ENCLOSURE 9

ESFAS RADIATION MONITOR

SINGLE FAILURE ANALYSIS

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1. BRIEF DESCRIPTION OF ICCN / CCN:

This is a complete document ICCN. The following are the changes:

1. Provided references to J-SPA-279, FHIS Radiation Monitor Software Mode Failure Evaluation and J-SPA-289, ESFAS Radiation Monitor Software Common Mode Failure Analysis to explain the inter-relationship between these documents.
2. Revised the FMEA Tables to reflect the most current vendor documentation and plant test results.
3. Verified and updated Calculation Cross-Index and Reference revision numbers.
4. Updated the Functional Block Diagrams to reflect the current design.
5. Reformatted document to start each major Section on a separate page and corrected minor typos.
6. Moved the Results/Conclusions section from Section 8.0 to Section 4.0; renumbered remaining sections.

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INITIATING DOCUMENT (DCP, FCN, OTHER) DCP 6926.01SJ (& AR 970600653) REV. 0

2. OTHER AFFECTED DOCUMENTS (CHECK AS APPLICABLE FOR CCN ONLY):

○ YES ◉ NO OTHER AFFECTED DOCUMENTS EXIST AND ARE IDENTIFIED ON ATTACHED FORM 26-503.

3. APPROVAL:

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CCN CONVERSION: CCN NO. CCN--

Calculation No. J-SPA-269, ESFAS Radiation Monitoring Single Failure Analysis

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Analysis rev. number and responsible supervisor initials and date	INPUTS: These interfacing calculations and/or documents provide input to the subject calculation, and if revised may require revision of the subject calculation.		OUTPUTS: Results and conclusion of the subject calculation are used in these interfacing calculations and/or documents.		Does the out-put interface calc/ document require revision?	Identify output interface calc/document CCN, DCN, TCN/Rev., FIDCN, or tracking number.
	Calc/Document No.	Rev. No.	Calc/Document No.	Rev. No.	YES / NO	
0 CS 7/9/98	Calc No. N-4072-001	4	DBD-SO23-690	1	No	
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	SO123-606-1-167 shts. 1, 2, & 3	5				
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	SO123-606-1-180	2				
	SO123-606-1-175 shts. 1 & 2	5				
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	SO123-606-1-359	1				
	SO123-606-1-354	1				

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1.0 SUMMARY.

Design Change Package, DCP 2&3 6926.01SJ, changes the radiation monitors used in Engineered Safety Featured Actuation Systems (ESFAS) from a totally analog design to a predominantly digital design. This Failure Evaluation has been performed to support the required 10CFR50.59 safety evaluations to the DCP and any associated Affected Section Changes (ASC).

The approach used in this evaluation was to analyze a series of single failure scenarios. No common mode failure was assumed. A software common mode failure analysis of all the ESFAS radiation monitors is addressed in J-SPA-289, ESFAS Radiation Monitor Software Common Mode Failure Evaluation[6.41]. A software common mode failure of the FHIS monitor only is addressed in J-SPA-279, FHIS Radiation Monitor Software Mode Failure Evaluation[6.40]. Hardware, individual software functional modules, communications and power losses were considered. In all cases, whether by fail safe mechanisms or redundancy, the safety function will be initiated or maintained as necessary to mitigate safety analysis accident conditions.

2.0 PURPOSE.

The purpose of this document is to perform a single failure evaluation on the safety related radiation monitoring channels being replaced by DCP 2&3-6926.01SJ. This failure evaluation will aid in determining the impact of these changes on plant safety and determining whether there are any unreviewed safety questions.

This document is also intended to confirm that the radiation sensor portion will respond in a similar manner as shown in the system level UFSAR Section 7 Failure Modes and Effects Analysis (FMEA) Tables as revised by DCP 2&3 6926.01SJ.

3.0 OBJECTIVE.

The objective of this evaluation is to assess the impact of single failures on the ESFAS radiation monitoring systems and to demonstrate that the protective functions of these systems are not lost as a result of these failures.

The objectives are met by using the following methods:

1. Identifying single mode failures to each sub-system of the replacement radiation monitor ESFAS.

2. Analyzing how each failure affects an individual channel operation and identifying how this failure is identified to the operator.

3. Showing how system function can be maintained with a single failure.

There are ten (10) radiation monitors with a combined total of fourteen (14) channels that form part of the ESFAS and Containment Leak Detection system. The evaluation is limited to these replacement monitors. The fourteen (14) channels are:

1. Containment Airborne Radiation Monitor channels; 2(3)RE7804G1, 2(3)RE7804P1, 2(3)RE7807G2 and 2(3)RE7807P2

2. The Fuel Handling Building Monitor Radiation Monitor channels; 2(3)RE7822G1 and 2(3)RE7823G2

3. The Control Room Intake Air Radiation Monitor channels; 2/3RE7824G1 and 2/3RE7825G2

This document is not intended to supersede any of the FMEA Tables contained in the UFSAR. (Tables 7.3-20, 7.3-22, 7.3-23).

4.0 RESULTS/CONCLUSIONS.

4.1 The Containment Air monitor configuration has the most number of components; the configurations of the Fuel Handling Building and the Control Room monitors are essentially subsets of the Containment Air monitor. Each control function has a fully redundant monitor performing the identical function. The redundant monitors are powered from alternate power sources and therefore, are not subject to common mode power losses. The failure of any single monitor does not prevent the control function from being performed.

4.2 Testing of prototype monitors has shown that the electronics are not susceptible to electro-magnetic interferences. Where shielding failures occur, EMI can cause communication failures. The communications software is designed such that if a communication message fails because of EMI, the re-transmission of the message will automatically occur. Unless the EMI is continuously broadcast, the re-transmission of the message will be successful. Where continuous failure of the communications occur, the operator will be alerted, via the annunciator panel, that the safety channel has failed.

4.3 If a detector input signal cabling has faulty shielding, EMI generated in this location could cause an increase in the count rate measured at the input. It is expected that, during surveillances, the measured concentrations in each redundant detector would differ. If the EMI effects were sufficiently large to cause an alarm, an isolation or alarm action would take place erroneously on a single train. While this incorrect action may be inconvenient, it would be conservative from a safety standpoint.

4.4 The ESFAS FMEA tables listed in the UFSAR have been modified by DCP 2&3-6926.01SJ. The results from this single failure evaluation are consistent with the modified UFSAR FMEA Tables (Section 7) as they refer to the sensor entries.

5.0 INPUTS/ASSUMPTIONS.

5.1 Section 3 of IEEE 279-1971[6.3] requires design bases for each ESFAS radiation monitor. The design bases for these monitors are contained in document DBD-SO23-690[6.35].

5.2 Each monitor is examined primarily based on the input and output failures of each functional block (Ref. Figures 8.1, 8.2, 8.3) within the monitor system. Tests have shown that the equipment is not susceptible to Electro-Magnetic Interference (EMI)[6.14]. In the instances where the operation of a monitor could be affected by external EMI as a result of failures, these failures have been limited to pulse counting and communication interferences. The basis for this assumption is that the probability of cable shielding becoming defective is much higher than the loss of shielding integrity within a conductive metal housing.

5.3 Software failures are considered to be undefined design deficiencies that occur under circumstances not covered during Validation and Verification (V & V) Testing. The V & V tests, developed in accordance with methods described in References 6.22 and 6.23, are intended to eliminate systemic failures. Single failure evaluation is therefore restricted to individual software functional modules where failures will not produce errors in each redundant monitoring channel.

5.4 The outputs from a failed digital device can be either high or low. Failed analog device outputs (radiation sensors) can be low, open, shorted or in limited cases, fail high. The bases for using these analog states are determined from a review of the circuitry and components used in these measuring channels.

5.5 Access to change software critical parameters is password protected. Only personnel with the correct level of authorization can access and change these parameters. It is assumed that this protection process will limit the possibility of a failure from being introduced either deliberately or inadvertently at the first three levels of access.

5.6 Sample pump motor power for monitors 2(3)RE7804G1, 2(3)RE7804P1, 2(3)RE7807G2, 2(3)RE7807P2, 2(3)RE7822G1 and 2(3)RE7823G2 is supplied from a Class 1E Motor Control Center (MCC) (Ref. 6.2 Table 2.5).

5.7 Instrument power for monitors 2(3)RE7804G1, 2(3)RE7804P1, 2(3)RE7807G2, 2(3)RE7807P2, 2(3)RE7823G1 and 2(3)RE7823G2 is supplied from the vital bus inverters (Ref. 6.2 Table 2.5).

5.8 Instrument power for monitors 2/3RE7824G1 and 2/3RE7825G2 is supplied from the vital busses (Battery back up) (Ref. 6.2 Table 2.5). No MCC power is required since these monitors have no sample pumps.

5.9 None of these monitors are required to operate in a harsh environment and therefore will not be subjected to excessive integrated radiation doses, high temperatures and pressures or caustic spray conditions.

5.10 The equipment has been successfully seismically tested to design bases limits[6.13]. Based on this qualification, the equipment is assumed not to fail as a result of a seismic event at the plant.

6.0 REFERENCES.

6.1 SO123-606-1-12 Rev.2, Radiation Monitoring and Sampling System Replacement Supplier Scope of Work.

6.2 DCP 2&3-6926.01SJ Rev. 0, Obsolete Equipment: Radiation Monitoring Systems Replacement Project.

6.3 IEEE Std 279-1971 "IEEE Standard Criteria for Protection Systems for Nuclear Power Generating Stations".

6.4 IEEE Std 379-1988 "IEEE Standard Applications of the Single Failure Criterion to Nuclear Power Generating Station Safety Systems".

6.5 MGP Document No. 45254BA Rev. 0, RMS General, pages 32-61.

6.6 MGP Document No. 45504EA Rev. 0, Radiation Monitoring Systems, pages 35-37.

6.7 SCE VPL No. SO123-606-1-164 Rev. 3, DRMS Skids 7804, 7807 P&ID.

6.8 SCE VPL No. SO123-606-1-167 Shts 1, 2, & 3 Rev. 5, DRMS Skid 7804, 7807 Wiring Diagram.

6.9 SCE VPL No. SO123-606-1-166 Rev. 4, DRMS Skid 7804, 7807 Power Distribution & Control Panel Electrical Schematic.

6.10 SCE VPL No. SO123-606-1-180 Rev. 2, DRMS Skid 7822, 7823 P&ID.

6.11 SCE VPL No. SO123-606-1-175 Shts 1, & 2 Rev. 5. DRMS Skid 7822, 7823 Wiring Diagram.

6.12 SCE VPL No. SO123-606-1-174 Rev. 4, DRMS Skid 7824, 7823 Power Distribution & Control Panel Electrical Schematic

6.13 SCE VPL No. SO123-606-1-354 Rev. 1, Nuclear Environmental Qualification Test Program on a Digital Radiation Monitoring System.

6.14 SCE VPL No. SO123-606-1-359 Rev. 1, Electromagnetic Interference (EMI) Test Report on the Radiation Monitoring System.

6.15 SCE VPL No. SO123-606-1-118 Rev. 4, DRMS In-Duct & Non Intrusive Liquid JB Wiring Diagram.

6.16 SCE Drawing No. 31213 Rev. 16, Elementary Diagram CPIS Train A.

6.17 SCE Drawing No. 31214 Rev. 16, Elementary Diagram CPIS Train B.

6.18 SCE Drawing No. 31394 Rev. 17, Elementary Diagram CRIS Train A.

6.19 SCE Drawing No. 31395 Rev. 16, Elementary Diagram CRIS Train B.

6.20 SCE Drawing No. 31428 Rev. 15, Elementary Diagram FHIS Train A.

6.21 SCE Drawing No. 31429 Rev. 14, Elementary Diagram FHIS Train B.

6.22 IEEE Std 730.1-1989 Standard for Software Quality Assurance Pla

6.23 IEEE Std 1012-1986 Standard for Software Verification and Validation Plans.

6.24 SCE Loop Drawings 2(3)RE7804G1 & 2(3)RE7807G2 Rev. 0.

6.25 SCE Loop Drawings 2(3)RE7822G1 & 2(3)RE7823G2 Rev. 0

6.26 SCE Loop Drawings 2/3RE7824G1 & 2/3RE7825G2 Rev. 0.

6.27 SCE Drawing No. 40170A Rev. 19, P & I D Containment HVAC System.

6.28 SCE Drawing No. 40177A Rev. 17, P & I D Misc. Ventilating System (Fuel Handling Building).

6.29 SCE Drawing No. 40173A Rev. 17, P & I D Control Room Complex HVAC.

6.30 San Onofre Units 2 & 3 Operating Licenses No. NPF-10/15 Rev. 132/121.

6.31 San Onofre Units 2 & 3 Updated Final Safety Analysis Rev. 11

6.32 SCE Abnormal Operating Instruction SO23-13-20 Rev. 1 TCN 1-17, Refueling Accidents.

6.33 SCE Abnormal Operating Instruction SO23-13-14 Rev. 0 TCN 0-15, Reactor Coolant Leak.

6.34 SCE Operating Instruction SO23-5-1.8 TCN 3-32, Shut Down Operation (Mode 5 & 6).

6.35 Design Bases Document DBD-SO23-690 Rev. 1, Radiation Monitoring Systems.

6.36 R.G. 1.45, Reactor Coolant Pressure Boundary Leakage Detection Systems, May 1973.

6.37 SCE Calculation N-4072-001 Rev. 4, Fuel Handling Accident Inside the Fuel Handling Building - CR & Offsite Doses.

6.38 SCE Calculation N-4072-003 Rev. 2, Fuel Handling Accident Inside the Containment - Control Room and Offsite Doses.

6.39 SCE Calculation J-SPA-179 Rev. 0, Control Room/Fuel Handling Building Monitor Setpoints.

6.40 SCE Document J-SPA-279, Rev. 0, FHIS Radiation Monitor Software Mode Failure Evaluation.

6.41 SCE Document J-SPA-289, Rev. 0, ESFAS Radiation Monitor Software Common Mode Failure Evaluation.

7.0 GENERAL EQUIPMENT DESCRIPTION.

7.1 Containment Airborne Radiation Monitor Channels, 2(3)RE7804G1, 2(3)RE7807G2, 2(3)RE7804P1 and 2(3)RE7807P2.

The Containment Airborne monitors perform multiple functions. The ESFAS function assigned to these monitors is the alarming and closure of the Containment Purge supply and exhaust valves for both Main and Mini purges under accident conditions.

The Containment Airborne monitor has both Noble Gas and Particulate detectors. Only the Noble Gas detector is used as the ESFAS protection sensor. The function of the Particulate is Reactor Coolant System (RCS) leakage detection[6.36].

A sample of the Containment air is extracted from the Containment. Prior to the sample entering a 7.825 liter sample chamber, Particulate and Iodine activities are removed. The Noble Gas detection system uses a Sodium Iodide scintillator coupled to a photomultiplier to generate electrical pulses at a rate proportional to the containment sample activity disintegration rates.

The photomultiplier detector operates with a high voltage (~1000 volts) power supply. The gain of the photomultiplier is sensitive to changes in high voltage. High voltage control is maintained using the output of an embedded standard Am-241 source in the Sodium Iodide crystal. The output from this source can be measured separately and used to adjust the high voltage in order to maintain a constant gain value.

The detector output electrical pulses are shaped, discriminated and counted in registers for predetermined time intervals. The accumulated counts per time interval will statistically vary with constant Noble Gas concentration. A software module averages these values and produces average count rates in counts per second.

Other software modules convert the averaged count rate into Noble Gas concentrations using stored calibration values for this conversion. The output is given in µCi/ml. When trip set points are exceeded, alarm status bits are set. The concentration and status are serially communicated to both the Local Display Unit (LDU) and to the Remote Display Unit (RDU).

The particulate channel consists of a Passivated Impregnated Planar Silicon (PIPS) detector located close to the filter area used to trap the airborne particulate matter contained in the incoming air stream. The detector is powered with a low voltage bias supply (<25 volts). The activity build up on the filter increases with time until an equilibrium state is reached with the decay of the short lived isotopes. The resulting count rate is proportional to the leak rate of the RCS into the Containment.

A secondary PIPS detector measures gamma activity induced from the background field present around the detector. The count rate values collected from this particulate detector are subtracted from the primary detector count rates to compensate for gamma background count contributions.

The detector output electrical pulses are shaped, discriminated and counted in registers for predetermined time intervals. The accumulated counts per time interval will statistically vary for a constant filter activity. The same software module averages these values and produces average count rates in counts per second.

The LDU performs the function of locally displaying Noble Gas concentration values and alarm status. The RDU has the same functions as the LDU except for operating remotely. In addition, the RDU operates relays used to actuate the Containment purge valves.

7.2 Fuel Handling Building Airborne Monitors, 2(3)RE7822G1, 2(3)RE7823G2.

The Fuel Handling Building monitors perform an isolation function. The ESFAS function assigned to these monitors is the alarming and switching of the Fuel Handling Building flow path into a closed loop under accident conditions. Outside air is restricted from entering and all the contained air in the building is recirculated through a filtration system.

The Fuel Handling Building monitors consist of Noble Gas detectors. This detector is used as the ESFAS protection sensor. This detector operates by measuring samples of the air at the exit of the building. Prior to the sample entering a 300 milliliter sample chamber, Particulate and Iodine activities are removed. The Noble Gas detection system uses a Passivated Impregnated Planar Silicon (PIPS) detector. This detector uses a low voltage bias voltage (<25 volts). The output of this detector produces pulses proportional to the Fuel Handling Building sample activity disintegration rates.

A secondary PIPS detector measures gamma activity induced from the background field present around the detector. The count rate values collected from this detector are subtracted from the primary detector count rates to compensate for gamma background count contributions.

The detector output electrical pulses are shaped, discriminated and counted in registers for predetermined time intervals. The accumulated counts per time interval will statistically vary for a constant concentration. A software module averages these values and produces average count rates in counts per second.

Other software modules convert the averaged count rate into Noble Gas concentration using stored calibration values for this conversion. The output is given in µCi/ml. When trip set points are exceeded, alarm status bits are set. The concentration and status are serially communicated to both the Local Display Unit (LDU) and to the Remote Display Unit (RDU).

The LDU has the function of locally displaying Noble Gas concentration values and alarm status. The RDU has the same functions as the LDU except for operating remotely. In addition, the RDU operates relays used to actuate the Fuel Handling Building isolation valves.

7.3 Control Room Intake Air Monitors, 2/3RE7824G1, 2/3RE7825G2.

The Control Room Intake Air monitors perform an air flow path switching function. The ESFAS function assigned to these monitors is to switch from a normal single source, recirculated air flow configuration to a redundant, highly filtered, recirculating, emergency mode flow path. Postulated accidents have releases that are drawn into the Control Room air system. The monitors are located in the incoming air ducting.

The Control Room Intake Air monitors consist of Noble Gas detectors. The detectors operate by directly measuring the air activity in the duct at the entrance to the Control room. The Noble Gas detection system uses a Sodium Iodide scintillator with a photomultiplier. The output of this detector produces pulses proportional to the inlet duct activity disintegration rates.

The photomultiplier detector operates with a high voltage (~1000 volts) power supply. The gain of the photomultiplier is sensitive to changes in high voltage. High voltage control is maintained using the output of an embedded Am-241 standard source in the Sodium Iodide crystal. The output from this source can be measured separately and used to adjust the high voltage in order to maintain a constant gain value.

The detector output electrical pulses are shaped, discriminated and counted in registers for predetermined time intervals. The accumulated counts per time interval will statistically vary with a constant concentration. A software module averages these values and produces average count rates in counts per second.

Other software modules convert the averaged count rate into Noble Gas concentrations using stored calibration values for this conversion. The output is given in µCi/ml. When trip set points are exceeded, alarm status bits are set. The concentration and status are serially communicated to both the Local Display Unit (LDU) and to the Remote Display Unit(RDU).

The LDU has the function of locally displaying Noble Gas concentration values and alarm status. The RDU has the same functions as the LDU except for operating remotely. In addition, the RDU operates relays used to actuate the Control Room Air path valves and dampers.

8.0 SINGLE FAILURE ANALYSIS.

8.1 Functional Block Diagrams.

Figures 8-1, 8-2 and 8-3 show the block diagrams for each ESFAS monitor in the system. Functional block diagrams for each of the ESFAS monitors were derived from wiring and loop diagrams (Refs. 6.8, 6.11, 6.15, 6.24, 6.25, 6.26).

The failure modes for each monitor are determined, in part, by failures in the inputs and outputs from each function block. Failures and their effect on the system are tabulated in Section 8.4. The analysis is limited to major components of each monitor.

8.2 Equipment Locations.

LPUs, LDUs and skid assemblies (where provided), are located at the process measurement points (Containment Air samples, Fuel Handling Building outlet air ducts, Control Room intake air duct). The RDU is located in the Control Room Area. Annunciator windows that are initiated from High and Fail alarms, are located within the Control Room.

8.3 System Response.

No credit is taken for the isolation of CPIS and FHIS. Analysis has shown that without isolation, accident dose levels to the public will not exceed 10CFR100 limits [6.37, 6.38]. Therefore, the response times of the ESFAS radiation monitors used to provide isolation are not considered in this analysis. The CRIS radiation ESFAS monitors are required to isolate within 3 minutes[6.3]. Analysis has shown that these monitors will respond in less than 3 minutes[6.39].

8.4 Tabulated Failure Modes and Effects.

Failures for each ESFAS system are identified in Tables 8-1, 8-2 and 8-3. Included in these tables are:

1. The function of each monitor sub-assembly
2. The failure mode of the sub-assembly. This is the manner in which the failure presents itself.
3. The failure mechanism of the sub-assembly. This is the reason for the occurrence of the failure mode.
4. The effect of the sub-assembly/component failure on the system.
5. The method of identifying the equipment failure.
6. The indication to the operations staff of the sub-assembly/ component failure.
7. The overall effect on the individual channel function.
8. The overall effect on the ESFAS system function.

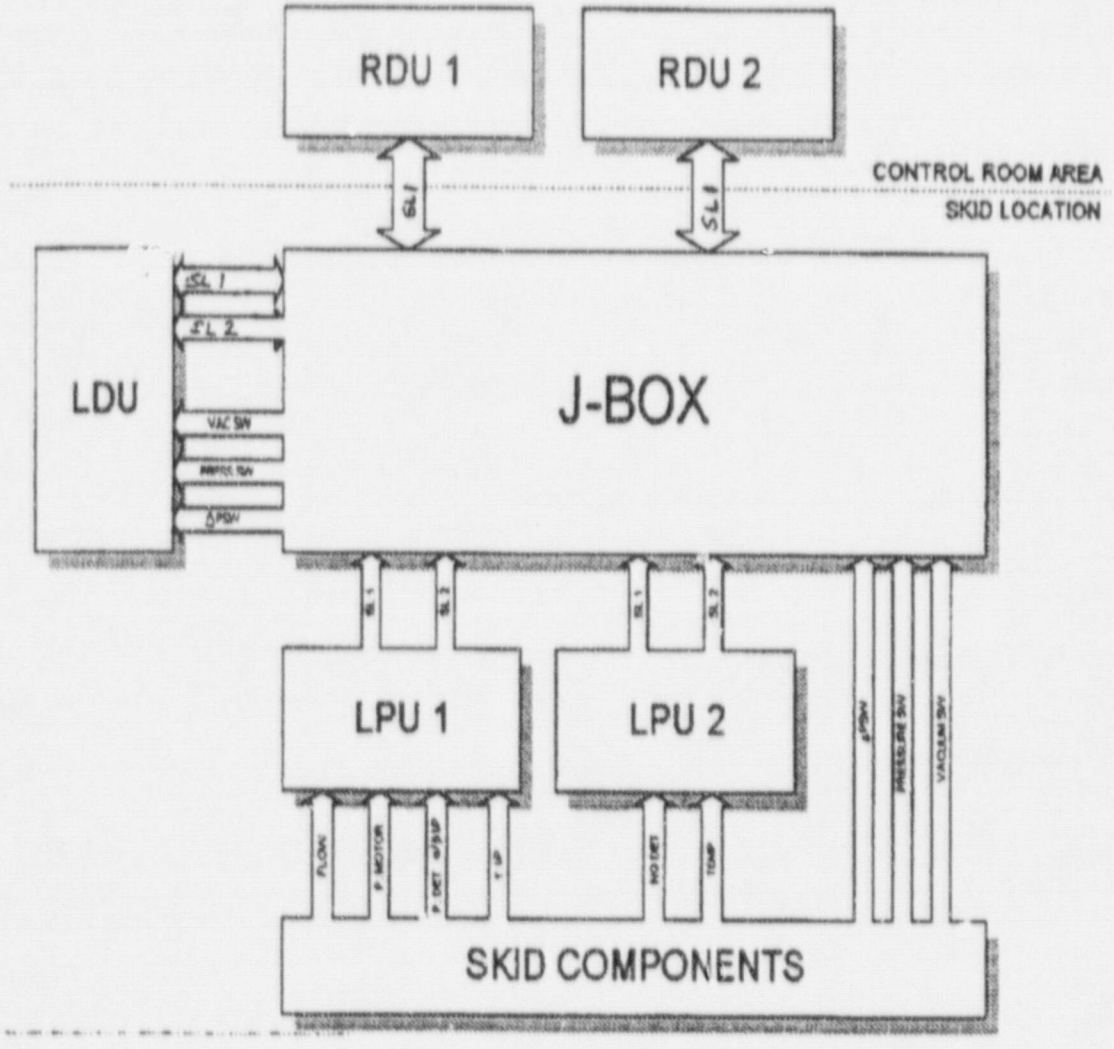

Figure 8-1 Block Diagram - Containment Airborne Monitor

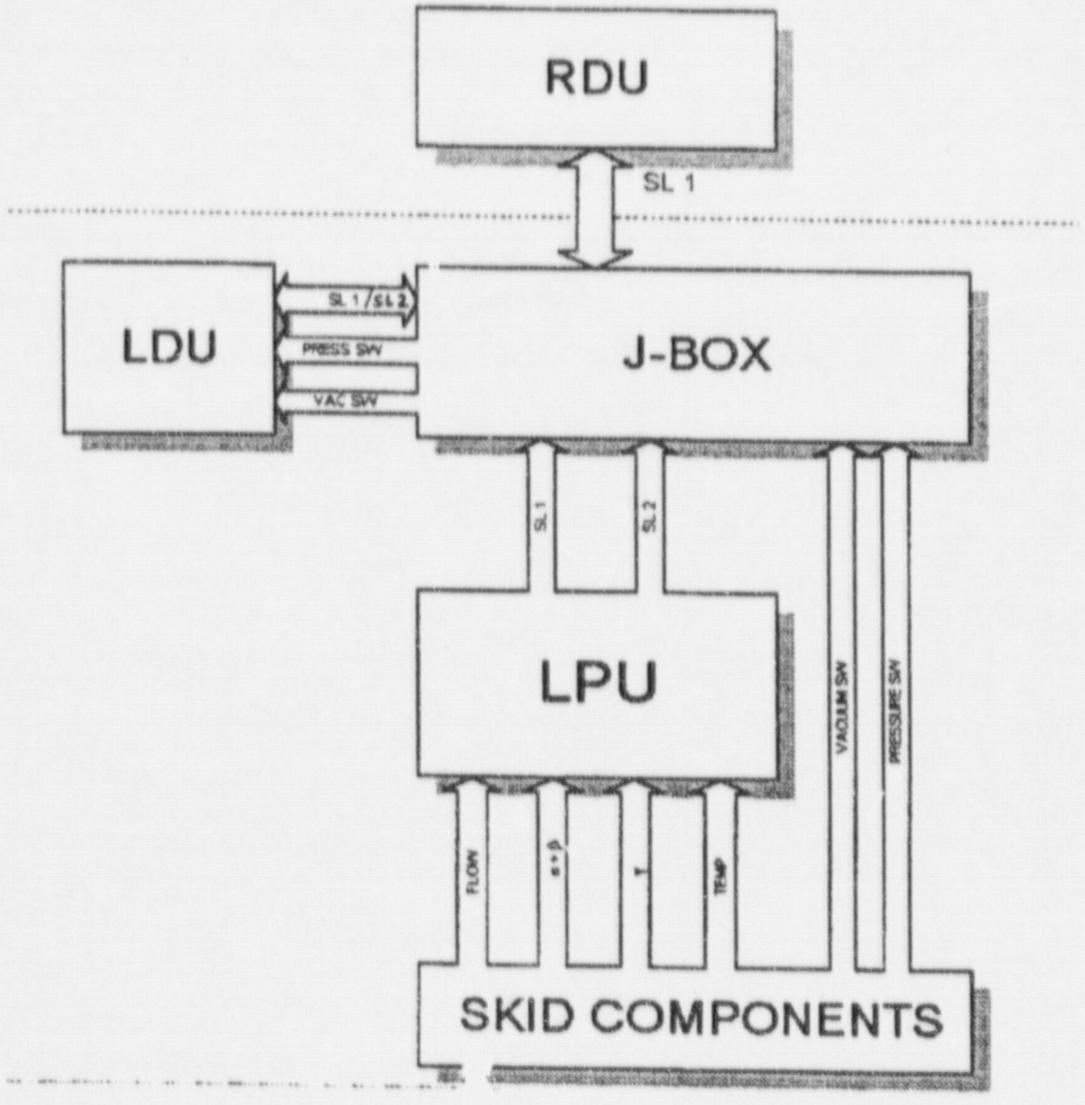

Figure 8-2 Block Diagram - Fuel Handling Building Noble Gas Monitor

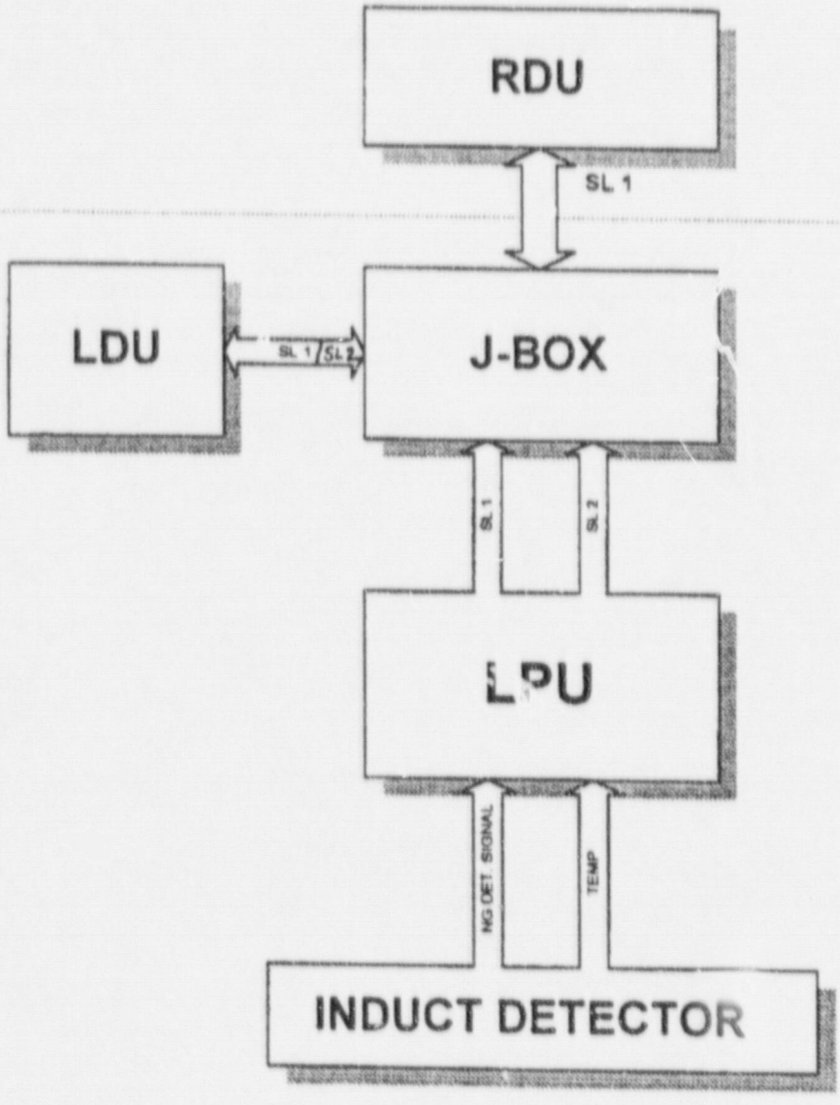

Figure 8-3 Block Diagram-Control Room Noble Gas Monitor

NOTE: The Containment Airborne radiation monitor consists of Noble Gas and Particulate channels. Only the Noble Gas channel will initiate a Containment Purge Isolation Signal (CPIS). Therefore, Table 8.1 will only address those component failures that have the potential to affect the Noble Gas channel.

Table 8.1 Containment Airborne Monitor Single Failure Evaluation

Component Identification	Function	Failure Modes	Failure Mechanism	Effect on System	Equipment Method of Failure Detection	Operations Failure Indication	Effect on Channel CPIS Function	Effect on System CPIS Function
1. Noble Gas Detector 2(3)RE7804G1 2(3)RE7807G2 Model No. RMS-9116-SR & Particulate Detector 2(3)RE7804P1 2(3)RE7807P2 Model No. RMS-8064	Noble gas concentration signal & Particulate concentration signal	Fail Off	1. Open Circuit 2. Short Circuit 3. Detector fail Low	No Noble Gas or Particulate concentration indication at RDU or LDU. No ability to alarm.	LPU senses detector loss of counts. Detector failure indicated by : 1. Connection fail 2. Loss of counts	Instrument Fail at U2/U3 INSTR FAIL window & RDU out of Operate.	Loss of affected channel ESFAS protective function.	None- Redundant channel functional.
		EMI induced into signal cable	Faulty shield	Possible high or incorrect Noble Gas concentration indications. Possible alarm or trip.	If noise collected in Am-241 reference peak, then count test will fail.	Possible U2/U3 CONTAINMENT RAD HI window & RDU HI alarm. Compare with redundant channel if alarming.	Possible affected channel trip.	None- Redundant channel functional.
	Particulate Filter	Filter fails	Torn or broken paper. Failed drive mechanism.	Excessively high sample flow under normal conditions. Particulate contamination in gas sample chamber.	High or low ΔP fault. Flow rate fault.	DAS alarm & RDU fault.	Affected NG channel may indicate high.	None - Redundant channel functional.

Table 8.1 Containment Airborne Monitor Single Failure Evaluation

Component identification	Function	Failure Modes	Failure Mechanism	Effect on System	Equipment Method of Failure Detection	Operations Failure Indication	Effect on Channel CPIS Function	Effect on System CPIS Function
2. LPU #2 2(3)RT7804G1 2(3)RT7807G2 Model No. RMS-9042-SR	Serial Link #1	Fail Off	1. Open Circuit 2. Short Circuit	Failed serial communication with RDU #2.	Communication link watchdog fault.	Instrument Fail at U2/U3 INSTR FAIL window & RDU out of Operate.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
		EMI Induced (Intermittent)	Faulty shield.	Degraded serial communication with RDU #2.	Software watchdog communication check automatically initiates re-transmission.	None	None	None
		EMI Induced (Continuous)	Faulty shield.	Failed serial communication with RDU #2.	Communication link watchdog fault.	Instrument Fail at U2/U3 INSTR FAIL window & RDU out of Operate.	Loss of affected channel ESFAS protective function.	Non-Redundant channel functional.
	Serial Link #2	Fail Off	1. Open Circuit 2. Short Circuit	Failed serial communication with LDU. Loss of local indication, control and alarms.	Communication link watchdog fault.	DAS alarm & RDU slave fault.	None	None
		EMI Induced (Intermittent)	Faulty shield.	Degraded serial communication with LDU.	Software watchdog communication check automatically initiates re-transmission.	None	None	None

Table 8.1 Containment Airborne Monitor Single Failure Evaluation

Component Identification	Function	Failure Modes	Failure Mechanism	Effect on System	Equipment Method of Failure Detection	Operations Failure Indication	Effect on Channel CPIS Function	Effect on System CPIS Function
2. LPU #2 (continued)	Serial Link #2 (cont'd)	EMI Induced (Continuous)	Faulty shield.	Failed serial communication with LDU. Loss of local indication, control and alarms.	Communication link watchdog fault.	DAS alarm & RDU slave fault.	None	None
	Detector Bias Power Supply	Fail Off	1. Open Circuit 2. Short Circuit	Loss of detector signal. No Noble Gas concentration indications.	Loss of counts fault. Internal Power Supply voltage test fault.	DAS alarm & RDU slave fault.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
		Degraded	Control Circuit fail	Possible degradation in measured output during steady state.	Internal Power Supply voltage test fault.	DAS alarm & RDU slave fault.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
	Power Supply (Common to LPU, LDU & RDU)	120 vac failure.	1. Open Circuit 2. Short Circuit	Loss of detector signal. No Noble Gas concentration indication. RDU control relay changes state from CLOSED to OPEN.	Communication link watchdog fault. Loss of counts fault. Total failure of the LPU.	U2/U3 CONTAINMENT RAD HI window & RDU HI Alarm.	Affected channel trip.	CPIS Actuation.

Table 8.1 Containment Airborne Monitor Single Failure Evaluation

Component Identification	Function	Failure Modes	Failure Mechanism	Effect on System	Equipment Method of Failure Detection	Operations Failure Indication	Effect on Channel CPIS Function	Effect on System CPIS Function
2. LPU #2 (continued)	Acquisition	Preamplifier & discriminator fail	Hardware failure	No concentration indication.	Loss of counts fault.	DAS alarm & RDU slave fault.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
		Timers fail	Hardware/ software failure					
		Counters fail						
		Software failure	Software module fails					
	Memory	EPROM, EEPROM, Flash failure	Hardware/ Software failure	Possible LPU failure.	CRC16 checksum test fault.	DAS alarm & RDU slave fault.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
		RAM fail	Hardware/ Software failure	Possible LPU failure.	RAM test fault. Operation alarm at LPU.			
	Watchdog timer	Timer failure	Hardware/ Software failure	No indication of module failures associated with main software loop & real time processing.	Software check indicates fault alarm.	DAS alarm & RDU slave fault.	Possible loss of affected channel ESFAS protective function.	None-Redundant channel functional.

Table 8.1 Containment Airborne Monitor Single Failure Evaluation

Component Identification	Function	Failure Modes	Failure Mechanism	Effect on System	Equipment Method of Failure Detection	Operations Failure Indication	Effect on Channel CPIS Function	Effect on System CPIS Function
3. RDU #2 2(3)RC7804G1 /7807G2 2(3)RCH7804G 1/7807G2 2(3)RSA7804G 1/7807G2 2(3)RSL7804G 1/7807G2 Model No. RMS-9009-SR	Processing Software	Fault in software/ component failure.	Hardware/ Software failure	No indication of concentration or communications.	Watchdog timer identifies a processing fault.	DAS alarm & RDU fault.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
	Serial Link #1	Fail	1. Short Circuit 2. Open circuit 3. Software failure	Failed serial communication with LPU #1, LPU #2, and LDU. Loss of remote control of skid components from RDU.	Communication link watchdog fault.	Instrument Fail at U2/U3 INSTR FAIL window & RDU out of Operate.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
		EMI Induced (Intermittent)	Faulty Shield	Degraded serial communication with LPU #2.	Software watchdog communication check automatically initiates re-transmission.	None	None	None
		EMI Induced (Continuous)	Faulty Shield	Failed serial communication with LPU #1, LPU #2, and LDU. Loss of remote control of skid components from RDU.	Communication link watchdog fault.	Instrument Fail at U2/U3 INSTR FAIL window & RDU out of Operate.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.

Table 8.1 Containment Airborne Monitor Single Failure Evaluation

Component Identification	Function	Failure Modes	Failure Mechanism	Effect on System	Equipment Method of Failure Detection	Operations Failure Indication	Effect on Channel CPIS Function	Effect on System CPIS Function
3. RDU #2 (continued)	High Radiation Alarm Relay	Fails coil energized.	1. Short circuit 2. Software fail	Alarms/Control valves cannot actuate.	None	Periodic testing (24 months)	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
		Fails coil de-energized	1. Open Circuit 2. Software fail	Alarms/Control valves automatically actuated.	Relay contacts change state from CLOSED to OPEN.	U2/U3 CONTAINMENT RAD Hi window & RDU HI Alarm.	Affected channel trip.	CPIS Actuation.
	Power	120 vac failure	1. Open circuit 2. Short circuit	Loss of power to High Radiation Alarm Relay.	Relay contacts change state from CLOSED to OPEN	U2/U3 CONTAINMENT RAD HI window & RDU HI Alarm.	Affected channel trip.	CPIS Actuation.
4. Sample Pump 2MP7804-1 2MP7807-2	Activity sample flow	Loss of pump power.	1. Open circuit 2. Short Circuit	Loss of sample flow. Noble gas detector continues to measure invalid residual gas in sample chamber.	Low sample flow fault.	DAS alarm & RDU fault.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
		Restricted flow.	1. Blocked inlet line (Vacuum switch) 2. Blocked outlet line (Pressure sw)	Degraded sample flow until sample pump trip on low suction pressure or high discharge pressure.	Low sample flow fault.	DAS alarm & RDU fault.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.

Table 8.1 Containment Airborne Monitor Single Failure Evaluation

Component Identification	Function	Failure Modes	Failure Mechanism	Effect on System	Equipment Method of Failure Detection	Operations Failure Indication	Effect on Channel CPIS Function	Effect on System CPIS Function
5. LDU 2(3)RUIC7804-1/7807-2 Model No. RMS-9003-SR	Serial Link #1	Fail Off	1. Open circuit 2. Short circuit	Failed serial communication with LPU #1 and LPU #2. Loss of local indication, control and alarms.	Communication link watchdog fault.	DAS alarm & RDU slave fault.	None	None
		EMI Induced (Intermittent)	Faulty shield	Degraded serial communication with LPU #1 and LPU #2.	Software watchdog communication check automatically initiates re-transmission.	None	None	None
		EMI Induced (Continuous)	Faulty Shield	Failed serial communication with LPU #1 and LPU #2. Loss of local indication, control and alarms.	Communication link watchdog fault.	DAS alarm & RDU fault.	None	None

Table 8.1 Containment Airborne Monitor Single Failure Evaluation

Component Identification	Function	Failure Modes	Failure Mechanism	Effect on System	Equipment Method of Failure Detection	Operations Failure Indication	Effect on Channel CPIS Function	Effect on System CPIS Function
5. LDU (continued)	Serial Link #2 (cont'd)	Fail Off	1. Open circuit 2. Short circuit	Failed serial communication with RDU #1 and RDU #2. Loss of remote control of skid components from RDU.	Communication link watchdog fault.	Instrument Fail at U2/U3 INSTR FAIL window & RDU out of Operate.	None	None
		EMI Induced (Intermittent)	Faulty shield	Degraded serial communication with LDU #1 and LDU #2.	Software watchdog communication check automatically initiates re-transmission.	None	None	None
		EMI Induced (Continuous)	Faulty Shield	Failed serial communication with RDU #1 and RDU #2. Loss of remote control of skid components from RDU.	Communication link watchdog fault.	Instrument Fail at U2/U3 INSTR FAIL window & RDU out of Operate.	None	None
	Memory	EPROM, EEPROM, Flash failure	Hardware/ Software failure	Possible loss of local indication, control and alarms.	CRC16 checksum test fault.	DAS alarm & RDU slave fault.	None	None
		RAM fail	Hardware/ Software failure	Possible loss of local indication, control and alarms.	RAM test fault. Operation alarm.			

Table 8.1 Containment Airborne Monitor Single Failure Evaluation

Component Identification	Function	Failure Modes	Failure Mechanism	Effect on System	Equipment Method of Failure Detection	Operations Failure Indication	Effect on Channel CPIS Function	Effect on System CPIS Function
5. LDU (Continued)	Watchdog Timer	Timer failure	Hardware/ Software failure	No indications of module failures associated with main software loop & real time processing. Possible loss of local indication, control and alarms.	Software check indicates fault alarm.	DAS alarm & RDU slave fault.	None	None
	Processing Software	Fault in software/ component failure.	Hardware/ Software failure.	No indications of concentration or communications. Loss of local indication, control and alarms.	Watchdog timer identifies a processing failure.	DAS alarm & RDU slave fault.	None	None
6. Skid 2(3)RU7804-1 2(3)RU7807-2	Activity sample measurement	Loss of power.	1. Open circuit 2. Short circuit	Loss of power to LPU, LDU & sample pump.	Communication link watchdog fault. Low sample flow fault.	Instrument Fail at U2/U3 INSTR FAIL window & RDU out of Operate.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
	Temperature measurement	Loss of sensor input.	1. Open circuit 2. Short circuit	No gain correction for temperature swings.	LPU senses loss of input.	DAS alarm & RDU fault.	Affected NG channel output may be inaccurate. Trip function still available.	None-Redundant channel functional.

Table 8.1 Containment Airborne Monitor Single Failure Evaluation

Component Identification	Function	Failure Modes	Failure Mechanism	Effect on System	Equipment Method of Failure Detection	Operations Failure Indication	Effect on Channel CPIS Function	Effect on System CPIS Function
6. Skid (Continued)	Sample line outlet pressure measurement	Pressure switch fails open.	Hardware failure.	Loss of sample flow due to sample pump trip.	Low sample flow fault. High pressure fault.	DAS alarm & RDU fault.	Loss of affected channel ESFAS protective function.	None-Redundant channnel functional.
		Pressure switch fails closed.	Hardware failure.	Loss of sample pump trip protection on blocked outlet flow.	None	Periodic testing (24 months)	None	None
	Sample line inlet vacuum measurement	Vacuum switch fails open.	Hardware failure.	Loss of sample flow due to sample pump trip.	Sample flow fault. High vacuum fault.	DAS alarm & RDU fault.	Loss of affected channel ESFAS protective function.	None-Redundant channnel functional.
		Vacuum switch fails closed.	Hardware failure.	Loss of sample pump trip protection on blocked inlet flow.	None	Periodic testing (24 months)	None	None

Table 8.1 Containment Airborne Monitor Single Failure Evaluation

Component Identification	Function	Failure Modes	Failure Mechanism	Effect on System	Equipment Method of Failure Detection	Operations Failure Indication	Effect on Channel CPIS Function	Effect on System CPIS Function
6. Skid (Continued)	Filter ΔP measurement	High ΔP switch fails open.	Hardware failure.	Incorrectly indicates blocked filter. Sample pump stops and filter advances.	ΔP fault, filter fault, and sample flow fault.	DAS alarm & RDU fault.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
		High ΔP switch fails closed.	Hardware failure.	Filter paper will not automatically advance when required due to high ΔP.	None	Periodic testing (24 months)	None - loss or degraded particulate channel indication only.	None
		Low ΔP switch fails open.	Hardware failure.	Incorrectly indicates torn or broken filter. Sample pump stops and filter advances.	ΔP fault and filter fault.	DAS alarm & RDU fault.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
		Low ΔP switch fails closed.	Hardware failure.	Filter paper will not automatically advance when required due to low ΔP.	None	Periodic testing (24 months)	None - loss or degraded particulate channel indication only.	None

Table 8.2 Fuel Handling Building Monitor Single Failure Evaluation								
Component Identification	Function	Failure Modes	Failure Mechanism	Effect on System	Method of Failure Detection	Operations Failure Indication	Effect on Channel FHIS Function	Effect on System FHIS Function
1. Noble Gas Detector 2(3)RE7822G1 2(3)RE7823G2 Model No. RMS-9087-SR	Noble gas concentration signal.	Fail Off	1. Open Circuit 2. Short Circuit 3. Detector fail Low	No Noble Gas concentration indication at RDU or LDU. No ability to alarm.	LPU senses detector loss of counts. Detector failure indicated by : 1. Connection fail 2. Loss of counts fault	Instrument Fail at U2/U3 INSTR FAIL window & RDU out of Operate.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
		EMI induced into signal cable	Faulty shield	Possible high or incorrect Noble Gas concentration indications. Possible alarm or trip.	If noise collected in Am-241 reference peak, then count test will fail.	Possible U2/U3 FHB RAD HI alarm window & RDU HI alarm. Compare with redundant channel if alarming.	Possible affected channel trip.	None-Redundant channel functional.
2. LPU 2(3)RT7822G1 /G2 Model No. RMS-9042-SR	Serial Link #1	Fail Off	1. Open Circuit 2. Short Circuit	Failed serial communication with RDU.	Communication link watchdog fault.	Instrument Fail at U2/U3 INSTR FAIL window & RDU out of Operate.	Loss of affected channel ESFAS protective function	None-Redundant channel functional.
		EMI Induced (Intermittent)	Faulty shield.	Degraded serial communication with RDU.	Software watchdog communication check automatically initiates re-transmission.	None	None	None

Table 8.2 Fuel Handling Building Monitor Single Failure Evaluation

Component Identification	Function	Failure Modes	Failure Mechanism	Effect on System	Method of Failure Detection	Operations Failure Indication	Effect on Channel FHIS Function	Effect on System FHIS Function
2. LPU (continued)	Serial Link #1 (cont'd)	EMI Induced (Continuous)	Faulty shield.	Failed serial communication with RDU.	Communication link watchdog fault.	Instrument Fail at U2/U3 INSTR FAIL window & RDU out of Operate.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
	Serial Link #2	Fail Off	1. Open Circuit 2. Short Circuit	Failed serial communication with LDU. Loss of local indication, control and alarms.	Communication link watchdog fault.	DAS alarm & RDU slave fault.	None	None
		EMI Induced (Intermittent)	Faulty shield.	Degraded serial communication with LDU.	Software watchdog communication check automatically initiates re-transmission.	None	None	None
		EMI Induced (Continuous)	Faulty shield.	Failed serial communication with LDU. Loss of local indication, control and alarms.	Communication link watchdog fault.	DAS alarm & RDU slave fault.	None	None

Table 8.2 Fuel Handling Building Monitor Single Failure Evaluation

Component Identification	Function	Failure Modes	Failure Mechanism	Effect on System	Method of Failure Detection	Operations Failure Indication	Effect on Channel FHIS Function	Effect on System FHIS Function
2. LPU (continued)	Detector Bias Power Supply	Fail Off	1. Open Circuit 2. Short Circuit	Loss of detector signal. No Noble Gas concentration indications.	Loss of counts fault. Internal Power Supply voltage test fault.	DAS alarm & RDU slave fault.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
		Degraded	Control Circuit fail.	Possible degradation in measured output during steady state.	Internal Power Supply voltage test fault.	DAS alarm & RDU slave fault.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
	Power Supply (Common to LPU, LDU & RDU)	120 vac failure.	1. Open Circuit 2. Short Circuit	Loss of detector signal. No Noble Gas concentration indication and control relay. RDU control relay changes state from CLOSED to OPEN.	Communication link watchdog fault. Loss of counts fault. Total failure of the LPU.	U2/U3 FHB RAD HI alarm window & RDU HI Alarm.	Affected channel Trip.	FHIS Actuation.
	Acquisition	Preamplifier & discriminator fail	Hardware failure	No concentration indication.	Loss of counts fault.	DAS alarm & RDU slave fault.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
		Timers fail	Hardware/ software failure.					
		Counters fail						
		Software failure	Software module fails					

Table 8.2 Fuel Handling Building Monitor Single Failure Evaluation

Component Identification	Function	Failure Modes	Failure Mechanism	Effect on System	Method of Failure Detection	Operations Failure Indication	Effect on Channel FHIS Function	Effect on System FHIS Function
2. LPU (Continued)	Memory	EPROM, EEPROM, Flash failure	Hardware/ Software failure	Possible LPU failure.	CRC16 checksum test fault.	DAS alarm & RDU slave fault.	Loss of affected channel ESFAS protective function.	None- Redundant channel functional.
		RAM fail	Hardware/ Software failure	Possible LPU failure.	RAM test fault. Operation alarm at LPU.			
	Watchdog timer	Timer failure	Hardware/ Software failure	No indication of module failures associated with main software loop & real time processing.	Software check indicates fault alarm.	DAS alarm & RDU slave fault.	Possible loss of affected channel ESFAS protective function.	None- Redundant channel functional.
3. RDU 2(3)RIC7822G1 2(3)RCH7822G 1 2(3)RSA7822G 1 2(3)RSL7822G 1 2(3)RIC7823G2 2(3)RCH7823G 2 2(3)RSA7823G 2 2(3)RSL7823G 2 Model No. RMS-9009-SR	Processing Software	Fault in software/ component failure.	Hardware/ Software failure.	No indication of concentration or communications.	Watchdog timer identifies a processing failure.	DAS alarm & RDU fault.	Loss of affected channel ESFAS protective function.	None- Redundant channel functional.
	Serial Link #1	Fail	1. Short Circuit 2. Open circuit 3. Software failure	Failed serial communication with LPU & LDU. Loss of remote control of skid components from RDU.	Communication link watchdog fault.	Instrument Fail at U2/U3 INSTR FAIL window & RDU out of Operate.	Loss of affected channel ESFAS protective function.	None- Redundant channel functional.
		EMI Induced (Intermittent)	Faulty Shield.	Degraded serial communication with LPU & LDU.	Software watchdog communication check automatically initiates re-transmission.	None	None	None

Table 8.2 Fuel Handling Building Monitor Single Failure Evaluation								
Component Identification	Function	Failure Modes	Failure Mechanism	Effect on System	Method of Failure Detection	Operations Failure Indication	Effect on Channel FHIS Function	Effect on System FHIS Function
3. RDU (continued)	Serial Link #1 (cont'd)	EMI induced (Continuous)	Faulty Shield.	Failed serial communication with LPU & LDU. Loss of remote control of skid components from RDU.	Communication link watchdog fault.	Instrument Fail at U2/U3 INSTR FAIL window & RDU out of Operate.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
	High Radiation Alarm Relay	Fails coil energized.	1. Short circuit 2. Software fail	Alarms/Control Dampers cannot actuate.	None	Periodic testing (18 month period)	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
		Fails coil de-energized	1. Open Circuit 2. Software fail	Alarms/Control Dampers automatically actuated.	Relay contacts change state from CLOSED to OPEN.	U2/U3 FHB RAD HI alarm window & RDU HI Alarm.	Affected channel trip.	FHIS actuation.
	Power	120 vac failure	1. Open circuit 2. Short circuit	Loss of power to High Radiation Alarm Relay.	Relay contacts change state from CLOSED to OPEN.	U2/U3 FHB RAD HI alarm window & RDU HI Alarm.	Affected channel trip.	FHIS actuation.

Table 8.2 Fuel Handling Building Monitor Single Failure Evaluation

Component Identification	Function	Failure Modes	Failure Mechanism	Effect on System	Method of Failure Detection	Operations Failure Indication	Effect on Channel FHIS Function	Effect on System FHIS Function
4. LDU 2(3)RUIC7822 G1 2(3)RUIC7823 G2 Model No. RMS-9003-SR	Serial Link #1	Fail Off	1. Open circuit 2. Short circuit	Failed serial communication with LPU. Loss of local indication, control and alarms.	Communication link watchdog fault.	DAS alarm & RDU slave fault.	None	No
		EMI Induced (Intermittent)	Faulty shield.	Degraded serial communication with LPU	Software watchdog communication check automatically initiates re-transmission.	None	None	None
		EMI Induced (Continuous)	Faulty shield.	Failed serial communication with LPU. Loss of local indication, control and alarms.	Communication link watchdog fault.	DAS alarm & RDU slave fault.	None	None
	Serial Link #2	Fail Off	1. Open circuit 2. Short circuit	Failed serial communication with RDU. Loss of remote control of the skid components from the RDU.	Communication link watchdog fault.	Instrument Fail at U2/U3 INSTR FAIL window & RDU out of Operate.	None	None

Table 8.2 Fuel Handling Building Monitor Single Failure Evaluation

Component Identification	Function	Failure Modes	Failure Mechanism	Effect on System	Method of Failure Detection	Operations Failure Indication	Effect on Channel FHIS Function	Effect on System FHIS Function
4. LDU (continued)	Serial Link #2 (cont'd)	EMI Induced (Intermittent)	Faulty shield.	Degraded serial communication with RDU.	Software watchdog communication check automatically initiates re-transmission.	None	None	None
		EMI Induced (Continuous)	Faulty shield.	Failed serial communication with RDU. Loss of remote control of the skid components from the RDU.	Communication link watchdog fault.	Instrument Fail at U2/U3 INSTR FAIL window & RDU out of Operate.	None	None
	Memory	EPROM, EEPROM, Flash failure	Hardware/ Software failure	Possible loss of local indication, control and alarms.	CRC16 checksum test fault.	DAS alarm & RDU slave fault.	None	None
		RAM fail	Hardware/ Software failure	Possible loss of local indication, control and alarms.	RAM test fault. Operation alarm			
	Watchdog Timer	Timer failure	Hardware/ Software failure	No indications of module failures associated with main software loop & real time processing. Possible loss of local indication, control and alarms.	Software check indicates fault alarm.	DAS alarm & RDU slave fault.	None	None

Table 8.2 Fuel Handling Building Monitor Single Failure Evaluation

Component Identification	Function	Failure Modes	Failure Mechanism	Effect on System	Method of Failure Detection	Operations Failure Indication	Effect on Channel FHIS Function	Effect on System FHIS Function
4. LDU (Continued)	Processing Software	Fault in software/ component failure	Hardware/ Software failure	No indications of concentration or communications. Loss of local indication, control and alarms.	Watchdog timer identifies a processing failure	DAS alarm & RDU slave fault.	None	None
5. Sample Pump 2(3)MP7822 2(3)MP7823	Activity sample flow	Loss of pump power	1. Open circuit 2. Short circuit	Loss of sample flow. Noble Gas detector continues to measure invalid residual gas in sample chamber.	Low sample flow fault.	Instrument Fail at U2/U3 INSTR FAIL window & RDU out of Operate.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
		Restricted flow	1. Blocked inlet line (Vacuum switch) 2. Blocked outlet line (Pressure sw)	Degraded sample flow until sample pump trip on low suction pressure or high discharge pressure.	Low sample flow fault.	Instrument Fail at U2/U3 INSTR FAIL window & RDU out of Operate.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.

Table 8.2 Fuel Handling Building Monitor Single Failure Evaluation

Component Identification	Function	Failure Modes	Failure Mechanism	Effect on System	Method of Failure Detection	Operations Failure Indication	Effect on Channel FHIS Function	Effect on System FHIS Function
6. Skid 2(3)RU7822-1 2(3)RU7823-2	Activity sample measurement	Loss of power.	1. Open circuit 2. Short circuit	Loss of power to LPU, LDU & sample pump.	Communication link watchdog fault. Low sample flow fault.	Instrument Fail at U2/U3 INSTR FAIL window & RDU out of Operate.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
	Temperature measurement	Loss of sensor input.	1. Open circuit. 2. Short circuit.	No gain correction for temperature swings.	LPU senses loss of input.	DAS alarm & RDU fault.	Affected NG channel output may be inaccurate. Trip function still available.	None-Redundant channel functional.
	Sample line outlet pressure measurement.	Pressure switch fails open.	Hardware failure.	Loss of sample flow due to sample pump trip.	Low sample flow fault. High pressure fault.	DAS alarm & RDU fault.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
		Pressure switch fails closed.	Hardware failure.	Loss of sample pump trip protection on blocked outlet flow.	None.	Periodic testing (18 months)	None	None

Table 8.2 Fuel Handling Building Monitor Single Failure Evaluation

Component Identification	Function	Failure Modes	Failure Mechanism	Effect on System	Method of Failure Detection	Operations Failure Indication	Effect on Channel FHIS Function	Effect on System FHIS Function
6. Skid (continued)	Sample line inlet vacuum measurement.	Vacuum switch fails open.	Hardware failure.	Loss of sample flow due to sample pump trip.	Low sample flow fault. High vacuum fault.	DAS alarm & RDU fault.	Loss of affected channel ESFAS protective function.	None- Redundant channel functional.
		Vacuum switch fails closed.	Hardware failure.	Loss of sample pump trip protection on blocked inlet flow.	None	Periodic testing (18 months)	None	None

Table 8.3 Control Room Monitors Single Failure Evaluation

Component Identification	Function	Failure Modes	Failure Mechanism	Effect on System	Method of Failure Detection	Operations Failure Indication	Effect on Channel FHIS Function	Effect on System FHIS Function
1. Noble Gas Detector 2/3RE7824G1 2/3RE7825G2 Model No. SAS-4129-SR	Noble gas concentration signal.	Fail Off	1. Open Circuit 2. Short Circuit 3. Detector fail Low	No Noble Gas concentration indication at RDU or LDU. No ability to alarm.	LPU senses detector loss of counts. Detector failure indicated by : 1. Connection fail 2. Loss of counts fault	Instrument Fail at U2/U3 INSTR FAIL window & RDU out of Operate.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
		EMI induced into signal cable	Faulty shield	Possible high or incorrect Noble Gas concentration indications. Possible alarm or trip.	If noise collected in Am-241 reference peak, then count test will fail.	Possible U2/U3 CONTROL ROOM RAD HI alarm window & RDU HI alarm. Compare with redundant channel if alarming.	Possible affected channel trip.	None-Redundant channel functional.
2. LPU 2/3RT7824G1 2/3RT7825G2 Model No. RMS-9042-SR	Serial Link #1	Fail Off	1. Open Circuit 2. Short Circuit	Failed serial communication with RDU.	Communication link watchdog fault.	Instrument Fail at U2/U3 INSTR FAIL window & RDU out of Operate.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
		EMI Induced (Intermittent)	Faulty shield.	Degraded serial communication with RDU.	Software watchdog communication check automatically initiates re-transmission.	None	None	None

Table 8.3 Control Room Monitors Single Failure Evaluation

Component Identification	Function	Failure Modes	Failure Mechanism	Effect on System	Method of Failure Detection	Operations Failure Indication	Effect on Channel FHIS Function	Effect on System FHIS Function
2. LPU (continued)	Serial Link #1 (cont'd)	EMI Induced (Continuous)	Faulty shield.	Failed serial communication with RDU.	Communication link watchdog fault.	Instrument Fail at U2/U3 INSTR FAIL window & RDU out of Operate.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
	Serial Link #2	Fail Off	1. Open Circuit 2. Short Circuit	Failed serial communication with LDU. Loss of local indication and alarms.	Communication link watchdog fault.	DAS alarm & RDU slave fault.	None	None
		EMI Induced (Intermittent)	Faulty shield.	Degraded serial communication with LDU.	Software watchdog communication check automatically initiates re-transmission.	None	None	None
		EMI Induced (Continuous)	Faulty shield.	Failed serial nication with s of local alarms.	Communication link watchdog fault.	DAS alarm & RDU slave fault.	None	None

Table 8.3 Control Room Monitors Single Failure Evaluation

Component Identification	Function	Failure Modes	Failure Mechanism	Effect on System	Method of Failure Detection	Operations Failure Indication	Effect on Channel FHIS Function	Effect on System FHIS Function
2. LPU (continued)	Detector Bias Power Supply	Fail Off	1. Open Circuit 2. Short Circuit	Loss of detector signal. No Noble Gas concentration indications.	Loss of counts fault. Internal Powar Supply voltage test fault.	DAS alarm & RDU slave fault.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
		Degraded	Control Circuit fail.	Possible degradation in measured output during steady state.	Internal Power Supply voltage test fault.	DAS alarm & RDU slave fault.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
	Power Supply (Common to LPU, LDU & RDU)	120 vac failure.	1. Open Circuit 2. Short Circuit	Loss of detector signal. No Noble Gas concentration indication and control relay. RDU control relay changes state from CLOSED to OPEN.	Communication link watchdog fault. Loss of counts fault. Total failure of the LPU.	U2/U3 CONTROL ROOM RAD HI alarm window & RDU HI Alarm.	Affected channel Trip.	CRIS Actuation.
	Acquisition	Preamplifier & discriminator fail	Hardware failure	No concentration indication.	Loss of counts fault.	DAS alarm & RDU slave fault.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
		Timers fail	Hardware/ software failure.					
		Counters fail						
		Software failure	Software module fails					

Table 8.3 Control Room Monitors Single Failure Evaluation

Component Identification	Function	Failure Modes	Failure Mechanism	Effect on System	Method of Failure Detection	Operations Failure Indication	Effect on Channel FHIS Function	Effect on System FHIS Function
2. LPU (Continued)	Memory	EPROM, EEPROM, Flash failure	Hardware/ Software failure	Possible LPU failure.	CRC16 checksum test fault.	DAS alarm & RDU slave fault.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
		RAM fail	Hardware/ Software failure	Possible LPU failure.	RAM test fault. Operation alarm at LPU.			
	Watchdog timer	Timer failure	Hardware/ Software failure	No indication of module failures associated with main software loop & real time processing.	Software check indicates fault alarm.	DAS alarm & RDU slave fault.	Possible loss of affected channel ESFAS protective function.	None-Redundant channel functional.
3. RDU 2/3RIC7824G1 2/3RCH7824G1 2/3RSL7824G1 2/3RIC7825G2 2/3RCH7825G2 2/3RSL7825G2 Model No. RMS-9009-SR	Processing Software	Fault in software/ component failure.	Hardware/ Software failure.	No indication of concentration or communications.	Watchdog timer identifies a processing failure.	DAS alarm & RDU fault.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
	Serial Link #1	Fail	1. Short Circuit 2. Open circuit 3. Software failure	Failed serial communication with LPU & LDU.	Communication link watchdog fault.	Instrument Fail at U2/U3 INSTR FAIL window & RDU out of Operate.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
		EMI Induced (Intermittent)	Faulty Shield.	Degraded serial communication with LPU & LDU.	Software watchdog communication check automatically initiates re-transmission.	None	None	None

Table 8.3 Control Room Monitors Single Failure Evaluation

Component Identification	Function	Failure Modes	Failure Mechanism	Effect on System	Method of Failure Detection	Operations Failure Indication	Effect on Channel FHIS Function	Effect on System FHIS Function
3. RDU (continued)	Serial Link #1 (cont'd)	EMI Induced (Continuous)	Faulty Shield.	Failed serial communication with LPU & LDU.	Communication link watchdog fault.	Instrument Fail at U2/U3 INSTR FAIL window & RDU out of Operate.	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
	High Radiation Alarm Relay	Fails coil energized.	1. Short circuit 2. Software fail	Alarms/Control Dampers cannot actuate.	None	Periodic testing (18 month period)	Loss of affected channel ESFAS protective function.	None-Redundant channel functional.
		Fails coil de-energized	1. Open Circuit 2. Software fail	Alarms/Control Dampers automatically actuated.	Relay contacts change state from CLOSED to OPEN.	U2/U3 CONTROL ROOM RAD HI alarm window & RDU HI Alarm.	Affected channel trip.	CRIS actuation.
	Power	120 vac failure	1. Open circuit 2. Short circuit	Loss of power to High Radiation Alarm Relay.	Relay contacts change state from CLOSED to OPEN.	U2/U3 CONTROL ROOM RAD HI alarm window & RDU HI Alarm.	Affected channel trip.	CRIS actuation.

Table 8.3 Control Room Monitors Single Failure Evaluation

Component Identification	Function	Failure Modes	Failure Mechanism	Effect on System	Method of Failure Detection	Operations Failure Indication	Effect on Channel FHIS Function	Effect on System FHIS Function
4. LDU 2/3RUIC7824G 1 2/3RUIC7825G 2 Model No. RMS-9003-SR	Serial Link #1	Fail Off	1. Open circuit 2. Short circuit	Failed serial communication with LPU. Loss of local indication and alarms.	Communication link watchdog fault.	DAS alarm & RDU slave fault.	None	None
		EMI Induced (Intermittent)	Faulty shield.	Degraded serial communication with LPU.	Software watchdog communication check automatically initiates re-transmission.	None	None	None
		EMI Induced (Continuous)	Faulty shield.	Failed serial communication with LPU. Loss of local indication and alarms.	Communication link watchdog fault.	DAS alarm & RDU slave fault.	None	None
	Serial Link #2	Fail Off	1. Open circuit 2. Short circuit	Failed serial communication with RDU.	Communication link watchdog fault.	Instrument Fail at U2/U3 INSTR FAIL window & RDU out of Operate.	None	None
		EMI Induced (Intermittent)	Faulty shield.	Degraded serial communication with RDU.	Software watchdog communication check automatically initiates re-transmission.	None	None	None

Table 8.3 Control Room Monitors Single Failure Evaluation								
Component Identification	Function	Failure Modes	Failure Mechanism	Effect on System	Method of Failure Detection	Operations Failure Indication	Effect on Channel FHIS Function	Effect on System FHIS Function
4. LDU (Continued)	Serial Link #2 (cont'd)	EMI Induced (Continuous)	Faulty shield.	Failed serial communication with RDU.	Communication link watchdog fault.	Instrument Fail at U2/U3 INSTR FAIL window & RDU out of Operate.	None	None
	Memory	EPROM, EEPROM, Flash failure	Hardware/ Software failure	Possible loss of local indication and alarms.	CRC16 checksum test fault.	DAS alarm & RDU slave fault.	None	None
		RAM fail	Hardware/ Software failure	Possible loss of local indication and alarms.	RAM test fault. Operation alarm			
	Watchdog Timer	Timer failure	Hardware/ Software failure	No indications of module failures associated with main software loop & real time processing. Possible loss of local indication and alarms.	Software check indicates fault alarm.	DAS alarm & RDU slave fault.	None	None
	Processing Software	Fault in software/ component failure	Hardware/ Software failure	No indications of concentration or communications. Loss of local indication and alarms.	Watchdog timer identifies a processing failure	DAS alarm & RDU slave fault.	None	None

ENCLOSURE 10

NUCLEAR CONSOLIDATED DATABASE

SELECTED DOCUMENTS

Documents include:

Loop 2FT0202 Rev. 1	Loop 2FT0212 Rev. 1	Loop 2FT1011 Rev. 0
Loop 2FT1021 Rev. 0	Field Change Notice (FCN) F5596J Rev. 0	Loop 2LT1113-1 Sheet 1/Rev. 1
Loop 2LT1113-2 Sheet 1/Rev. 1	Loop 2LT1113-3 Sheet 1/Rev. 1	Loop 2LT 1113-4 Sheet 1/Rev. 1
Loop 2LT1123-1 Sheet 1/Rev. 1	Loop 2LT1123-2 Sheet 1/Rev. 1	Loop 2LT1123-3 Sheet 1/Rev. 0
DCN ABG-7982 Rev. 0	Loop 2LT1123-4 Sheet 1/Rev. 0	DCN ABG-7983
Loop 2LT 5853-1 Rev. 1	Loop 2LT 5853-2 Rev. 2	Loop 2LT9386-1 Rev. 1
FCN F6846J	FCN 5140J	Loop 2LT9389-2 Rev. 2
FCN 7052J	Loop 2PT1013-1 Sheet 1/Rev. 0	Loop 2PT1013-2 Sheet 1/Rev. 0
Loop 2PT1013-3 Sheet 1/Rev. 0	Loop 2PT1013-4 Sheet 1/Rev. 0	Loop 2PT1023-1 Sheet 1/Rev. 0
Loop 2PT1023-2 Sheet 1/Rev. 0	Loop 2PT1023-3 Sheet 1/Rev. 0	Loop 2PT1023-4 Sheet 1/Rev. 0
Loop 2RE7820-1 Rev. 0	Loop 2RE7820-2 Rev. 0	Field-generated Interim Design Change Notice (FIDCN) J-5825
Loop 2RE7820-2 Rev. 0 **BEFORE**	Loop 2RE7820-2 Rev. 0 **AFTER**	Loop 2RE7828C Rev. 0
Loop 2RE7845 Rev. 0	Loop 2RE7848 Rev. 0	Loop 2RE7850 Rev. 0
Loop 2/3RE7851 Rev. 0	Loop 2RE7865A1 Sheet 1/Rev. 0	Loop 3FT0202 Rev. 1
Loop 3FT0212 Rev. 1	Loop 3FT1011 Rev. 0	FCN 5673J Rev. 0
Loop 3FT1021 Rev. 0	FCN 5676J	Loop 3LT1113-1 Sheet 1/Rev. 1
Loop 3LT 1113-2 Sheet 1/Rev. 1	Loop 3LT1113-3 Sheet 1/Rev. 1	Loop 3LT1113-4 Sheet 1/Rev. 1
Loop 3LT1123-1 Sheet 1/Rev. 1	Loop 3LT1123-2 Sheet 1/Rev. 1	Loop 3LT1123-3 Sheet 1/Rev. 0
DCN ABG-7990 Rev. 0	Loop 3LT1123-4 Sheet 1/Rev. 0	DCN ABG-7991 Rev. 0
Loop 3LT5853-1 Rev. 1	Loop 3LT5853-2 Rev. 1	FIDCN J-5598
Loop 3LT9386-1 Rev. 1	FCN F6849J	FCN F5148J
Loop 3LT9389-2 Rev. 2	FCN F7054J	DCN NT 2
Loop 3PT1013-1 Sheet 1/Rev.0	Loop 3PT1013-2 Sheet 1/Rev. 0	Loop 3PT1013-3 Sheet 1/Rev. 0
Loop 3PT1013-4 Sheet 1/Rev. 0	Loop 3PT1023-1 Sheet 1/Rev. 0	Loop 3PT1023-2 Sheet 1/Rev. 0
Loop 3PT1023-3 Sheet 1/Rev. 0	Loop 3PT1023-4 Sheet 1/Rev. 0	Loop 3RE7820-1 Rev. 0
Loop 3RE7820-2 Rev. 0	FIDCN J-5826	Loop 3RE7820-2 Rev. 0 **BEFORE**
Loop 3RE7820-2 Rev. 0 **AFTER**	Loop 3RE7828C Rev. 0	Loop 3RE7845 Rev. 0
Loop 3RE7848 Rev. 0	Loop 3RE7850 Rev. 0	Loop 3RE7865A1 Sheet 1/Rev. 0

Wiring Diagram-Control Building-PPS Cabinet 2L&3L032 (31541 Sheet 9/Rev. 6).

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