SARGENT & LUNDY ENGINEERS	Calcs. For POEM Mobile Fire Detection System			Calc. No. CMED-058398	
		Safety-Related	X Non-Safety Related	Rev. 00	Date 12/29/93
				Page 1	of 13

Client	Commonwealth Edison Company		Prepared by Shafique R. Khan	Date 12/29/93
Project	Zion Station - Units 1 & 2		Reviewed by S. Akhtar	Date 12-29-93
Proj. No.	9140-67	Equip. No. Various	Approved by [signature]	Date 12.29.93

1.0 Purpose

The propose of this evaluation is to demonstrate that the POEM Mobile Fire Detection System Units when installed in any part of the Zion Station's auxiliary building will perform its intended fire detection function and identify replacement intervals, if any. Although the mobile units are non-safety-related, it is important to establish that the fire detectors are reliable units and thus, its application requires that an evaluation be performed to demonstrate environmental suitability in areas (zones) experiencing moderately high temperatures and radiation doses.

2.0 Discussion

The Mobile Fire Detection Units are being purchased from POEM Lighting Company. These units will replace the current system where the fire monitoring function is conducted by site personnel on a periodic (shift) basis. These mobile units therefore represent continuous fire detection capability as opposed to the existing practice of using plant personnel to monitor fire periodically.

The analysis will review the plant's temperature/radiation requirements and assess its impact on the age sensitive components of the POEM Fire Detection Units. Material and test data as applicable will be presented to support the analysis. In cases, where sufficient information is not available, assumption and engineering judgement will be appropriately documented.

Client	Commonwealth Edison Company	Prepared by	Date
Project	Zion Station - Units 1 & 2	Reviewed by	Date
Proj. No. 9140-67	Equip. No. Various	Approved by	Date

3.0 References

3.1 EPRI Final Report NP-2129, " Radiation Effects on Organic Materials in Nuclear Plants, dated November 1981.

3.2 REG Guide 1.89, "Environmental Qualification of Certain Electric Equipment Important to Safety for Nuclear Power Plants", revision 1, dated June 1984.

3.3 NUREG/CR-3156, "Survey of State-of-the-Art in Aging of Electronics with Application to Nuclear Power Plant Instrumentation", dated February 1983.

3.4 Sargent & Lundy Material Data and Shelf Life Guidelines.

3.5 Zion EQ Report, Rev. 09, dated 06-10-93.

3.6 Pyrotector Instructions for Ultraviolet Flame Detector, Models 30-2021 and 30-2021E (Attachment 1).

3.7 Protector Instructions for Explosion Proof Smoke Detector Model 30-3003 (Attachment 2).

3.8 ADEMCo Catalog for 5140XM Fire and Burglary Control System (Attachment 3).

3.9 POEM Lighting Company Proposal No. CE1004, dated 05-29-93 (Attachment 4).

3.10 Letter from Carlos J. Diaz to M. H. Sanwarwalla dated 12/06/93 (Attachment 5).

3.11 MIL-R-39008C, "General Specification for Resistors, Fixed Composition (Insulated), Established Reliability".

3.12 ANSI C83.48-74/EIA RS-172-B, "Fixed Composition Resistors".

3.13 ANSI C50.32-74/IEEE 117-1974, "IEEE Standard Test Procedure for Evaluation of Systems of Insulating Materials for Random-Wound AC Electric Machinery".

3.14 Wyle Report No. NES 26320, "Final Aging Evaluation Report for Various Class 1E Electrical and Electronic Components for use in Nuclear Power Generating Station", dated 06-06-80.

3.15 EPRI NP-RPI.1707-4, "Correlation between Aging and Seismic Qualification for Nuclear Power Plant Electrical Components Phase 2".

3.16 NUREG/CR-3691, "An Assessment of Terminal Blocks in the Nuclear Power Industry", September 1984.

3.17 ANSI/IEEE C37.90-1989, "IEEE Standard for Relays and Relay Systems Associated with Electric Power Apparatus".

3.18 Main Line Engineering Association of Project No. 88011, "Quad Cities Units 1&2, Commonwealth Edison Company, Environmental Qualification of Cutler Hammer Unitrol 250v DC Motor Control Centers 1A & 2A, "Quad EQ-67, Rev. 01, dated 12/29/89.

3.19 Joint Electronic Device Engineering Council (JEDEC) Specifications for diodes and transistors.

3.20 MIL-S-19500, "General Specification for Semiconductor Devices."

4.0 Assumptions

The POEM fire detection system uses various types of components. These components and their material of construction have been identified in section 5.0. However, due to limited information, the material of construction of some of the components have been assumed as follows:

1. The transformer winding insulation is normally constructed of polyurethane and is usually rated as class A or better (Ref. 3.15).

2. The relay coil normally is constructed of PVC/polyester polyurethane insulation and the bobbin of nylon/polycarbonate. The relay's body is generally phenolic/polyester glass (Ref. 3.18).

3. The battery casing is usually made of polysulfane and therefore, it is considered as such in this analysis.

4. The fuses are constructed of the following non-metallic materials: fiber, fiberglass, melamine, glass and ceramic (Ref. 3.15).

5.0 Evaluation

The subject mobile fire detection unit is evaluated for reliable performance in the various environmental zones of the auxiliary building. The evaluation is based on the effects of the environment on the materials of construction of the components used to manufacture the Mobile Fire Detection Units. The Units are basically compromised of the following major devices:

1. Central Station Control System
2. Smoke Detector
3. Flame Detector

Based on the review of References 3.6, 3.7, 3.8, 3.9 and 3.10, the above mentioned devices of the Mobile Fire Detection Unit can be further broken down into subcomponents as follows:

1. <u>Central Station Control System</u> (Refs. 3.8 & 3.9)

   A. Console (Ref. 3.10):
      1. Integrated Circuits (ICs)/IC Sockets
      2. Diodes
      3. Transistors
      4. Rectifier
      5. Capacitors
      6. Resistors
      7. Inductors
      8. Varistor
      9. Potentiometer
      10. Surge Protector/Transient Suppressor
      11. Resonator
      12. Optical Isolator
      13. PTC Device
      14. Printed Circuit Board

   B. Relays

   C. Tamper Switch and Assembly

   D. Removable Terminal Blocks

   E. Fuse

   F. Battery (Gel Type):
      12VDC lead acid battery

G. Transformer (72VA):
120/18 VAC, 60HZ

H. Cables (Ref. 3.4):
1. Communication (Phone cord/PVC)
2. Control (Polyethylene)

2. <u>Smoke Detector</u> (Ref. 3.7 & 3.9)

A. Solid state infra-red emitting diode
B. Photovoltaic cell
C. Explosion proof enclosure

3. <u>Flame Detector</u> (Ref.3.6 & 3.9)

A. Detection tube
B. Encapsulated solid state circuitry
C. Dry contact Form C (SPDT Alarm Relay)
D. Explosion proof enclosure

Item 1 can be further expanded to show the details of the electronic components. Per reference 3.10 (attached), the type of electronic devices which are used in the Central Station Control System are shown in Table 5.1. The temperature and radiation qualification of the devices is discussed in Table 5.2.

TABLE 5.1 - Type Of Electronic Components

Electronic Device	Description
Integrated Chips (ICs)	CMOS, LIN, Voltage Regulator, Dual Comparator EEROM, ICPLD, Optical Isolator
Diodes	Zener, Schottky, Silicon, Signal, Rectifiers
Transistors	NPN, PNP
Capacitors	Ceramic, Electrolytic (Tantalum & Aluminum)
Resistors	Regular
Inductors	Resistive
Varistor	Metal Oxide Disc
Potentiometer	Resistive Element
Surge Protector	No description provided
PTC Device	No description provided
Printed Circuit Board	No description provided

Most of the components of the fire detection unit, as noted above, consist of semiconductor devices.

TABLE 5.2- Qualification of Devices on Flame Detector

Device Type	Qualification Level			Comments
	Temp. (°F)	Radiation Threshold (Rads)	Refs.	
Communication Wires, Control Cable, Hookup Wire, Appliance Cord, etc.	175 (79.44°C)	1×10^5	3.4	Per Ref. 3.4, the most widely used primary insulation or jacket is PVC or polyethylene. Between these two cable insulation, PVC is more susceptible to both temperature and radiation environments. PVC has a continuous resistance to heat at **175°F (79.44°C)** and radiation to **1×10^5** rads (Ref. 3.4). Reference 3.1 states that the threshold dose of PVC (plasticize) is **5×10^5**. Therefore the cable/wire system of the Mobile fire detection system will be subjected to insignificant degradation at the normal temperature of 120°F **(48.89°C)** and radiation level of **1×10^4** rads.
Transformer	221 (105°C)	$> 1 \times 10^6$	3.14 & 3.15	The transformer winding insulation normally constructed of kraft paper and polyester/polyurethane magnet wire is usually class A or better. The class A or better insulation can withstand a radiation level above **1×10^6** rads without any degradation (Ref. 3.15). Therefore the transformers will be subjected to insignificant degradation at the normal temperature of **120°F (48.89°C)** and radiation level of **1×10^4** rads.
Resistors, Varistors, Potentiometer, Surge Protector, Inductor	158 (70°C)	1×10^8 to 1×10^9	3.3, 3.11, 3.12 & 3.14	These resistive devices are among the most stable electronic components with respect to steady state nuclear radiation damage. Per Reference 3.3, the resistance changes in the order of 25% have been found for some of these resistors irradiated to **1×10^8** - **1×10^9** rads. The resistive devices can perform the function at a continuous operating temperature of 158°F (70°C) without any derating (Ref. 3.11, 3.12).
Fuses		1×10^6	3.15	the fuses are constructed of following non-metallic: fiber, fiberglass, melamine, glass and ceramic (Ref. 3.15). Of these materials only melamine is susceptible to temperature and radiation. Per Ref. 3.15, the fuses were exposed to the radiation level 1×10^6 Rads without any degradation. Also as per Ref. 3.16, melamine is qualified for temperatures exceeding 212°F (100°C). However, the temperature rating for fuses is more dependent on the current carrying fuse material rather than the non-metallic.
Electrolytic Capacitors (Aluminum or Tantalum)	212°F (100°C)	1×10^5	3.3, 3.15	Electrolytic capacitors of aluminum and tantalum are permanently damaged for gamma doses of **1×10^5** rads (Ref. 3.3, Sec. 4.2). However, the tantalum capacitors are generally more radiation resistant. In normal operation, the failure mechanism in the aluminum electrolytic capacitors is loss of electrolyte, and this is a direct function of the core temperature. The maximum limit of temperature including heat rise is **212°F (100°C)**. In addition, the aluminum capacitors generally have a short shelf life. The predominant failure mode in solid tantalum capacitors is electrical shorting caused by impurities. The housekeeping and storage procedures of a given nuclear power plant is controlled and is implemented in a manner such that it ensures relative cleanliness of the area from any dust accumulation or impurities buildup. Therefore, the electrolytic capacitors can be safely used in nuclear radiation environments below **1×10^5** rads and temperatures below 212°F (100°C).

TABLE 5.2- Qualification of Devices on Flame Detector

Device Type	Qualification Level			Comments
	Temp. (°F)	Radiation Threshold (Rads)	Refs.	
Semiconductor Devices and Integrated Circuits	> 165 (75°C)	$1x10^4$	3.2, 3.3, 3.19 & 3.20	Semiconductor devices (transistors and diodes) and integrated circuits are the most sensitive and vulnerable parts in an electronic circuit in a radiation environment. Typical tolerances for semiconductor devices is 1×10^4 rads for commercial hybrids and integrated circuits (Ref. 3.2 & 3.3). Specially fabricated or selected radiation hardened devices can tolerate up to 1×10^6 rads. Never the less, per References 3.1 and 3.3, the semiconductor devices (i.e., MOSFETS, transistors, diodes, rectifier, photocells, integrated circuits, etc.) can satisfactorily perform their functions in a radiation environment reaching 1×10^4 rads. Because of the inherent construction, these devices are rated for operation at temperatures exceeding 165 °F (75°C) (Ref. 3.19 & 3.20).
Terminal Blocks	> 212 > (100°C)	$1x10^6$	3.16	Terminal blocks are usually made of phenolic which is basically age insensitive and can withstand radiation level above 1×10^6 rads without any degradation.
Relay	131 °F (55 °C)	$1x10^5$	3.3 & 3.17	The non-metallic material in a relay normally comprises of a coil wound on a bobbin, some moving arms and a phenolic/polyester glass case. The Bobbin is either made of nylon or polycarbonate material. The coil normally has PVC/polyester/polyurethane and silicone varnish insulation. The weakest radiation links is PVC which can withstand radiation to 1×10^5 Rads. As per ANSI Standard (Ref. 3.17) these are rated for continuous operating temperature of 131 °F (55°C)
Switch	> 212 > (100°C)	$1x10^6$	3.16	The switch is usually made of phenolic (organic) material which has been discussed above.
Battery casing	-150°F to +300°F	$5x10^7$	3.4	The battery casing is usually made of polysulfane. Per Reference 3.4, polysulfane maintain its property in temperatures ranging from -150°F to 300°F. The radiation threshold damage occurs at approximately 5×10^7 rads.

Based on the evaluation of the materials of construction of the Mobile Fire Detection Unit, it is determined that all of the subcomponents can perform their intended function in a radiation environment of 1×10^4 rads and temperature reaching 120°F without any significant degradation.

Zion's auxiliary building is divided into environmental zones as shown in Tables 6.1 and 6.2. Each zone is represented by an Alpha-Numeric designation. Eighteen zones from zone A01 through zone A18 make up the auxiliary building. Per Reference 3.5, the zones are grouped as follows:

Table 6.1: Areas with normal Temperature ≤ 105°F (Except as noted) and normal 40 years radiation operating exposure of $\leq 1.4 \times 10^3$ Rads.

Table 6.2: Areas with temperatures ranging from 65°F to 120°F and radiation in excess of 1.0×10^4.

The worst case normal temperature of the zones as listed in Table 1 is 105°F with the exception of zones A5 and A17 where the temperature may reach a maximum of 120°F. The high temperatures are caused due to transient conditions. Even at these temperatures as shown in Table 5.2, the equipment will performs its design function and will not be subjected to any significant thermal degradation. Based on the evaluation , it is evident that the subject Mobile Fire Detection Unit is suitable for application in zones experiencing temperatures ≤ 120°F and radiation less than 1×10^4 rads.

Per the review of Table 6.2, it can be observed that the radiation dose rate in these zones vary from 11.95 rads-c/hr to as high as 306.6 rads-c/hr. Based on the lowest radiation dose rate of Table 6.2 (i.e. 11.95

rads/hr), it is expected that the devices in these areas will receive total integrated doses in excess of 1.05×10^5 rads/year. The lives of the electronic devices were determined based on the limiting radiation dose of less than or equal to 1.0×10^4 rads. Replacement intervals of the electronic devices are as shown in the last column of Table 2.

6.0 Conclusion

Based on the above evaluation, it is determined that the POEM Mobile Fire Detection Unit are suitable for use in Zion station's auxiliary building. In zones identified in Table 6.1, these five detection can be relied upon for an extended period of time to perform their design function. However, for application in zones identified in Table 6.2, frequent replacements, may be necessary for these fire detections to perform reliably.

Table - 6.1

Environmental Conditions

Envr. Zone	Area (Rooms)	Temp. (°F)	40 Years Operating Exposure (Rads)	Radiation Ref. (ATD Calcs.)
A1	Control Room, Aux. Electrical Equip. Room	74-76	70	ZIO-EQ-AX01 - AX02
A2	M-G Set Rm. Non-Ess SWGR Rm. Battery Rm.	65-105	1.4×10^3	ZIO-EQ-AX04 - AX05
A3	Essential SWGR Rm.	65-105	7.0×10^2	ZIO-EQ-AX06
A4	Lower Cable Spreading, HVAC Equip. Rm.	80-85	1.4×10^3	ZIO-EQ-AX07 - AX08
A5	Diesel-Generator/Diesel Oil Storage Rooms	65-115 (Note 2)	1.4×10^3	ZIO-EQ-AX09 - AX10
A6	Lab, Counting Rm., Rad Offices, Hot Instr. Rm., Record Rm., Kitchen, Shift Foreman and Eng., Chem and Rad. Office Toilet, Instr. Rm., Computer/Work Rm.	74-76	1.4×10^3 (Limiting Condition)	ZIO-EQ-AX13 - AX14
A7	Auxiliary Bldg. General (Accessible) Areas and Fuel Handling Building Laundry Room Elec. Penetration Areas	65-105	1.4×10^3 (Limiting Condition)	ZIO-EQ-AX15 - AX23
A8	Auxiliary Bldg. (Accessible Areas) (Note 1)	65-105	1.4×10^3	ZIO-EQ-AX24
A9	Auxiliary Bldg. (Accessible Areas)	65-105	1.4×10^3	ZIO-EQ-AX26 - AX28
A16	ESF Battery Room	74-76	70	ZIO-EQ-AX48
A17	Purge Valve Enclosure	40-120 (Note 2)	7.0×10^2	ZIO-EQ-AX49

Notes:

1. Concentrate holding tank is excluded from Zone A8 as its radiation requirement is 5.77×10^6 rads (Ref. ATD Calc. ZIO-EQ-AX25).

2. Although the temperatures in these rooms may reach a maximum of 120°F, it is assumed that for most part of the year the temperature will be on the average at 104°F (40°C). However, the analysis shows that the Mobile Fire Detection Units are suitable for application at 120°F.

Table - 6.2

Environmental Conditions

Envr. Zone	Area (Rooms)	Temp. (°F)	40 Years Operating Exposure (Rads)	Dose Rate (Rad-C/hr)	Radiation Ref. (ATD Calcs.)	Replacement Intervals
A10	Seal water and Letdown Heat Exchanger Rooms	65-115	7.32×10^7	11.95	ZIO-EQ-AX30	34 days
	Volume Control Tank Room	65-115	5.32×10^7	15.18	ZIO-EX-AX29	27.4 days
A11	Equip. Coll. Drain Tank & Pumps	65-120	5.78×10^6	16.51	ZIO-EQ-AX32	25 days
	Gas Decay Tank Rooms	65-120	7.44×10^6	21.25	ZIO-EQ-AX31	19.5 days
A12	Pipe Tunnels & Penet. Areas	65-120	4.18×10^6	11.95	ZIO-EQ-AX33	34 days
	Anion and Cation Demin. Tank Filters, Pipe Tunnels Aux. Bldg., Mixed Bed Demin Tanks & Filters, Waste Evap. Tanks and Hold-up Tank Rooms	65-120	5.78×10^6	16.51	ZIO-EQ-AX34 - AX36	25 days
A13	Aux. Bldg. Cubicles, (with Coolers), Cont. Spray Pump, RHR Pump, SI Pump Rooms and Certify Fill Pumps	65-105	4.18×10^6	11.95	ZIO-EQ-AX37 - AX40	34 days
A14	Centrifugal Changing Pump Rooms	65-105	4.18×10^6	11.95	ZIO-EQ-AX41	34 days
A15	RHR Heat Exchanger, Waste Gas Comp., Aux. Bldg. Floor and Equip. Drain Anal. Tanks & Pumps, Boric Eval. Equip. Drain Tank & Pumps, Solid Rad. Drum Storage	65-105	2×10^7 (Limiting Condition)	Varies from 11.95 to 306.6 during refueling	ZIO-EQ-AX42 - AX47	34 days @ 11.95 rads/hr. 1.3 day @ 306.6 rads/hr.
A18	Boric Acid Evap. Radwaste Evap. & Drum Fill Area	65-105	5.78×10^6	16.51	ZIO-EQ-AX50 - AX53	25 days