# Development of a field portable tritium instrument - applicable detector technologies


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# Talk Outline

- Why develop a field portable tritium monitor?

- Problems associated with portable tritium measurement

-**Approaches** - possible detector types

    - Gas filled detectors

    - Scintillation based detectors

    - Solid-state detectors

- Potential sample handling techniques

- **Summary** - where to go next ?

# Why develop a field portable tritium instrument?

- Numerous applications for $^{3}H$ $\Rightarrow$ set to increase?

  fission, fusion, research etc, decommissioning…

- Currently, a high percentage of samples are sent to third party labs:

  Sampling $\Rightarrow$ Extraction $\Rightarrow$ Measurement $\Rightarrow$ reporting

  **- Costly**

  **- Not in-situ**

  **- Time consuming**


Raddec Pyrolyser and Wallac Quantalus for tritium extraction and measurement. Images courtesy of GAU

**Aim:**

To develop a ‘field-portable’ instrument capable of extracting and measuring tritium in a wide range of materials with detection limits of 10’s of Bq $g^{-1}$.

# Problems associated with tritium monitoring

- $^3$H is a very weak pure beta emitter - $E_{max}$ ~ 18.6 keV, $E_{ave}$ ~ 6 keV

$\Rightarrow$ such low energies require specialised equipment / techniques

- **Ideally:**

Sample should be in intimate contact or VERY close to the detector (or inside in the case of proportional counters) - maximum range of $^3$H beta's in air ~ 1mm or 1$\mu$m in solids / liquids (Wampler and Doyle, 1994).

Should be viewed with a 4$\pi$ geometry to maximise efficiency.

Detector should be designed with maximum tritium counting efficiency in mind - i.e. thin / no entrance window, low noise…

Background should be as low as reasonably possible, including compensation for other radionuclides e.g. Radon and other mixed $\alpha/\beta/\gamma$

**In addition a portable detector must be light, robust, reliable…**

# Approaches - possible detectors:

-Detectors for $^3H$ measurement can be broadly broken down into three categories:

Gas Filled detectors - ion chambers, GM, GFPC

Scintillation detectors - solid and liquid

Solid state detectors

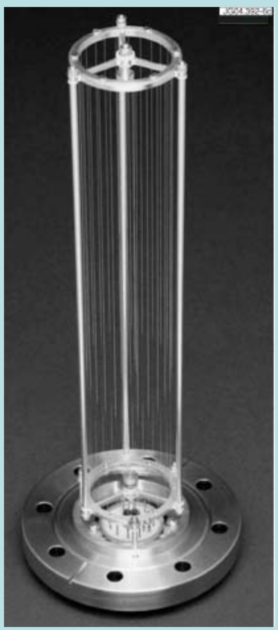
All have advantages and disadvantages that should be considered!

# Gas filled detectors for $^{3}H$

- **Ionisation chambers** - current, charge integration or pulse mode
- Low activities can be detected, the LOD will be a function of:

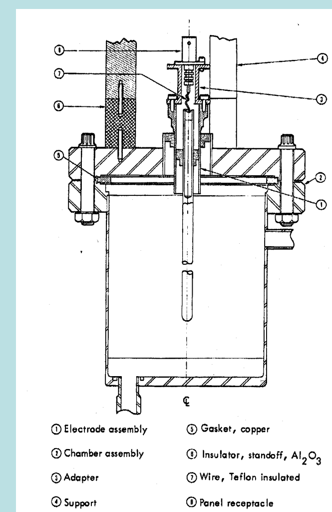
Chamber volume, electronics, count time, background

- Memory affects - contamination resistant chambers



(Worth et al. 2005) Low internal surface area, 400 $cm^3$, fine wire electrodes tested to 51 Bq $cm^{-3}$

(Colmenares, 1974) Contamination resistant, no elastomeric material, 1000 $cm^3$, LOD of 18.5 Bq $cm^{-3}$




Additional ion chambers developed for tritium include: Pearson et al. 1991, and Weesner and McManus, 1988

# Commercially available portable ionisation based tritium monitors

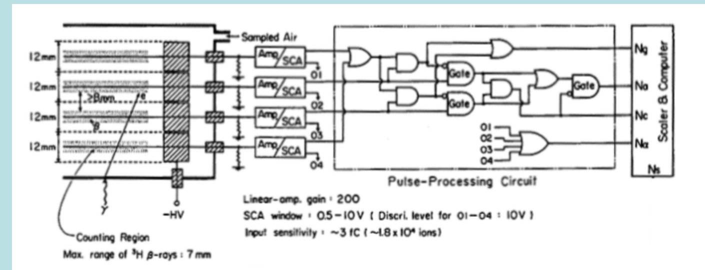
| Model | Configuration | γ compensation | LOD |
|---|---|---|---|
| Technical Associates PTG-7 | 2000 cm$^3$ chamber including filter and de-ioniser on input | Sealed 2000 cm$^3$ reference chamber | 0.037 Bq cm$^{-3}$ |
| Overhoff SP1400DD | 1400 cm$^3$ chamber including filtered input, HTO/DTO option | 1400 cm$^3$ reference chamber | 0.037 Bq cm$^{-3}$ |
| Sartrex 309 | 250 cm$^3$ chamber including filtered input | Sealed 250 cm$^3$ reference chamber | 0.037 Bq cm$^{-3}$ |
| Premium Analyse βIonix | 100 or 1000 cm$^3$ chamber, 5 kg weight | Sealed 100 / 1000 cm$^3$ reference chamber | 0.0025 Bq cm$^{-3}$ |
| Lab Impex Systems H35L-P | 2000 cm$^3$ chamber including filter and de-ioniser on input | Sealed 2000 cm$^3$ reference chamber | 0.033 Bq cm$^{-3}$ |
| Canberra TAMD-73 | 2400 cm$^3$ chamber including filtered input. | Sealed 2400 cm$^3$ reference chamber, radon compensation | 0.037 Bq cm$^{-3}$ |

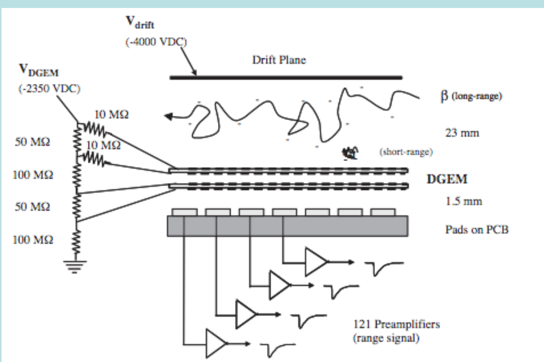


# Gas filled detectors for $^3H$ (2)

- **Proportional counters** - internal gain, but usually require a gas supply
- Energy information - energy discrimination

(Aoyama et al. 1987) Air flow counter, $\gamma/\beta$ compensation by two guard counters. LOD of 0.037 Bq $cm^{-3}$




(Surette and Dubeau 2005) DGEM and PCB collector pads, $\gamma/\beta$ compensation. LOD 0.074 Bq $cm^{-3}$

Commercially available detectors include Raytest RAGA, Protean instruments MPC, Berthold LB 110, and Tech. Assoc. PTS-26.

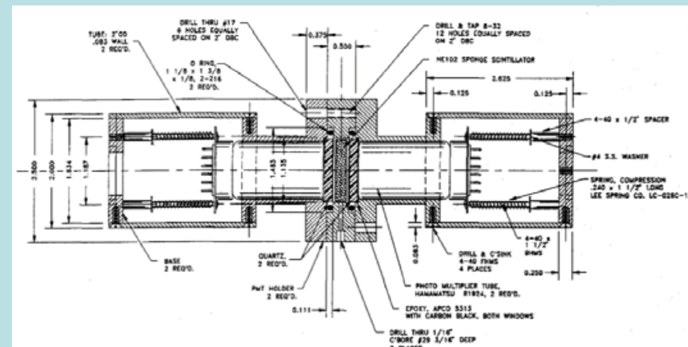
**GM** - Seimiya et al. (1965) - ultra-thin polycarbonate windowed GM capable of measuring tritium

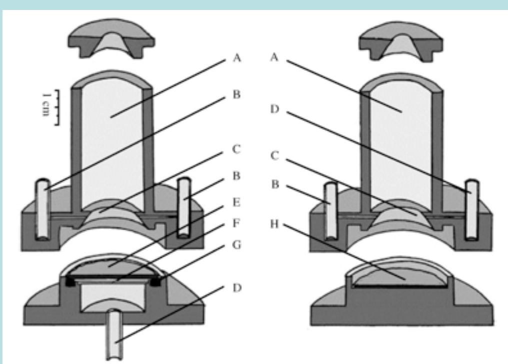
# Scintillation detectors for $^{3}H$

- Solid or liquid scintillators, latter may offer higher efficiency, but creates a waste stream ⇒ solid scintillators often re-usable.

- **Solid scintillant** tritium monitors:

Flow through (liquid) - Rathnakaran et al. (2000), Falter and Bauer (1992) - ‘sponge’ filled cell formed from perforated scintillating film. LOD 37 Bq $ml^{-1}$ / 5 minute count.



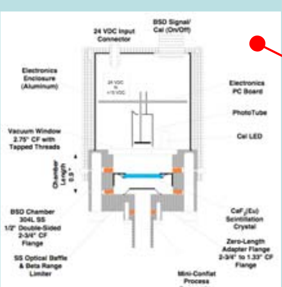



Gaseous - Arosio et al. (2000) - a personal monitor using a scintillating filter (Cerium-activated Y Al Perovskite powder) or plastic disc. LOD of 0.8 Bq $cm^{-3}$.

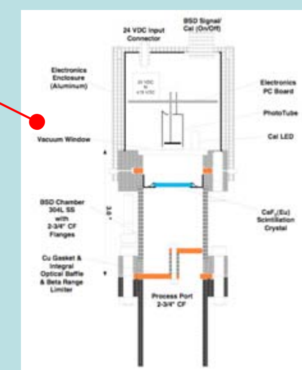
Others include Colmenares et al. (1974) and Ellefson et al. (1995).

# Commercially available solid scintillant $^{3}$H monitors





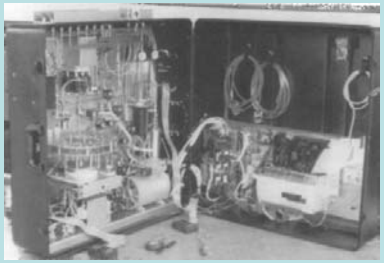
| Model | Configuration | Background & E | LOD |
|---|---|---|---|
| Technical Associates SSS-33M8 | Flow through cell with scintillating micro-crystals and 2 PMT's | - | 3.7 Bq $ml^{-1}$ |
| Raytest RAMONA | Flow through solid / liquid cell radio-HPLC detector, 2 PMTs | Up to 20% | 4Bq $ml^{-1}$ |
| Berthold LB 509 | Flow through cell radio-HPLC detector | 8-10 cpm, 8 - 50% | - |
| Mound BSD275 | 60 $cm^3$ sample chamber and $CaF_2$[Eu] crystal | - | |
| Mound BSD133 | 20 $cm^3$ sample chamber and $CaF_2$[Eu] crystal | - | |

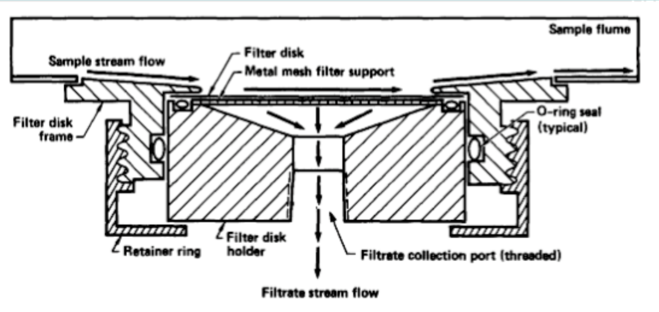



# Scintillation detectors for $^3$H (2)

-**Liquid scintillant** tritium monitors - usually designed around lab based systems made 'portable'!

Hofstetter et al. (1998/9) - 'FDTAS' based on automated sample / scintillant mixing system and Packard 525TR LSC. LOD of 6.4*$10^{-3}$ Bq $ml^{-1}$ (100 min, 0.025 cps bkd).






Huntzinger et al. (1984) - real time monitor based on a cross flow filter to collect samples from a sample stream and Radiometric Instruments Flo-One LSC. LOD 9.8 Bq $ml^{-1}$ (20 min).

# Commercially available portable LSC for $^{3}H$ monitoring



| Model | Configuration | Background / E | LOD |
|---|---|---|---|
| Hidex Triathler | Single vial manual LSC with single PMT and optional shielding | Tritium efficiencies of >45% | ~25 Bq $ml^{-1}$ |
| Raytest Malisa Star | Single vial manual LSC with shielding option | - | As low as 0.1 Bq $ml^{-1}$ |
| Technical Associates SSS-12 | Single vial manual LSC with single PMT and optional shielding | Energy discrimination for noise and background reduction | - |
| Technical Associates SSS-22P | Single vial manual LSC specifically for tritium, dual PMT, shielding | Tritium efficiencies of >60% | - |
| Lumi-scint DOE | Drawer loading single vial LSC. | Threshold based noise reduction | ~ 0.9 Bq $ml^{-1}$ |
| IN/US β-RAM | Flow through cell radio-HPLC detector | <3 cpm, >50% | - |



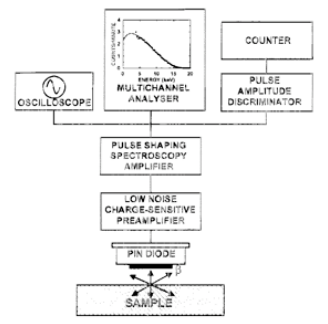

Other counters not designed specifically for tritium may also be applicable such as the Ballard MicroCount.

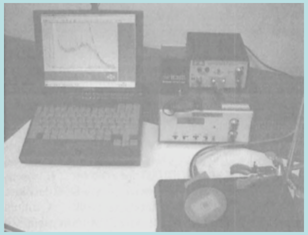
# Solid-state $^3$H monitors

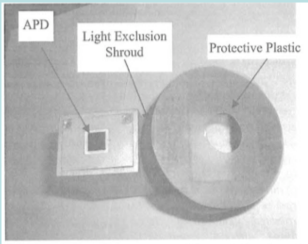
- Usually based on PIN photo-diodes or Avalanche photodiodes (APD's - offer the benefit of additional internal gain).

- McGann et al. (1988) - first to really investigate use of diodes for tritium detection - APD system with an LOD of 33 Bq cm$^{-2}$ (500 s count)

Wampler and Doyle (1994) - Hamamatsu PIN diodes used in portable and bench-top monitors. LOD of 10 Bq cm$^{-2}$.






Scott Willms et al. (2005) - utilised a large area APD from Radiation monitoring devices Inc. LOD of 0.17 Bq cm$^{-2}$ (96 hr count!)

Additional detectors include Surette et al. (2007) who have developed a PIN diode based dosimeter and Shah et al. (1990).

# Summary

- A large range of detectors have been developed for tritium monitoring.
- Examples of all three types may offer suitable detection limits, however:

Both proportional counters and LSC systems require consumables, and in some cases create additional waste.

Proportional counters that utilise air are both susceptible to variations in T, P and humidity and maybe fragile in construction.

Ionisation chambers are prone to memory effects, particularly at low levels, and require large sample volumes.

As a result, the most suitable detector types to pursue maybe either solid scintillators or solid-state detectors as they are potentially robust, compact and reusable.

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