WASHINGTON STATE UNIVERSITY

Nuclear Radiation Center

Date: October 8, 2013

To: Document Control Desk

From: Donald Wall, Ph.D.
Director

Re: Proposed Technical Specification Modification

The purpose of this letter is to request an amendment to the Technical Specifications for facility License R-76, Docket number 50-27. Specifically, this request proposes to modify the range of allowed ventilation system flow rates. The document which is included with this letter provides a complete data analysis to show the impact of ventilation system flow rates on whole body and thyroid doses for reactor personnel within the reactor pool room and for offsite individuals. The proposed modification to the Technical Specifications will allow greater operational flexibility within the range of proposed ventilation system flow rates while also remaining well below the dose limits for personnel and the public.

I declare under penalty of perjury that the foregoing is true to the best of my knowledge.

Respectfully Submitted

Donald Wall
10/8/13

Donald Wall

P.O. Box641300, Pullman, WA 99164-1300
509-335-8641 • Fax: 509-335-4433 • www.wsu.edu/nrc

A020
NRR

Analysis of the Influence of Ventilation System Flow Rates on Radiation Doses Following a Maximum Hypothetical Accident

1.0 Introduction

The purpose of this letter is to provide an analysis of doses to individuals in the reactor pool room and to members of the public who could be off-site during the course of a Maximum Hypothetical Accident (MHA). The type of releases arising from an MHA considered in this letter are elevated releases through the Dodgen Research Facility exhaust stack. The current Technical Specifications prescribe specific ventilation system flow rates. The present analysis will show that the ventilation system flow rates that are prescribed in the Technical Specifications are much greater than necessary to provide adequate protection for facility personnel and members of the public. WSU therefore proposes to modify the Technical Specifications 3.4(1)(a) and 3.4(1)(b) to allow a range of acceptable ventilation system flow rates.

Technical Specifications 3.4(1)(a) and 3.4(1)(b) were added after discussions with the U.S. NRC at the time of the renewal of facility license R-76. The requirement was added on the basis of the MHA analysis that was presented in Appendix MHA in a letter to the U.S. NRC dated June 13, 2008 (ML0832380265). The MHA analysis presented doses and dose rates under various scenarios, but did not present results as a function of ventilation system flow rate. The present analysis expands the examination of the release scenarios by presenting the dose rates and doses as functions of ventilation system flow rates for personnel in the reactor pool room, and for a maximally exposed member of the public external to the facility.

The current Technical Specification for exhaust system flow rates is listed below, followed by the proposed modification.

2.0 The WSU Technical Specifications Section 3.4.(1).

3.4 Ventilation System

Specifications:

(1) The reactor shall not be operated unless the facility ventilation system is operable and operating, except for periods of time not to exceed 48 hours to permit repair or testing of the ventilation system. The ventilation system is operable when flow rates, dampers and fans are functioning normally. The normal, dilute and isolation modes shall be operable for the ventilation system to be considered operable.

a. The exhaust flow rate of the ventilation system in the normal mode, from the reactor pool room, shall be not less than 4000 cfm.
b. The exhaust flow rate of the ventilation system in dilute mode, from the reactor pool room, shall be 300 cfm.

3.0 Proposed Modification to Technical Specification Section 3.4.(1)

WSU proposes to change the text of section 3.4(1) of the Technical Specifications to the following (the proposed change is marked with a change bar):

3.4 Ventilation System

Specifications:

(1) The reactor shall not be operated unless the facility ventilation system is operable and operating, except for periods of time not to exceed 48 hours to permit repair or testing of the ventilation system. The ventilation system is operable when flow rates, dampers and fans are functioning normally. The normal, dilute and isolation modes shall be operable for the ventilation system to be considered operable.

a. The exhaust flow rate of the ventilation system in the normal mode, from the reactor pool room, shall be not less than 1000 cfm.
b. The exhaust flow rate of the ventilation system in dilute mode, from the reactor pool room, shall be not less than 100 cfm.
c. The flow rate from the fresh air makeup supply to the exhaust from the reactor pool room, when in the dilute mode, shall be at least 4 times greater than the pool room exhaust flow rate.

4.0 Comparison to Other Research Reactor Facilities

The Technical Specifications of some other research reactor facilities were surveyed for the purpose of determining a general practice of including ventilation system requirements in the Limiting Conditions of Operation. The following facilities were surveyed:

Facility	Facility License Number	ADAMS Accession Number (a)	Ventilation System Flow Rate Specification
Texas A & M University	R-83	ML12110A116	No
Oregon State University	R-106	ML052290051	No
Dow Chemical Company	R-108	ML110490391	No
Kansas State University	R-88	ML080580275	No
Reed College	R-112	ML120530021	No
United States Geological Survey	R-113	ML092120136	No
University of California-Irvine	R-116	ML12087A215	Yes
University of Maryland	R-70	ML11124A124	No
University of Utah	R-126	ML112500333	No
University of Wisconsin	R-74	ML110340310	Yes

(a) The ADAMS Accession Number indicates the source document for the Technical Specifications

Texas A & M University, Oregon State University, Dow Chemical Company, Kansas State University, Reed College, United States Geological Survey, University of Maryland and University of Utah do not have a Technical Specification which stipulates a specific ventilation system flow rate.

The University of California-Irvine TS 3.5.1(a)(2) states the reactor shall not be operated unless the ventilation system is operating, as indicated by: "a minimum total exhaust flow rate from the reactor area of 4000 cfm is present." The Basis for the TS indicates that the flow rate requirement arises from air effluent releases of Ar-41. No mention is made of MHA influence upon ventilation system flow rate requirements.

The University of Wisconsin Technical Specification 3.5 stipulates an exhaust system flow rate of at least 9600 scfm. The Basis indicates that the flow rate requirement arises from air effluent releases of Ar-41. No mention is made of MHA influence upon ventilation system flow rate requirements.

5.0 Analysis of the Impact of Flow Rate upon Dose

The quantity of volatile radionuclides that could be released following an MHA (cladding failure in air of a single TRIGA fuel rod) have been previously determined and documented. An analysis was presented in the June 13, 2008 letter (ML0832380265) and again in a letter submitted to the U.S. NRC on July 18, 2011. The July 18, 2011 letter describes the dose to a member of the public at the nearest occupied residence due to a ground release when the ventilation system is in the isolate mode.

In the present analysis it is assumed that a member of the public remains off-site during the amount of time that is required to release 99.9% of the airborne radionuclide inventory from the reactor facility. The dose to a maximally exposed individual, given as the product of the time-integrated concentration and the dose conversion factor, may be used as an upper limiting value when the individual is exposed for the entire duration of the release.

Table I provides the radionuclide inventory released into the pool room, (as calculated by General Atomics and documented in the June 13, 2008 letter to the U.S. NRC) following failure of the fuel cladding of a single TRIGA fuel rod in air.

Table I. Volatile Fission Products and Quantities

Isotope	Activity released (μCi)
Br-82	26
Br-83	3300
Br-84	6400
Br-85	7500
I-131	17,800
I-132	26,800
I-133	41,300
I-134	47,600
I-135	38,700
Kr-83m	3300
Kr-85m	7500
Kr-85	500
Kr-87	15,300
Kr-88	21,700
Xe-131m	200
Xe-133m	1200
Xe133	40,300
Xe-135m	7200
Xe-135	27,500
Xe-138	39,100

The volume of the WSU reactor pool room used in these calculations is 1×10^9 mL. The amount of time that is required for 99.9% release from the pool room is illustrated in Figure 1.

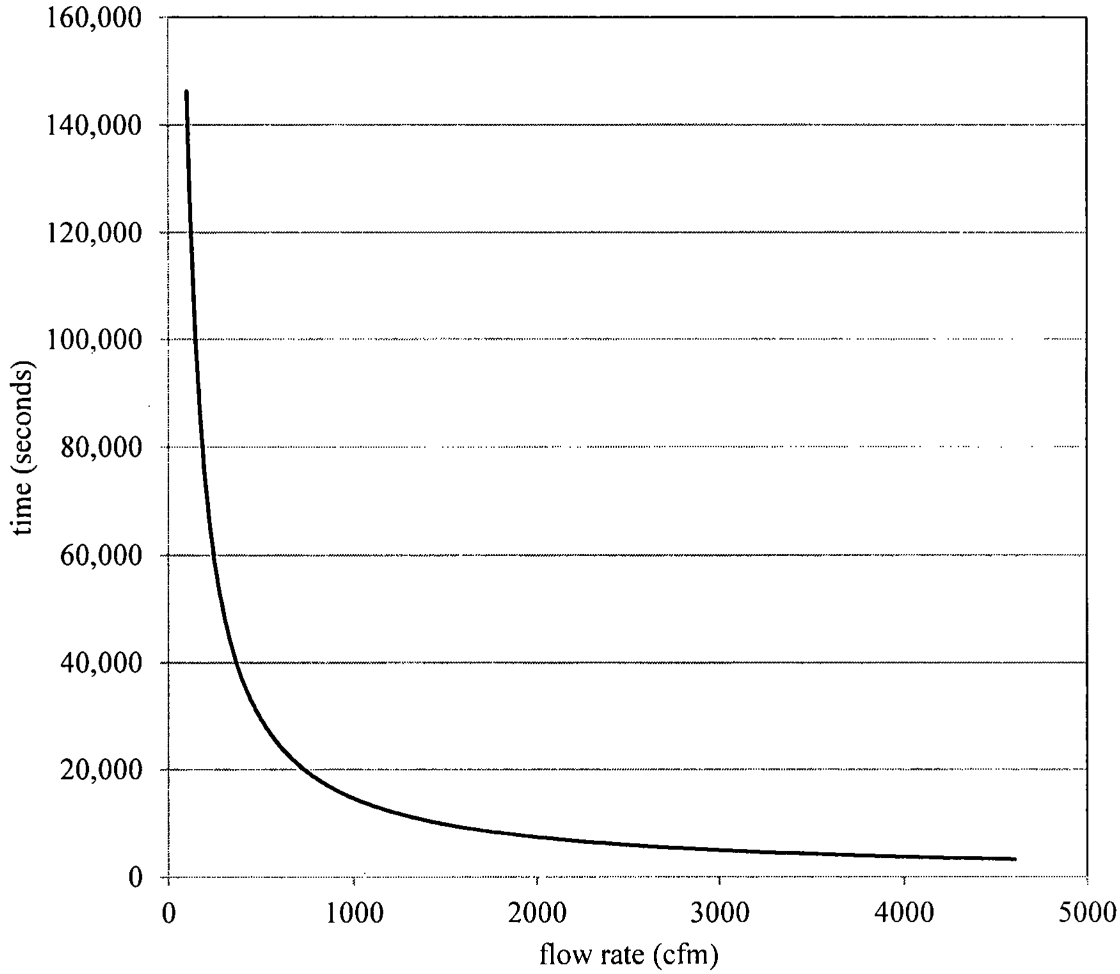

Figure 1. The figure illustrates the amount of time, as a function of ventilation system exhaust rate, that is required for 99.9% turnover of the air in the pool room.

The ventilation system design flow rates when in the normal mode are 4250 cfm input and 4500 cfm exhaust, as described in the WSU Safety Analysis Report of 2002. The air exhaust exits the reactor building through an elevated exhaust stack and is swept away by air movement which is conservatively set at 1 m/s in the present analysis.

In the cases of offsite exposure the assumption is made that the member of the public is not evacuated and remains exposed to the plume during the entire time of passage of the plume. The amount of time for plume passage depends upon the ventilation system flow rate, as illustrated in Figure 1.

The dose depends upon the product of the dilution factor, dose conversion factor, airborne radionuclide concentration, time of exposure and ventilation system flow rates. The dilution factor only applies when the ventilation system is in the dilute mode—no dilution factor applies when the ventilation system is in the normal mode.

The present analysis assumes a complete release of volatile fission products, including iodine. The present analysis also assumes that a member of the public is exposed to the plume formed by the exhaust gas effluent for the entire time that it is required for 99.9% turnover of air in the pool room. Thus, no credit is taken for a limited time of exposure that would result if an evacuation of the vicinity of the facility were conducted. As a result, these two assumptions set a bounding condition for the upper limit of exposure under a worst-case scenario.

Table II provides dose conversion factors for thyroid and whole body exposure. The values are taken from "*Manual of Protective Action Guides and Protective Actions for Nuclear Incidents*", U.S. Environmental Protection Agency, EPA-400-R-92-001.

Table II Dose Conversion Factors for Whole Body and Thyroid Exposure

radionuclide	Whole Body Dose Conversion Factors [rem/(μCi•cm^{-3}•hr^{-1})]	Thyroid Dose Conversion Factors [rem/(μCi•cm^{-3}•hr^{-1})]
Br-82	1250	
Br-83	83	
Br-84	125	
Br-85	115	
I-131	220	1.3×10^6
I-132	1400	7.7×10^3
I-133	350	2.2×10^5
I-134	1600	1.3×10^3
I-135	950	3.8×10^4
Kr-83m	100	
Kr-85m	93	
Kr-85	1.3	
Kr-87	510	
Kr-88	1300	
Kr-89	1200	
Xe-131m	4.9	
Xe-133m	17	
Xe-133	140	
Xe-135m	250	
Xe-135	140	
Xe-137	110	
Xe-138	710	

5.1 Dose calculations for personnel dose for 5 minute exposure in the pool room

The time integrated concentration (TIC) for personnel exposure in the reactor pool was calculated for an exposure time of 5 minutes according to the following equation:

$$\mathrm{TIC}(300\mathrm{s}) = \frac{A}{V(\lambda_V + \lambda_{DK})}\left[1 - e^{-(\lambda_V + \lambda_{DK})300\mathrm{s}}\right]$$

Where TIC is the time integrated concentration for either thyroid or whole body dose, A is the activity in μCi, V is the pool room volume in cm^3, λ_V is the pool room ventilation rate in s^{-1}, λ_{DK} is the radioactive decay rate constant. For example the TIC for a 300 second pool room exposure to ^{82}Br with the ventilation system flow rate of 300 cfm is calculated as follows:

$$TIC(300s) = \frac{26\mu Ci}{1\times10^{9}cm^{3}(1.42\times10^{-4}s^{-1}+5.45\times10^{-6}s^{-1})}\left[1-e^{-(1.42\times10^{-4}s^{-1}+5.45\times10^{-6}s^{-1})300s}\right]$$

$$= 7.63\times10^{-6}\mu Ci\cdot s\cdot cm^{-3}$$

where the ventilation flow rate constant, λ_V is given by the flow rate, 141,584 cm^3/s (300 cfm in the present example) divided by the pool room volume in cm^3, λ_{DK} is the radioactive decay rate constant for ^{82}Br.

The dose to an exposed individual in the reactor pool room is given by

$$\text{Dose (mrem)} = TIC(\mu Ci\cdot s\cdot cm^{-3}) \times DCF(rem/\mu Ci\cdot s\cdot cm^{-3}) \times [1000(mrem/rem)/3600(s/hr)]$$

Continuing with the example of ^{82}Br in the reactor pool room:

$$\text{Dose(mrem)} = (7.63\times10^{-6}\mu Ci\cdot s\cdot cm^{-3})\times(1250\ rem/\mu Ci\cdot s\cdot cm^{-3})\times[(1000\ mrem)/(rem/3600\ s/hr)]$$
$$= 2.65\times10^{-3}\,mrem$$

Doses to personnel in the pool room were calculated in the same manner for a variety of exhaust rates from the pool room. Doses to personnel in the pool room are dependent upon the ventilation system exhaust rate but are independent of the ventilation system mode, thus plots of personnel doses are presented as functions of exhaust flow rate only. The doses for each individual radionuclide are plotted in Figures 2 through 5. Figure 6 provides the total dose as a sum of the contributions from each radionuclide in Figures 2 – 5.

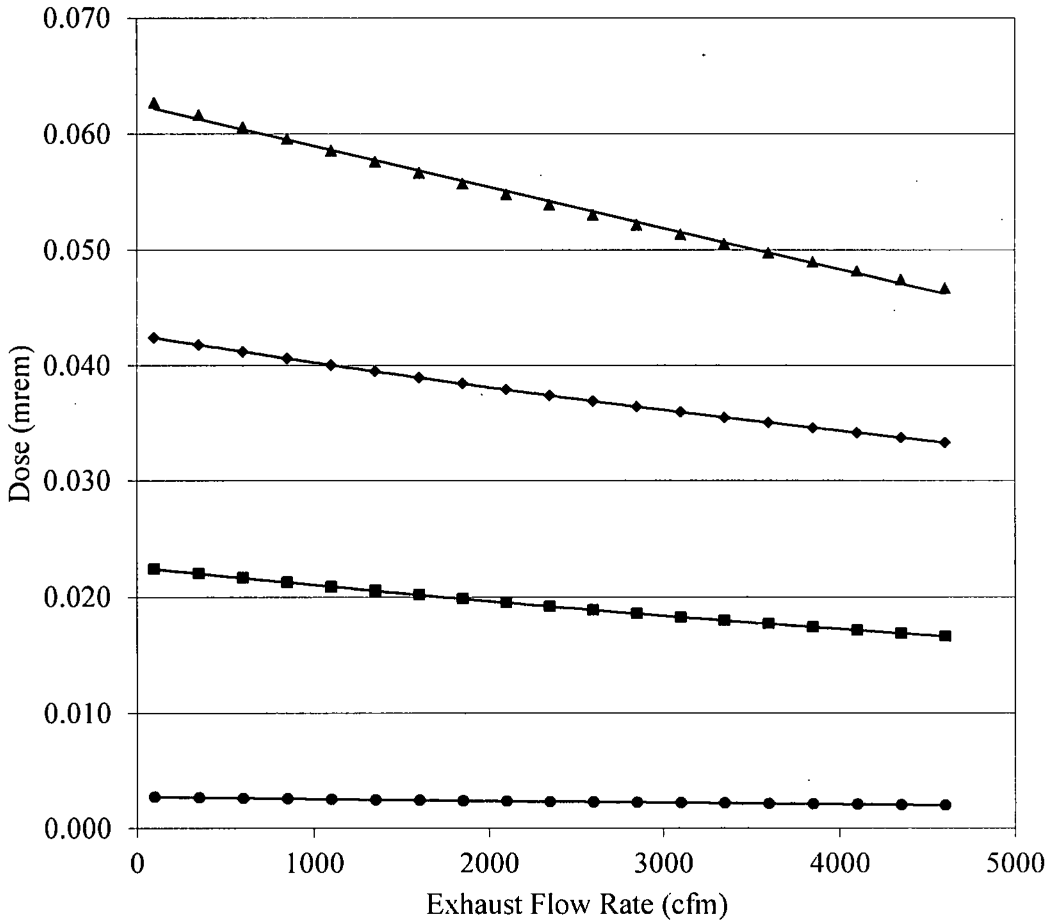

Figure 2. Whole body doses arising from exposure to Br-82 (●), Br-83 (■) , Br-84 (▲), Br-85 (♦) in the reactor pool room for 300 seconds as a function of pool room exhaust flow rate. The doses are not dependent on the ventilation system mode.

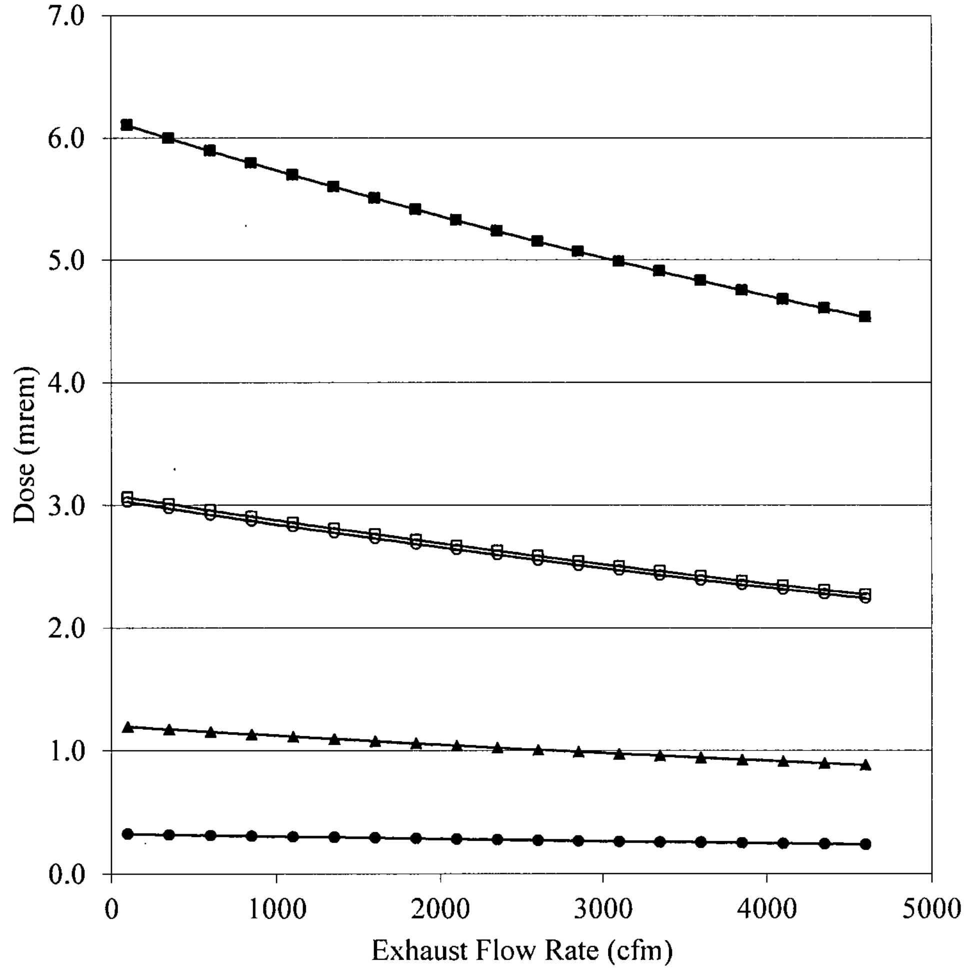

Figure 3. Whole body doses arising from exposure to I-131 (●), I-132 (□), I-133 (▲), I-134 (■), I-135 (○) for 300 seconds in the reactor pool room. The doses are not dependent on the ventilation system mode.

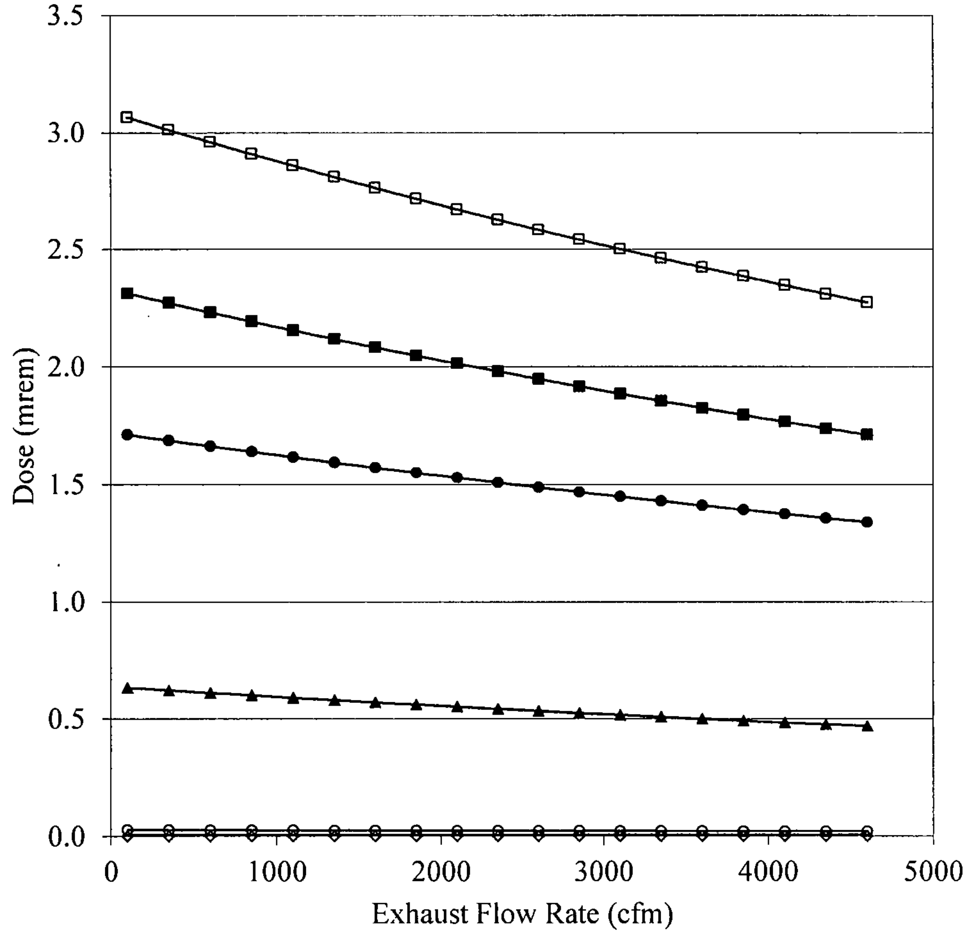

Figure 4. Whole body doses arising from exposure to Kr-83m (○), Kr-85m (□), Kr-85 (◊), Kr-87 (▲), Kr-88 (■), Kr-89 (●) for 300 seconds in the reactor pool room. The doses are not dependent on the ventilation system mode.

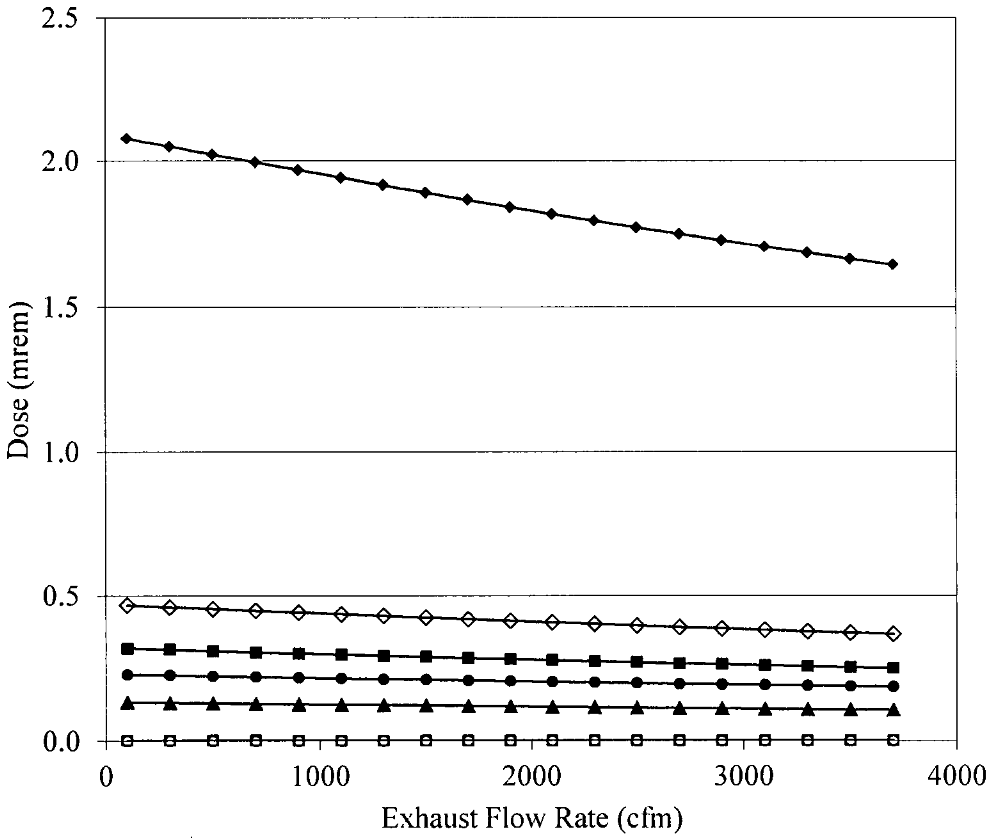

Figure 5. Whole body doses arising from exposure to Xe-131m (○), Xe-133m (□), Xe-133 (◊), Xe-135m (▲), Xe-135 (■), Xe-137 (●), Xe-138 (♦) for 300 seconds in the reactor pool room. The doses are not dependent on the ventilation system mode. Xe-131m and Xe-133m both lie on the baseline.

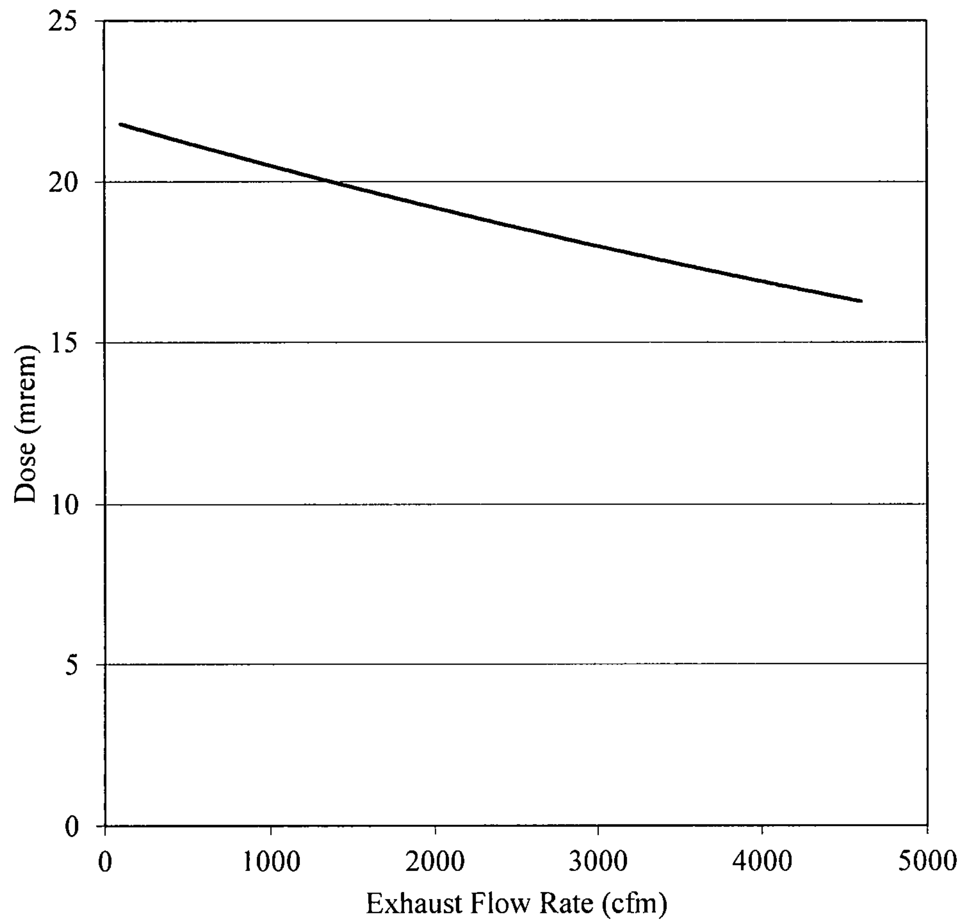

Figure 6. Whole body dose for a 300 second exposure in the pool room, summed for all contributing radionuclides. The dose is not dependent on the ventilation system mode of operation.

5.2 Dose calculations for a member of the public for a 99.9% turnover of the pool room air

The Time Integrated Concentration at the site boundary is given by:

$$TIC(s) = \left(\frac{\chi}{Q}\right)\frac{A \times DF}{V(\lambda_V + \lambda_{DK})}\left[1 - e^{-(\lambda_V + \lambda_{DK})t_s}\right]$$

Where TIC is the time integrated concentration for either thyroid or whole body dose, $\left(\frac{\chi}{Q}\right)$ is a parameter that describes the initial dimensions of the plume, A is the activity in μCi, DF is the dilution factor that arises from the mixing of pool room exhaust air with fresh outside air when the ventilation system is in the dilute mode, V is the pool room volume in cm^3, λ_V is the pool room ventilation rate for a particular ventilation system flow rate, λ_{DK} is the radioactive decay rate constant. The unitless dilution factor is:

$$DF = \frac{CFM_{exhaust}}{CFM_{exhaust} + CFM_{fresh}}$$

Where $CFM_{exhaust}$ is the flow rate out of the pool room, and CFM_{fresh} is the flow rate of fresh outside air that is used to dilute the pool room air before release through the exhaust stack.

The $\left(\frac{\chi}{Q}\right)$ term is defined as:

$$\left(\frac{\chi}{Q}\right) = \frac{1}{\pi\sigma_y\sigma_z u}$$

Where u is the windspeed in m/s, and σ_y and σ_z are the initial dimensions of the plume, given by

$$\sigma_y = \frac{W_b}{4.3} = \frac{17.07}{4.3} = 3.970$$

and

$$\sigma_z = \frac{H_b}{2.15} = \frac{8.53}{2.15} = 3.97$$

W_b is the width of the building in meters (17.07 m) and H_b is the height of the building in meters (8.53 m). Using a conservative wind speed of 1 m/s the $\left(\frac{\chi}{Q}\right)$ value for the nearest member of the public is:

$$\left(\frac{\chi}{Q}\right) = \frac{1}{\pi\sigma_y\sigma_z u} = 0.0202\text{s/m}^3$$

The χ/Q value acts as a dilution factor for plume dispersion, and is valid as long as the effluent release rate is enough lower than the air movement rate such that the effluent disperses within the air volume created within the lee of the building without significant displacement of the air. Consequently, the χ/Q value is normalized and may be treated as a unitless dilution factor.

The TIC for an offsite exposure to ^{82}Br with 99.9% air turnover from the pool room with the ventilation system flow rate of 300 cfm and a fresh air addition rate of 1700 cfm is calculated as follows

$$\text{TIC} = \frac{(0.0202)\times 26\,\mu\text{Ci}\times 300\text{ cfm}/(300\text{ cfm}+1700\text{ cfm})}{1\times 10^9\text{cm}^3\times(1.42\times10^{-4}\text{s}^{-1}+5.45\times10^{-6}\text{s}^{-1})}\left[1-e^{-(1.42\times10^{-4}\text{s}^{-1}+5.45\times10^{-6})48{,}789\text{s}}\right]\times 10^6\,\text{cm}^3/\text{m}^3$$

$$= 0.54\,\mu\text{Ci}\cdot\text{s}\cdot\text{m}^{-3}$$

The time integrated whole body dose rate, or dose, to an offsite individual exposed to ^{82}Br for 48,789 seconds, or approximately 13.6 hours that is required for 99.9% turnover of pool room air at 300 cfm flow rate is given by

$$\text{Dose(mrem)} = \text{TIC}(\mu\text{Ci}\cdot\text{s}\cdot\text{m}^{-3})\times\text{DCF}(\text{rem}\cdot\text{cm}^3\cdot\text{hr}\cdot\mu\text{Ci}^{-1})\times(1000\text{mrem}/\text{rem})\times\ldots$$
$$\ldots(3600\text{s}/\text{hr})\times(10^{-6}\text{m}^3/\text{cm}^3)$$

$$\text{Dose} = (0.54\,\mu\text{Ci}\cdot\text{s}\cdot\text{m}^{-3})\times(1250\,\text{rem}\cdot\text{cm}^3\cdot\text{hr}\cdot\mu\text{Ci}^{-1})\times(1000\text{ mrem/rem})\times(3600\text{ s/hr})\times(10^{-6}\text{m}^3/\text{cm}^3)$$

$$= 1.86\times10^{-4}\text{ mrem}$$

Doses to an exposed individual offsite were calculated for dilute mode for a variety of exhaust rates from the pool room, assuming a constant fresh air addition rate in dilute mode of 1700 cfm. Doses were also calculated for an exposed offsite individual with the ventilation system in normal mode. The only difference is that a dilution factor is used for the dilute mode calculations, whereas no dilution factor is used for the normal mode calculations. Since a constant 1700 cfm flow rate is assumed for the fresh air addition rate when in dilution mode, it is apparent that the dilution factor depends upon the pool room exhaust rate. The normal mode doses do not include a dilution factor at all; it may be concluded that all flow rates for both pool room exhaust and fresh air makeup are bounded by doses arising from normal mode for normal flow rates that are equal to dilute mode pool room exhaust rates. The doses to an offsite individual arising from each individual radionuclide, with the ventilation system in dilute mode, are presented in Figures 8 - 10. Figure 11 provides the total dose as a sum of the contributions from each radionuclide in Figures 8 - 10. The doses to an offsite individual arising from each radionuclide, with the ventilation system in normal mode, are presented in Figures 12 - 15. Figure 16 provides the total dose as a sum of the contributions from each radionuclide in Figures 12 - 15.

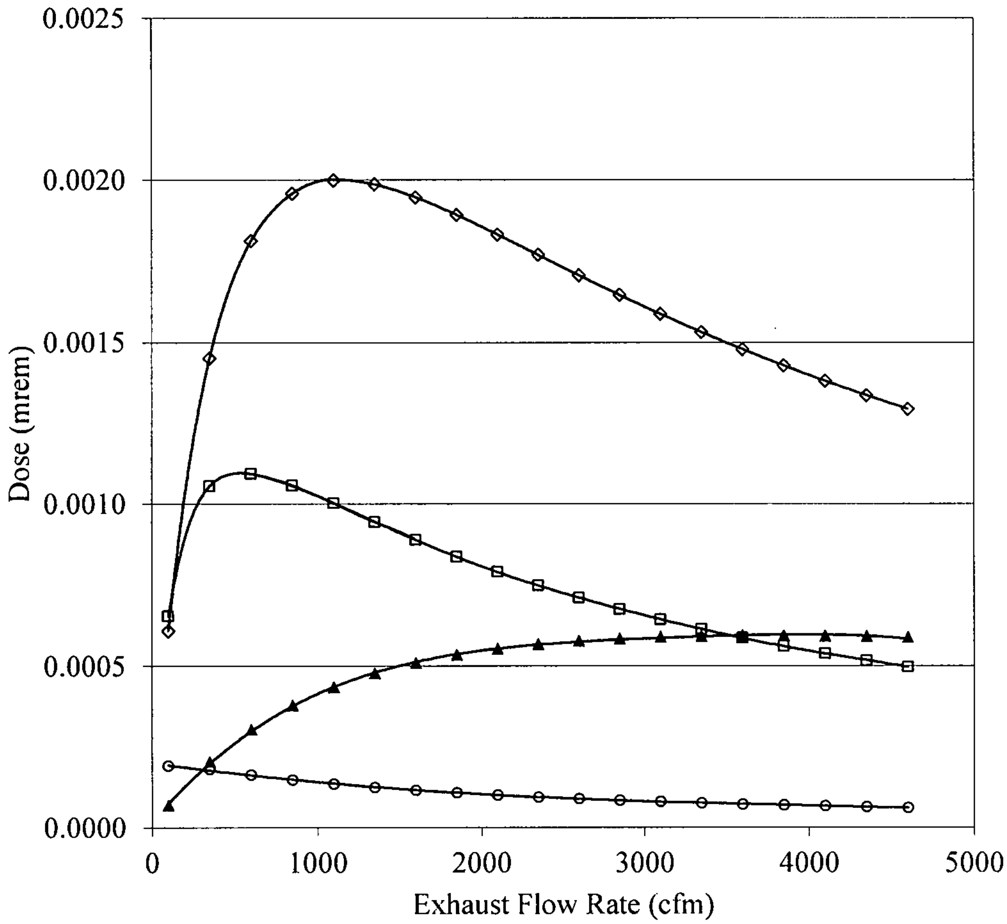

Figure 7. Whole body doses as a function of pool room exhaust flow rate arising from offsite exposure to Br-82 (○), Br-83 (□), Br-84 (◊), Br-85 (▲) with the ventilation system in dilute mode.

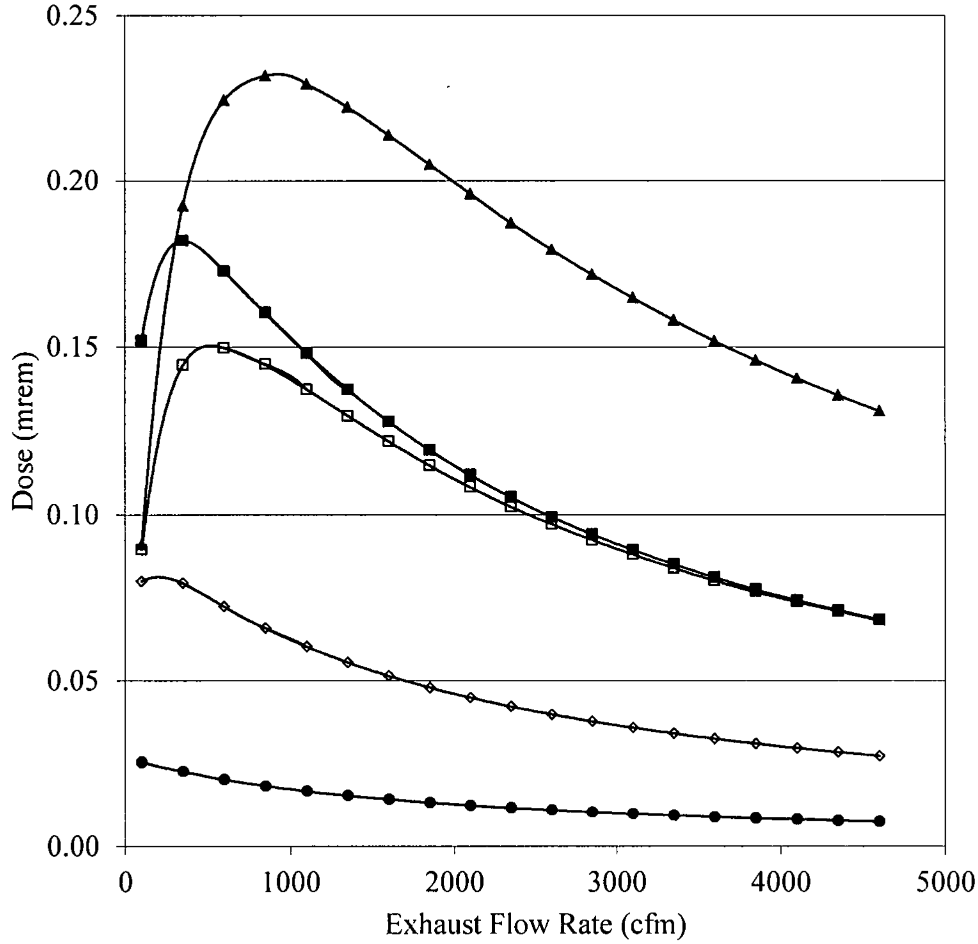

Figure 8. Whole body doses as a function of pool room exhaust flow rate arising from offsite exposure to I-131 (●), I-132 (□), I-133 (◊), I-134 (▲), I-135 (■) with the ventilation system in dilute mode.

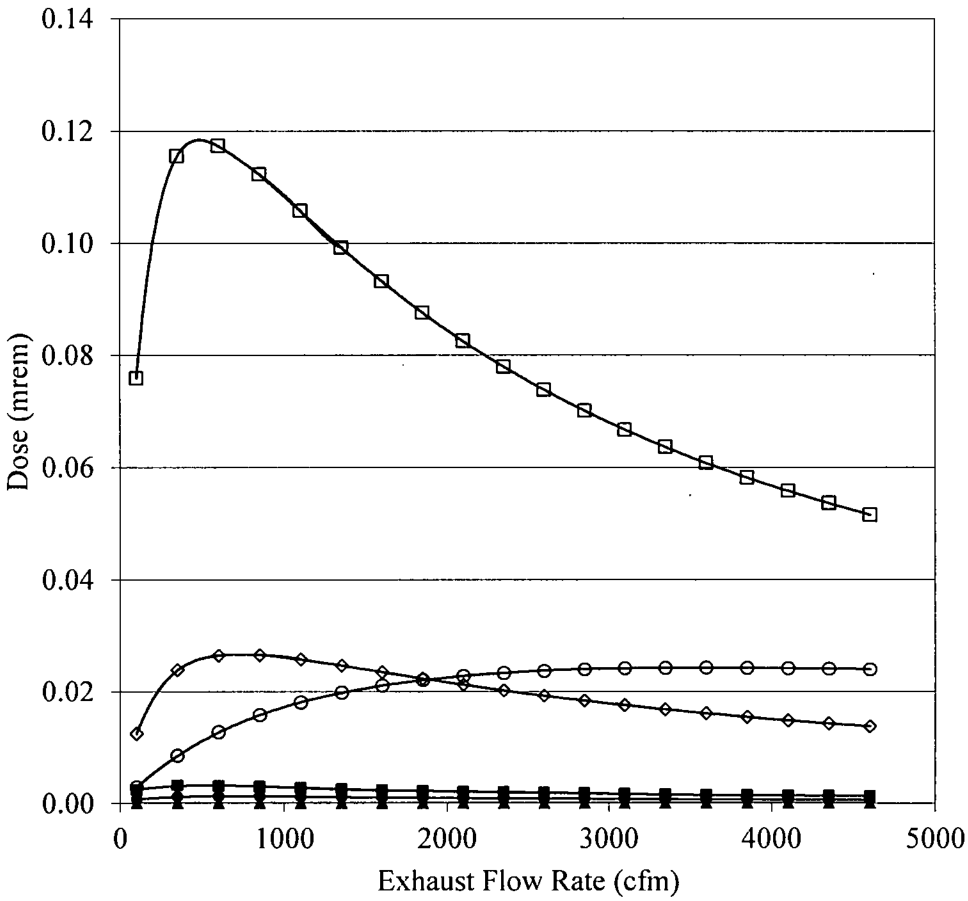

Figure 9. Whole body doses arising from offsite exposure to Kr-83m (●), Kr-85m (■), Kr-85 (▲), Kr-87 (◊), Kr-88 (□), Kr-89 (○) with the ventilation system in dilute mode.

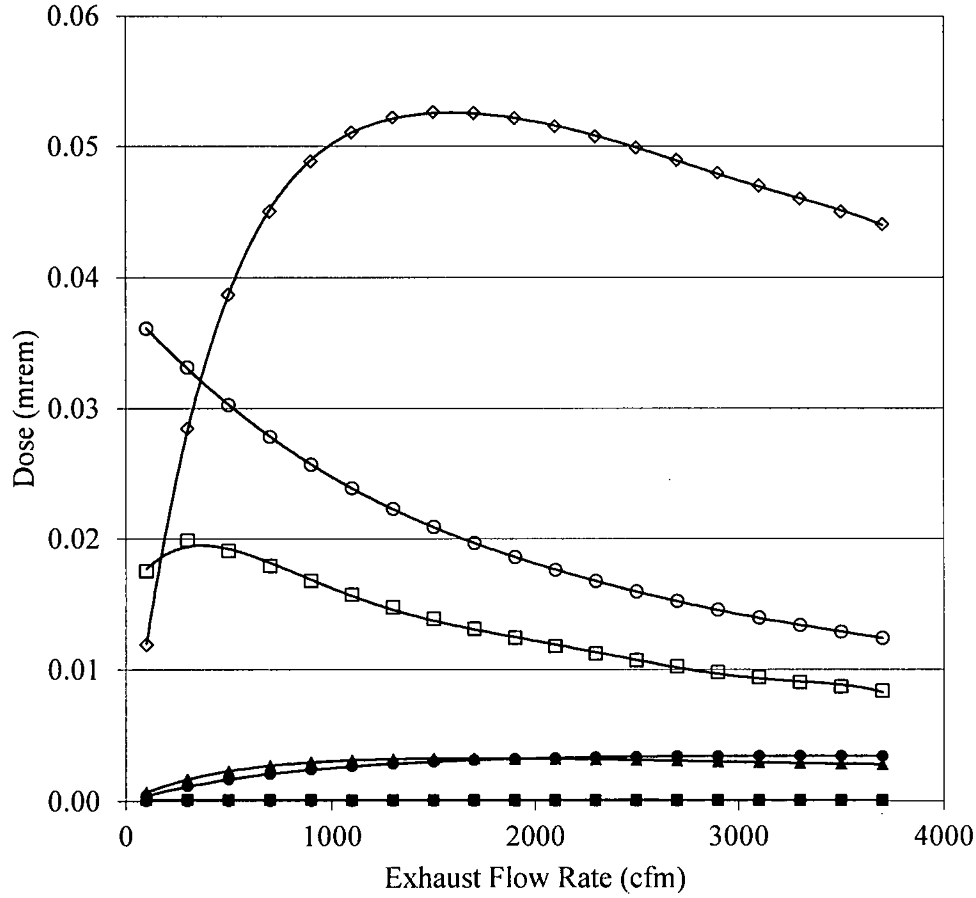

Figure 10. Whole body doses arising from offsite exposure to Xe-131m (●), Xe-133m (■), Xe-133 (○), Xe-135m (▲), Xe-135 (□), Xe-137 (●) and Xe-138 (◊) with the ventilation system in dilute mode.

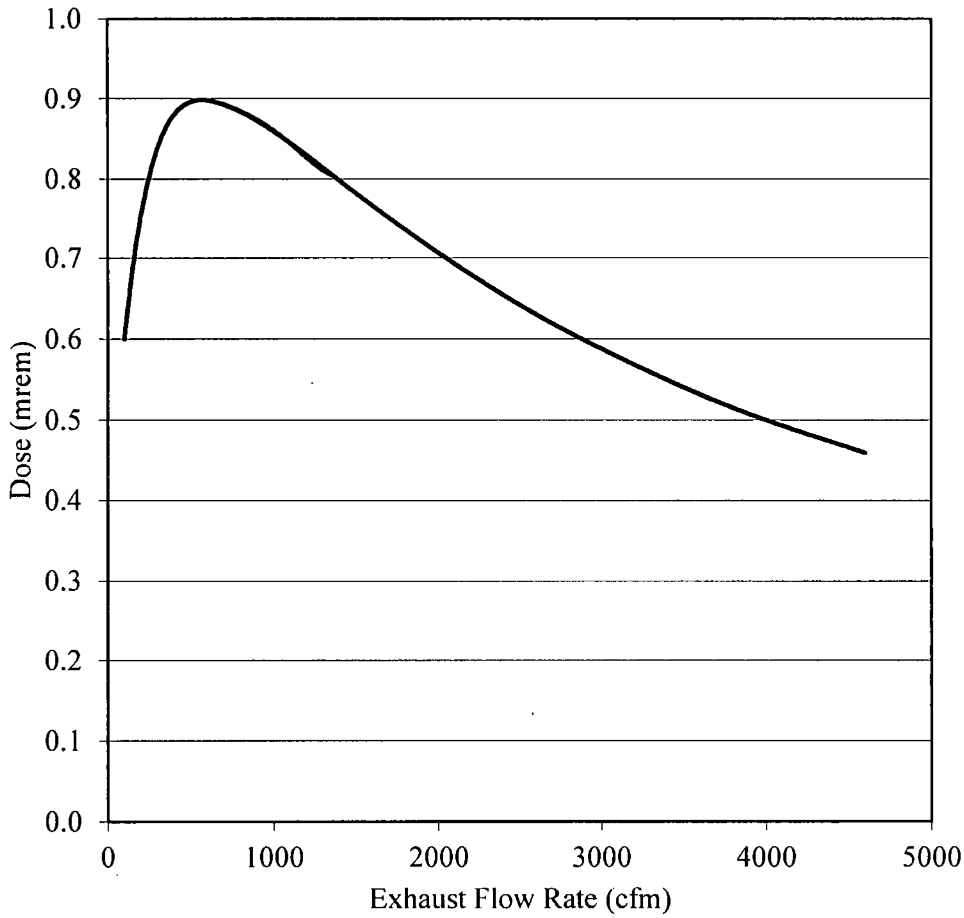

Figure 11. Whole body dose for an offsite exposure, with the ventilation system in dilute, summed for all contributing radionuclides.

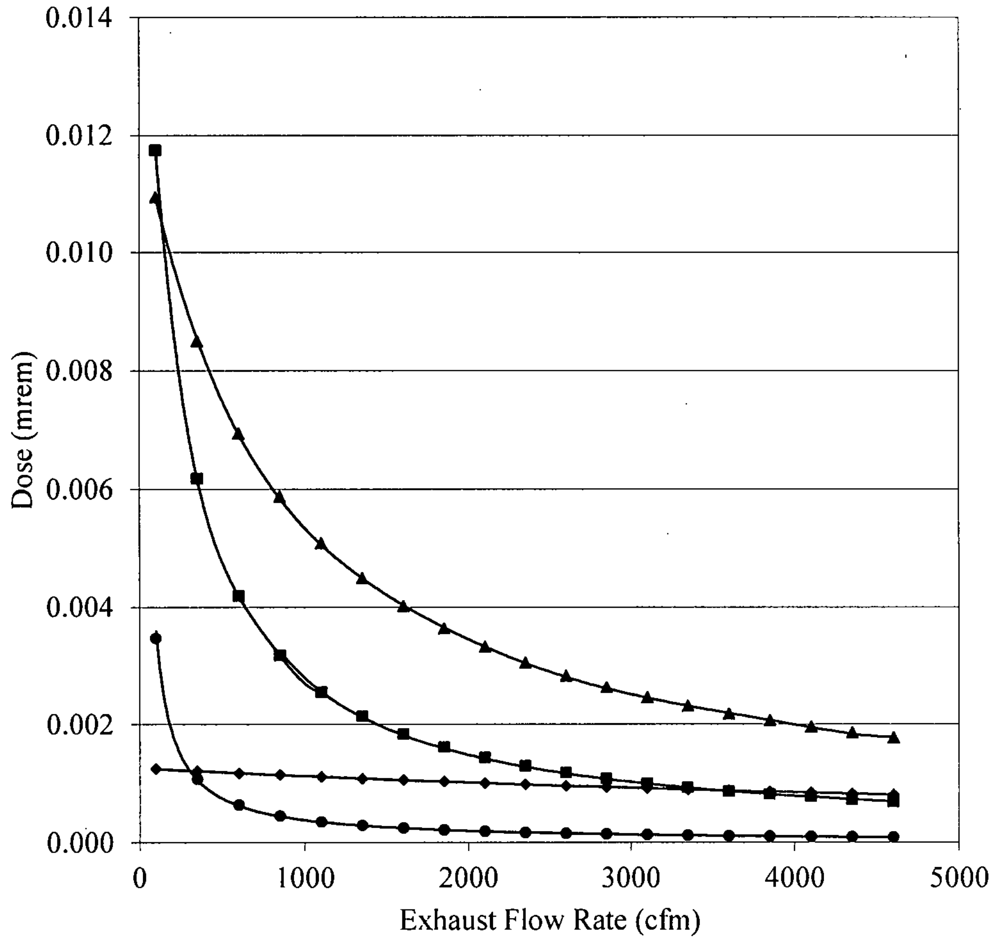

Figure 12. Whole body doses arising from offsite exposure to Br-82 (●), Br-83 (■), Br-84 (▲) and Br-85 (♦) with the ventilation system in normal mode.

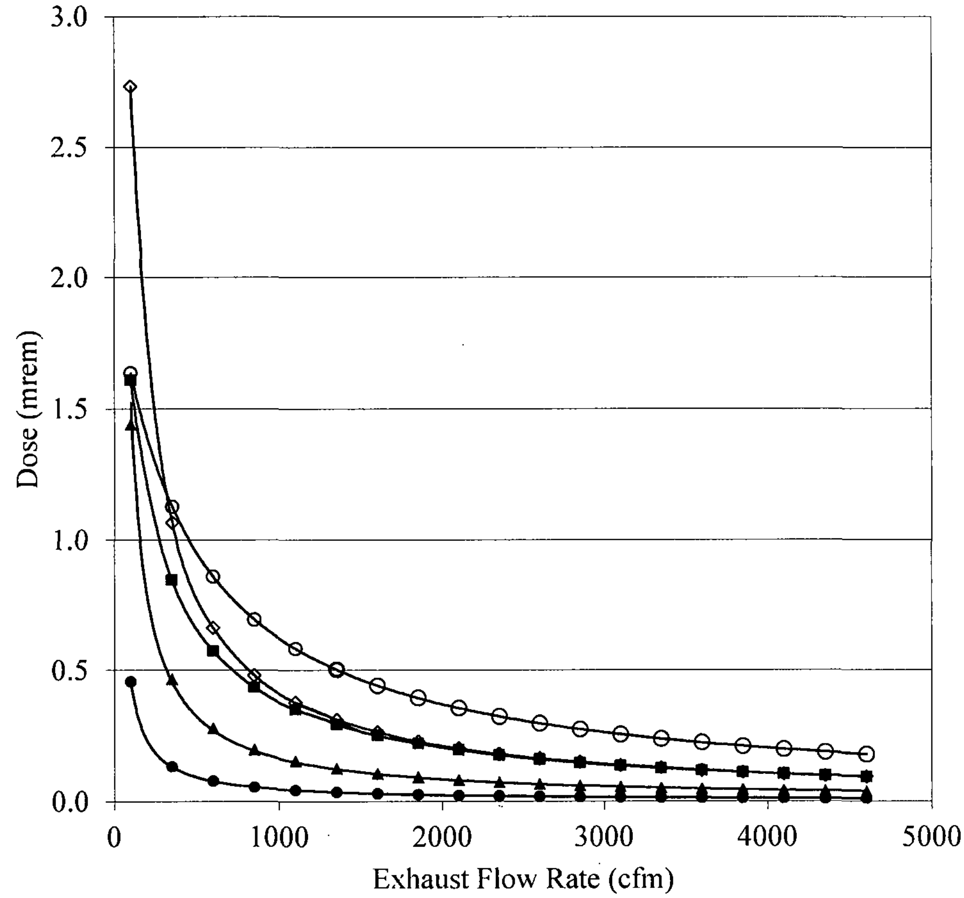

Figure 13. Whole body doses arising from offsite exposure I-131 (●), I-132 (■), I-133 (▲), I-134 (○) and I-135 (◊) with the ventilation system in normal mode.

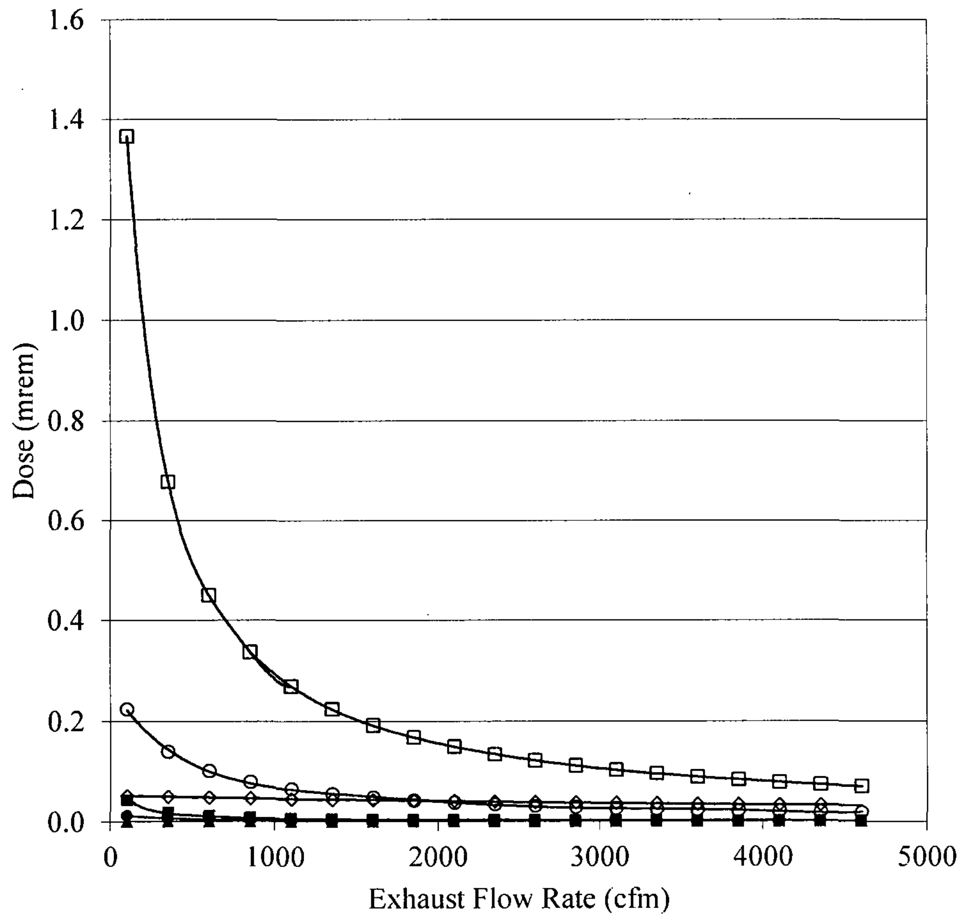

Figure 14. Whole body doses arising from offsite exposure Kr-83m (●), Kr-85m (■), Kr-85 (▲), Kr-87 (○), Kr-88 (□) and Kr-89 (◊) with the ventilation system in normal mode.

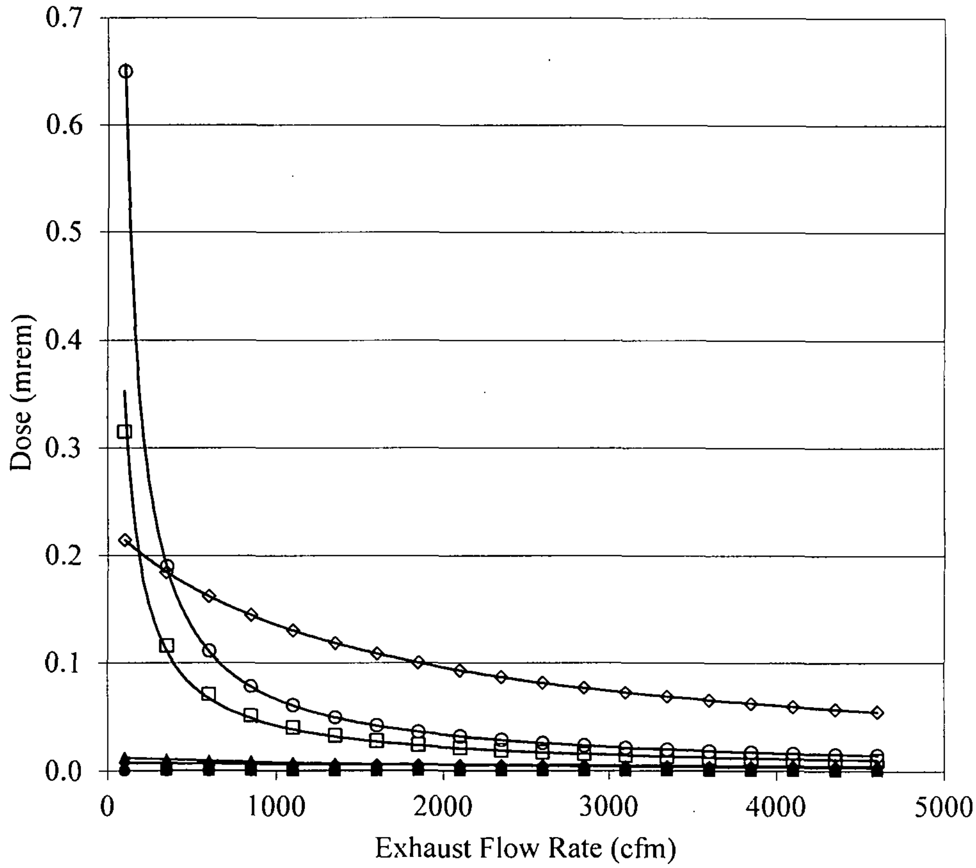

Figure 15. Whole body doses arising from offsite exposure to Xe-131m (●), Xe-133m (■), Xe-133 (○), Xe-135m (▲), Xe-135 (□), Xe-137 (♦) and Xe-138 (◊) with the ventilation system in normal mode.

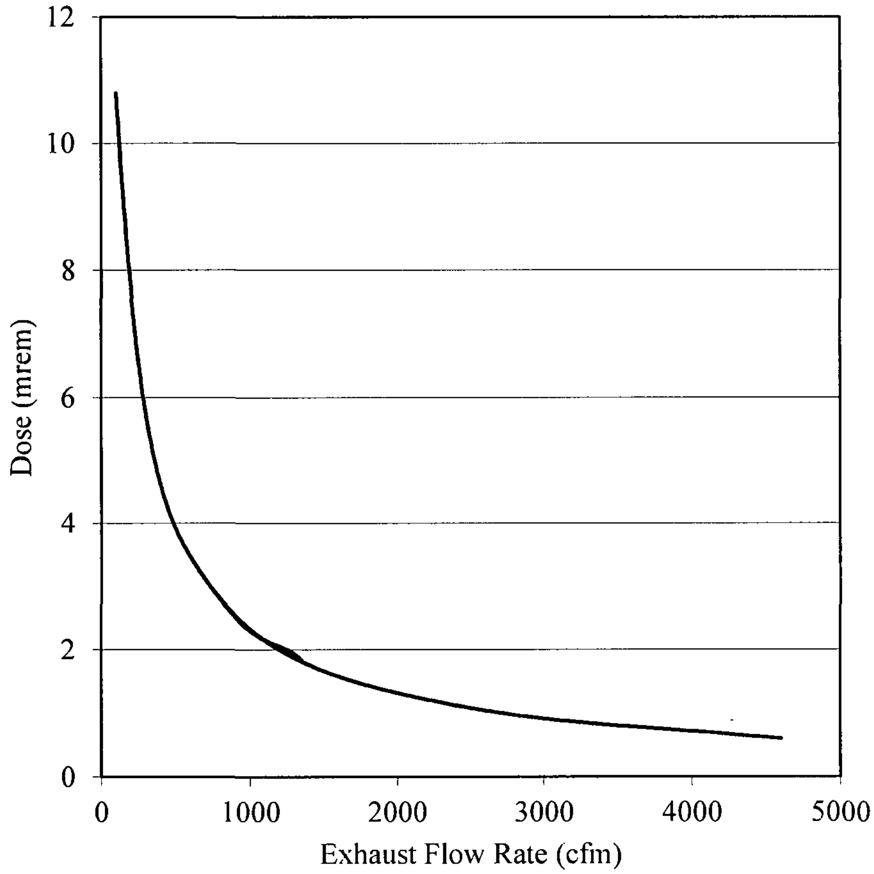

Figure 16. Whole body dose for offsite exposure, with the ventilation system in normal, summed for all contributing radionuclides.

5.3 Thyroid doses

The equations that are used to calculate thyroid doses are nearly the same as for whole body doses, with the only changes being that only the isotopes of iodine are considered, and the dose conversion factors for radioiodine imparted doses are different than for whole body doses. The thyroid doses for each isotope of iodine for a 300 second exposure in the pool room are presented in Figure 17, and Figure 18 illustrates the sum of the contribution of each radionuclide to the total thyroid dose for an individual in the pool room. Figure 19 shows the contribution of each isotope of iodine to offsite exposure, with the ventilation system in dilute mode. The sum of the contribution of each isotope to the total thyroid dose to an offsite individual, with the ventilation system in dilute mode is illustrated in Figure 20. Figure 21 shows the contribution of each isotope of iodine to offsite exposure, with the ventilation system in normal mode. The sum of the contribution of each isotope to the total thyroid dose to an offsite individual, with the ventilation system in normal mode is illustrated in Figure 22.

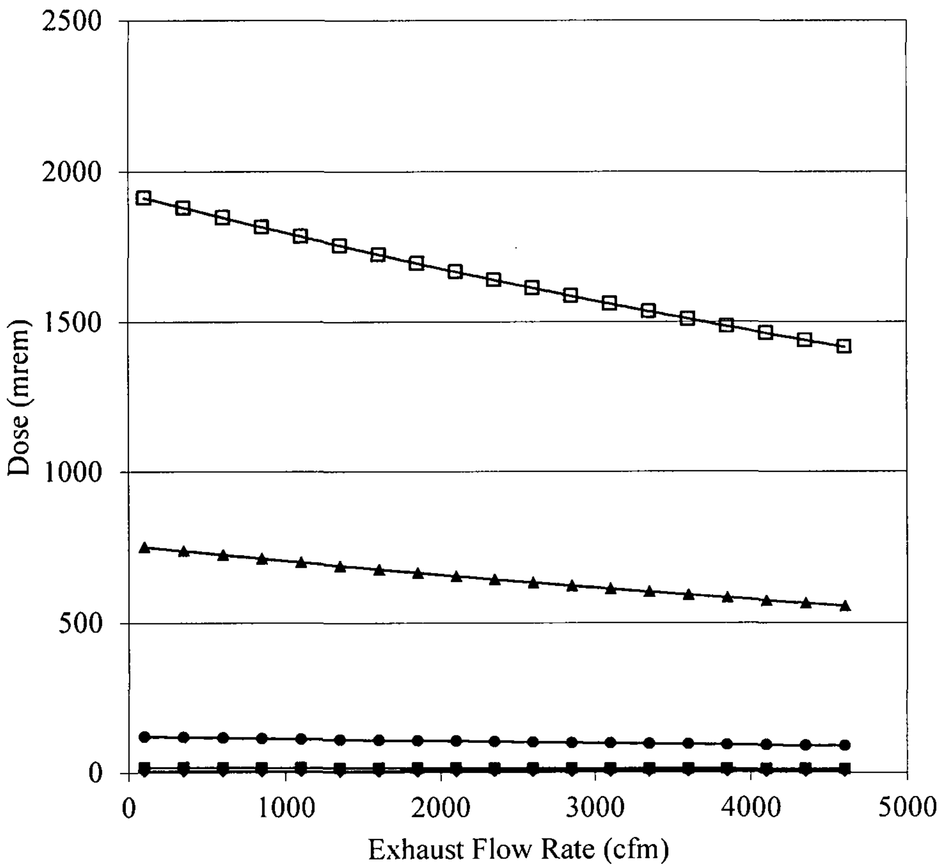

Figure 17. Thyroid doses arising for a 300 second pool room exposure to I-131 (□), I-132 (■), I-133 (▲), I-134 (♦), I-135 (●). The doses are not dependent on the ventilation system mode.

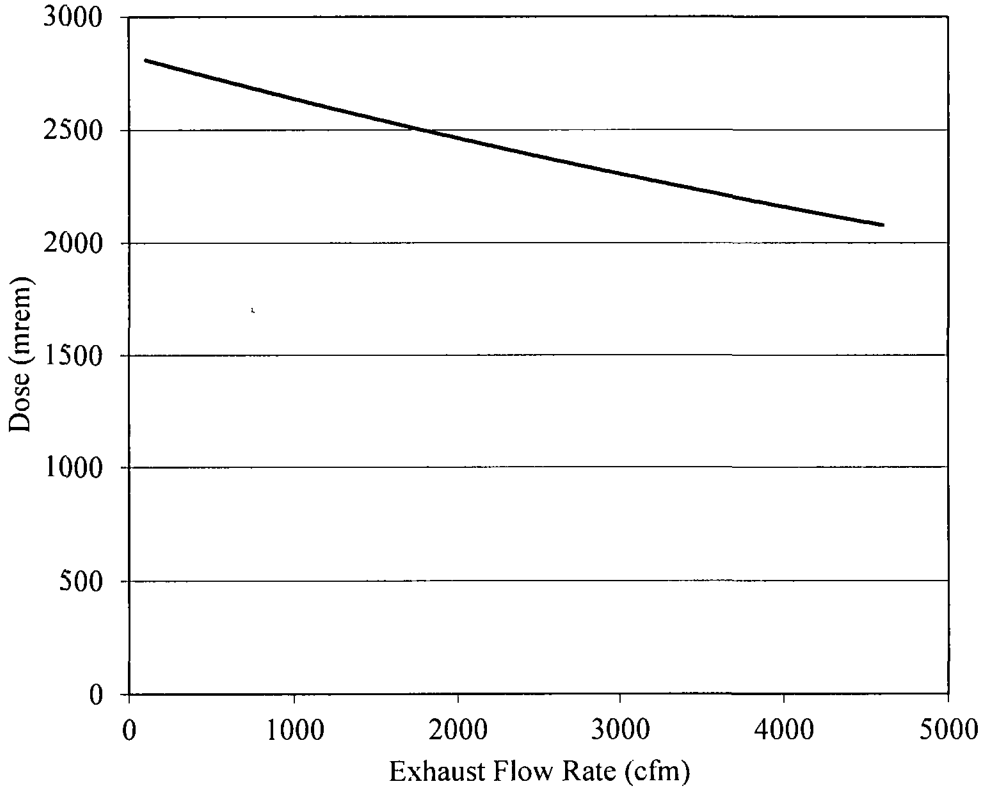

Figure 18. Thyroid dose for a 300 second exposure in the pool room, summed for all contributing iodine radionuclides. The dose is not dependent on the ventilation system mode of operation.

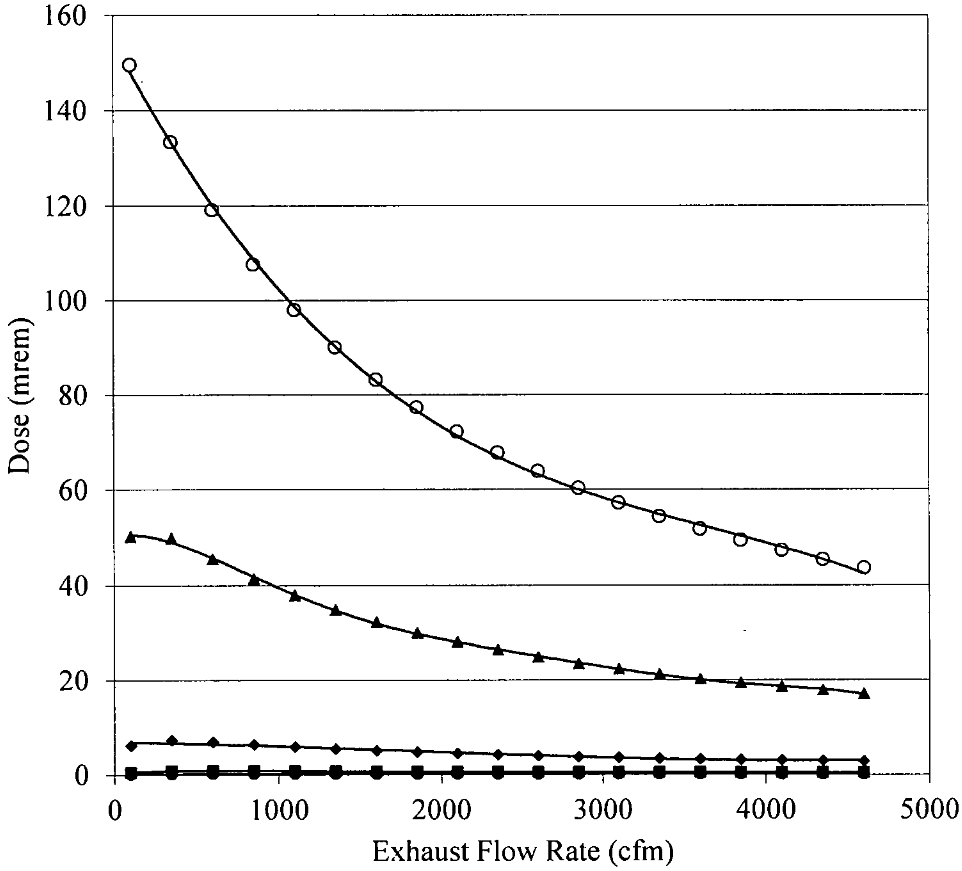

Figure 19. Thyroid doses arising from offsite exposure to I-131 (○), I-132 (■), I-133 (▲), I-134 (●), I-135 (♦) with the ventilation system in dilute mode.

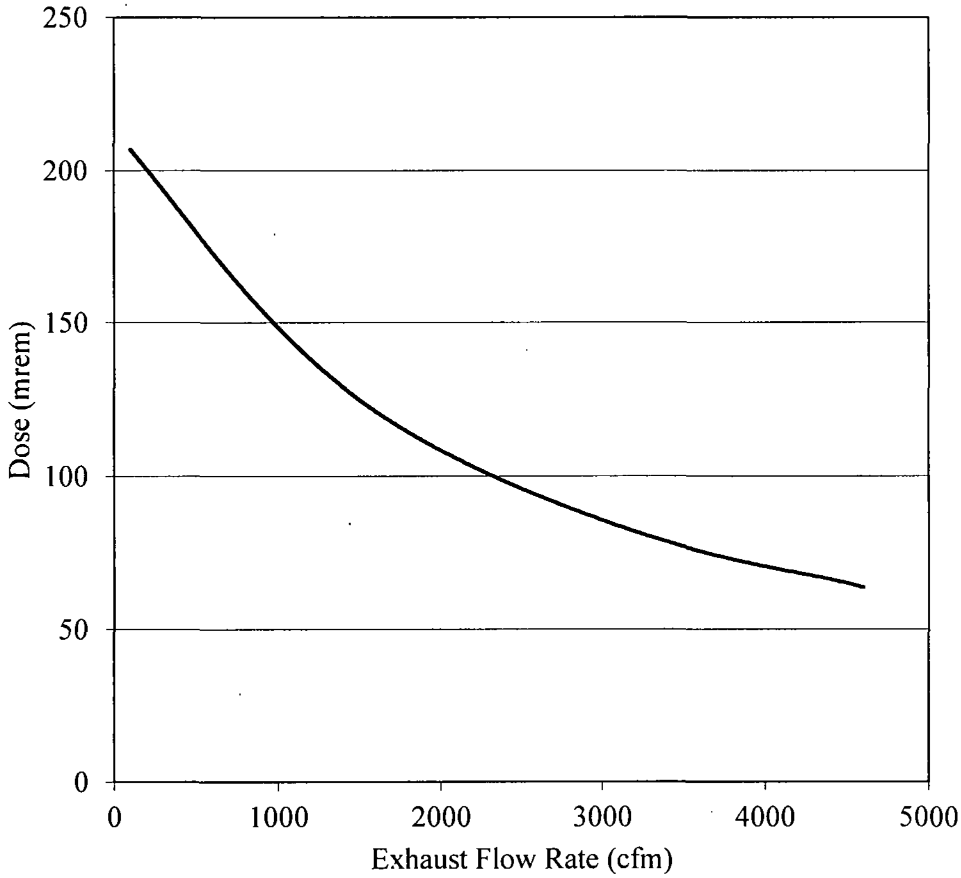

Figure 20. Thyroid dose for an offsite exposure, with the ventilation system in dilute, summed for all contributing iodine radionuclides.

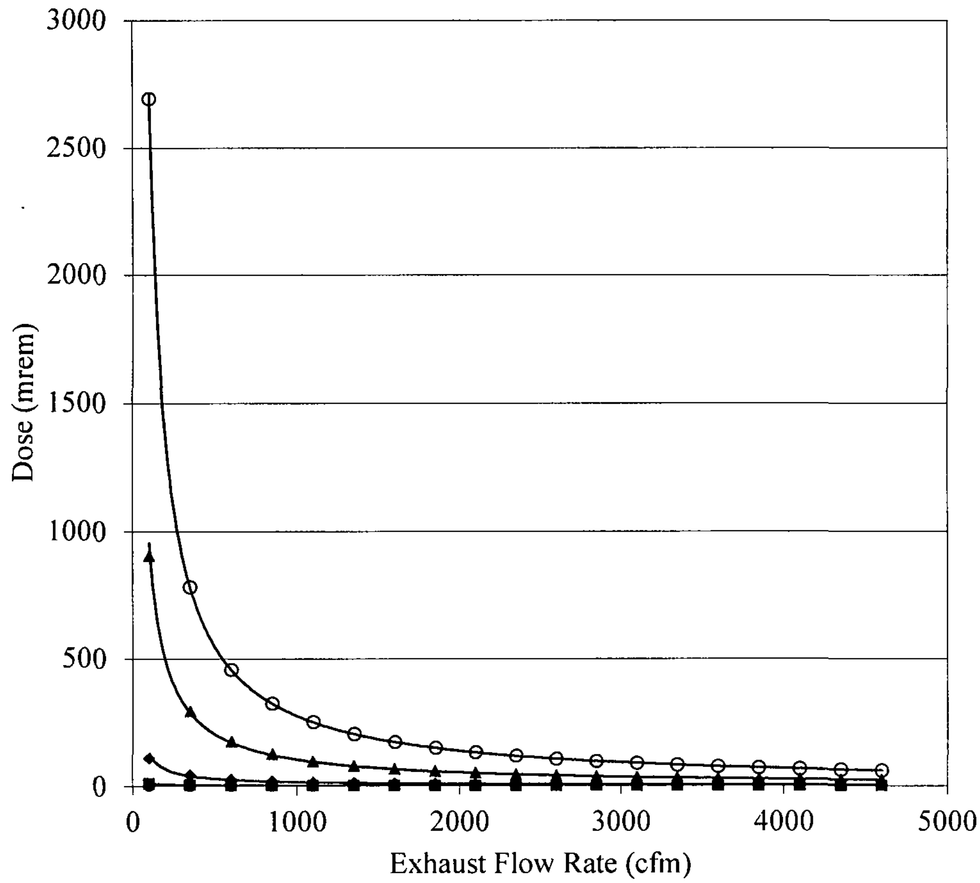

Figure 21. Thyroid doses arising from offsite exposure to I-131 (○), I-132 (■), I-133 (▲), I-134 (●), I-135 (♦) with the ventilation system in normal mode.

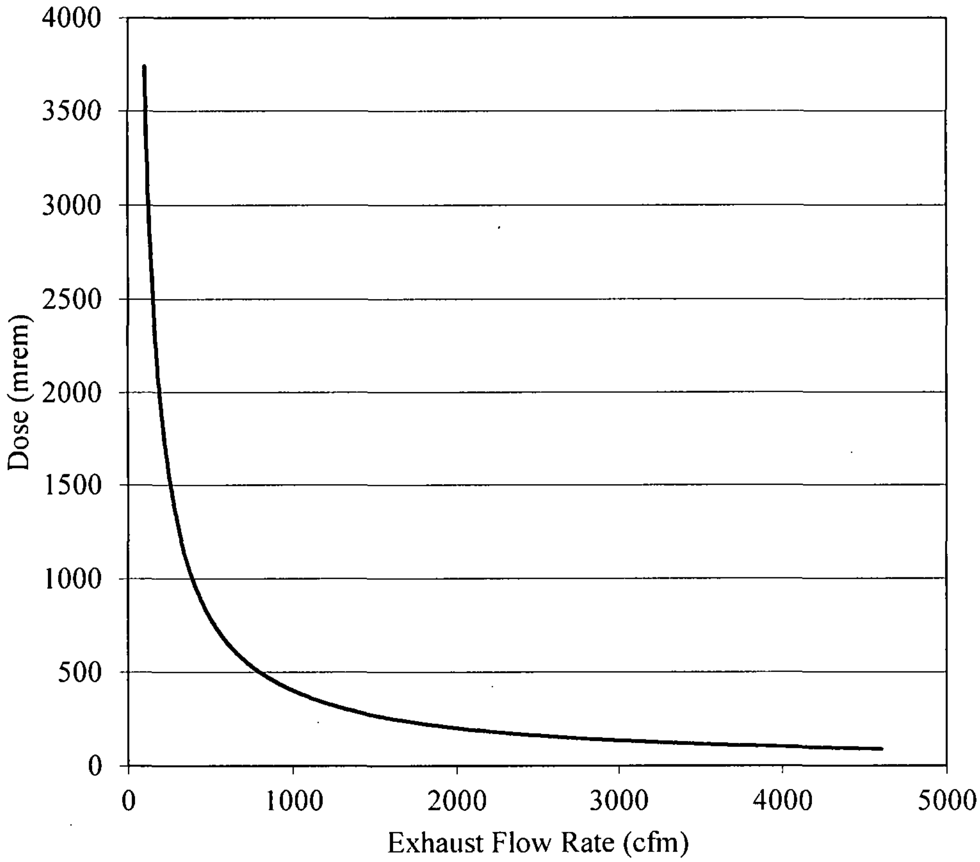

Figure 22. Thyroid dose for an offsite exposure, with the ventilation system in normal mode, summed for all contributing iodine radionuclides.

6.0 Discussion

Whole body doses imparted by individual radionuclides are plotted for a 300 second exposure in the pool room, and offsite exposure with the ventilation system in either dilute or normal mode. Plotting the doses individually provides insight into the relative contribution to the total dose contribution by each radioactive isotope.

The individually plotted doses as functions of exhaust system flow rates show different types of dependencies on flow rate. Dose dependence upon exhaust flow rate is more apparent for offsite exposure than pool room exposure because the doses depend upon radionuclide inventory release, dose conversion factors and radionuclide half-life. Most dose curves for personnel within the pool room show only a slight curvature in the dependencies as functions of exhaust rate due to the short exposure time—there is not sufficient pool room air turnover, even at the highest flow rates, to cause a significant deviation from linearity for the short exposure time. Much longer exposure times are used for an offsite individual due to the assumption that the person remains at the offsite location for the amount of time that is necessary to achieve 99.9% turnover of the pool room air. Consequently, the offsite doses exhibit a greater dependency upon the half-lives of the radionuclides.

The doses that are calculated for the dilute mode differ from the doses in normal mode for the same pool room exhaust flow rates. This is because an assumption is made that the fan which supplies fresh outside air as diluent is providing air at a constant rate of 1700 cfm, thus requiring the incorporation of a dilution factor which is also dependent upon pool room exhaust flow rate, i.e. the magnitude of the dilution factor decreases as pool room exhaust flow rates increase.

It was chosen to carry out the calculations over a pool room exhaust flow rate range of 100 – 4600 cfm. The lower limit, 100 cfm was chosen because it would balance the estimated leak rate from the pool room when the ventilation system is in the ISOLATE mode. An exhaust rate of 100 cfm would prevent a ground release, and remove pool room air from the building via the ventilation exhaust stack. An upper limit of 4600 cfm was chosen to bracket the upper range of the ventilation system design of 4500 cfm exhaust flow rate and the 4000 cfm Technical Specification limit. In all cases, doses to both personnel and offsite individuals decrease with increasing flow rates beyond 4000 cfm, making the 4600 cfm rate a conservative upper limit for the calculations.

The doses summed across all radionuclides generate the criteria by which it is possible to define acceptable exhaust flow rates. NUREG-1537 stipulates dose limits of 5 rem whole body and 30 rem thyroid dose for research reactors licensed before January 1, 1994.

Figure 6 illustrates the whole body dose for a 300 second exposure of personnel within the pool room. Personnel exposure within the pool room is independent of ventilation system operational mode, but depends only upon pool room exhaust flow rate. Figure 6 shows that the maximum dose of 22 mrem occurs at the minimum flow rate of 100 cfm, and decreases as exhaust flow rate increases. A 22 mrem dose is well below the 5000 mrem whole body dose limit. As a result, there is no possible exhaust flow rate in excess of 100 cfm that would cause the dose to exceed the whole body dose limit for personnel in the pool room.

Figure 18 shows that the maximum thyroid dose occurs at an exhaust flow rate of 100 cfm for a 300 second exposure within the pool room. The thyroid dose at 100 cfm exhaust flow rate is 2808 mrem, which is much less than the 30,000 mrem limit of NUREG 1537. Consequently, there is no possible exhaust flow rate greater than 100 cfm that would cause the dose to exceed the thyroid dose limit for personnel in the pool room.

Figure 11 illustrates the whole body dose for an offsite exposure, summed across all of the Br, I, Kr and Xe isotopes that are released. The figure shows a maximum whole body dose of 0.90 mrem at about 600 cfm. Flow rates that are lower than 600 cfm provide more time for short-lived radionuclides to decay, thus decreasing the dose, and at flow rates greater than 600 cfm the exposure time becomes increasingly important because the time of exposure decreases as flow rate increases. A dilution factor of 0.26 is used for the 600 cfm calculation ((600 + 1700)/2300 = 0.26). The 0.90 mrem whole body dose is less than the 500 mrem whole body dose limit provided by NUREG-1537. It is not necessary to also carry out the calculations with varied fresh air makeup flow rates other than 1700 cfm because the worst-case scenario for any offsite whole body dose is given by doses arising from releases when the ventilation system is in the normal mode, which does not include a dilution factor, provided that compliance is also maintained at all possible flow rates when in the normal mode (see below).

Figure 20 shows the thyroid dose for an offsite exposure with the ventilation system in dilute mode. The maximum dose of 207 mrem occurs at a flow rate of 100 cfm. At 100 cfm exhaust rate the dilution factor is 100/1800 = 0.056, which steadily decreases as pool room exhaust flow rate increases, as long as the fresh makeup air flow rate is maintained at 1700 cfm. Any makeup air flow rate in excess of 1700 cfm will decrease the dilution factor, thereby decreasing the dose. As a result, any pool room exhaust flow rate is acceptable as long as the makeup air flow rate is at least 1700 cfm. The worst case scenario occurs when the makeup air flow rate decreases to 0 cfm, in which case, the dilute mode doses would be identical to normal mode doses for the same pool room exhaust rates. However, even a minimal amount of makeup flow has a substantial impact upon offsite doses. For example, a makeup flow rate of 0 cfm with the pool room exhaust flow rate at 100 cfm would lead to an offsite thyroid dose of 3718 mrem, which is identical to a 100 cfm pool room exhaust flow rate in normal mode. However, when in dilute mode, and a 100 cfm pool room exhaust flow rate, a makeup air flow rate of only 50 cfm will lower the thyroid dose for an offsite person to 2479 mrem. Setting an administrative limit for an offsite person thyroid dose of one-fourth the NUREG-1537 limit, or 750 mrem, provides limiting values for the allowed flow rates for both pool room exhaust and makeup air flow rate, i.e. a minimum of 100 cfm for pool room exhaust and a minimum of 395 cfm for makeup fresh air. Any combination of pool room exhaust and makeup fresh air flow rates will lead to an offsite thyroid dose of 750 mrem or less, as long as the pool room exhaust rate is at least 100 cfm and the makeup fresh air flow rate is at least 395 cfm. This letter proposes

Applying the same criterion, (i.e. 750 mrem maximum thyroid dose for an offsite individual) to setting the boundary condition for pool room exhaust flow rate when in normal mode, it becomes possible to set a minimum flow rate, which must be higher than the pool room exhaust flow rate in dilute mode because no dilution is available in normal mode. The pool room exhaust flow rate which yields a 750 mrem offsite thyroid dose is 528 cfm. Consequently, any pool room exhaust flow rate greater than 528 cfm will lead to an offsite thyroid dose less than 750 mrem. A conservative pool room exhaust flow rate of 1000 cfm would lead to a dose of 399 mrem.

7.0 Comparison with the Technical Specifications of Other Licensed Facilities

The table in section 4.0 provides a summary of the ventilation system specifications at 10 other licensed facilities. There are only 2 facilities, the University of California-Irvine, and the University of Wisconsin, which stipulate specific flow rate requirements. In both cases the requirements are put in place to account for Ar-41 releases. None of the 10 listed facilities has a ventilation system flow rate requirement which is based upon MHA releases.

8.0 Summary

None of the 10 other facilities which have been surveyed (see Section 2.0) have ventilation system flow rate requirements based upon MHA analysis. This document shows that there is a wide variety of exhaust system flow rates that provide acceptable protection to the facility personnel and to members of the public. Consequently, WSU proposes to modify Technical Specifications 3.4(1)(a) and 3.4(1)(b) to allow a range of acceptable exhaust system flow rates. The requested modification is provided in Section 3.0 of this document.