CANBERRA CRITICALITY ACCIDENT ALARM SYSTEMS: Recent Developments

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Introduction

EDAC-21 is CANBERRA’s current generation Criticality Accident Alarm System (CAAS), with a 30+ year history in the field

- Developed for single-area monitoring inside a hot cell or small hot area
- Neutron and gamma sensitivity
- More than 50 EDAC systems with over 800 probes have been in use worldwide, some in continuous operation since 1980
- Mean time before failure (MTBF) of 56 years, without a single instance of a system failing to alarm when required.

Recent R&D efforts

- Support EDAC-21 and enhance for wide area coverage
- Develop Next Generation CAAS system: EDAC-21 → CAAS-3S
The EDAC $\gamma+n$ probe:
- PVT gamma scintillator
- Boron-loaded ZnS neutron scintillator
- Both sensors optically couple to single phototube
- Light-emitting diode provides continuous state of health monitoring.
- Processing electronics board

EDAC processing cabinet monitors 3 or 4 probes (choice of voting logic)

Power supply cabinet ensures full functionality during power outages

Supervisory software for remote monitoring and control
CAAS R&D objectives

Support & enhance current generation EDAC-21 system
- Address parts obsolescence, minimize future obsolescence risks
- Enhance probe performance to increase coverage area

Develop next generation system
- Response to US market needs for wide area coverage of larger facilities
- Update system architecture for multi-zone monitoring
- Update & modernize electronics for control, state-of-health monitoring
- Maintain continuity with established performance history
- Availability target Q1 2014
EDAC-21 support and enhancement

► Obsolescence management
  ◆ Photomultiplier tube
    • New supplier identified
    • Limited New Old Stock in inventory to sustain previous generation probes
  ◆ Neutron detector
    • Replaced Boron-loaded ZnS with Li-6 sensor (new supplier)

► Increased probe sensitivity for expanded coverage area
  ◆ Alarm threshold setting: 20 mGy/h (2 R/h) → 1 mGy/h (100 mR/h)

<table>
<thead>
<tr>
<th>Probe Detection</th>
<th>Dose (Gy)</th>
<th>Dose rate (Gy/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gamma + Neutron (High Range)</td>
<td>25x10^-6</td>
<td>1x10^-3</td>
</tr>
<tr>
<td>Gamma</td>
<td>25x10^-6</td>
<td>5x10^-4</td>
</tr>
<tr>
<td>Neutron</td>
<td>25x10^-6</td>
<td>1x10^-3</td>
</tr>
<tr>
<td>Gamma + Neutron (Normal Range)</td>
<td>25x10^-6</td>
<td>20x10^-3</td>
</tr>
</tbody>
</table>

► Alarm processing circuitry is unchanged, maintaining performance lineage of the system.

Qualification Testing: Gamma Response

- Response measured over 100 keV-1.33MeV range (IRSN, Canberra Loches)
- Co-60, Co-57, Cs-137, Am-241 sources
- Variation in response can not exceed 35% rel. to Co-60.
- EDAC probe meets all requirements
- Exceeds energy range down to 59keV
Qualification Testing: Neutron Response

- AMANDE neutron accelerator (IRSN Cadarache, France) generates neutrons from the keV range up to 15 MeV.

- The probe energy response was measured from 7.5 keV up to 2.5 MeV.

- Measured Neutron Response vs Energy enables simulation for probe placement.
Qualification Testing: Temperature Stability

- Probe performance was tested from -10°C to 60°C
- No thermally induced false alarms
- Stable response within +/- 6%

![Graph showing probe performance drift compared to 20°C across different temperatures. The graph illustrates the stability of the probe performance within the tested temperature range.](image)
Probes tested at two criticality reactor facilities (PROSPERO and CALIBAN) to demonstrate response to criticality event

- **CALIBAN**: criticality events with time constants smaller than probe electronics (60µsec – 2.1 msec)
- **PROSPERO**: response to longer events

EDAC probe response time << 300ms requirement

Verify gamma-to-neutron response ratio unchanged between new, old probe designs (ongoing…)

### Criticality Reactor Tests

<table>
<thead>
<tr>
<th>Standard</th>
<th>ANSI</th>
<th>IEC</th>
<th>ISO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detection criterion</td>
<td>0.2Gy in 60 sec at 2m</td>
<td>0.2 Gy in 60 sec at 2m</td>
<td>0.2Gy/min at 2m</td>
</tr>
<tr>
<td>Time to alarm</td>
<td>500 msec after accident detection</td>
<td>300 ms after exposure to twice the alarm threshold</td>
<td>-</td>
</tr>
</tbody>
</table>

**Probe Response Time**

- Caliban Synch.
- EDAC v1
- EDAC v2
- ADAC v3
Next Generation: The CAAS-3S System

- New System Architecture to support multi-zone
- The CAAS-3S probe is built on the same detection technology
- All signal detection electronics intentionally preserved as analog
- Non-safety related features enhanced with Digital- FPGA based electronics:
  - Enhanced diagnostics & state-of-health
  - Tracking of criticality accident
  - Temperature drift compensation
  - Radiation hardened digital technology (Anti-fuse FPGA) was selected to resist integrated dose in the range of 5000 Gy.
  - This electronics architecture is currently under development
Processing cabinets

- Support up to 30 probes each
- Monitor up to 10 zones (3 probes per zone, 2 out of 3 voting logic)
- Monitor up to 7 zones (for 4 probes per zone, 3 out of 4 voting logic)
- Cabinets located outside the hot cell / processing area

Alarm cabinet:

- Houses PLC control of horns and beacons
- Up to ten alarm cabinets per processing cabinet
- Up to 80 alarms per alarm cabinet

Supervisory Software

- Control and state of health monitoring can be done remotely through client-server supervisory software
EDAC-21 → CAAS-3S: Network Architecture

Alarm Cabinet

Up to 80 Horns & Beacons
Per Alarm Cabinet

1 Processing Cabinet
Can manage 10 Alarm Cabinets

1 Processing Cabinet:
Up to 30 probes
(10 zone monitoring)

Power supply
Canberra’s EDAC-21 CAAS has a long, reliable performance and maintenance history.

Recent R&D efforts have sustained and enhanced this product line.

Current Generation - EDAC-21
- Addressed obsolescence issues on components
- Increased probe sensitivity for single-area monitoring applications.

Next Generation System In Development
- CAAS-3S
  - Supports large-area multi-zone monitoring
  - Maintains continuity of the detection components with previous generations

With each new development the system is re-qualified to ensure that all criticality standards are met.
Gamma Response Vs. Energy

Graph 1: Probe response (V/cGy/h) vs. Energy (MeV)

Graph 2: Probe response vs. Energy (MeV) normalized to Co-60