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SPEED OF RESPONSE OF SOME CRITICALITY DETECTORS

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ABSTRACT

The Appendix B published with ANSI 8.3 in both the present and previous editions, contains a calculation example for distance of coverage of a CAAS. In it, a trip point multiplication factor of 2500 is included to address system under response to a short pulse of radiation. While the text describes this to accommodate “needle response”, it might seem that this would be unnecessary with modern circuitry. An investigation of the response of some radiation detectors used in alarm systems shows some fundamental effects still make such a consideration necessary.

Outputs and alarms from an ionization chamber system are examined for response to a fast pulse reactor, and some. gamma detectors response to pulse radiation are examined including GM and scintillation detectors, and an ionization chamber.

In addition, time to alarm by typical personal alarming dosimeters is determined by exposure to step – increase radiation and pulse radiation. This type of commercial instrument has been considered for the application as a portable criticality alarm as addressed in section 4.4.2 of ANSI 8.3- 1997. There are variations in alarm signal activation delay depending on the amount of signal processing involved, with the greatest delay from those using digital data processing.

Key Words:Criticality Alarm, Radiological Detection

1 INTRODUCTION

Criticality alarm detectors may be sensitive to gamma, neutron, or sensitive to both, but almost all use a specified fixed value of dose rate to define the alarm threshold. Implementing the threshold in routine applications involves determining an appropriate dose rate expected from the event to be detected, and then calibrating the instruments to alarm at the defined rate. To achieve reproducible results in a field environment, steady-state radiation levels are usually used, such as from a isotopic emitter.

Postulated criticality events are modeled by criticality safety organizations to determine locations for placing detectors to assure they will be subjected to dose rates greater than the selected alarm rate. This document will discuss response of instrument systems to the short initial radiation released from a fast-burst type of criticality, where the steady-state defined alarm point is usually not the value where electronic system will produce an alarm.

1.1 Criticality Instrument Test Observations

[*] Footnote, if necessary, in Times New Roman font and font size 9

1.1.1 Ionization Chambers

Ionization Chamber detectors exhibit charge collection time response which is a function of chamber and amplifier characteristics (Reference 2). Alarm system output is observed to be reduced from the steady-state response when the input radiation is from a short-duration event, in relation to the resulting system response time. Figure 1 shows detector chamber output from reactor excursion at White Sands Fast Burst facility, with nominal 50 uSec FWHM duration. (Reference 3)

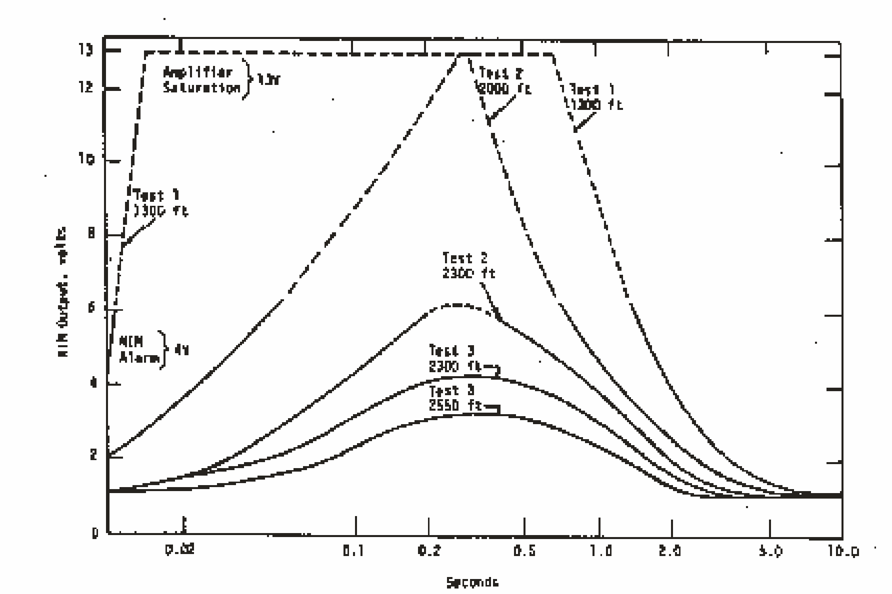

Figure 1 – Detector Systems response to 50 uSec Fast Burst Radiation

Numerous dose rates are represented by the family of traces above, but significantly the "Test 3" trace represents about 51,000 R/hr gamma dose rate, while the 4 volt peak output of the detector system is in calibration environment produced by a steady-state dose of 1.0 R/hr.

Tests conducted at the Sandia SPR III facility provide comparison with wider pulses in the 200 uSec range. Correlation with traces from co-located commercial ionization chambers and current amplifier is presented in the following graph of dose rates.

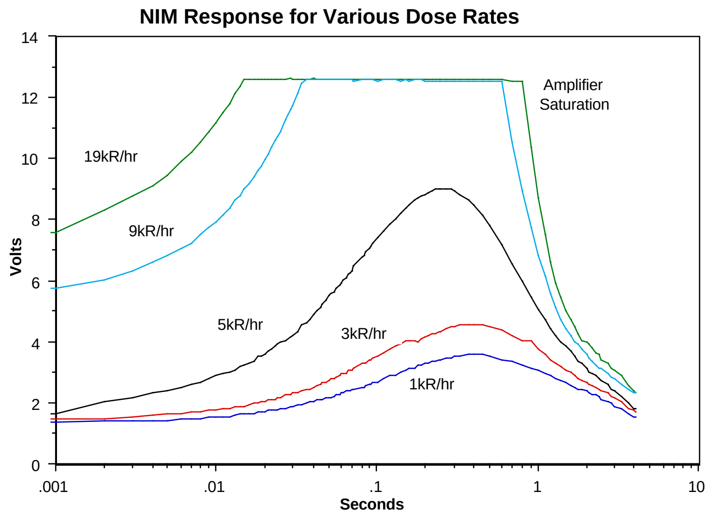

Figure 2. Traces Showing Response to Sandia SPR III Bursts

Because of the longer duration souce radiation pulse, the detector has a response less attenuated than to the 50 uSEC stimulus in Figure 1.

1.1.2 Pulse mode detectors

Pulse processing detector systems such as GM tubes and scintillation detectors will also show rate-sensitivity due to effects such as saturation or pulse pileup. A large dose rate for will produce the output pulse rate limited by the system response time. A scintillation detection system was tested at large distances from the HPRR burst reactor, with FWHM in the hundreds of uSec to to 3 msec range. That system change was noted to correlate inversely with fission yield, since the pulse width decreased as yield increased., Detector response was determine to be in the range of 1/1700 to 1/5600 (reference 4).

Alarming Personal Criticality Dosimeter (APCD) instrument candidates was examined to determine response to short radiation stimulus. A pulsed x-ray generator delivering discrete 50 nSec pulses, was used to produce dose accumulation. Using the assumption that such a short pulse could only produce one internal pulse for signal processing, a "conversion factor" was determined representing the dose per pulse as interpreted by the instrument. Pulse trains at 15 pulses per second were directed to the dosimeters in increments of 10 and 20. Displays were read between delivery events. Table 1 shows the responses and results from that test

Table 1. Single Pulse Dose Response of Some Dosimeters

Detector Type	C-GM	C GM	R SS	R SS	S SS	S SS
mr/ pulse at 10 Ft	0.065	0.06	0.00125	0.001	0.0014	0.0012
CFactor based on .025 mR/pulse	0.38	0.42	20	25	17.54	21.28

The data shows similarity of interpretative processing for the two using solid state detector types. The third identified as C displayed an over-response, and has a GM tube detector. Accuracy of the tests is subject to dosimeter resolution, the statistical limits of low count exposures, and detector differences in response to rate and energy. Per-pulse dose at the exposed distance was calculated from vendor specification, and independently verified using the same commercial nitrogen-filled ionization chamber and current amplifier as used for data in Figure 2.

An interesting side issue is that the response speed of the commercial nitrogen-filled ion chamber system is much faster than the site-developed ion chamber systems. The amplifier has a variable rise time control, which switches capacitance in the processing circuitrywhich , was set at “3 ms”. It has shown tracking of the 250 uSec SPR III burst matching the facility instrumentation for the assembly, and its response to the 50 nSec x-ray pulse, while slower, was correctly integrated to produce confirming dose information on the pulse. Figure 3 shows the SPR III assembly thermocouple trace along side the Ionization chamber output trace. Response to Criticality Alarm foes such as RF and humidity have not been evaluated.

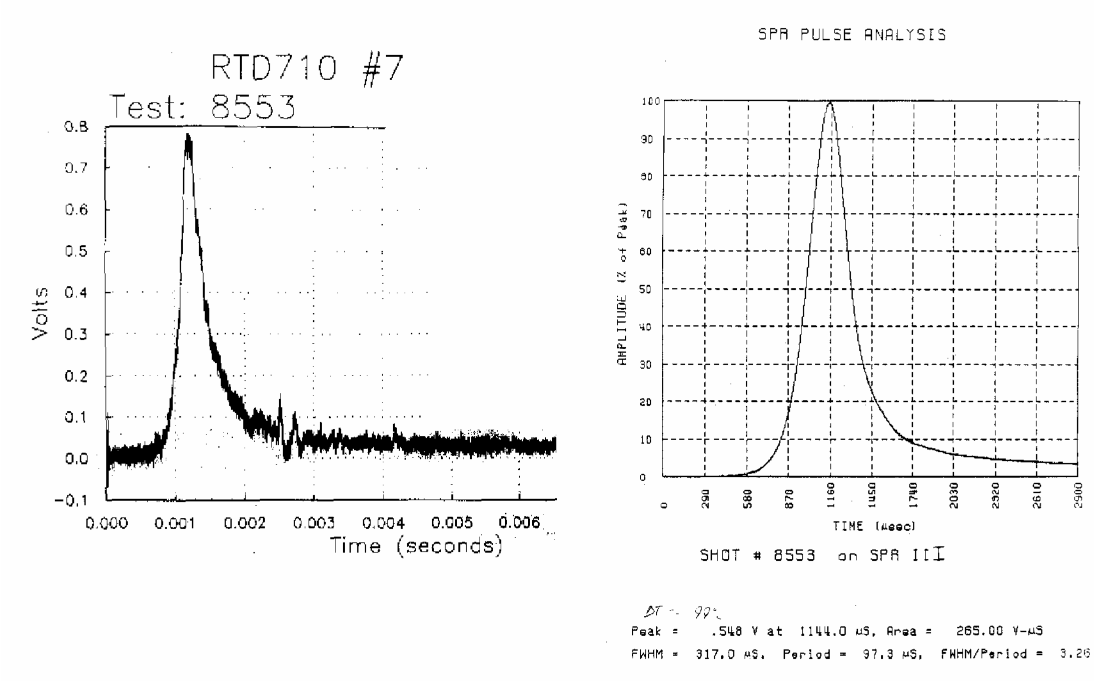

Figure 3. Reactor Facility Trace Compared to Commercial Ionization Chamber Response

1.2 Activation of Detector Systems.

Some dosimeters being considered for APCDs were subjected to step radiation inputs to determine their ability to generate an alarm versus The Standard’s ½ second requirement. In these a microprocessor is used to provide flexibility and varied functionality while minimizing control and display count. There was a concern about signal processing having an effect on presenting an alarm signal within the time limitation. A panoramic irradiator with relatively quick source presentation (tenths of a second) was used to compare dosimeter response time. No fast burst facility is currently available with sufficient long-distance target locations to achieve the dose rates challenging to dosimeter set points. The times to produce audible alarm with 35 mR/ Hr setpoints after exposure to 900 mR/hr field, is recorded in Table 2.

Table 2. Dosimeters Tested for Alarm Delay After Step Radiation Exposure

Detector ID & Type	R-SS	C GM	S-SS
Radiation detected	gamma and X-rays	Gamma, Neutron	Gamma, Neutron
Time to alarm	0.1 Sec	3.7 Sec	3.5 Sec

1.3 Opportunities for Placement Calculation Refinement

The sample calculations in appendix B of ANSI/ANS 8.3 (reference 1) demonstrates the adequacy of using steady state criticality dose rate to determine a bounding coverage distance for detector placement. The need to be more frugal in equipment installations presents a need to reduce unnecessary conservativness in determining the distance an alarm detector can cover. Taking credit for the greatly increased dose rate actually experienced during a fast burst event can increase allowed coverage increases of double or more as shown in the referenced sample calculation, and others. The benefit can be realized with the added burden, however, of accurate modeling of the source term, in the calculations.

2 CONCLUSIONS

It has been previously shown that the criticality dose rate estimation based on steady state fission rate conservatively bounds a fast burst dose calculation, which includes consideration of burst duration and alarm instrument characteristics. Refinement of source term modeling could be a basis for reducing unnecessary conservatism in placement calculations, if reliable characteristics of potential criticality mechanisms can be identified and included in the calculations. This refined calculation also requires detector response characteristics be verified and considered in the calculations.

3 ACKNOWLEDGMENTS

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