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Radiation Tolerance Assessment of a Criticality Accident Alarm System

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Radiation Tolerance Testing

- Why is Radiation Tolerance Testing required?
- Method for testing CIDAS MkXI
- Results and Conclusions

Introduction

- A CIDAS® MkXI system has been developed with a new components and technology:
  - Logic
  - Tone Generation
  - Amplifiers
  - FPGAs are used
- New Generation UPS
- New detector options
- Alternative annunciator

Requirement For Testing

- Standards define radiation tolerance requirements:

  SRD R 309 – Design Criteria and Principles for Criticality Detection and Alarm Systems

  Delafield and Clifton

  ISO 7753 – Performance and Testing Requirements for Criticality Detection and Alarm Systems

  International Standardization Organisation

  IEC 60860 – Warning Equipment for Criticality Accidents

  International Electrotechnical Commission

  ANSI / ANS 8.3 – Criticality Accident Alarm System

  American Nuclear Society

Requirement For Testing

- CIDAS® must continue to operate when subjected to high levels of radiation from accidental excursion.
- Experimental testing with a critical pulse is required to be certain of system tolerance.
- Experiments on CIDAS® MkX resulted in failure of DC-DC Converters (2002)
- Design change on MkX from 48VDC to 24VDC UPS

Test Methodology

- Testing is required to deliver defined gamma / neutron dose to various components.
- Specified levels for our tests in line with UK customer standard and exceeding other standards:

Equipment	Simulated Distance from Pulse of 10^{18} fissions / m	Neutron Fluence / cm^{-2}	Neutron Dose / Gy	γ Dose / Gy	γ Dose Rate / $Gy.hr^{-1}$
CIDAS® Detectors / Speakers / Lamp Modules	1	$2.0x10^{13}$	300	200	$\sim 7.2x10^{8}$
CIDAS® MkXI Main Panel & UPS	20	$5.0x10^{10}$	0.75	0.50	$\sim 1.8x10^{6}$

Test Methodology

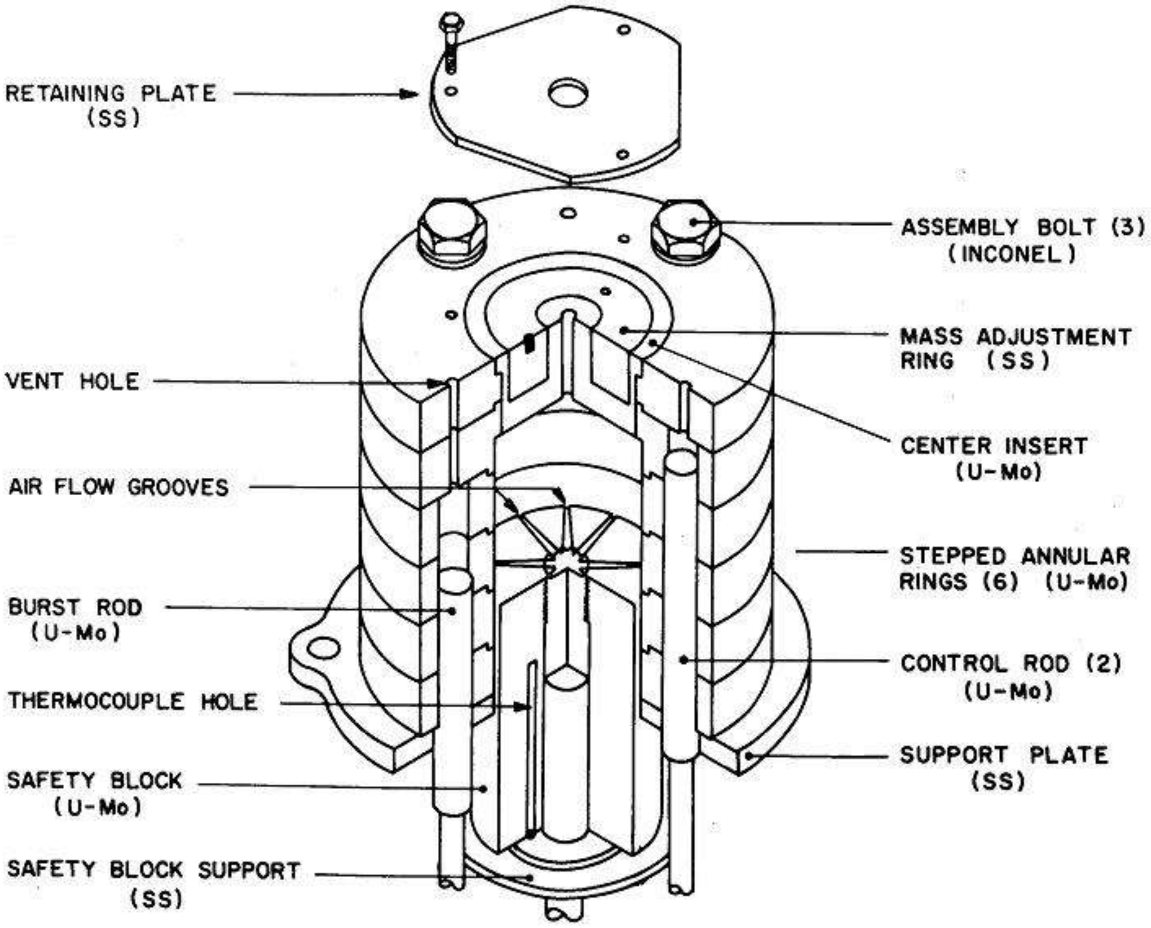
- Testing is required to deliver defined gamma / neutron dose to various components.
- Key considerations:
  - Achieving correct dose level
  - Reliable remote monitoring of component functionality
  - Minimising number of pulses
  - Ensuring successful collection of required data
- Method was planned and rehearsed in detail prior to performing tests.

Test Methodology

- Location - White Sands Missile Range, US
- Reactor - Molly-G - Fast Burst Reactor (FBR)

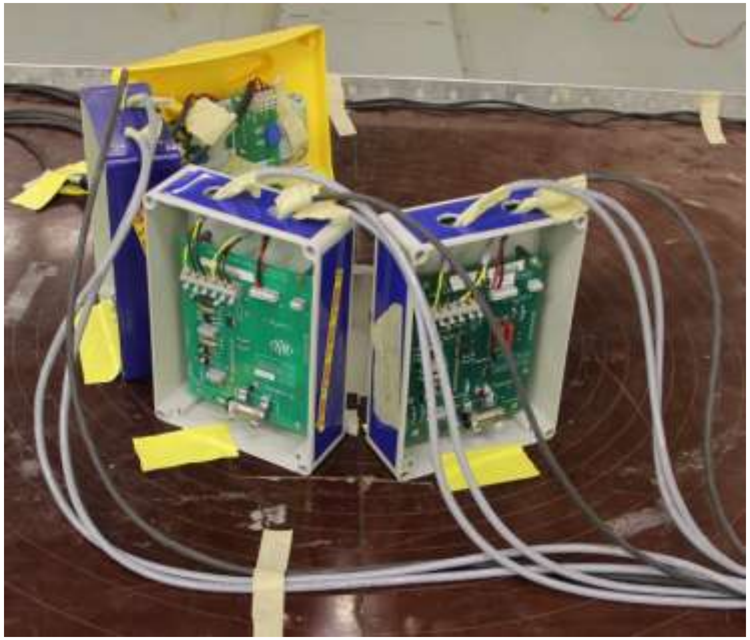
  (un-moderated, un-reflected bare critical assembly of the Godiva II type)

WSMR Fast Burst Reactor



Test Methodology - Positioning

- Achievement of correct dose level relies on:
  - Correct specification
  - Good characterisation of reactor
  - Careful design of test geometry



Test Methodology – Dose Measurement

- The dose that each component received was measured during each pulse.
  - TLDs were used to measure γ dose
  - Sulphur activation was used to measure n fluence
- Dose was measured at several points for large items
- Applied dose was taken as the geometrical average over item.

Equipment	**Required Neutron Fluence / cm^{-2}**	**Average Received Neutron Fluence / cm^{-2}**	**Range of Fluence**	**Required γ Dose / Gy**	**Average Received γ Dose / Gy**	**Range of Dose**
CIDAS® Detectors / Speakers / Lamp Modules	2.0×10^{13}	2.6×10^{13}	99 – 178%	200	53.8	20 – 39%
CIDAS® MkXI Main Panel & UPS	5.0×10^{10}	5.8×10^{10}	92 – 152%	0.50	0.24	42 – 58%

Test Methodology - Monitoring

- Reliable monitoring of component functionality was achieved by:
  - Multiple storage scope channels
  - Measurement of component current draw
  - Microphones to convert alarm sounds to signals

Test Methodology

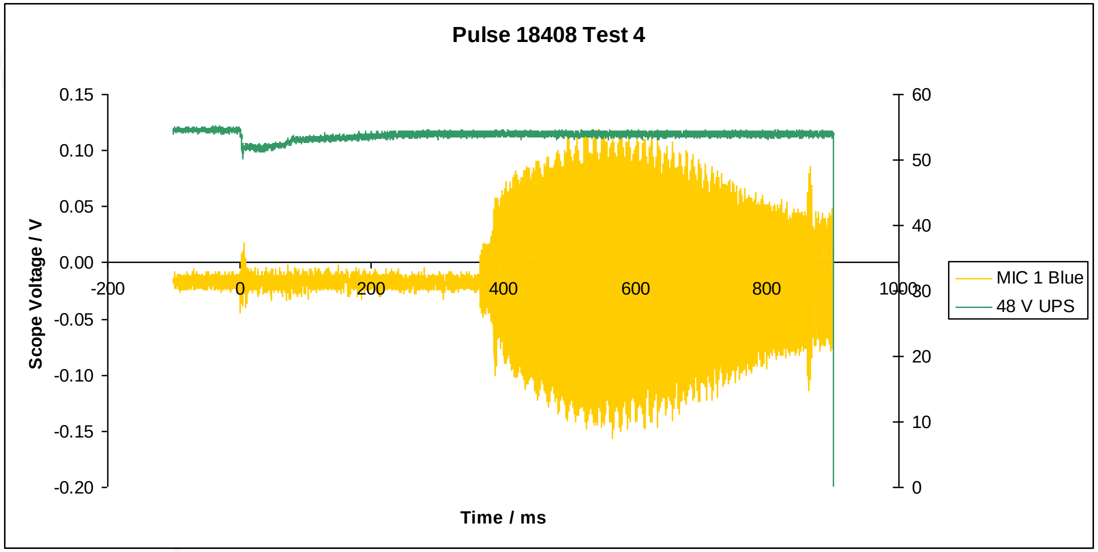
- Reliable monitoring of component functionality:
  - In-cell video equipment
  - Connection to out-cell sounders
  - Use of bulb loads on amplifiers

- 2 individual pulses used for CIDAS® MkXI components

- Component functionality was monitored before, during and for 40 minutes after each pulse

Radiation Tolerance Testing

- Several parameters were measured including:
  - time for speakers to sound from the initiation of the criticality pulse
  - 48V output of the UPS
- The system was subjected to two pulses
- All tests were successful



Test Results – Pulse 1

- CIDAS® MkXI with 2 MkX and 1 MkXI detectors.
- Success:
  - Criticality alarm sounded with no audible / measurable break
  - NAWLs lit constantly with no visible / measurable break
  - KOWLs lit constantly with no visible / measurable break
  - No break in UPS supply
- Issues:
  - Detectors had ‘pre-tripped’
  - Detector Zone Activated not annunciated
  - UPS fell back to battery for < 6 mins after pulse

Test Results – Pulse 2

- CIDAS® MkXI with 2 MkXI and 1 MkX (LND) detectors.
- Success:
  - System tripped into alarm within 380ms of criticality
  - Criticality alarm sounded immediately
  - NAWLs lit immediately
  - KOWLs lit immediately
  - No break in UPS supply
- Issues:
  - Detector Zone Activated not annunciated
  - UPS fell back to battery supply for ~20s after pulse

Conclusions

- The following CIDAS® MkXI components successfully passed the testing:
  - Main CIDAS® MkXI Panel
  - KOWL driver
  - Erskine 48Vdc UPS panel
  - MkXI detector (except open collector output)
  - Detectors with replacement LND GM tubes
  - Ametek and Omniflex Annunciators

- CIDAS® MkXI passed its radiation tolerance testing babcock

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