Lawrence Livermore National Laboratory

LLNL Plutonium Facility Criticality Alarm System

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LLNL Pu Facility CAS System

- *Gamma ray detector based system,*
- *Current system went into service in 1995 after a rigorous factory acceptance test and a three month burn-in test after installation,*
- *In compliance with ANSI/ANS 8.3 requirements,*
- *28 detectors currently in use in the RMA.*

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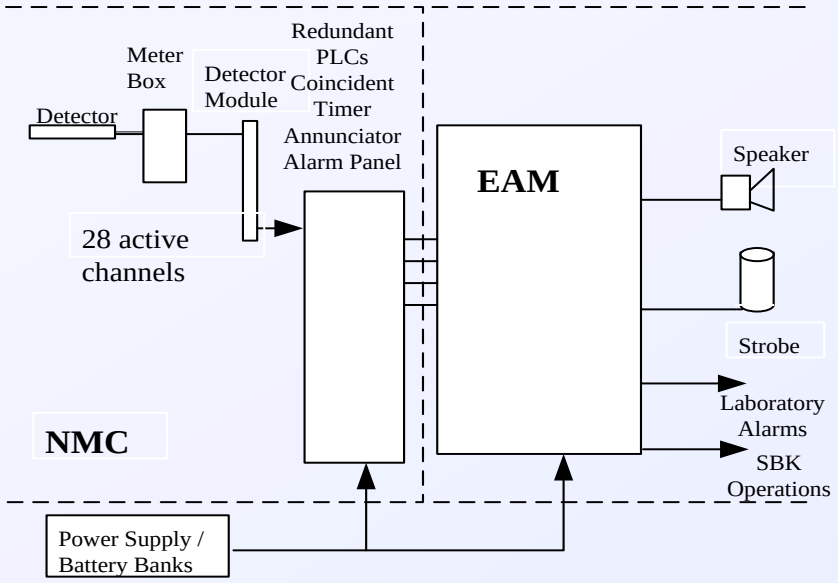
CAS System



Designed on

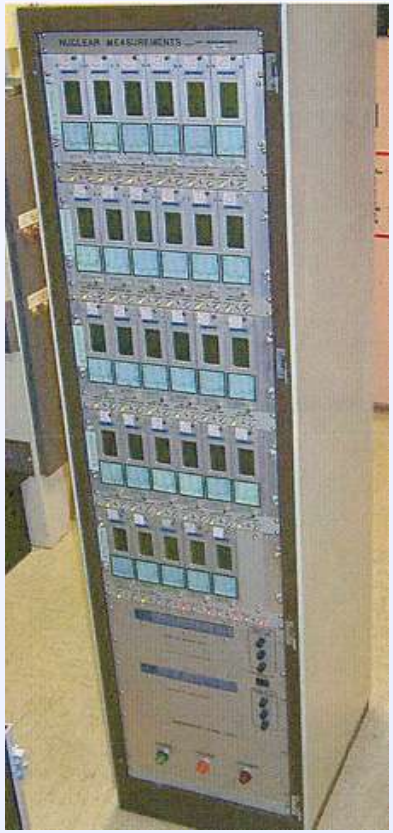
Three Subassemblies,

- *Radiation Detection*
- *Evacuation Alarm Module*
- *Power Supply*

CAS Detectors

- *Sensitive to gamma rays,*
- *Uses a plastic scintillator to convert radiation to photons,*
- *Located in the Radiation Material Area*
- *Requires 2 or more detectors in alarm to generate an evacuation alarm*
- *Analog meter box provides continuous radiation readings*

Radiation Detection

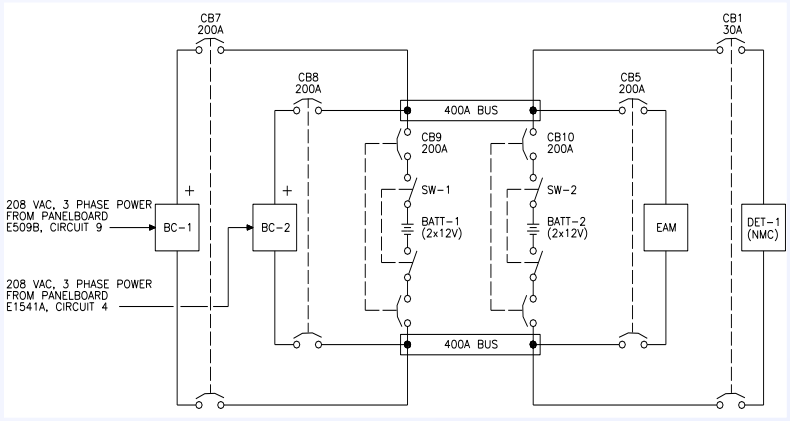


- *Off-the-Shelf equipment,*
- *Equipment was purchased from Nuclear Measurement Corporation,*
- *26 detectors was initially installed*
- *28 active detector/detector modules,*
- *Operating range is from 0.1 mR/hr to 100 R/hr, setpoint is 100mR/h*
- *Threshold and alarm set points are set by the keypad on the module,*
- *Redundant PLC (SLC500) monitoring of all inputs.*

Evacuation Alarm

- *LLNL designed and fabricated,*
- *Relay Logic controlled,*
- *Displays system conditions,*
- *Latches alarm indications on until manual reset is performed,*
- *Horns (106) and strobes (8) are off-the-shelf Federal devices.*
- *Horns operates on 450-500 hertz with a modulated tone of 4-5 hertz, 92 – 115 db*

Power Supply



- *Provides power to Radiation Detection and EAM subassemblies,*
- *24 volt DC system,*
- *Redundant battery charger/power supply,*
- *Parallel battery banks*

CAS Testing

- *Perform a channel check weekly using the built-in light source,*
- *Perform a semiannual criticality radiation detector electronic check of each detector, including alarm setting and readout,*
- *Verify the alarm response of the CAS semiannually with two or more criticality radiation detectors at high alarm,*
- *Verify semiannually that all criticality horns and strobe lights are functional,*
- *Perform a battery load test and a visual inspection semiannually,*
- *Source check all active criticality radiation detectors semiannually.*

Detector Placement Analysis

Analytical Calculations:

- *Determine the minimum fission yields for 20 rad in free air at the distance of 2 m from the reacting material within 60 sec,*
- *Calculate dose rates at the gamma detectors,*

  (set point: 100 mR/hr)

In-Situ Measurements Using Co-60 Source:

- *Determine the response of the heads,*
- *Confirm the estimated response of the detectors.*

Minimum Fission Yield

For the absorbed dose of 20 rad at a distance of 2 m in air in 60 sec, 20 (rad) = f (fissions) × $\Sigma [y_i$ (rad/fission)]

System Type	Neutron Dose, y_1 (rad/fission)	Secondary Gamma Dose, y_2 (rad/fission)	Prompt Gamma Dose, y_3 (rad/fission)	Fission Product Gamma Dose, y_4 (rad/fission)	Total (rad/fission) Σy_i	Minimum Fission Yield (fissions), f
Pu Metal	1.822×10^{-15}	1.633×10^{-18}	6.703×10^{-16}	6.703×10^{-16}	3.164×10^{-15}	6.321×10^{15}
U Metal	1.092×10^{-15}	8.633×10^{-19}	3.810×10^{-16}	3.810×10^{-16}	1.855×10^{-15}	1.078×10^{16}
Pu Moderated	7.260×10^{-16}	1.151×10^{-18}	5.117×10^{-15}	5.117×10^{-15}	1.096×10^{-14}	1.825×10^{15}
U Moderated	5.729×10^{-16}	1.078×10^{-18}	4.008×10^{-15}	4.008×10^{-15}	8.590×10^{-15}	2.328×10^{15}

Detector Response to the Minimum Fission Yield

- *Calculated gamma ray flux based on the minimum fission yield,*
- *Source placed in each room maximizing the distance from the detectors,*
- *28 detectors placed on walls throughout the RMA,*
- *Confirmed by Co-60 Measurements.*

12-rad Boundary Analysis

- *Bounding fission yield estimated based on facility activities,*

  - Pu, U, and/or Np in the form of metal alloy and oxide

- *Historical accidents for bare and reflected metal systems*
  - Total fissions ranged from 3 x 10^{15} to 3.7 x 10^{17}

- *For reflected bulk metal and metal pieces or solid fines, such as powder that are moderated and reflected, 1 x 10^{18} fissions in a single burst is assessed to be bounding reference value and is believed to be very conservative (DOE-HDBK-3010-94)*

Three Incidents that Caused False Alarms

- *July 2004, After returning CAS to normal operation condition, it was discovered that various detector modules on start up acted differently.*
- *June 2005, In preparing for CAS testing, the tester activated the CAS audible/visual output,*
- *March 2010, In modifying the building paging system in the RMA, an audible alarm was generated which sounded like the criticality alarm audible output.*

Summary

- *In-Situ Co-60 measurements determine the response of the heads as well as confirm the estimated response of the CAS detectors for the minimum accident of concern and the 12-rad boundary analyses,*
- *LLNL CAS actively monitors and collects dosimetry data for assessing background radiation levels and for monitoring post-accident conditions remotely,*
- *Planned to remain active after completion of de-inventory of security category I/II materials in the near future.*