CRITICALITY ACCIDENT ALARM SYSTEM AT THE
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

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CRITICALITY ACCIDENT ALARM SYSTEM AT THE FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

Purpose

The purpose of this paper is to give a description of the Criticality Accident Alarm System (CAAS) presently installed at the Fernald Environmental Management Project (FEMP) for monitoring areas requiring criticality controls, and some of the concerns associated with the operation of this system. The system at the FEMP is known as the Radiation Detection Alarm (RDA) System.

History of the FEMP RDA System

In former years a large amount of low-enriched uranium was stored and processed at the FEMP. RDAs were installed in various locations of the production area and the Lab Building in recognition of the theoretical possibility that a criticality accident could occur, although the probability of such an occurrence is extremely low. The instruments - Nuclear Measurements Corporation's (NMC) Model GA-2 - were designed to detect the radiation from a criticality accident and initiate an alarm so that the affected areas could be evacuated in a safe and timely manner. The system consisted of two detectors and a logic control box, and utilized a one out of two logic system. A typical setup of this system is shown in Figure 1. Over the years, these units became obsolete, and increasingly difficult to maintain due to the difficulty in obtaining replacement parts. Therefore, in 1990 a new state-of-the-art RDA System was installed at the FEMP.

Description of the Current RDA System Detection System

The new RDAs are NMC Model GA-6, which is basically a scintillation integrator. The system consists of a scintillation crystal, a photomultiplier tube, a transistor amplifier, a 0 to 1 mA indicating meter, a regulated voltage supply, an audible and visual local alarm, and a 4-20 mA output. Each unit has an adjustable high and low alarm set point, and an adjustable artificial background. The artificial background is set at some level between the high and low set points. An instrument reading above the high alarm set point triggers an "ALARM" signal. A reading below the low alarm set point initiates a "TROUBLE" signal, indicating some type of detector failure. Three units (Figure 2) are installed at each RDA location. They are linked to the Enunciation System by a logic control box which requires a two out of three logic in order to send a high alarm signal to the Enunciation System Horn, Warning and site Communications Center.
Power Supply and Batteries

The normal power supply consists of a full wave rectifier which takes Fernald site power (120V-15A) and supplies 31 VDC to a regulator. The output of the regulator supplies the operating voltage (27 VDC) for the module. A second regulator supplies 11-15 VDC to the detector. This regulator is adjustable to accommodate variations in the photomultiplier tubes.

Emergency power is supplied by four 6.5 AH 6 VDC GELL Cells, connected in series for a 24 VDC battery supply. The 27 VDC regulator is used as a charger for the batteries. The charging current to the batteries is limited to a maximum of 400 mA. Using battery power, the detector is designed to operate for 16 hours in normal mode and 4 hours in ALARM status. Once the batteries are drained, it takes 24 to 48 hours to recharge.

Description of Enunciation System

The Enunciation System consists of two sets of redundant air horns (Figure 3). Under normal conditions, the Air Horn System operates off of the Plant Air System which supplies a minimum of 50 psig to the Horn control boxes. In the event that the Plant Air System fails to deliver the minimum 50 psig, the Horn Control Box will automatically switch to a nitrogen cylinder for the necessary pressure. The nitrogen cylinder is located beneath each Horn Control Box. When Plant Air service is restored, the Horn Control Box will automatically switch back to it when the pressure in the Plant Air System reaches 57 psig.

The air horn used at the FEMP is a Strombos horn that operates at a minimum of 10 cfm and 50 psig and is rated at 100 decibels at 100 feet. Once the RDA is activated, the timer located in the logic relay box will cause the solenoid-pilot operated valve in the Horn Control Box to open and close. This will cause the horn to pulse. The horns will continue to pulse until the RDA is manually reset or until the nitrogen cylinder is empty (if the Plant Air System is not operating). A nitrogen cylinder will take 5 to 10 minutes to empty depending on how full it is.

In order to warn personnel approaching the buildings, rotating red lights (Figure 4) are located outside the buildings.

The logic relay box (Figures 5&6) is designed to activate three relays once the system is in the ALARM mode. The three relays activate: (1) the repeat timer, which in turn activates the horns, (2) the red warning lights, and (3) the Honeywell Alarm System which notifies the Communication Center.

The TROUBLE circuit for the RDA System is connected to the Communication Center through the Honeywell Alarm System. A TROUBLE Signal will be indicated in the event of any of the following: (1) detector failure, (2) loss of line voltage, (3) loss of artificial background, or (4) low or loss of gas pressure to a horn control box. The type of trouble/failure cannot be identified at the Communications Center, so immediate action is required to correct the problem.
TROUBLE indication is assumed to remove the entire station from operation and is always investigated immediately.

**Honeywell Interface**

The RDA System is connected to the Communications Center via the Honeywell Alarm System. This system is shared with the Fire Control System, and other safety systems. A Honeywell Data Gathering Point (DGP) will monitor and operate each station to provide the following capabilities.

1. A RDA station failure will enunciate at the command center central console PC when a failure is indicated at the station or the air horn station pressure switch indicates there is reduced air pressure at the horn.

2. A RDA station criticality alarm point will enunciate at the command center central console PC when the criticality alarm condition is indicated at the station.

3. An analog 4-20 mA signal from any of the station's three monitoring units will allow the command center console to display the radiation level (0-1000 mR/hr) detected at that unit.

4. By manual command of a reset point at the central console, a DGP operated relay will momentarily make a set of contacts to provide remote reset of all components of the RDA station. An alarm reset switch located inside the logic relay box will allow the station to be reset locally.

5. By manual command of a Test point at the central console, a DGP operated relay will make and maintain a closed set of contacts that will cause the RDA station to go into a remote "test" condition. With the test point "On", the air horn station and exterior building rotating red lights will activate. The Test point must be commanded "Off" to return the station to normal condition. A key operated switch at the logic relay box will allow local testing of the panel lamps and air horn station. When in the "Test" condition, the criticality ALARM and FAILURE outputs will become disabled.

The command center central console PC displays, prints, and stores in historical files activities associated with the system points. The printer will supply a hard copy printout of any change of state conditions and allow log printouts. A printer sounds a bell to alert Security Personnel, whether it is an ALARM signal or a trouble signal, in order for them to respond accordingly.
Description of The Calibration and Maintenance Program

The FEMP RDA calibration and maintenance program is governed by use of the appropriate procedures. There is a monthly operational check, where the horns and lights are activated. Also, at this time, a check is made of the backup batteries, and alarm set points. The detectors are subjected to an in-place source check on a quarterly basis.

Annually, the electronics are removed, taken to the instrument lab, and bench calibrated as a matched set of electronics and detectors. The sources used are traceable to the National Institute of Science and Technology (NIST), formerly known as the National Bureau of Standards (NBS).

Maintenance/Operational Concerns

In a review of some of the maintenance records for a six month period failures in the system were determined to be: (1) general appearance, (2) artificial background, (3) alarm set point, (4) timer relay, (5) pilot light, (6) trouble light, (7) local bell, (8) battery, (9) exterior lights, (10) air horns, (11) RDA station, (12) nitrogen cylinder, (13) plant air, and (14) auto switch. (Figures 7, 8, 9, & 10).

Another operational problem arose when it was determined that the detector was qualified from -20 deg F to 120 deg F, however the logic control box was qualified from 32 deg F to 120 deg F. This restricted the movement of enriched/restricted material at temperatures below 32 degrees. The manufacturer, at our request performed cryogenic tests (Reference 1) and the operation of the detection system was verified to 0 deg F. However, there is some degradation in efficiency, as shown in Figure 11.

Placement of Detectors

Originally, the detectors were placed using the methods given in ANSI/ANS 8.3-1986 (Reference 2), accounting for shielding using the method given in United States Nuclear Regulatory Commission (USNRC) Regulatory Guide 3.34 (Reference 3), and assuming a source term of 10E-15 fissions, a detector Alarm set point of 80 mr/hr. With this method and assumptions, a distance of 120 meters in free air (Figure 12) is calculated, with reduced distances when shielding is accounted for.

In 1991 the FEMP initiated a study (Reference 4) by Oak Ridge National Laboratory (ORNL) to determine the dose rates to the RDAs from a criticality occurring in the various storage areas on site. The purpose was to determine if the RDAs provided adequate coverage due to the change from operation to storage, and the resultant shielding of a criticality from the detectors by the large number of drums (Figure 13) now stored in the various buildings. Plant 6 (Figure 14) and Plant 1 (Figure 15) were the greatest concern, and were modelled as they are. Most of the other calculations of this study were purposely generic in nature (Figures 16, 17, & 18), and
became the basis for determining RDA coverage for the other plants (Figures 19, 20, & 21) on the site by developing reduction ratios and applying them to various other locations.

Future Plans

Because the FEMP is now moving into the Safe Shutdown Program, and there is expected to be continual movement of material, we have developed a portable RDA System (Figure 22). This system employs the same two-out-of-three logic as the fixed systems. We have designed a system to connect the portable RDA to the plant Honeywell System by radio, but have determined it not to be cost beneficial at this time. However, should the need arise, this would give us the ability to set up temporary storage areas, with full RDA coverage, as buildings are dismantled, without the great expense of installing permanent RDAs.

Plans are under way to have the ORNL group which performed the placement calculations to expand the analyses to two dimensions so that the results will not be quite so conservative.

References


2. ANSI/ANS 8.3-1986, "Criticality Accident Alarm System".


FIGURE 2
TYPICAL PRESENT NMC GA-6 SYSTEM
FIGURE 3
AIRHORN
FIGURE 5
HORN CONTROL SYSTEM SCHEMATIC
FIGURE 6
HORN CONTROL SYSTEM
Radiation Detection Alarm System
RDA Station Component Failures

Number of Failures


Local Failures
System Failures

(January 1991-July 1992)

FIGURE 7
RDA STATION COMPONENT FAILURES
Radiation Detection Alarm System
RDA Station Component Failures

Number of Failures

Pilot Lt. | Alarm Lt. | Trouble Lt. | Local Bell | Battery
---|---|---|---|---
23 | 5 | 10 | 8 | 18

Local Failures
System Failures

(January 1991-July 1992)

FIGURE 8
RAD SYSTEM COMPONENT FAILURES
Radiation Detection Alarm System
System, Exterior Light, and Horn Deficiencies

Number of Failures

Local Failures
System Failures

Exterior Lights  Air Horns  RDA Station

(January 1991-July 1992)

FIGURE 9
SYSTEM, EXTERIOR LIGHT AND HOME DEFICIENCIES
Radiation Detection Alarm System
Horn Control Deficiencies

Number of Failures

(January 1991-April July)

FIGURE 10
HORN CONTROL DEFICIENCIES
Detector Response with Various Strength Sources vs Temperature

FIGURE 11
The dose should be

\[ D_y = 2.1 \times 10^6 \times \frac{N}{d} \]

where

- \( D_y \) = gamma dose (rem)
- \( N \) = number of fissions
- \( d \) = distance from source (km).

Data presented in The Effects of Nuclear Weapons (Ref. 11, p. 364) may be used to develop dose reduction factors. For concrete, the dose should be reduced by a factor of 2.5 for the first 8 inches, a factor of 5.0 for the first foot, and a factor of 5.5 for each additional foot.

**FIGURE 12A**
ANSI/ANS 8.3

**FIGURE 12B**

**FIGURE 12C**

**CALCULATIONS & ASSUMPTIONS**
FIGURE 13
PLANT 6 AISLE
FIGURE 14
SIDEVIEW OF PLANT 6
FIGURE 15
GENERAL CONFIGURATION 1 (PLANT 1)

Dose from Source 1 3.03 R/h
Dose from Source 2 1.54 R/h
GENERAL CONFIGURATION

FIGURE 16

Distance (in.)

<table>
<thead>
<tr>
<th>Dose Rate (R/h)</th>
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<tbody>
<tr>
<td>0.213 R/h</td>
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<tr>
<td>0.235 R/h</td>
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<tr>
<td>0.333 R/h</td>
</tr>
<tr>
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<td>13.5 R/h</td>
</tr>
<tr>
<td>27.2 R/h</td>
</tr>
</tbody>
</table>

Every spaced dose points

0 100 200 300 400 500 600 800 1000 1200 1400 15000
FIGURE 17
GENERAL CONFIGURATION 3
FIGURE 18
GENERAL CONFIGURATION 4
FIGURE 19
GENERAL CONFIGURATION 5
FIGURE 21
SCHEMATIC SAMPLE OF STORAGE AREA REQUIRING RDA COVERAGE
FIGURE 22
SAMPLE OF RDA COVERAGE CALCULATION
FIGURE 23
SAMPLE OF RDA COVERAGE CALCULATION
FIGURE 24A
PORTABLE RDA
FIGURE 24B
PORTABLE RDA
END
9/13/94
FILMED DATE