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1.0 Objective

The objective of this calculation is to determine the airborne radiation doses at the Exclusive Area Boundary (EAB), the Low Population Zone (LPZ), and in the control room following a Reactor Coolant Pump (RCP) Locked Rotor Accident (LRA) with the modified control room ventilation system. The calculation assumes a simultaneous Loss of Offsite Power (LOOP) following the high radiation alarm signal generated by the control room intake monitors, with the subsequent delay in switching from the normal operation mode to the emergency operation mode of the control room ventilation system. The calculation utilizes the automatic selection capability of the radiation monitors to select the less contaminated CR intake. In addition, it assumes that only one Unit's CR emergency ventilation system is available.

Additionally, control room operator doses are calculated for a case that assumes the control room is already in the emergency ventilation mode when the accident occurs.

This calculation also determines the process safety limit for the control room air-intake monitors.

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3.0 Assumptions

1. Iodine partition factor in SGs is assumed to be 0.01. [Ref.1]

   The assumption of iodine partition factor in the SGs of 0.01 is appropriate for the portion of the primary leakage which does not flash. The P-S leakage of 1 gpm will not cause flashing when the steam generator tubes are fully covered with water.

2. The X/Q values for the more favorable intake are used when the control HVAC is in emergency mode, taking credit for the automatic selection of the more favorable intake by the control room radiation monitors. [Ref.1]

3. The time for the control room EACS Fans to reach full speed after restart is assumed to to be 15 seconds. [Ref.1]

4. The unfiltered inleakage after control room is pressurized due to ingress/egress is assumed to be 10 cfm, based on SRP 6.4. [Ref.1]
   The unfiltered inleakage after control room is pressurized due to ductwork is assumed to be 50 cfm.

5. The required filtered emergency makeup flow to pressurize the control room is assumed to be 2000 cfm. [Ref.1]

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4.0 Data

1. Fraction of failed fuel after the accident [Ref.1]
   5%

2. Fraction of the fuel activity in the gap [Ref.1]
   10%

3. The gap activity of the failed fuel that is released to RCS (0.5% of the core inventory) is presented in Table 1. [Ref.1]

4. The initial primary coolant activity including pre-accident iodine spike is given in Table 2. The initial secondary coolant activity is also given in Table 2. [Ref.1]

5. Primary to secondary leak rate - 1 gpm [Ref.1]

6. Primary coolant volume - 10,892 cubic feet [Ref.1]

7. Steam releases [Ref.1]
   0 - 2 hr - 654,600 lbs
   2 - 8 hr - 540,300 lbs
   8 -32 hr - 2,161,200 lbs

8. Post-accident steam generator liquid mass 106,860 lbs for each steam generator [Ref.1]

9. Offsite X/Q's (from Unit 2 MSSVs) [Ref.1]

	EAB (S/m^3)	LPZ (S/m^3)
0-2 hr	1.30E-4	1.86E-5
2-8 hr		7.76E-6
8-24 hr		5.01E-6
1-4 day		1.94E-6
4-30day		4.96E-7

Unit 2 accident will result in greater doses because of worse X/Q values.

10. Offsite Breathing rate [Ref.1,5]

0- 8 hr - 3.47E-4 m^3/sec
8- 24 hr - 1.75E-4 m^3/sec
24-720 hr - 2.32E-4 m^3/sec

11. Control room intake X/Q's (from Unit 2 MSSVs) [Ref.1]

	Unit 1 intake (S/m^3)	Unit 2 intake (S/m^3)
0-2 hr	1.96E-3	4.17E-3
2-8 hr	2.13E-3	1.00E-2
8-24 hr	1.80E-3	8.32E-3
1-4 day	1.25E-3	5.54E-3
4-30day	7.46E-4	3.09E-3

Unit 2 accident will result in greater doses because of worse X/Q values.

12. CONTROL ROOM PARAMETERS - Modified design [Ref.1]

* Control room pressure envelope volume:
  81,420 ft^3
* Normal unfiltered air intake rate:
  1200 cfm (1320 cfm including 10% margin)
* Filtered emergency makeup flow- 2000 cfm; see assump.5 (2200 cfm including 10% margin)
* Total unfiltered inleakage- 60 cfm (10 cfm from ingress/egress; 50 cfm from Ductwork leakage; see assumption 4)
* Filtered recir flow rate
  5000 cfm - one EACS fan operation
  (= 8000 cfm fan capacity- 800 cfm (10% margin) -2200 cfm makeup flow)
  12,200 cfm - two EACS fans operation ++
  (= 16000 cfm fan capacity- 1600 cfm (10% margin) -2200 cfm makeup flow)

* Intake and recirculating filter efficiencies:
  Elemental iodine - 95%
  Organic iodine - 95%
  Particulate - 95%

++ ONE FAN PER EACS FILTRATION TRAIN.

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* Control room occupancy factors: [Ref.1]

Time from Start of Accident	Occupancy Factors
0 to 8 hrs	1.0
8 to 24 hrs	1.0
1 to 4 days	0.6
4 to 30 days	0.4

* Breathing rate - 3.47E-4 m^3/sec [Ref.1,8]

13. The control room intake damper closure time: 20 seconds. [Ref.1]

14. The time for the diesel generators to become fully operational after LOOP: 13 seconds [Ref.1]

15. Data for Control Room Intake Monitors [Ref.1]

* Monitor response time - Table 6-1 of Ref.[11] [Ref.11]
The Salem control room monitors are Sorrento Electronic in-duct monitor RD-25A with micro-processor RM-2000. The monitor response time in Table 6-1 of Ref.[11] is for filter constant (FC) equal to 6. FC=6 is the SE recommended value (Ref.[1]).

* Noise reject delay time = 5 x 600 msec
= 3 sec [Ref.1]
The noise reject time count of 5 is recommended by SE (Ref.[1]). 600 msec is the RM-2000 shift register time segment.

* Detector Response - Xe133: 6.21E7 cpm/(μCi/cc) [Ref.12]
Kr85: 2.58E8 cpm/(μCi/cc)

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Table 1

Gap activity in the Failed Fuel*
(Ci)

Nuclide	Activity
I131	4.95E+5
I132	7.00E+5
I133	1.00E+6
I134	1.10E+6
I135	9.50E+5
Kr85m	1.30E+5
Kr85	5.50E+3
Kr87	2.35E+5
Kr88	3.35E+5
Xe131m	3.50E+3
Xe133m	1.45E+5
Xe133	1.00E+6
Xe135m	2.00E+5
Xe135	2.50E+5
Xe138	8.00E+5

* From Ref.[1].

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Table 2
Primary Coolant and Secondary Coolant Activity*
(Ci)

Primary Coolant with Pre-accident Iodine Spike

Nuclide	Activity
I131	1.04E+4
I132	3.58E+3
I133	1.60E+4
I134	2.02E+3
I135	8.08E+3
Kr85m	4.4E+2
Kr85	2.1E+3
Kr87	2.6E+2
Kr88	7.8E+2
Xe131m	5.4E+2
Xe133m	4.4E+3
Xe133	6.7E+4
Xe135m	1.3E+2
Xe135	2.2E+3
Xe138	1.6E+2

Secondary Coolant 4 Steam Generators

Nuclide	Activity
I131	1.28E+1
I132	4.40E+0
I133	2.00E+1
I134	2.40E+0
I135	1.00E+1

* From Ref.[1].

7.2 Control Room Intake Monitor Response Time

The intake monitor response time is determined by the final count rate at the detector (C_f), the monitor setpoint (C_s), the background count rate (C_o), and the time constant of the micro-processor (RC). The new Salem control room intake monitors consists of Sorrento Electronic beta sensitive in-duct detectors and RM-2000 micro-processor. The smoothing algorithm of RM-2000 will generate an effective time constant for a step change of the detector count rate. The effective time constant depends on the initial count rate, the final count rate, and the smoothing filter constant (fc). The time constant corresponding to the 95% observation time (i.e. 3RC) given in Table 6.1 of reference[11] is for fc=6 and will be used to determine the monitor response time.

The detector response function (cpm per μCi/cc) for Xe-133 and Kr-85 are listed below :

Xe-133	- 6.21E7 cpm/(μci/cc)
Kr-85	- 2.58E8 cpm/(μci/cc)

The process safety setting for the intake monitors is determined in Appendix A to be 4E-5 μci/cc (Xe-133). This value will be conservatively used as the monitor alarm setpoint for response time calculation.

$$C_s = 4E{-}5 \ \mu ci/cc \times 6.21E7 \ cpm/(\mu ci/cc) = 2484 \ cpm$$

The initial Xe-133 and Kr-85 concentrations at the control room intake for the design basis RCP LRA are calculated as follows:

$$Conc = (Gap \ \& \ RCS \ activity)/(RCS \ Volume) \times 1 \ gpm \ leak \ rate \times (X/Q)$$

$$Conc_{xe\text{-}133} = (1E6 \ Ci + 6.7E4 \ Ci) \ /(10892 \ ft^3) \times (1 \ gal/min) \times (62.4/45.3) \times (4.17E{-}3 \ s/m^3) \ / \ (7.481 \ gal/ft^3) \ / \ (60 \ s/min)$$

$$= 1.25E{-}3 \ Ci/m^3 = 1.25E{-}3 \ \mu Ci/cc$$

$$Conc_{Kr\text{-}85} = (5.5E3 \ Ci + 2.1E3 \ Ci) \ /(10892 \ ft^3) \times (1 \ gal/min)$$

$$\times (62.4/45.3) \times (4.17\text{E-}3\ s/m^3) / (7.481\ gal/ft^3) / (60\ s/min)$$
$$= 8.93\text{E-}6\ Ci/m^3 = 8.93\text{E-}6\ \mu Ci/cc$$

In above calculations, the 1 gpm primary-to-secondary leak rate at room temperature was adjusted by the ratio of primary coolant density at room temperature to that at power operation temperature. (See sect. 7.4 for details.)

The step increase of the instantaneous detector raw count rate at the arrival of the contaminated air is:

$$C_f - C_o = (1.25\text{E-}3\ \mu Ci/cc \times 6.21\text{E}7\ cpm/(\mu ci/cc)) + (8.93\text{E-}6\ \mu Ci/cc \times 2.58\text{E}8\ cpm/(\mu ci/cc)) = 7.99\text{E+}4\ cpm$$

From Table 6.1 of ref.[11], the three times time constant of the monitor response for a step increase of 1E+4 cpm is 0.95 min. Therefore, the effective time constant (RC) for a step increase of 7.98E+4 cpm will be less than 0.95/3 = 0.317 min. The monitor response time, t*, is determined by:

$$C_s = C_o + (C_f - C_o)(1-e^{-t^*/RC})$$

$$(C_s - C_o)/(C_f - C_o) = (1-e^{-t^*/RC})$$

$$2484/79900 = 1-e^{-t^*/0.317}$$

$$t^* = 0.01\ min = 0.6\ sec$$

To avoid spurious alarm due to noise count rate, RM-2000 features a noise rejection algorithm. The noise rejection response time is equal to the reject time count (5, recommended by SE) multiplied by the shift register time segment (600 msec). Therefore, noise rejection response time = 5 x 600 msec = 3 sec

The over-all monitor response time = 3 +0.6 = 3.6 sec

Four seconds will be used as the monitor response time for the RCP Locked Rotor accident.

8.0 Results and Conclusions

The calculated EAB, LPZ and control room doses from the airborne source due to a RCP Locked Rotor Accident for the modified control room ventilation design are summarized below. The 10CFR100 and GDC 19 dose limits are also listed for comparison:

	Calculated EAB Dose	10 percent of 10CFR100 Limit
Thyroid	0.53 Rem	30 Rem
Whole Body	0.11 Rem	2.5 Rem

	Calculated LPZ Dose	10 percent of 10CFR100 Limit
Thyroid	0.61 Rem	30 Rem
Whole Body	0.04 Rem	2.5 Rem

	Calculated CR Dose with Selection of Better Intake*	GDC 19 & Equivalent Dose Limit
Thyroid	7.6 Rem	30 Rem
Whole Body	0.40 Rem	5 Rem
Beta	4.6 Rem	30 Rem

* Automatic selection of the better intake with only one unit EACS operating.

	Calculated CR Dose with ** Pre-existing Emergency Mode	GDC 19 & Equivalent Dose Limit
Thyroid	18 Rem	30 Rem
Whole Body	1.7 Rem	5 Rem
Beta	19 Rem	30 Rem

** Assumes worst case CR intake but that the CR EACS for both units are available.

It is concluded that the calculated doses are within the allowable limits for the RCP Locked Rotor Accident.

The process safety limit for the control room intake monitors is determined in Appendix A based on the more stringent limit of the following two criteria:

(1). The control room activity concentration shall be less than 1 Derived Air Concentration (DAC) listed in 10CFR20, Appendix B, Table I, Column 3.

(2). The dose rate contributed by the airborne activity shall not exceed the radiation zone limit of the control room. The control room is designated as radiation zone I with maximum dose rate of 0.25 mr/hr according to FSAR sect.12.1.

The process safety limit is determined to be 4E-5 μCi/cc (Xe-133). The actual monitor setpoint shall include loop allowance and a safety margin.