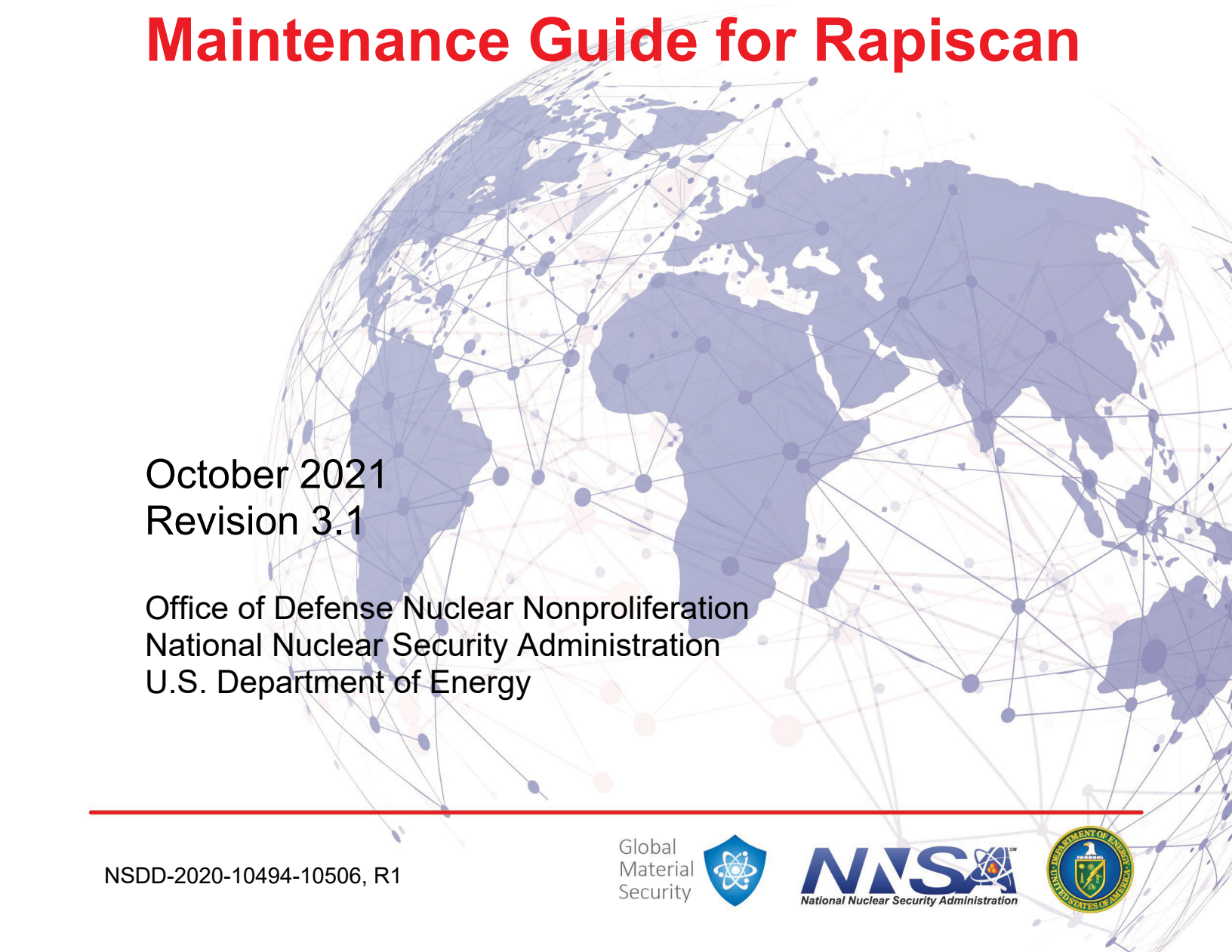
NSDD
NUCLEAR SMUGGLING DETECTION AND DETERRENCE

Radiation Portal Monitor
Maintenance Guide for Rapiscan



October 2021
Revision 3.1

Office of Defense Nuclear Nonproliferation
National Nuclear Security Administration
U.S. Department of Energy

NSDD-2020-10494-10506, R1

Global Material Security

National Nuclear Security Administration

Table of Contents

Acronyms and Abbreviations

AC	Alternating current
Ahr	Ampere hour
BNC	Connector for co-axial signal cable
Bq	Becquerel
CAS	central alarm station
Ci	curie
CKT	circuit
CM	corrective maintenance
ConOps	conduct of operation
cps	counts per second
DC	direct current
DET	detection
DMM	digital multimeter
DOE	US Department of Energy
FCT	functional compliance test
FCTD	functional compliance test datasheet
GA	gamma alarm
GB	gamma background
GH	gamma high background fault
GL	gamma low background fault
GPRB	general purpose relay board (in SC-770)
HHD	handheld device
HV	high voltage
IR	infrared
kBq	kilo Becquerel
LANL	Los Alamos National Laboratory
LLD	lower-level discriminator
µCi	micro-curies
MCA	multichannel analyzer
MCAAW	MCA Alignment Wizard
MDS	Mobile Detection System
MHV	miniature high voltage
n/s	neutrons per second
NA	neutron alarm
NB	neutron background
NH	neutron high background fault

NNSA	National Nuclear Security Administration
NSDD	Nuclear Smuggling Detection and Deterrence
NORM	naturally occurring radioactive material
OCC	occupancy
ORNL	Oak Ridge National Laboratory
PMFX	neutron signal pickoff box
PMT	photomultiplier tube
PNNL	Pacific Northwest National Laboratory
POST	power on self-test
PWR	power
RAP	Rapiscan Systems
RAVEN	Radiation Alarm and Video Event Notification
RDS	radiation detection system
RID	radioisotope identification device
RM	routine maintenance
RPM	radiation portal monitor
SC	system controller
SCA	single channel analyzer
SM	sustainability manager
SNL	Sandia National Laboratories
T/S	troubleshooting
TB	terminal block
TP	test point
TSA	TSA Systems, Ltd.
ULD	upper-level discriminator
UPS	uninterruptable power supply
V	volt
Vac	volts alternating current
VD	voltage divider
VDC	volts direct current
XMTR	transmitter

Glossary

Alarm: An alarm is a particular type of event generated by a radiation portal monitor (RPM) that requires immediate action/attention by the system operators in accordance with the workflow defined for the system.

Background Fault: A gamma high, gamma low, or neutron high background fault is an event generated by an RPM when the level of gamma or neutron radiation exceeds (or falls below) the configured threshold level when the RPM scan area is unoccupied.

Central Alarm Station (CAS): A CAS is a central control location where the alarm and event evaluation is undertaken by designated host country staff.

Event: An event in the CAS System occurs when one (1) of the detection devices sends a message associated with a particular event. In addition, CAS System events can be triggered by a change in status of system components, such as the Status of Health (SOH) change. Events can include radiation alarms, RPM faults, tamper faults generated by the detection devices and SOH events such as camera faults or portal faults.

Fault: A fault is a type of event generated when an unusual equipment condition is detected.

LLD/ULD (lower-level and upper-level discriminator): Provides an adjustable threshold that determines the lowest and highest voltage pulse that will be counted by the system's electronics.

Occupancy: An occupancy is an event which occurs when a person, vehicle, or object passes through the field of view of the occupancy sensor triggering the RPM to initiate fast-count mode and begin making alarm decisions.

Rabbit Board: SC-770 controller firmware is stored and executed by the rabbit board. The rabbit board is responsible for sending the raw data stream to the central alarm station for display and adjudication.

Radiation Portal Monitor (RPM): The sensor device installed at a control point through which traffic passes. There are pedestrian, vehicle, conveyor, and cargo (rail) RPMs as well as mobile detection systems (MDS) that can be used for pedestrians or vehicular traffic.

Radiation Alarm: A gamma or neutron radiation alarm is an event generated by the RPM controller when the level of gamma or neutron radiation exceeds the configured threshold level during occupancy.

Radioisotope Identification Device (RID): A handheld instrument that allows the operator to identify the specific radioisotope that caused the portal to alarm.

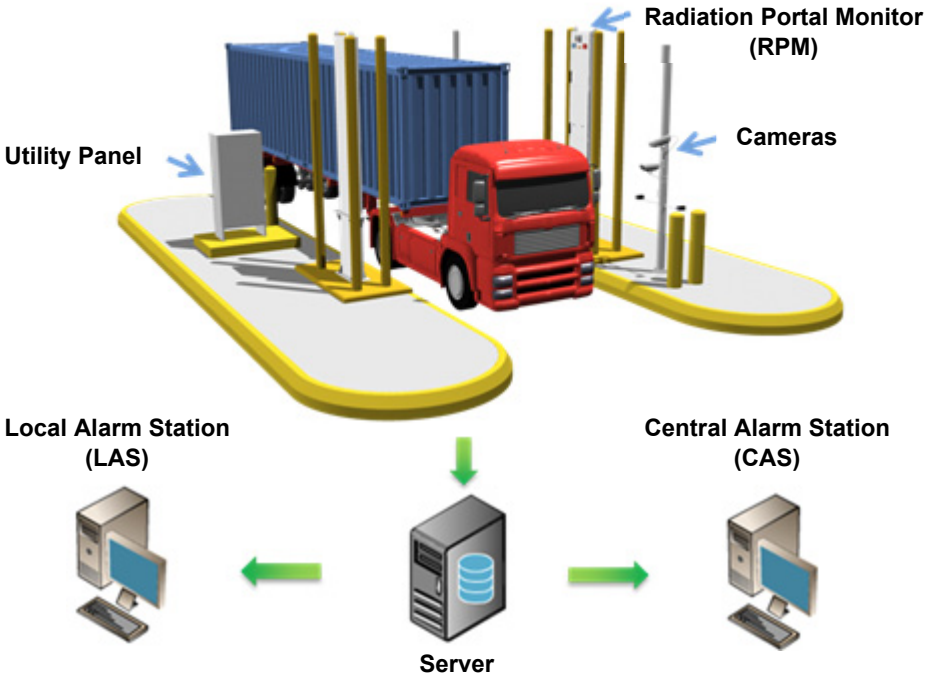
Power On Self-Test (POST): A self-diagnostic routine run by each Rapiscan RPM as part of the power on sequence.

Procedure Reference

Procedure Reference

Radiation Detection System Overview

A radiation detection system (RDS) is a collection of specialized instrumentation installed for detection, identification, and interdiction of radioactive and special nuclear materials (SNM).



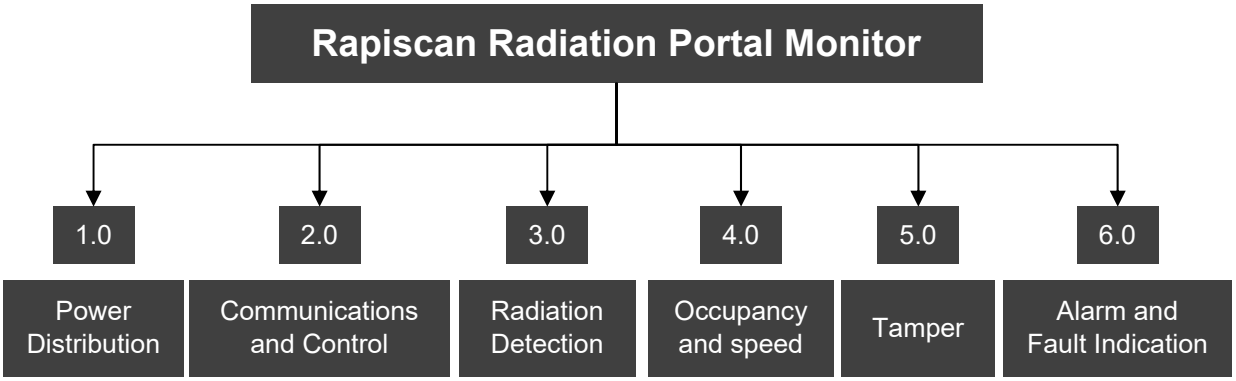
The NSDD-provided radiation detection system typically consists of the elements pictured above including:

- A radiation portal monitor containing gamma and neutron detectors to detect radioactive materials. The RPM also contains occupancy sensors, cabinet tampers, and alarm and fault indications.
- Central and local alarm stations (CAS/LAS) consisting of various workstations and peripherals to display data, notify operators of alarms and faults, and facilitates adjudication and documentation of these events.
- A server to receive, process, and archive data from the various types of lane equipment.
- Cameras to help identify the person or vehicle responsible for the alarm.
- Lane side utility panels to supply alternating current (AC) power to lane equipment and network equipment to transfer information to the server.

The scope of this maintenance guide is limited to the RPMs and does not address maintenance of the communications system (network, server, CAS Software), cameras, or handheld instruments. There is a separate guide (*Handheld Instrument Maintenance Guide*) published for the maintenance of handheld instruments, including the radiation detection backpack, survey instrument, personal radiation detector, and the radioisotope identification device.

RPM Functional Hierarchy

Components of an RPM are categorized into six (6) subsystems based on the function they perform. An understanding of the purpose of each of these subsystems and the components that comprise them is critical to reduce the time and effort required to service, diagnose, repair, and re-test malfunctioning equipment when required. A brief description of each subsystem and components is provided below.



1. Power Distribution Subsystem

The power distribution subsystem provides the appropriate power to the various components and subsystems of the RPM. Components of the Power Distribution subsystem include:

- AC input power – AC terminal block, power breaker, line filter
- +15 VDC power supply – Adjustable AC to DC converter which supplies DC power to RPM components and maintains charge on the battery. Typically set at +14.6 VDC
- Load Disconnect (LD-260) – basically the RPM on/off switch
- Battery – +12 VDC battery
- Terminal blocks
- Cables, wires, and connectors

The RPM Power Distribution subsystem starts at the AC terminal strip/power breaker in the control pillar. For RPM maintenance purposes, any equipment or components outside of the RPM which supply AC power are not considered part of the power distribution subsystem of the RPM.

When discussing the functionality, maintenance, and troubleshooting of the RPM, the voltages in the system are nominally referred to as +15 VDC. The typical operational range will vary between +10.5 and +14.6 VDC. This variability stems from how the RPM is being powered at the time a voltage measurement is made, and where in the RPM the measurements are made. Generally, there are two distinct ranges of voltages that may occur in the RPM:

<u>When operating on battery only (between approximately +10.5 and +12.8 VDC)</u>

- This voltage range is normal when the RPM is powered solely by the battery. The Load Disconnect (LD-260) will power down the RPM at approximately +10.5 VDC. Provided that the LD-260 is operating correctly, voltage measurements lower than +10.5 VDC are unlikely.

When operating on AC power (between +12 and +14.6 VDC)

- This voltage range is normal when the RPM is connected to external AC power and the +15 VDC power supply is functioning. The power supply is typically adjusted to 14.6 VDC, but voltages measured at various points in the +12 VDC power distribution system will range from +12 to +14.6 VDC.

2. Communications and Control Subsystem

The communications and control subsystem contains the firmware which controls operation of the RPM and allows the users to interface with the radiation detection system during operation and maintenance activities. Components of the communications and control subsystem include:

- SC-770 Controller Module – The controller receives data input from the SCA-775 modules and uses it to makes alarm decisions. Those decisions and data are communicated through the SC-771/Rabbit board assembly through the utility panel (if installed) and RDS communications network to the CAS.
- Ethernet to fiber optic converter (some RPM installations) – Ethernet-Fiber Converter transforms the signal from a RJ45 Ethernet link (Rabbit board output) to one (1) that can be used by a fiber optic transceiver.
- Data Concentrator and associated media converter used for detection systems for Raven CAS software.
- Cables, wires, and connectors.

3. Radiation Detection Subsystem

The RPM contains specialized detectors and electronic circuitry for detecting and measuring gamma and neutron radiation. Understanding which components of the RPM are common to both gamma and neutron detection and which are exclusive to each will make troubleshooting and maintenance easier. Components of the Radiation Detection subsystem include:

Common to both gamma and neutron circuits:

- SCA-775 single channel analyzer module (SCA-774 and HHV-448/458 boards)
- SC-770 controller module (SC-771/Rabbit board assembly)
- Cables, wires, and connectors

Gamma Only:

- DA-630 or DA-1248 gamma detector assembly
- VD-580 (high voltage divider)
- Gamma HHV-448/458 (HV power supply)

The size and number of gamma detectors varies depending on the specific model of RPM.

Neutron Only:

- Neutron detector assembly/Helium-3 (He-3) tubes
- PMFX Box

- Neutron HHV-448/458 (HV power supply)

The number of neutron detector banks in an RPM varies depending on the specific model of RPM. The number of neutron tubes in each neutron detector bank can also vary depending on the needs/conditions of the specific installation.

4. Occupancy and Speed Subsystem

The occupancy sensors and associated circuitry detect objects between the RPM pillars or moving within a specified distance of a conveyor monitor. Vehicle and Rail monitors typically have two (2) different types of occupancy sensors, one (1) of which is also used to calculate the speed of the conveyance passing through it in addition to detecting portal occupancy. Depending on the model and age, the RPM may have one (1) of several models of occupancy sensors installed. Components of the occupancy and speed subsystem include:

Occupancy Sensors:

- Banner radar sensor
- Wizard (IR and radar) sensor
- Senix Ultrasonic sensor
- Spy-2 Infrared (IR) sensor

Speed and Occupancy Sensors:

- Banner IR “break beam” sensors – Two (2) occupancy sensor, at a specific spacing, send “OCCUPIED” and “UNOCCUPIED” state changes to the Nanocontroller.

Additional Components:

- SCA-775 single channel analyzer module (SCA-774 board) – Monitors RPM occupancy status and transmits the state change to the SC-770 controller.
- SC-770 controller module (SC-771/Rabbit board assembly) – When an occupancy sensor is triggered, the controller enters fast-count mode and begins comparing the detector count rate to the alarm threshold.
- Nanocontroller – Monitors the state of IR break beam sensors and transmits occupancy information to the SCA-774 board, sends vehicle speed information to the SC-770 controller (via the RS232/485 converter).
- RS-232/485 Converter – Receives the vehicle speed information via a RS-232 signal from the Nanocontroller and converts it to a RS-485 signal sent to the SC-771/Rabbit board assembly.
- Cables, wires, and connectors.

5. Tamper Subsystem

All RPMs are equipped with tamper switches to warn operators when the RPM cabinet doors are opened and/or upon a loss of AC power to the RPM cabinet. At some installations there is also a tamper switch in the utility panel that services that RPM lane. The tamper subsystem is comprised of various numbers of tamper switches, depending on the model, which are wired in series with a contact in the LD-260. Opening any cabinet door or disconnecting AC power from

the RPM will open the series circuit and result in a TAMPER fault indication. Components of the Tamper subsystem include:

- Tamper Switches – Magnetic tamper switches are most common, older models of RPMs may use spring loaded switches. These are located in the RPM and utility panel doors.
- LD-260 – Monitors the output of the +15 VDC power supply and opens a contact if the power supply output is disrupted and the RPM begins to operate on battery power only.
- SCA-775 single channel analyzer module (SCA-774 board) – Monitors status of the tamper circuit and relays status to the SC-770 controller.
- SC-770 controller module (SC-771/Rabbit board assembly and General Purpose Relay Board [GPRB]) – Processes tamper input from the SCA-775 modules and communicates fault indications through SC-771/Rabbit board assembly to the GPRB and to the CAS.
- Cables, wires, and connectors.

6. Alarm and Fault Indications Subsystem

Alarm and fault indications for the RPM can occur in four (4) places: Display of SC-770 controller, control pillar, AM-270, and on the CAS user interface. Control pillar visual and audible alarm and fault indications occurs if the RELAY OUTPUT parameter is enabled. Components of the Alarm and Fault Indication subsystem include:

Rail and vehicle monitors:

- Blue neutron alarm strobe
- Red gamma alarm strobe
- Amber fault LED
- AM-270
- SC-770 controller module (SC-771/Rabbit board assembly and GPRB)
- Cables, wires, and connectors

Rail and Vehicle Monitors Only:

- ELK Siren
- ELK Driver

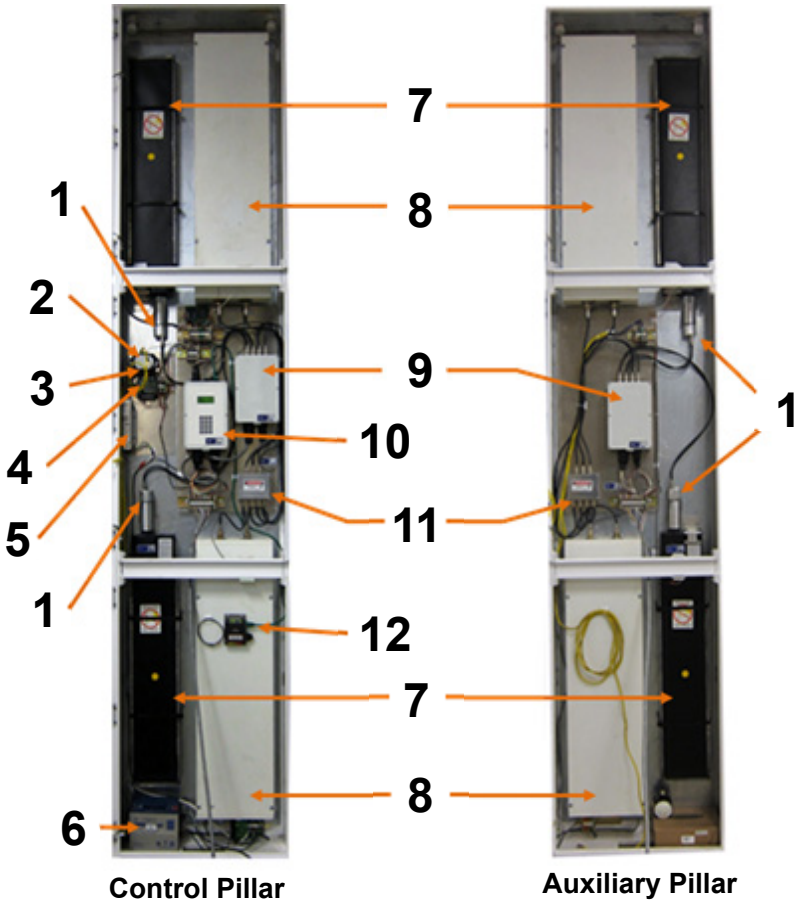
Pedestrian Monitors Only:

- Gamma Sonalert siren
- Neutron Sonalert siren

Conveyor Monitors Only:

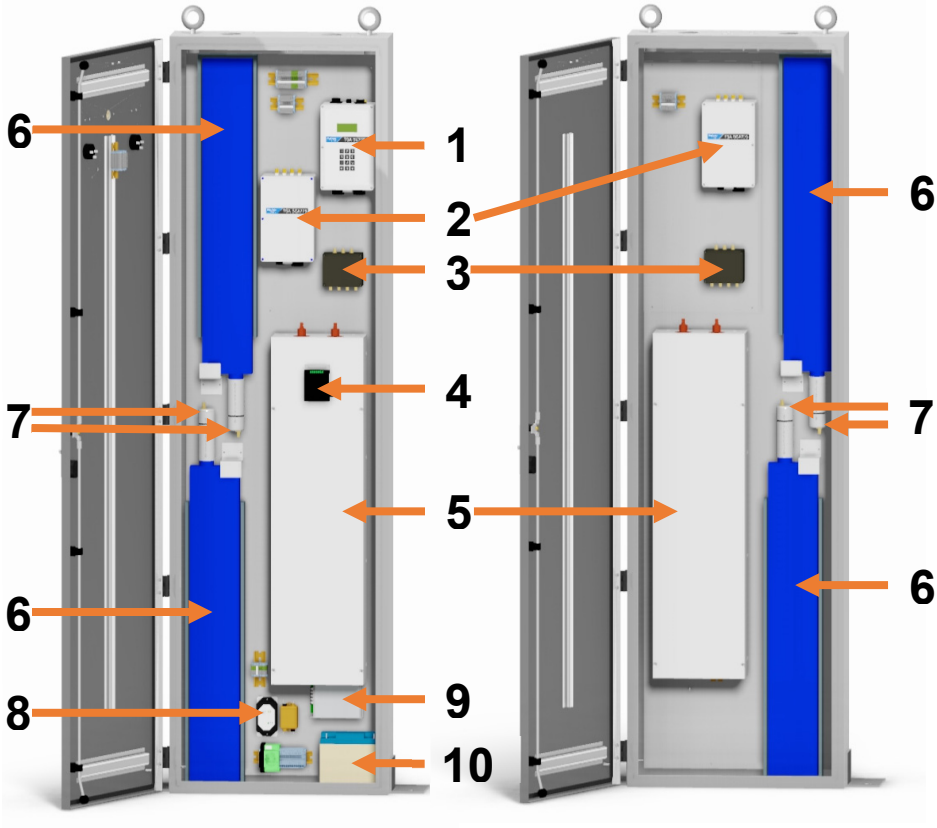
- Alarm and fault indicator column

VM-250-AGN Vehicle Monitor – Component Identification



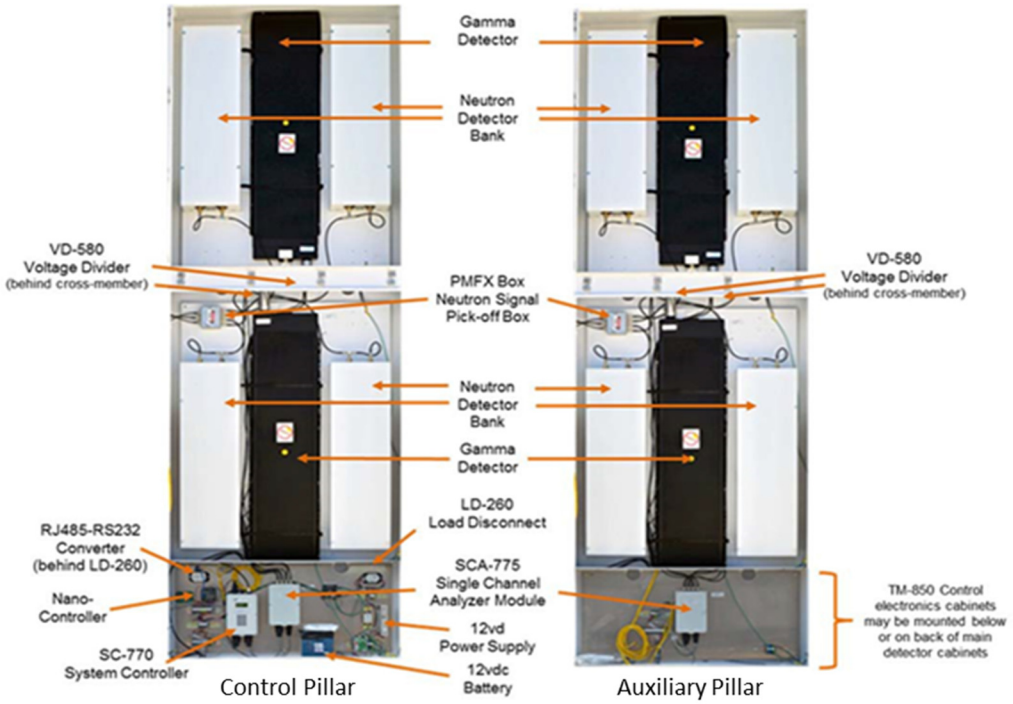
	Description of Component
1	Voltage Divider (VD-580)
2	Load Disconnect (LD-260)
3	RS-232 to RS-485 Converter (behind LD-260)
4	Nanocontroller
5	+15 VDC power supply
6	Battery +12 VDC 18 Ahr
7	6”x30” Gamma Detector (DA630)
8	Neutron Detector Assembly
	He-3 Tube (no replacement available)
	High Density Polyethylene Chamber
9	Single Channel Analyzer Module (SCA-775)
	Single Channel Analyzer Board (SCA-774)
	High Voltage Power Supply Board (HHV-448/458)
10	System Controller Module (SC-770)
	System Control Board (SC-771)
	General Purpose Relay Board (GPRB-756)
11	Neutron Signal Pick-Off Box (PMFX)
12	Media Converter

PM-700 Pedestrian Monitor – Component Identification



	Description of Component
1	System Controller Module (SC-770)
	System Control Board (SC-771)
	General Purpose Relay Board (GPRB-756)
2	Single Channel Analyzer Module (SCA-775)
	Single Channel Analyzer Board (SCA-774)
	High Voltage Power Supply Board (HHV-448/458)
3	Neutron Signal Pick-Off Box (PMFX)
4	Media Converter
5	Neutron Detector Assembly
	He-3 Tube (no replacement available)
	High Density Polyethylene Chamber
6	6”x30” Gamma Detector (DA630)
7	Voltage Divider Network (VD-580)
8	Load Disconnect (LD-260)
9	+15 VDC power supply
10	Battery +12 VDC 18Ahr

TM-850 Rail Monitor - Component Identification



Description of Component
AC Line Filter
RS-232 to RS-485
Battery +12V 18 AMP-Hours (option)*
Charger +15V 5AMP
Speed Sensor Kit (not shown)
Radar Sensor (not shown)
Siren Driver (ELK-100)
Media Converter
SEC-771 Rev 7 Board (inside SC-770)
SC-770
MHV FEM-FEM T CONN.
Magnetic Tamper Switch (not shown)
Gamma DET (12” x 48”)**
3He Neutron Detector Bank
HHV-448/458 (POTTED) (inside SC-775)
LD-2608
PMFX4 (POTTED)
SCA-774 Board (inside SC-775)
SCA-775
5 AMP Fuse (inside LD-260)
2 AMP Fuse (inside of +15 VDC Power Supply)

CM-267 Conveyor Monitor - Component Identification

	Description of Component
1	System Controller Module (SC-770)
	System Control Board (SC-771)
	General Purpose Relay Board (GPRB-756)
2	Single Channel Analyzer Module (SCA-775)
	Single Channel Analyzer Board (SCA-774)
	High Voltage Power Supply Board (HHV-448/458)
3	Neutron Signal Pick-Off Box (PMFX)
4	Media Converter
5	Neutron Detector Assembly
	He-3 Tube (no replacement available)
	High Density Polyethylene Chamber
6	6”x30” Gamma Detector (DA630)
7	Voltage Divider Network (VD-580)

Maintenance Overview

Maintenance is defined as an action taken to preserve, restore, verify, and/or improve an asset's functional capability.

Proper care and regular maintenance are critical to ensure that the equipment and associated electronics are functioning within the desired parameters. Neglected and/or improperly performed maintenance will adversely impact the operation and reduce sensitivity of the equipment. Improperly functioning equipment and reduced sensitivity will impact system operations and greatly reduce the effectiveness of the equipment. A disciplined approach to maintenance is crucial to properly functioning equipment.

Proper, regular maintenance has several benefits, including:

- Improved system availability
- Reduced lifecycle costs
- Increased service life
- Appropriate sensitivity to radioactive and special nuclear materials

Maintenance Types

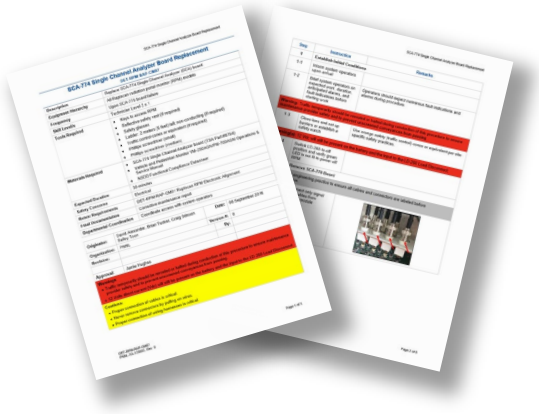
Routine – Tasks performed on a regular schedule to preserve the functionality, availability, and sensitivity of the equipment.

Corrective – Tasks performed to restore the functionality of equipment after a failure or damage.

Upgrade – Tasks performed to add capabilities, improve functionality, and/or extend the service life of the equipment.

Maintenance Procedure Overview

Proper function of the equipment will be preserved or restored through the use of procedures. Both routine and corrective maintenance procedures use a similar format and are included in this guide. Each procedure is comprised of several sections. Familiarity with the structure and features of the procedures will make their use in maintenance of the equipment easier and more efficient. The sections of a procedure include the following:



Title Section

Beyond the title and procedure number this section contains important information to help the technician prepare for the procedure.

- Description – A brief description of what the procedure is designed to accomplish.
- Equipment Hierarchy – A brief description of the equipment the procedure applies to.
- Frequency – How often and/or under what circumstances the procedure will be performed.
- Skill Level/Number of Technicians – Knowledge/skill level and number of technicians required to safely and successfully complete the procedure (e.g., Technician 2 x 2).

- Tools Required – A bulleted list of the tools necessary to complete the processes described.
- Materials Required – Supplies other than the tools required (i.e., replacement parts).
- Expected Duration – Describes how long a person of average ability will require to complete the procedure.
- Safety Concerns – A bulleted list of potential safety hazards.
- Retest Requirements – Follow-on procedures and other testing requirements necessary to show that the equipment has been restored to full function.
- Final Documentation – Typically a routine or corrective maintenance report. May include documentation in an operations or maintenance log, or other required documentation.
- Departmental Coordination – Describes coordination with other departments that may be using the equipment during the time that the maintenance is schedule.

Approval Section

Information regarding the formal documentation of the procedure is presented here, and included the following:

- Author(s) of the procedure
- Organization responsible for technical content
- Date approved for use
- Current version number
- Short description of revisions made since the original was published
- Names of the approvers

Warnings and Cautions

This section includes the warnings and cautions related to this procedure. Warnings and cautions are color coded to make them easy to find.

- Warnings include items that may be cause harm or be hazardous to the person(s) completing the procedure.
- Cautions include items that may cause damage or be hazardous to the equipment.

Warnings and cautions are inserted in the procedure again immediately before the step to which they apply.

Instructions and Remarks

The body of the procedure is a collection of numbered steps that must be completed in the order in which they are listed to assure successful completion. Each numbered step contains an instruction to be performed. It may also include remarks and/or pictures to clarify the instruction for that step.

Notes and standards are inserted in the procedure immediately before the step to which they apply. Notes and standards are not included at the beginning of the procedure like warnings and cautions, but are color coded to make them easy to find.

- Notes include information to clarify details concerning the procedural step about to be performed.
- Standards include information about measurements, specifications, limits, or requirements that must be met to assure proper function of the radiation detection system (RDS) when the procedure is complete.