ユーザーセミナー
2015
CANBERRA
キャンペラジャパン株式会社
Canberra iCAM: the worldwide alpha/beta air monitoring solution

James Forde-Johnston
EMS Product Manager
Japan User Group Meeting
CAM Detection Overview

► What is a CAM (Continuous Air Monitor) for?
► To detect and alarm *as quickly as possible* when hazardous levels of alpha and beta particulates are present

► The Alpha Hazard
  ► 1 DAC of $^{238, 239, 240}\text{Pu} \& ^{241}\text{Am} = 0.1 \text{ Bq/m}^3$
  ► DAC Definition: $2000 \text{ DACHrs} = 1 \text{ DAC} \times 2000 \text{ hours working year}$
  ► $2000 \text{ DACHrs} = \text{Annual Limit of Intake (ALI)} = 20 \text{ mSv dose}$
    • DACHr measurement = total exposure or dose equivalent
    • Typical alarm level = 1 - 8 DACHrs (= 0.01 - 0.08 mSv)

► The Beta Hazard
  ► 1 DAC of mixed fission products (typical) = 100 Bq/m$^3$
iCAM - The intelligent Alpha Beta CAM

- Simultaneous alpha & beta air monitor
  - Optional gamma dose rate monitoring
- A light & compact integrated unit
  - Stand alone or network operation
- Comprehensive facilities on board
  - Multiple relays, current loop outputs, alarms, data logging, communications & setup
- Robust & easy to maintain
- High Reliability
  - Certified to IEC61508 SIL1
- Sophisticated Radon compensation
  - Worldwide patents
- Market leader in UK, USA
  - Gaining rapidly in France/Europe & RoW
iCAM - Main Benefits

- **Ease of use**
  - Menu driven graphical display
  - Automated calibration

- **Lowest False Alarm rates**
  - Rn/Th compensation algorithms monitor and adapt to changes in spectrum shape, resulting in
    - Lower false alarm rates
    - Low alarm levels
    - Less frequent filter changes

- **Tested & Certified to:**
  - IEC 61172, 60761-1 & -2, 61578, 61508
  - Real Pu$^{239}$ & Cs$^{137}$ aerosol tests at CEA Saclay
    - Type tested to ANSI 42.17B for USA
Air is drawn through the instrument by means of an external pump or other means, and airborne particulate material is deposited on a filter.

The filter is monitored by a Canberra PIPS ion-implanted silicon radiation detector, which allows simultaneous measurement of both alpha and beta radioactivity deposited on the filter.
iCAM Overview - Standard Air Sampling

- Air flow
- Absorber
- Card mounting for ease of handling, replacement and (optional) bar coding
- Alpha/Beta detector (25mm diameter)
- Glass fibre filter (25mm diameter)
- To flowmeter (2.22m³/hr) and pump

Gamma background detector
iCAM - High Particulate Collection Efficiency on Filter

Polymer Latex Particle Test Results @ 37 L/min

Collection Efficiency (%) vs. Particle Size (µm)
iCAM Detection Overview

- 90% of real alarms are from rapid short term releases, not slow trends!
  - So rapid response is vital to protect personnel

- iCAM’s high efficiency (24.5% for alpha) gives high sensitivity & good counting statistics
  - After 1 hr at 0.1 Bq/m³ $^{239}$Pu activity on filter = 0.054 cps, or 3.3 cpm
  - A typical first alarm level = 26.4 cpm
  - Doesn’t look difficult......BUT.......
The Radon Background Problem

- Typical Radon count rates are 500 cpm, with up to 10,000 cpm in poorly ventilated areas
  - Highest seen > 30,000 cpm!

- How to prevent high radon giving false alarms?
  - iCAM uses Alpha Spectrometry and a patented spectrum stripping method to separate Radon from activity of interest in a 256 channel MCA
  - iCAM compensates both alpha and beta measurements for radon background
Radon & Thoron Decay

**Rn-222 (RADON)**
- **(3.82d)**
  - **5.49 MeVα**
  - **Po - 218 (RaA)**
    - **(3.05min) 6.0 MeVα**
  - **Pb - 214 (RaB)**
    - **(26.8 min) 0.67 MeV (max) β**
    - **Bi - 214 (RaC)**
      - **(19.7 min) 3.26 MeV (max) β**
      - **Po - 214 (RaC)²**
        - **(164 µsec) 7.68 MeVα**
      - **Pb - 210 (RaD)**
        - **(22y)**
          - **Pb – 206 (STABLE)**

**Rn - 220 (THORON)**
- **(54.5 sec)**
  - **6.29 MeVα**
  - **Po - 216 (ThA)**
    - **(0.16 sec) 6.78 MeVα**
  - **Pb - 212 (ThB)**
    - **(10.6h) 0.58 MeV (max)β**
    - **Bi - 212 (ThC)**
      - **(60.5 min) 2.25 MeV (max) β**
      - **(36%) 6.05 MeV α**
      - **TI - 208 (ThC)²**
        - **(3.1 min) 1.8 MeV (max) β**
      - **Po - 212 (ThC)²**
        - **(0.3 sec) 8.78 MeV α**
      - **Pb - 208 (ThD)**
        - **(STABLE)**
Typical Filter Spectrum

5 minute Spectrum

U/Pu/Am region
3 - 5.7 MeV
Spectrum Shape Changes

i-CAM COMPARE SPECTRA RECORDED IN DIFFERENT LOCATIONS

Location: Pit 3
Location: G11

ITOTAL

U/Pu/Am region
3 - 5.7 MeV

Snaphot_icam191001
Snaphot_icam3801

Pit 3
RaA/ThC peak: CN 147
RaC' peak: CN 192
ThC' peak: CN 224

G11
RaA/ThC peak: CN 147
RaC' peak: CN 195
ThC' peak: CN 225
Radon/Thoron Compensation

- Filter spectrum captured over typically 5 min for activity measurement and 20 min for shape analysis
- Patented algorithm does successive exponential fit & strip to remove each component of the background individually

Results:
- lower alarm levels & lower false alarm rate, especially in difficult conditions
- extended filter lifetime
- ability to make measurements and set alarms over long timescale simultaneously with the foreground measurement
Spectrum Stripping: Raw Spectrum

Pulse-height Spectrum from iCAM Air Monitor

Spectrum Data File: Snap_P3_Nov19_0810_Total

Channel Number

Initial Channel Counts

Channel Counts

0 16 32 48 64 80 96 112 128 144 160 176 192 208 224 240 256

25000
20000
15000
10000
5000
0
First Stage Strip

iCAM Spectrum Strip: (1) Initial Spectrum, (2) Calculated ThC+ThC' Spectrum and (3) Spectrum after stripping-out the contribution of thoron daughters ThC+ThC'.
214Po (RaC’) Peak Fit

iCAM Alpha Spectrum Strip: RaC’ Fit

Channel Number

Channel Counts

AFTER ThC+ThC’ stripped
RaC’ Spectrum
Second Stage Strip

iCAM Spectrum Strip: Alpha Spectrum after ThC+ThC' & RaC' Strip

Channel Counts

0 20 40 60 80 100 120 140 160 180 200 220 240

Channel Number

AFTER ThC+ThC' stripped
AFTER RaC' & ThC+ThC' stripped
218Po (RaA) Peak Fit

iCAM Alpha Spectrum Strip: Step 3. RaA Spectrum Fit

- AFTER RaC’ & ThC+ThC’ stripped
- Fitted RaA Spectrum to be stripped
Third Stage Strip

iCAM Alpha Spectrum Strip: Before and after RaA strip

- AFTER RaC' & ThC+ThC' stripped
- AFTER RaA, RaC' & ThC+ThC' stripped

Channel Number vs. Channel Counts graph.
Fully Stripped Spectrum

iCAM Alpha Spectrum Strip: Initial Spectrum and Final Spectrum

Spectrum Data File: Snap_P3_Nov19_0810_Total

- Initial Channel Counts
- AFTER RaA, RaC' & ThC+ThC' stripped
i CAM - Short term Alpha Measurement

i-CAM. Alpha Response & radon/thoron daughters' background vs Time

- LT Alpha
- Rn+Tn alpha b/g (Bq.h/m3)

First Entry: 17:22  18/10/01
Last Entry: 10:25 22/10/01
LT Averaging Time = 60 min
Update interval = 15 secs
Archive interval = 5 mins
BG Averaging Time = 5 min

Filter changed on 18/10/01 at 17:22
Filter changed on 19/10/01 at 16:50
Spectrum Stripping Benefits

- Method adapts to variations in spectrum shape automatically
  - Extends filter life
  - Greatly reduced false alarm rate
- Allows measurement of all Rn/Th progeny activities
- Allows estimation of Rn/Th gas concentration
- Beta Rn background is calculated from measured alpha background
  - Beta Rn/Th background is more significant than gamma background up to ~ 10 µSv/hr
iCAM Range Summary

- iCAM/S & /D fixed filter
  - /G gamma dose rate option
- iCAM/MF – Moving Filter
- iCAM/MFS – MF stack/duct monitor
- iCAM-RH – Remote Head
- Iodine Channel
- iCAM PING
- Ethernet & WiFi options
- iCAM-HD
iCAM/S & iCAM/D Fixed Filter

- Versions with card mounted filter
  - Preferred versions where off-line measurement after sampling is required

- iCAM/S
  - 1 x PIPS for alpha & beta – up to 10 µSv/hr gamma background

- iCAM/D
  - Dual PIPS
    - Front PIPS for alpha et beta measurement
    - Second PIPS for gamma compensation of the beta measurement to > 150 µSv/hr
  - Manual filter change by operator – from 8 hours to 1 week
  - Filters available:
    - Glass fibre (GFA), FSLW membrane, activated charcoal (beta + Iodine), activated charcoal & GFA (alpha, beta + Iodine)

- Capable of external gamma dose rate measurement with optional G64 head
iCAM/MF Moving Filter

- Automatic filter change mechanism fits in place of fixed filter head
- Uses same detectors, amplifiers & algorithms as fixed head iCAM
- FSLW filter roll
  - 12 m roll gives 12 months autonomy @ 1 change per day
- > x2 Lower MDA than with GFA filter
  - FSLW filter gives better resolution & spectrum shape
- For ambient sampling or via pipe or hose
  - From duct or through wall/cabinets
  - Ideal for wide area environmental monitoring systems
**iCAM/MFS: High integrity Stack Monitor**

- **Separate Sampling Head**
  - Up to 10 m from head to controller
  - For high activity sampling
  - High Integrity design - Vacuum sealed
  - High sampling efficiency
    - Low losses & low internal contamination
  - Removeable cassette for the filter roll
    - Avoids handling highly active filter
      - Filter change can be done outside active area
  - Ideal for fixed pipework
    - No hinging of the head required to change the filter or for calibration
  - Active aerosol testing ($^{239}$Pu & $^{137}$Cs) completed
    - CTHIR certification to IEC61172, 60761-2 & 2 and 61578
iCAM/RH: Long Distance Remote Head

► Allows sampling up to 100m from the iCAM control unit
  ❖ Head contains amplifiers, flow & pressure measurement so no pipe required back to control unit
  ❖ 2 x coax cables & 1 serial data cable to iCAM CU
  ❖ Can be used in any orientation

► Any sampling head can be used
  ❖ Fixed filter /S, /D or MF

► No manual adjustments in head
  ❖ All calibration adjustments made at the iCAM CU
Installed Base

iCAM /S /D  iCAM /MF /MFS

- BNFL Sellafield > 1000 units –
- All UK NPPs ~ 100 units
- RWE Nukem (UK)
- AEA Technology Harwell & Winfrith > 50 units
- URENCO > 60 units
- US DOE Sites: WIPP > 20 units, Savannah River, West Valley > 40, LLNL (>100 units), Argonne NL, KAPL, Oak Ridge & Y12 > 80 units, Bechtel Nevada (Los Alamos)
- US NPPs: Progress Energy fleet & others
- US Army
- KAERI Korea
- KHNP Korea – Different sites ~ 30 units
- Grohnde & Philipsburg NPPs & Paul Scherrer Institute Germany
- ANSTO Australia
- Canada: AECL > 100 units, Cameco, Bruce Power & other NPPs > 100 units
- FBFC Romans France – 20 x iCAM/MF
- Areva: GBIIN, S RECl Comhurex etc: > 100 units
- CEA Saclay France
- CEA Cadarache
- UKAEA Harwell Winfrith & Dounreay – 4 year exclusive supply contract > 1000 units
- FUKKUSHIMA : 40 iCAMs D & MF

> 4000 sold !!!!
Latest Options and New Developments
iCAM Add-on Iodine Channel

- Add on detector allows iCAM to measure Iodine in addition to alpha & beta particulate

- Benefits
  - Add on channel to existing iCAMs - so don’t not have to buy a separate Iodine monitor
  - Provides a lower cost, portable option for NPPS to replace old skid based CAMs

- Detector: 2" x 2" NaI with integral electronics & shield
  - 2" lead shielding - weight ~ 160 kg
  - Cartridge: 2" dia x 1" thick plastic cartridge: F&J AGZC58 (silver zeolite) or TE2C58 (charcoal)
  - Can be plumbed between the iCAM and the pump or from a separate air inlet
Iodine Detector for iCAM

- Fully shielded (160 kg Pb)
  - partially shielded version for portability
- Future upgraded version: EcoSpec NaI detector with LED stabilisation
  - to give fully stabilized spectrometry based system (single peak counting): lower MDA
- Serial connection between iCAM and pump
  - (using iCAM flow measurement)
  - or parallel connection (with separate flow measurement)
**iCAM PING** Particulate Iodine & Noble Gas Skid

- External Iodine & NG Detectors in shielded samplers
  - Both 2in x 2in NaI detectors
  - Plastic scintillation detector for beta NG in development
  - Pressure correction for NG measurement

- Samplers connected in series with iCAM using a single pump
iCAM Ethernet Card

- Adds Ethernet port to any Mk2 iCAM
- Board fits internally
  - replaces system cover board on back of door
- Provides IP65 sealed RJ45 port on gland plate
  - TCP/IP or UDP comms
  - Can be used to upgrade existing iCAMs
  - iConfig can connect to Ethernet port
    - Eliminates need for RS232 on laptops
  - Currently with proprietary Canberra protocol
  - Other protocols can be implemented without modifying the iCAM firmware
    - ModBus TCP available
    - RadNet implementation?
WiFi Module

- External add on unit allows WiFi to Horizon Server & iConfig
  - 300 ft range LoS
    - Longer range antennas can be used
  - Single cable connection into iCAM
    - Or other devices eg G64, ASM1000?
  - WEP 64-bit/128-bit data encryption, AES, WPA & WPA Enterprise security (WPA2/802.11i)
  - Fully licensed /approved for use in Japan
iCAM-HD

- iCAM-HD is a higher flow rate version of the standard Canberra iCAM alpha/beta air monitor
  - Identical Radon compensation algorithms, detector technology (dual CAM PIPS), amplifiers/bias generator & system board/CPU
  - Sampling head size and filter & detector diameter increased to accommodate flow rates up to 120 l/min (7.2 m³/hr)
  - Can accept Moving Filter Cassette or Fixed Filter holder
New Sampling Head

- New design alpha/beta sampling head
  - 2 x CAM1700SMC 47 mm dia PIPS detectors
    - 7 mm air gap from alpha/beta detector to filter
  - Flow rate range: 60 – 120 l/min
  - Pressure drop: < 15 kPa @ 120 l/min
  - Entirely stainless steel construction

- Uses moving filter cassette
  - 15 m long x 75 mm wide FSLW filter
  - Or fixed filter holder w 47 mm dia filter
    - Uses 75 x 75 mm filter paper
    - Or NFSRPS carrier
iCAM-HD Applications

- Upgrade passive sampling ports to active monitoring
  - Often need sustained flow rate $>> 60$ l/min
    - Standard iCAM can’t sustain 60 l/min continuous
- High dust loading applications (mines etc)
  - Large filter gives very low DP – long filter life
- Wide area/Outdoor Environmental Monitoring
  - Large filter – low DP – long filter life
- Where large sample filters are needed
  - Counting rooms often set up for 47 mm filters
Firmware Upgrades from standard iCAM

- Spectrum storage on alpha alarm
  - Every interval after an alarm
- Calculation of concentrations of all Rn & Th progeny
- Display of Decision Level/MDA
  - Optional suppression of L1 alarms on high background
    - Reduces false alarm risk
- Archive: Several versions
  - Standard, Compact, Background
  - 75,000 lines in ‘Compact’ format = > 8 months, ~ 3 months ‘Standard’
- All upgrades will appear in future standard iCAM firmware
Hardware Modifications from standard iCAM

► System/CPU Board is a standard iCAM board

► New I/O Board
  ► 4 x beacons (green, amber, red, white),
  ► Outputs for Remote Slave Alarm Units & extra relay outputs
    • 6 x relays
      - All rated @ 250VAC 6A AC1 1500VA
    • All relay states verified by CPU (safety relays)
  ► 3 x 4 – 20 mA outputs & 1 x 4 – 20 mA input (stack flow rate)

► 2 x Ethernet ports
  ► Standard iCAM or Modbus/TCP protocol
  ► No Access to parameters

► Optional backup battery pack
iCAM-HD: Design
iCAM-HD Views