and thoron challenging to quantify).





Perform calibrations selectively: under high wind or low radon conditions, or use a long calibration history to derive linear calibration model, or transfer a calibration from a separate device

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Other uncertainty considerations

- **Uncertainty in STP correction** (through measured pressure and temperature)

  - pressure ±0.3 hPa according to manufacturer

  - temperature 0.22°C according to manufacturer

- **Uncertainty in water vapour correction** (if correcting to dry air values)

  - relative humidity uncertainty ±1% according to manufacturer

- **Uncertainty in external flow rate**

  - flow rate < ±3% for a given measurement period (according to manufacturer)

- **Uncertainty in internal flow rate**

  - standard deviation of Ventcaptor over a 1-hour measurement period ±0.12%

  (over whole PTB ICP σ = 0.53 m s^{-1}, or around 5%) - much lower than assumed 20%

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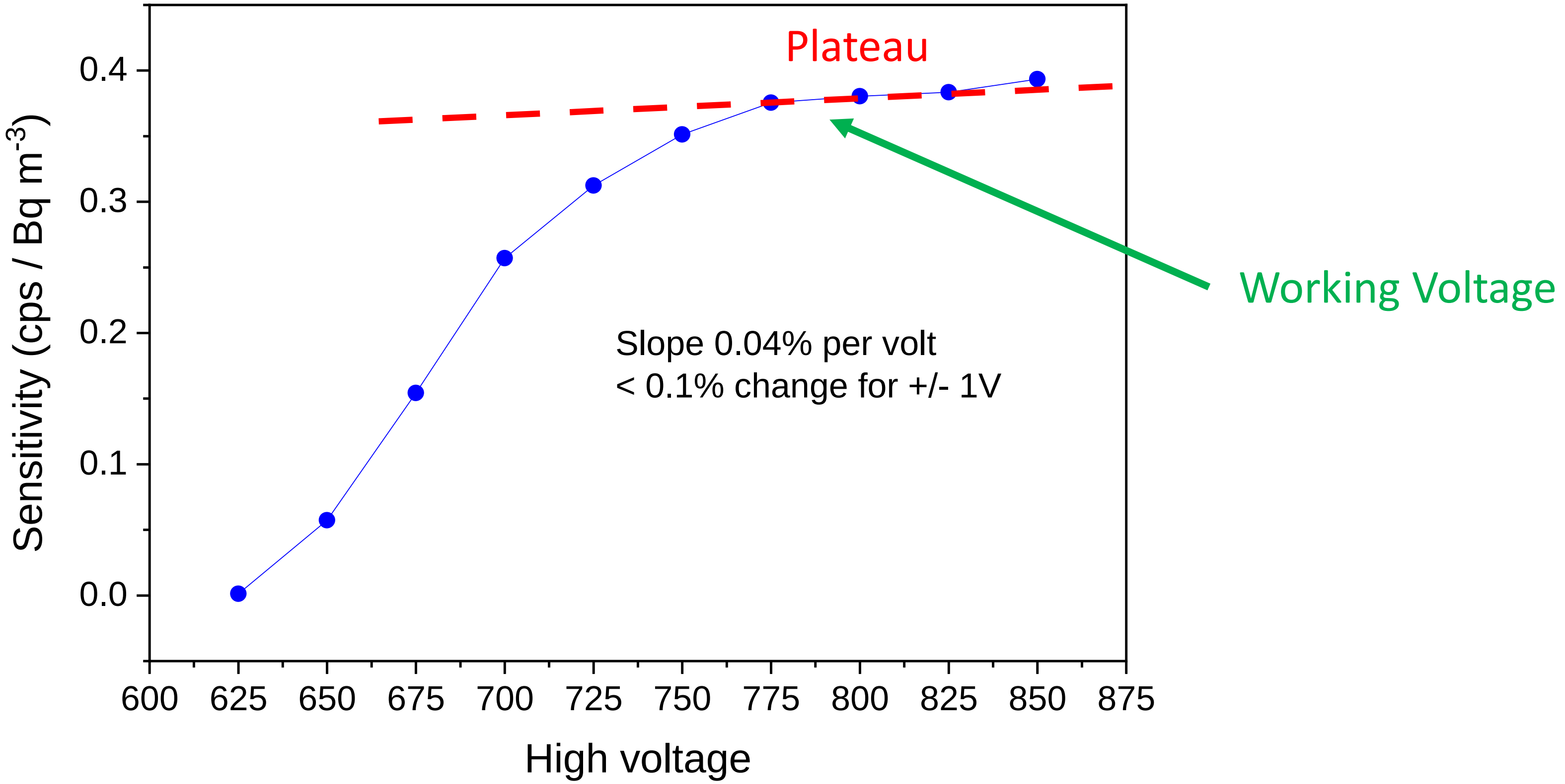
Uncertainty in high voltage supply

- ANSTO detectors are operated at a HV within a plateau of sensitivity response. Within this region the change in sensitivity with HV is small, of order **0.02 – 0.04% per volt**
- The standard deviation of HV for the ICP periods was around **1.1 V**



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Total uncertainty budget

$$C_{Rn} = \frac{G_\alpha - B}{t \cdot F_{cal}} \cdot C_P C_T \quad \Rightarrow \quad u^2(C_{Rn}) = \sum_{i=1}^{n} (\frac{\partial f}{\partial x_i})^2 u^2(x_i)$$

$$\begin{aligned} u^2(C_{Rn}) = & (\frac{C_P C_T}{t \cdot F_{cal}})^2 \cdot u^2(G_\alpha) \\ & + (-\frac{C_P C_T}{t \cdot F_{cal}})^2 \cdot u^2(B) \\ & + (\frac{C_P C_T}{t \cdot F_{cal}^2} \cdot (G_\alpha - B))^2 \cdot u^2(F_{cal}) \\ & + (\frac{C_T P_o}{t \cdot F_{cal} \cdot P^2} \cdot (G_\alpha - B))^2 \cdot u^2(P) \\ & + (\frac{C_T}{t \cdot F_{cal} \cdot T_o} \cdot (G_\alpha - B))^2 \cdot u^2(T) \end{aligned}$$

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Table 2.1: Uncertainty budget of the Ansto 200 l.

Quantity	Estimate	Uncertainty	Sensitivity Coefficient	Product
x_i		$u(x_i)$	c_i	$c_i^2 \cdot u^2(x_i)$
G_α	520.27 h^{-1}	22.8	$\frac{C_P C_T}{t \cdot F_{cal}}$	$c_i^2 \cdot u^2(G_\alpha)$
B	61.52 h^{-1}	8.28	$-\frac{C_P C_T}{t \cdot F_{cal}}$	$c_i^2 \cdot u^2(B)$
F_{cal}	0.03846 cps Bq·m^{-3}	0.0013	$\frac{C_P C_T}{t \cdot F_{cal}^2} \cdot (G_\alpha - B)$	$c_i^2 \cdot u^2(F_{cal})$
P	1004.7 hPa	0.3[a]	$\frac{C_T P_o}{t \cdot F_{cal} \cdot P^2} \cdot (G_\alpha - B)$	$c_i^2 \cdot u^2(P)$
T	301.64 K	0.22[b]	$\frac{C_T}{t \cdot F_{cal} \cdot T_o} \cdot (G_\alpha - B)$	$c_i^2 \cdot u^2(T)$

Table 2.2: Uncertainty budget of the Ansto 200 l without time response correction.

Quantity	Estimate	Uncertainty	Sensitivity Coefficient	Product of squares
G_α	520.27 h^{-1}	22.8	0.0073969	0.028443
B	61.52 h^{-1}	8.28	-0.0073969	0.002751
F_{cal}	0.03846 cps Bq·m^{-3}	0.0013	88.23028	0.0131559
P	1004.7 hPa	0.3[a]	0.223377	0.0000010
T	301.64 K	0.22[b]	0.0112496	0.0000061
			Sum	0.04536
			Square root	0.213 Bq·m^{-3}
			Percent of mean C_{Rn}	6.13 %

July 2022 SAC

Borrowed from D2

Calculated for C_{Rn} ~3.3 Bq m^{-3}

Using field background (high uncertainty)

5.67% for lab BG

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Table 2.3: Uncertainty budget of the Ansto 2001 with time response correction.

Quantity	Estimate	Uncertainty	Sensitivity Coefficient	Product of squares
G_α	520.27 h^{-1}	96.1	0.0073969	0.5053
B	61.52 h^{-1}	8.28	-0.0073969	0.002751
F_{cal}	0.03846 cps $Bq{\cdot}m^{-3}$	0.0013	88.23028	0.0131559
P	1004.7 hPa	0.3[a]	0.223377	0.0000010
T	301.64 K	0.22[b]	0.0112496	0.0000061
			Sum	0.52221
			Square root	0.723 $Bq{\cdot}m^{-3}$
			Percent of mean C_{Rn}	20.79 %

[a]derived from the manufacturer.
[b]derived from the manufacturer.

Deconvoluted
Borrowed from D2

Calculated for C_{Rn} ~3.3 Bq m^{-3}

Using field background (high uncertainty)

20.6% for lab BG

Note: This includes an assumed uncertainty for the internal flow rate that is at least 4 times too high based on detector performance for the traceRADON ICPs.

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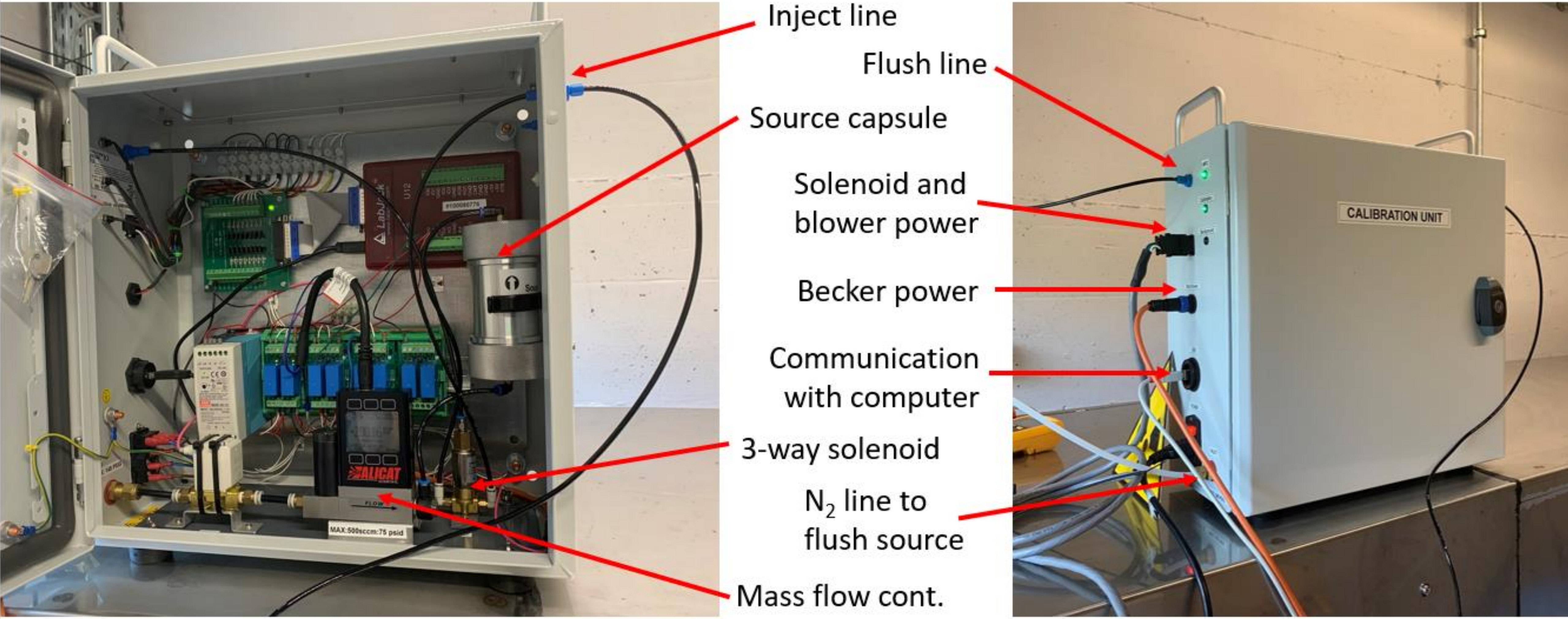
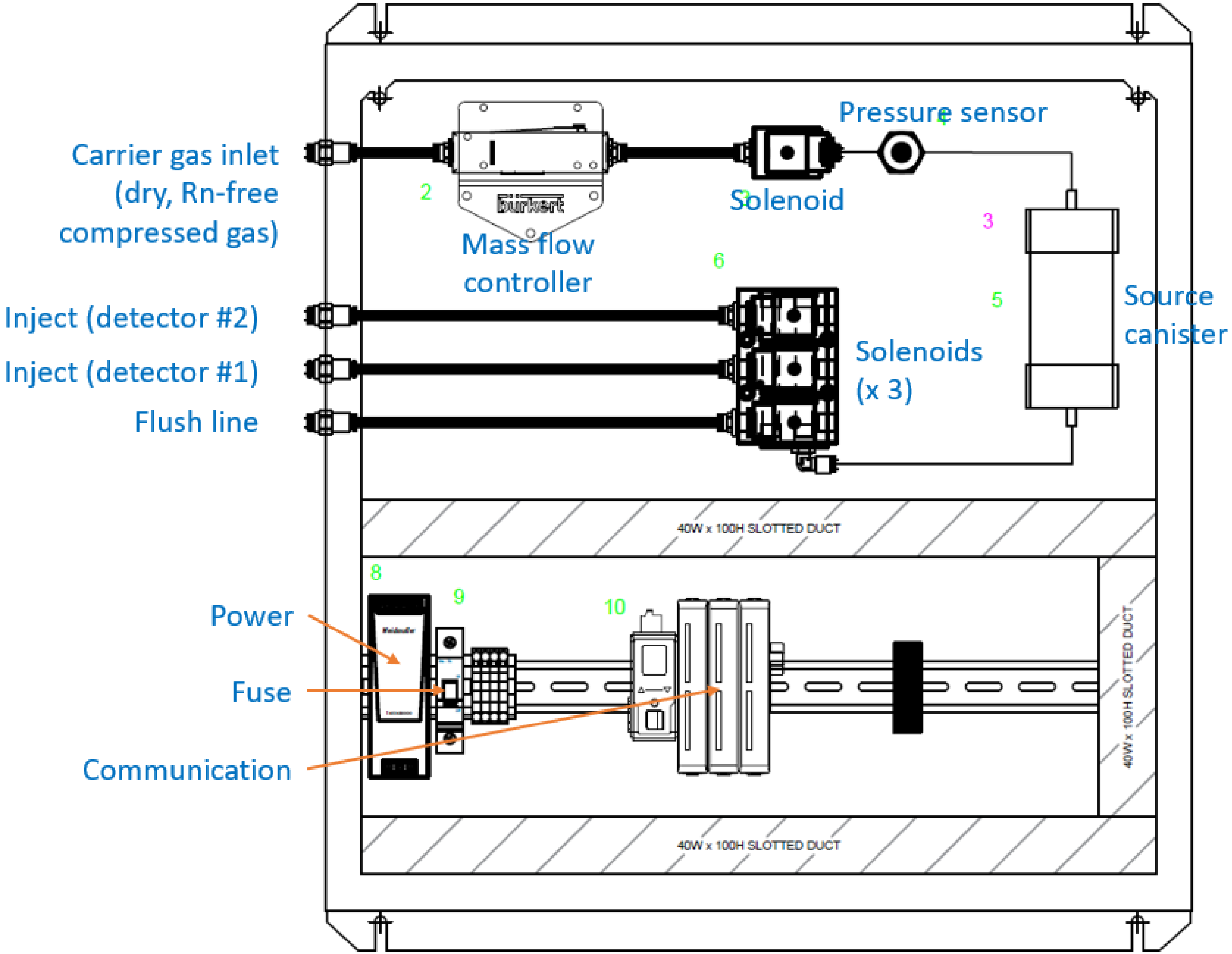
Scope for improvement …

Previous calibration systems



Newly designed field calibration system for ANSTO radon detectors



This new calibration system represents a great improvement on the existing systems. It should be more consistent, more reliable and require less maintenance. It is much more simple, and all parts are available worldwide and can readily be swapped out.

Conditioned compressed gas (at 0.1 – 0.2 L/min) is used as the carrier gas, not ambient air, and no pump is required.

The section between the solenoids can be sealed (and pressurised for leak testing). This allows two kinds of calibrations to be performed: (i) single pulse injections of accumulated radon, or (ii) continuous injection over 4 – 6 hours.

Further developments

- High voltage units have been redesigned (modernised)
- High voltage units being prepared for external manufacture
- Should result in more consistency between units & lower temperature sensitivity

- With the calibration system, HV units and logging systems all having their production outsourced, we are also aiming to **achieve CE certification** for the ANSTO radon detectors and autoflux systems **within 6 months**

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