

Characterising Radon Emanations from Radium-Dial Watches.

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Introduction – Context

Research during the latter half of 2011 has indicated that in addition to the hazard arising directly from the radium content of radium-dial watches, significant radon concentrations that exceed the UK Domestic and Workplace Action Levels of 200 Bq/m³ and 400 Bq/m³, respectively, can arise from watches stored in the built environment. In an extension to that earlier research, the radon emanations from the watches are being investigated in order to evaluate the radon hazard and the effective radium content of the watches.

We report here preliminary results from this ongoing investigation which suggest that radon emanation is not necessarily a straightforward function of radium content, as anticipated, but also depends on chamber temperature and humidity impacting upon watch-dependent factors such as design, construction, (non-radioactive) materials and wear-and-tear.

As well as variation in materials and manufacture between different watches, even between different production batches of the same brand and model, individual watches have been kept, used and handled differently since manufacture. Thus, different watches of identical manufacture can have very different radon emanation properties.

Measurement Method & Strategy

The radon measurements are made by placing the watches in a sealed chamber in a closed loop with a DurrIDGE RAD7 and a drying column, having total volume of 0.00868 m³ (8.68l).

Three sets of measurements are being made:

- Measurement of the entire collection of watches at one time. This is proving problematic due to the high level of radium in the collection and the high aggregate radon emanation.
- Measurement of the collection in four batches, two of pocket watches and two of wrist watches.
- Measurement of individual watches.

This presentation focuses on individual watch measurements. These are being performed to understand and characterise the influences on the emanation of radon from the watch interior to the external environment.

Typical pocket and wrist radium-dial watches are shown in Figure 1.



Fig 1. Typical Radium-Dial Watches
Left: Buren pocket watch, Swiss, 1940s
Centre: Ingersoll pocket watch, UK, 1930s-1950s
Right: Newmark wrist watch, UK, 1960s

Results: General

In all cases, the radon concentration measured by the RAD7 increases approximately exponentially from the background concentration in the laboratory (ca. 10 Bq m⁻³) to an equilibrium concentration determined by:

- the effective radium content of the watch(es) in the chamber;
- the total exponential rate-constant governing the concentration growth.

The effective radium content is the amount of unenclosed radium which would yield the same rate of radon generation as that enclosed in the watch(es). This will be less than the actual radium content.

The total exponential rate constant is the combination of the radioactive rate-constant and the leakage rate from (and plate-out rate inside) the closed loop.

Typical data (from the first batch of pocket watches, are shown in Figure 2.

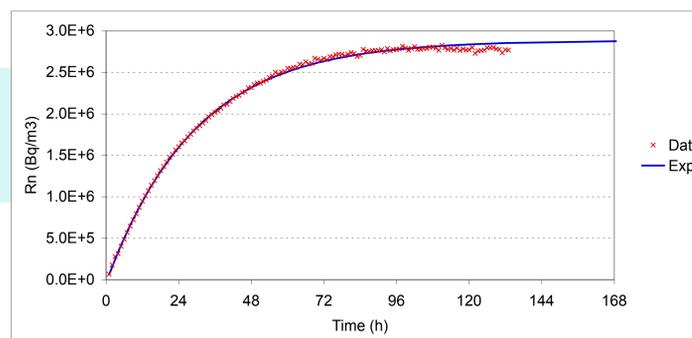


Fig 2. Pocket Watches, First Batch. Data shown by red crosses; exponential shown by blue line.

Results: Variation of Rate-Constant

Although not immediately apparent from the data, the exponential rate-constant varies during the measurement period, generally but not uniformly or monotonically decreasing with time.

A typical example of this is shown in Figure 3.

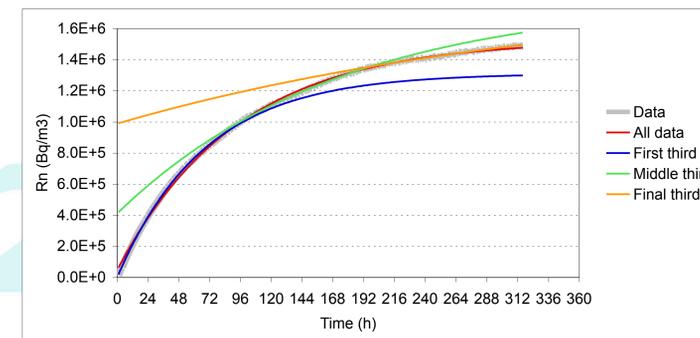


Fig 2. Radon Exponential Increase: Cyma Pocket Watch. The different exponential curves show the decrease in rate-constant with time.

For the Cyma pocket watch (Figure 3), the rate constant has an average value of 0.0107 h⁻¹:

- 0.0147 h⁻¹ over the first third of the data
- 0.0058 h⁻¹ over the middle third of the data
- 0.0028 h⁻¹ over the final third of the data

The RAD7 records temperature and relative humidity of the air in its chamber, as well as radon concentration. In all the data collected to date, the relative humidity decreases approximately exponentially from a first reading (at ca. 1 hour) of typically 10% to a steady value of 1-2% (the RAD7 records at 1% resolution). In most of the data collected to date, the temperature is close to uniform, typically varying by less than 1 °C about a mean of 20-22 °C.

Although the resolution of the RAD7 limits the precision of calculation, the actual moisture content of the air can be estimated from the temperature and relative humidity, and other research in progress at the University of Northampton is indicating that air moisture content (e.g. as indicated by vapour pressure or dew-point) is a better measure of influence on radon concentration than relative humidity.

The estimated water-vapour pressure for the Cyma pocket watch is shown in Figure 4. The estimate is constrained by the RAD7's precision in recording relative humidity.

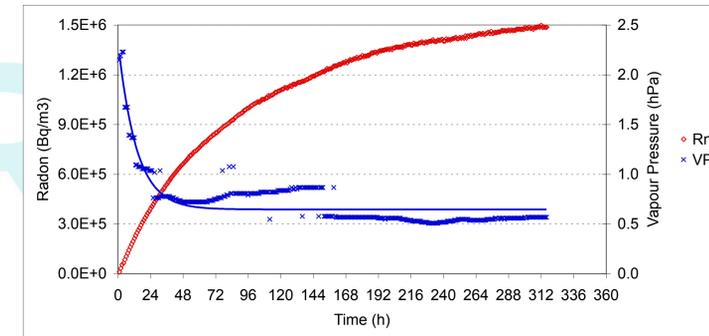


Fig 4. Radon and Water Vapour Pressure: Cyma Watch.

Further analysis currently in progress indicates, provisionally, that the exponential rate-constant decreases with decreasing air water-vapour content.

Decomposition of high-frequency “noise” components from the radon data indicates that the radon concentration curve becomes noisier, less smooth, at times where the decreasing trend in air water-vapour content is interrupted and the water-vapour “oscillates” for a few hours before returning to the decreasing trend.

Conclusions

The total radon activity of the watch collection is 220 kBq, obtained by aggregating the radon equilibrium concentrations from the four batch measurements. This implies the effective radium content/activity giving rise to “free” radon in the environment is 220 kBq.

This compares to a total inferred radium content/activity, for all the watches, of 390 kBq, i.e. the effective radium content is approximately 57% of the total radium content.

This radon activity of 220 kBq would give rise to very hazardous radon concentrations in domestic rooms such as might be used by private watch collectors to keep their collections (e.g. 7.3 kBq/m³ in a 2.5 x 3 x 4 m room).

References

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