ORNL/TM-8955

**OAK RIDGE
NATIONAL
LABORATORY**

MARTIN MARIETTA

**Calculations of Sodium Aerosol
Concentrations at Breeder Reactor
Air Intake Ports**

David E. Fields
Charles W. Miller

**DO NOT MICROFILM
COVER**

OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

NT MICROFILM COVER

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
NTIS price codes—Printed Copy: A03; Microfiche A01

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

ORNL/TM--8955

DE85 006052

Health and Safety Research Division

CALCULATIONS OF SODIUM AEROSOL CONCENTRATIONS AT BREEDER REACTOR AIR INTAKE PORTS

David E. Fields
Charles W. Miller

Date published: January 1985

Prepared for the
U.S. Department of Energy
Office of Breeder Reactor Technology Projects
FTP/A No. OH136

Project Monitor: J. L. Wantland

Prepared by the
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under Contract No. DE-AC05-84OR21400

MASTER

CONTENTS

	<u>Page</u>
LIST OF TABLES.	iii
ABSTRACT.	v
1. INTRODUCTION.	1
2. METHODOLOGY AND APPLICABILITY	2
3. PRIORITY 1 SCENARIO: ANALYSIS AND RESULTS.	9
4. PRIORITY 2 SCENARIO: ANALYSIS AND RESULTS.	11
5. PRIORITY 3 SCENARIO: ANALYSIS AND RESULTS.	13
6. EXTENSION OF PRIORITY 3 SCENARIO TO INCLUDE ACUTE RELEASES.	16
7. FEASIBILITY OF A MORE REFINED APPROACH.	16
REFERENCES.	22

LIST OF TABLES

<u>Table</u>		<u>Page</u>
1	Aerosol concentrations at selected air inlet ports is shown for a "priority one" release. The source strength is 1.9 kg/s and the source is located at the center of the steam generator building tower closest to the wash building (wind reference direction 180 degrees)	4
2	The scaling factor RF for wake-dominated air flow and diffusion is calculated for each wind direction, based on DS, the smallest building dimension perpendicular to the wind vector, and DL, the largest building dimension perpendicular to the wind vector.	12
3	Aerosol concentration at selected air inlet ports is shown for a "priority two" release. The source strength is 97.0 kg/s and the source is assumed located at the center of the steam generator building tower closest to the wash building (wind reference direction 180 degrees).	14
4	Aerosol concentration at selected air inlet ports is shown for a "priority three" release. The source strength is 1.9 kg/s and the source is located at the center of the steam generator building tower away from the wash building (wind reference direction 0 degrees).	17
5	Aerosol concentration at selected air inlet ports is shown as described in the extended discussion of "priority three" releases. The source strength is 97.0 kg/s and the source is assumed located at the center of the steam generator building tower closest to the wash building (wind reference direction 180 degrees).	19

CALCULATIONS OF SODIUM AEROSOL CONCENTRATIONS AT
BREEDER REACTOR AIR INTAKE PORTS

David E. Fields
Charles W. Miller

ABSTRACT

This report describes the methodology used and results obtained in efforts to estimate the sodium aerosol concentrations at air intake ports of a liquid-metal cooled, fast-breeder nuclear reactor. A range of wind speeds from 2-10 m/s is assumed, and an effort is made to include building wake effects which in many cases dominate the dispersal of aerosols near buildings. For relatively small release rates on the order of 1-10 kg/s, it is suggested that the plume rise will be small and that estimates of aerosol concentrations may be derived using the methodology of Wilson and Britter (1982), which describes releases from surface vents. For more acute releases with release rates on the order of 100 kg/s, much higher release velocities are expected, and plume rise must be considered. Both momentum-driven and density-driven plume rise are considered. An effective increase in release height is computed using the Split-H methodology with a parameterization suggested by Ramsdell (1983), and the release source strength was transformed to rooftop level. Evaluation of the acute release aerosol concentration was then based on the methodology for releases from a surface release of this transformed source strength.

Results described herein must be regarded as maximum aerosol concentrations, based on models derived from generic wind tunnel studies. More accurate and site-specific results may be obtained through wind tunnel simulations and through simulating emissions from release points other than those assumed here.

1. INTRODUCTION

Liquid-metal cooled nuclear reactors often use large quantities of sodium or sodium-potassium alloy, and evaluation of the possible consequences of a liquid metal fire, henceforth referred to as a sodium fire, is an important consideration of the design process. One facet of this evaluation is to determine the sodium aerosol concentration at the air intake ports. These ports are used for heat exchanger cooling, and blockage of a critical number of ports would lead to a significant cooling problem. To provide an added safety margin, extra cooling ports are included in the reactor design.

This report describes the methodology used and the results obtained in estimating the sodium aerosol concentrations at selected air intake ports of a liquid metal-cooled fast breeder nuclear reactor under medium wind-speed conditions during sodium aerosol fires. These calculations are important because they suggest that reactor cooling at safe levels may be possible even in the event of such fires. Building wake effects, which in many cases dominate the dispersal of aerosols near buildings, are included in these calculations. A proprietary reactor design was obtained, and the site was parameterized using architectural blueprints. These site parameters here serve as inputs for a methodology based on work by Wilson and Britter (1982), Briggs (1974), and Ramsdell (1983), which was used to determine the aerosol concentration values. Values were generated for a range of wind speeds from 2-10 m/s. Results described herein must be regarded as maximum aerosol concentrations, based on models derived from generic wind tunnel studies. More accurate and site-specific results may be obtained through wind tunnel simulations and through simulating emissions from release points other than those assumed here.

2. METHODOLOGY AND APPLICABILITY

It is generally agreed that wind tunnel experiments are the most reliable laboratory-scale method for predicting aerosol dispersion and aerosol concentrations in regions where building wake effects are dominant. In view of the complexity and expense of site-specific wind tunnel studies, generic wind tunnel studies have been performed that provide scaling factors and empirical coefficients that allow the prediction of maximum aerosol concentrations for general cases. One such study (Wilson and Britter, 1982) considers aerosol releases from surface and roof vents.

The ratio of the aerosol concentration CS (kg/m^3) at a building surface exhaust vent to the upper bound of the concentration C (kg/m^3) at a receptor point is shown (Wilson and Britter, 1982) to be

$$\frac{CS}{C} = \frac{KE}{B} \frac{R^2}{A}, \quad (1)$$

where

$$KE = (CS \ U \ A)/Q,$$

R = shortest distance between source and receptor, measured along building (m),

B = empirical constant of magnitude 9.0,

A = projected building frontal area (m^2),

U = windspeed at roof level far upwind of building (m/s),

Q = source intensity (kg/s).

Equation (1) and the expression for KE may be rearranged to yield

$$C = \frac{B \ Q}{UR^2}. \quad (2)$$

It is unlikely (except for very low wind speeds) that a significant fraction of aerosol particles will be transported against the prevailing wind. Although flow separation at roof and wall edge may occur in strong winds (Hosker, private communication), identification of the situations where this mechanism might lead to heightened inlet-port concentrations must be based on wind tunnel studies. The consideration

of wind direction is included by the introduction of a wind direction factor WDF. WDF is defined as $WDF = 1$ if the air inlet port lies in the downwind 180-degree sector from the release point, and otherwise by $WDF = 0$. The resulting equation for maximum aerosol concentration from a surface release with no plume rise is

$$C = \frac{B Q WDF}{UR^2} . \quad (3)$$

If plume rise is to be accounted for, it is necessary to compute an "effective" source strength normalized to the roof height and to use this normalized source strength in Eq. (3) to determine a concentration at points downwind. The sector average roof level concentration CC (kg/m^3) (for a downwind 22.5-degree sector) is given by the equation (Fields and Miller, 1980)

$$CC = \frac{2.032 Q}{xU\sigma_z} \exp - \frac{h^2}{2\sigma_z^2} , \quad (4)$$

where

x = source emission point to roof-edge distance (m),

σ_z = vertical dispersion coefficient (m),

h = plume rise (m), above the emission point. The height above the receptor point is determined from the receptor point elevation, given in Table 1.

The effective roof source strength QR for this concentration may be approximated by multiplying the concentration in Eq. (4) by the downwind plume areal cross section and the wind velocity. For the 22.5-degree sector plume, this correction yields

$$QR = 0.842 Q \exp - \frac{h^2}{2\sigma_z^2} . \quad (5)$$

Table 1. Aerosol concentration at selected air inlet ports is shown for a "priority one" release. The source strength is 1.9 kg/s and the source is located at the center of the steam generator building tower closest to the wash building (wind reference direction 180 degrees).

Port ^a No.	E ^a (m)	R ^a (m)	WD ^b (deg)	WDF ^c	Aerosol concentrations (kg/m ³) for wind speed U				
					U = 2 m/s	4 m/s	6 m/s	8 m/s	10 m/s
1	42.7	23.6	0	1.	1.5E-02	7.7E-03	5.1E-03	3.8E-03	3.1E-03
1	42.7	23.6	90	1.	1.5E-02	7.7E-03	5.1E-03	3.8E-03	3.1E-03
1	42.7	23.6	180	0.	0.0	0.0	0.0	0.0	0.0
1	42.7	23.6	270	0.	0.0	0.0	0.0	0.0	0.0
2	39.6	51.9	0	0.	0.0	0.0	0.0	0.0	0.0
2	39.6	51.9	90	1.	3.2E-03	1.6E-03	1.1E-03	7.9E-04	6.3E-04
2	39.6	51.9	180	1.	3.2E-03	1.6E-03	1.1E-03	7.9E-04	6.3E-04
2	39.6	51.9	270	0.	0.0	0.0	0.0	0.0	0.0
3	39.9	29.0	0	0.	0.0	0.0	0.0	0.0	0.0
3	39.9	29.0	90	0.	0.0	0.0	0.0	0.0	0.0
3	39.9	29.0	180	1.	1.0E-02	5.1E-03	3.4E-03	2.5E-03	2.0E-03
3	39.9	29.0	270	1.	1.0E-02	5.1E-03	3.4E-03	2.5E-03	2.0E-03
8#1	30.5	95.8	0	0.	0.0	0.0	0.0	0.0	0.0
8#1	30.5	95.8	90	1.	9.3E-04	4.7E-04	3.1E-04	2.3E-04	1.9E-04
8#1	30.5	95.8	180	1.	9.3E-04	4.7E-04	3.1E-04	2.3E-04	1.9E-04
8#1	30.5	95.8	270	0.	0.0	0.0	0.0	0.0	0.0
8#2	30.5	82.3	0	0.	0.0	0.0	0.0	0.0	0.0
8#2	30.5	82.3	90	1.	1.3E-03	6.3E-04	4.2E-04	3.2E-04	2.5E-04
8#2	30.5	82.3	180	1.	1.3E-03	6.3E-04	4.2E-04	3.2E-04	2.5E-04
8#2	30.5	82.3	270	0.	0.0	0.0	0.0	0.0	0.0

Table 1. (Continued)

Port ^a No.	E ^a (m)	R ^a (m)	WD ^b (deg)	WDF ^c	Aerosol concentrations (kg/m ³) for wind speed U				
					U = 2 m/s	4 m/s	6 m/s	8 m/s	10 m/s
6	30.5	35.0	0	1.	7.0E-03	3.5E-03	2.3E-03	1.7E-03	1.4E-03
6	30.5	35.0	90	1.	7.0E-03	3.5E-03	2.3E-03	1.7E-03	1.4E-03
6	30.5	35.0	180	0.	0.0	0.0	0.0	0.0	0.0
6	30.5	35.0	270	0.	0.0	0.0	0.0	0.0	0.0
7	30.5	41.7	0	1.	4.9E-03	2.5E-03	1.6E-03	1.2E-03	9.8E-04
7	30.5	41.7	90	1.	4.9E-03	2.5E-03	1.6E-03	1.2E-03	9.8E-04
7	30.5	41.7	180	0.	0.0	0.0	0.0	0.0	0.0
7	30.5	41.7	270	0.	0.0	0.0	0.0	0.0	0.0
Spare	30.5	37.0	0	1.	6.2E-03	3.1E-03	2.1E-03	1.6E-03	1.2E-03
Spare	30.5	37.0	90	1.	6.2E-03	3.1E-03	2.1E-03	1.6E-03	1.2E-03
Spare	30.5	37.0	180	0.	0.0	0.0	0.0	0.0	0.0
Spare	30.5	37.0	270	0.	0.0	0.0	0.0	0.0	0.0

^aElevation (E), port numbers, and source-to-receptor distance (R) values were taken from plant specifications and architectural drawings.

^bWind direction.

^cThe reference direction for wind velocity specification was assumed aligned along the axis of the reactor complex, with the wash building extended in the 180 degree direction (see Fig. 1). The wind direction factor, WDF, is defined by WDF = 1 if the air inlet port lies in the downwind 180-degree sector from the release point, and otherwise, by WDF = 0.

The value of the vertical dispersion coefficient σ_z in Eq. (5) is dependent on building roof wake effects. It may be approximated (Wilson and Britter, 1982) by

$$\sigma_z = 0.21 \text{ RF}^{0.25} x^{0.75} . \quad (6)$$

The scaling factor RF for wake-dominated air flow and diffusion (Wilson and Britter, 1982) is calculated for each wind direction, based on DS, the smallest building dimension perpendicular to the wind vector, and DL, the largest building dimension perpendicular to the wind vector. Its value is given by

$$\text{RF} = \text{DS}^{0.67} \text{DL}^{0.33} . \quad (7)$$

The amount of momentum-driven plume rise h above the emission point may be predicted (Ramsdell, 1983) from the exhaust port exit diameter D , the windspeed U , and the exhaust velocity W by the equation

$$h = 3 D W / U . \quad (8)$$

There exist, in addition to momentum-driven plume rise which results from the initial upward plume velocity, other mechanisms that increase the effective aerosol release-height. These other mechanisms, which are driven by density differences between the plume and the ambient air, result in a more gradual lofting of the plume in comparison to momentum plume rise. These density differences result from (1) temperature differences, (2) molecular weight differences, and (3) water droplet evaporation after plume emission. Briggs (1974) presents methods for estimating the plume rise from these effects.

Briggs' (1974) computes density-driven plume rise based on the parameter Δ_D , where Δ_D is defined by

$$\Delta_D = \Delta_T + \Delta_m + \Delta_w , \quad (9)$$

where

Δ_T = the temperature contribution to the relative density difference,

Δ_m = the molecular weight contribution, and

Δ_w = the liquid water contribution.

These contributions to Δ_D are evaluated as follows:

$$\Delta_T = -(c_{po}/c_p) (\Delta T/T) , \quad (10)$$

where

c_{po} = the specific heat capacity at constant pressure of the effluent,

c_p = the specific heat capacity of the ambient air
($c_p = 0.24$ cal/gm - °K),

ΔT = the difference between the effluent and ambient temperatures, and

T = the ambient absolute temperature;

$$\Delta_m = (1-28.9/m_o) , \quad (11)$$

where m_o is the reciprocal of the mean of the inverse molecular weight of the effluent; and

$$\Delta_w = 8 Q_w/Q_o , \quad (12)$$

where Q_w is the estimated mass flux of liquid water in the effluent and Q_o is the mass flux of the effluent.

Once parameter Δ_D is found, Briggs suggests that parameter F be computed using the equation

$$F = -2.6 \Delta_D Q_o , \quad (13)$$

and from this the density-driven plume rise Δh is given, for daytime conditions with the wind speed U greater than 3.5 m/s,

$$\Delta h = 21 F^{2/3} U, \quad (14)$$

and for nighttime conditions when the wind speed U is less than 3.5 m/s,

$$\Delta h = 19 F^{1/3}. \quad (15)$$

In summary, maximum aerosol concentrations expected on building surfaces from building surface releases with no plume rise may be determined using Eq. (3). If plume rise is expected, then Eqs. (5)-(8) may be used to estimate an effective source strength QR evaluated at the roof edge. This effective roof edge source strength may then be substituted into Eq. (3), where R in Eq. (3) becomes the receptor-to-roof edge distance. Eqs. (9)-(15) may be used to evaluate the magnitude of density-driven plume rise.

Even though zero aerosol concentrations will be predicted for receptor points having $WDF = 0$, small aerosol concentrations may indeed be measured. This is a result of complex building wake effects outside the range of applicability of the methodology described above. The method is also likely to give misleading results if the wind direction is highly variable, since such winds would disperse the aerosol over a much wider area.

Because transport of aerosols by momentum-driven plume rise, density-driven plume rise, and building wake effects are competing mechanisms, it seems reasonable in computing transport to evaluate those mechanisms having higher velocities first; therefore, momentum-driven plume rise is first considered, then building wake effect calculations are performed in evaluating receptor point concentrations.

3. PRIORITY 1 SCENARIO: ANALYSIS AND RESULTS

As an application of the methodology described in Chapter 2, we will consider a "priority 1" release. This release was specified as an example release by the reactor designer. The release consisted of the emission of 1.37×10^4 kg of sodium aerosol over a two-hour period. The source strength is therefore 1.9 kg/s. A convection-limited emission of zero exit velocity was assumed. The exit temperature was 204-260°C and the source was assumed located at the center of the steam generator building tower closest to the wash building (Fig. 1). This is one of two steam generator building towers, the high points in the reactor complex. A reference direction was chosen for specification of wind direction. The reference direction was assumed aligned along the axis of the reactor complex, with the wash building extending in the 180-degree direction. Directions are measured clockwise from the reference direction, which is assigned a value of 0 degrees. The release point was located in the steam generator building tower located in the wind reference direction of 180 degrees. Eight inlet ports were specified for the priority 1 scenario. These inlet ports will be referenced by port number and by the distance from the release point. Wind speeds ranging between 2 and 10 m/s, at increments of 2 m/s, were considered, because the building wake methodology is not expected to apply to wind speeds lower than 2 m/s, or to conditions of variable wind directions.

Table 1 summarizes the results of the aerosol concentration calculations described in Chapter 2 for a priority 1 release for selected ports described in proprietary architectural drawings. It should be emphasized that the concentration values shown are upper bounds for the nonzero values. Zero values were predicted for cases where WDF = 0. Initiation and termination of the aerosol concentration buildup at reactor inlet ports follows closely the profile of aerosol release at the emission points.

ORNL-DWG 83-17898

Fig. 1. Positions of the two steam generator building (SGB) towers are shown with respect to the other buildings of the reactor complex. This figure was abstracted from proprietary architectural drawings. The coordinate system has an arbitrary orientation, chosen to permit consideration of effects of winds from different directions (see text).

4. PRIORITY 2 SCENARIO: ANALYSIS AND RESULTS

"Priority 2" releases were much more acute than priority 1 releases; the specified aerosol release rate was 1364 kg in 14 s. This rate corresponds to a source strength of 97 kg/s. The exhaust port size was assumed to have a diameter of 1.93 m. This value corresponds to the 3.72-m^2 port (blow-out panel) area used by the reactor designers in exhaust velocity calculations. The specified peak exhaust velocity was 32.9 m/s, and a calculation of average exhaust velocity was made, using this value. Based on a triangular time dependence of pressure and with outflow velocity proportional to the square root of the differential pressure, the time-averaged outflow velocity is two thirds of the peak velocity, or 21.9 m/s. The specified exhaust temperature was 537°C. The values of R used for priority 2 calculations are the receptor point to roof edge distances, rather than the receptor point to emission point distance because it is necessary to use the effective roof-elevation source calculation for the rising plume.

The aerosol particle size and density have been specified by the reactor builder as 0.5 microns and 2.8 g/cm^3 . The corresponding particle fall velocity is less than 0.1 cm/s (Vanderhoven, 1968). With a typical reactor building dimension of 50 m, and a wind velocity of greater than 2 m/s, the plume will clear the building in less than 25 s, during which the particles will fall less than 3 cm. Using Eq. (8) and assuming a wind velocity range of from 2-10 m/s, the plume rise range between 12.7 and 63 m, much greater than the particle fall distance. Therefore particle fall is negligible in this case.

Table 2 presents values of the building dimensions DS and DL used in Eq. (7) and the corresponding values of RF for the four wind directions considered in priority 2 releases.

The release point, receptor point, and site parameterization for priority 2 releases corresponded closely to values used for Table 1, except that plume rise was considered in this case, and Eqs. (5)-(8) were applied to obtain effective roof-edge source strength values.

Table 2. The scaling factor RF for wake-dominated air flow and diffusion (Wilson and Britter, 1982) is calculated for each wind direction, based on DS, the smallest building dimension perpendicular to the wind vector, and DL, the largest building dimension perpendicular to the wind vector.

WD (day)	DS ^a (m)	DL ^a (m)	RF (m)
0	36.6	120.5	81.0
90	36.6	53.1	46.9
270	36.6	73.6	58.3
360	36.6	120.3	80.9

^aThese values are taken from plant specifications and architectural drawings.

Table 3 summarizes the results of the aerosol concentration calculations for a priority 2 release. Zero concentration values were predicted for cases where $WDF = 0$. This table indicates the advantage of having air intake ports located in varying directions from the emission point. It also suggests that advantages would accrue from providing the option for choosing the aerosol emission point, as well as the air intake point, based on the actual wind vector, in an accident situation.

For priority 2 releases, some plume rise due to density differences between the plume and the ambient air will occur. Momentum-driven transport will dominate, followed by building wake effects, followed by density-driven plume rise. The concentration values given in Table 3 are conservative (i.e., these concentration values are upper bound values) since density-driven plume rise effects are not included. For the priority 2 release, the temperature contribution is the most important of the three density mechanisms; values of the parameters in Eq. (9) are $\Delta_T = -1.8$, $\Delta_m = 0.2$, while Δ_w is approximately 0.0. The value of parameter F in Eq. (13) is 1086, and the density-driven plume rise Δh , in the absence of building wake effects, varies from 195 m (during low windspeed, nighttime conditions) to 1109 m (during low windspeed, daytime conditions). The corresponding value for winds of velocity 10 m/s and daytime conditions is 222 m. These values indicate that, for low wind speeds, the density-driven plume rise would significantly decrease concentrations predicted in the absence of consideration of this mechanism.

5. PRIORITY 3 SCENARIO: ANALYSIS AND RESULTS

The "priority 3" scenario corresponds closely to the priority 1 scenario. For the priority 3 event, the emission point was chosen on the alternate tower of the steam generator building, corresponding to wind direction 0 degrees. Site and wind parameters were determined, and the analyses were performed, in the same manner as described in Chapter 3 for a priority 1 scenario. The methodology described in this paper was developed for simple architectures, and its application to

Table 3. Aerosol concentration at selected air inlet ports is shown for a "priority two" release. The source strength is 97.0 kg/s and the source is assumed located at the center of the steam generator building tower closest to the wash building (wind reference direction 180 degrees).

Port ^a No.	E ^a (m)	R ^a (m)	WD ^b (deg)	WDF ^c	RF ^d	Aerosol concentrations (kg/m ³) for wind speed U				
						U = 2 m/s	4 m/s	6 m/s	8 m/s	10 m/s
1	42.7	9.8	0	1.	81.0	1.0E-21	7.7E-06	5.1E-03	4.3E-02	1.0E-01
1	42.7	9.8	90	1.	46.9	1.7E-28	1.6E-07	9.0E-04	1.6E-02	5.6E-02
1	42.7	9.8	180	0.	58.3	0.0	0.0	0.0	0.0	0.0
1	42.7	9.8	270	0.	80.9	0.0	0.0	0.0	0.0	0.0
2	39.6	38.2	0	0.	81.0	0.0	0.0	0.0	0.0	0.0
2	39.6	38.2	90	1.	46.9	1.1E-29	1.0E-08	6.0E-05	1.1E-03	3.7E-03
2	39.6	38.2	180	1.	58.3	9.6E-27	5.6E-08	1.3E-04	1.6E-03	4.9E-03
2	39.6	38.2	270	0.	80.9	0.0	0.0	0.0	0.0	0.0
3	39.9	15.3	0	0.	81.0	0.0	0.0	0.0	0.0	0.0
3	39.9	15.3	90	0.	46.9	0.0	0.0	0.0	0.0	0.0
3	39.9	15.3	180	1.	58.3	6.0E-26	3.5E-07	7.9E-04	1.0E-02	3.0E-02
3	39.9	15.3	270	1.	80.9	4.2E-22	3.2E-06	2.1E-03	1.8E-02	4.3E-02
8#1	30.5	82.1	0	0.	81.0	0.0	0.0	0.0	0.0	0.0
8#1	30.5	82.1	90	1.	46.9	2.5E-30	2.2E-09	1.3E-05	2.3E-04	8.0E-04
8#1	30.5	82.1	180	1.	58.3	2.1E-27	1.2E-08	2.7E-05	3.5E-04	1.1E-03
8#1	30.5	82.1	270	0.	80.9	0.0	0.0	0.0	0.0	0.0
8#2	30.5	68.6	0	0.	81.0	0.0	0.0	0.0	0.0	0.0
8#2	30.5	68.6	90	1.	46.9	3.6E-30	3.2E-09	1.8E-05	3.3E-04	1.1E-03
8#2	30.5	68.6	180	1.	58.3	3.0E-27	1.7E-08	3.9E-05	5.0E-04	1.5E-03
8#2	30.5	68.6	270	0.	80.9	0.0	0.0	0.0	0.0	0.0

Table 3. (Continued)

Port ^a No.	E ^a (m)	R ^a (m)	WD ^b (deg)	WDF ^c	RF ^d	Aerosol concentrations (kg/m ³) for wind speed U				
						U = 2 m/s	4 m/s	6 m/s	8 m/s	10 m/s
6	30.5	21.3	0	1.	81.0	2.2E-22	1.7E-06	1.1E-03	9.1E-03	2.2E-02
6	30.5	21.3	90	1.	46.9	3.7E-29	3.3E-08	1.9E-04	3.4E-03	1.2E-02
6	30.5	21.3	180	0.	58.3	0.0	0.0	0.0	0.0	0.0
6	30.5	21.3	270	0.	80.9	0.0	0.0	0.0	0.0	0.0
7	30.5	27.9	0	1.	81.0	1.3E-22	9.5E-07	6.3E-04	5.3E-03	1.3E-02
7	30.5	27.9	90	1.	46.9	2.1E-29	1.9E-08	1.1E-04	2.0E-03	6.9E-03
7	30.5	27.9	180	0.	58.3	0.0	0.0	0.0	0.0	0.0
7	30.5	27.9	270	0.	80.9	0.0	0.0	0.0	0.0	0.0
Spare	30.5	23.3	0	1.	81.0	1.8E-22	1.4E-06	9.1E-04	7.6E-03	1.9E-02
Spare	30.5	23.3	90	1.	46.9	3.1E-29	2.8E-08	1.6E-04	2.9E-03	1.0E-02
Spare	30.5	23.3	180	0.	58.3	0.0	0.0	0.0	0.0	0.0
Spare	30.5	23.3	270	0.	80.9	0.0	0.0	0.0	0.0	0.0

^aElevation (E), port numbers, and source-to-receptor distance (R) values were taken from plant specifications and architectural drawings.

^bWind direction.

^cThe reference direction for wind velocity specification was assumed aligned along the axis of the reactor complex, with the wash building extended in the 180 degree direction (see Fig. 1). The wind direction factor, WDF, is defined by $WDF = 1$ if the air inlet port lies in the downwind 180-degree sector from the release point, and otherwise, by $WDF = 0$.

^dValues of RF were taken from Table 2.

complex buildings, or to clusters of buildings, may be invalid. Thus, the uncertainties of values calculated for the priority 3 scenarios are greater than for priorities 1 and 2.

Table 4 summarizes the results of the priority 3 calculations. Differences between Tables 1 and 4 reflect the varying locations of the air intake vents with respect to the two towers of the steam generator building.

6. EXTENSION OF PRIORITY 3 SCENARIO TO INCLUDE ACUTE RELEASES

The priority 3 calculations were extended to include the acute release scenario described in Chapter 4. This situation is identical to the priority 2 release, except that the release is from the alternate tower (located on the 0-degree side of the steam generator building, away from the wash building). This release is from the same tower considered in Chapter 5.

Results of these calculations are provided in Table 5.

7. FEASIBILITY OF A MORE REFINED APPROACH

The methodology and analyses described in this report might be extended in several ways. Other wind speeds and directions might be considered. Investigation certainly should be made of the effects on the inlet port concentration of choosing other emission points and other emission vent diameters. As an indication of the value of such a calculation, one might consider restricting the emission vent diameter to achieve a higher exit velocity and greater plume rise. If the building would withstand the resulting pressure increase, intake port aerosol concentrations would be diminished.

Table 4. Aerosol concentration at selected air inlet ports is shown for a "priority three" release
The source strength is 1.9 kg/s and the source is located at the center of the steam generator
tower away from the wash building (wind reference direction 0 degrees).

Port ^a No.	E ^a (m)	R ^a (m)	WD ^b (deg)	WDF ^c	Aerosol concentrations (kg/m ³) for wind speed U				
					U = 2 m/s	4 m/s	6 m/s	8 m/s	10 m/s
1	42.7	51.9	0	1.	3.2E-03	1.6E-03	1.1E-03	7.9E-04	6.3E-04
1	42.7	51.9	90	1.	3.2E-03	1.6E-03	1.1E-03	7.9E-04	6.3E-04
1	42.7	51.9	180	0.	0.0	0.0	0.0	0.0	0.0
1	42.7	51.9	270	0.	0.0	0.0	0.0	0.0	0.0
2	39.6	23.6	0	0.	0.0	0.0	0.0	0.0	0.0
2	39.6	23.6	90	1.	1.5E-02	7.7E-03	5.1E-03	3.8E-03	3.1E-03
2	39.6	23.6	180	1.	1.5E-02	7.7E-03	5.1E-03	3.8E-03	3.1E-03
2	39.6	23.6	270	0.	0.0	0.0	0.0	0.0	0.0
3	39.9	29.0	0	1.	1.0E-02	5.1E-03	3.4E-03	2.5E-03	2.0E-03
3	39.9	29.0	90	0.	0.0	0.0	0.0	0.0	0.0
3	39.9	29.0	180	0.	0.0	0.0	0.0	0.0	0.0
3	39.9	29.0	270	1.	1.0E-02	5.1E-03	3.4E-03	2.5E-03	2.0E-03
8#1	30.5	55.6	0	0.	0.0	0.0	0.0	0.0	0.0
8#1	30.5	55.6	90	1.	2.8E-03	1.4E-03	9.2E-04	6.9E-04	5.5E-04
8#1	30.5	55.6	180	1.	2.8E-03	1.4E-03	9.2E-04	6.9E-04	5.5E-04
8#1	30.5	55.6	270	0.	0.0	0.0	0.0	0.0	0.0
8#2	30.5	42.1	0	0.	0.0	0.0	0.0	0.0	0.0
8#2	30.5	42.1	90	1.	4.8E-03	2.4E-03	1.6E-03	1.2E-03	9.6E-04
8#2	30.5	42.1	180	1.	4.8E-03	2.4E-03	1.6E-03	1.2E-03	9.6E-04
8#2	30.5	42.1	270	0.	0.0	0.0	0.0	0.0	0.0

Table 4. (Continued)

Port ^a No.	E ^a (m)	R ^a (m)	WD ^b (deg)	WDF ^c	Aerosol concentrations (kg/m ³) for wind speed U				
					U = 2 m/s	4 m/s	6 m/s	8 m/s	10 m/s
6	30.5	75.2	0	1.	1.5E-03	7.6E-04	5.0E-04	3.8E-04	3.0E-04
6	30.5	75.2	90	1.	1.5E-03	7.6E-04	5.0E-04	3.8E-04	3.0E-04
6	30.5	75.2	180	0.	0.0	0.0	0.0	0.0	0.0
6	30.5	75.2	270	0.	0.0	0.0	0.0	0.0	0.0
7	30.5	81.9	0	1.	1.3E-03	6.4E-04	4.2E-04	3.2E-04	2.5E-04
7	30.5	81.9	90	1.	1.3E-03	6.4E-04	4.2E-04	3.2E-04	2.5E-04
7	30.5	81.9	180	0.	0.0	0.0	0.0	0.0	0.0
7	30.5	81.9	270	0.	0.0	0.0	0.0	0.0	0.0
Spare	30.5	77.2	0	1.	1.4E-03	7.2E-04	4.8E-04	3.6E-04	2.9E-04
Spare	30.5	77.2	90	1.	1.4E-03	7.2E-04	4.8E-04	3.6E-04	2.9E-04
Spare	30.5	77.2	180	0.	0.0	0.0	0.0	0.0	0.0
Spare	30.5	77.2	270	0.	0.0	0.0	0.0	0.0	0.0

^aElevation (E), port numbers, and source-to-receptor distance (R) values were taken from plant specifications and architectural drawings.

^bWind direction.

^cThe reference direction for wind velocity specification was assumed aligned along the axis of the reactor complex, with the wash building extended in the 180 degree direction (see Fig. 1). The wind direction factor, WDF, is defined by $WDF = 1$ if the air inlet port lies in the downwind 180-degree sector from the release point, and otherwise, by $WDF = 0$.

Table 5. Aerosol concentration at selected air inlet ports is shown as described in the extended discussion of "priority three" releases. The source strength is 97.0 kg/s and the source is assumed located at the center of the steam generator building tower closest to the wash building (wind reference direction 180 degrees).

Port ^a No.	E ^a (m)	R ^a (m)	WD ^b (deg)	WDF ^c	RF ^d	Aerosol concentrations (kg/m ³) for wind speed U				
						U = 2 m/s	4 m/s	6 m/s	8 m/s	10 m/s
1	42.7	38.2	0	1.	81.0	6.9E-23	5.1E-07	3.4E-04	2.8E-03	6.9E-03
1	42.7	38.2	90	1.	46.9	1.1E-29	1.0E-08	6.0E-05	1.1E-03	3.7E-03
1	42.7	38.2	180	0.	58.3	0.0	0.0	0.0	0.0	0.0
1	42.7	38.2	270	0.	80.9	0.0	0.0	0.0	0.0	0.0
2	39.6	9.8	0	0.	81.0	0.0	0.0	0.0	0.0	0.0
2	39.6	9.8	90	1.	46.9	1.7E-28	1.6E-07	9.0E-04	1.6E-02	5.6E-02
2	39.6	9.8	180	1.	58.3	1.4E-25	8.4E-07	1.9E-03	2.4E-02	7.3E-02
2	39.6	9.8	270	0.	80.9	0.0	0.0	0.0	0.0	0.0
3	39.9	15.3	0	1.	81.0	4.3E-22	3.2E-06	2.1E-03	1.8E-02	4.3E-02
3	39.9	15.3	90	0.	46.9	0.0	0.0	0.0	0.0	0.0
3	39.9	15.3	180	0.	58.3	0.0	0.0	0.0	0.0	0.0
3	39.9	15.3	270	1.	80.9	4.2E-22	3.2E-06	2.1E-03	1.8E-02	4.3E-02
8#1	30.5	41.8	0	0.	81.0	0.0	0.0	0.0	0.0	0.0
8#1	30.5	41.8	90	1.	46.9	9.5E-30	8.6E-09	5.0E-05	8.9E-04	3.1E-03
8#1	30.5	41.8	180	1.	58.3	8.0E-27	4.6E-08	1.0E-04	1.4E-03	4.0E-03
8#1	30.5	41.8	270	0.	80.9	0.0	0.0	0.0	0.0	0.0
8#2	30.5	28.3	0	0.	81.0	0.0	0.0	0.0	0.0	0.0
8#2	30.5	28.3	90	1.	46.9	2.1E-29	1.9E-08	1.1E-04	1.9E-03	6.7E-03
8#2	30.5	28.3	180	1.	58.3	1.7E-26	1.0E-07	2.3E-04	2.9E-03	8.8E-03
8#2	30.5	28.3	270	0.	80.9	0.0	0.0	0.0	0.0	0.0

Table 5. (Continued)

Port ^a No.	E ^a (m)	R ^a (m)	WD ^b (deg)	WDF ^c	RF ^d	Aerosol concentrations (kg/m ³) for wind speed U				
						U = 2 m/s	4 m/s	6 m/s	8 m/s	10 m/s
6	30.5	61.4	0	1.	81.0	2.6E-23	2.0E-07	1.3E-04	1.1E-03	2.7E-03
6	30.5	61.4	90	1.	46.9	4.4E-30	4.0E-09	2.3E-05	4.1E-04	1.4E-03
6	30.5	61.4	180	0.	58.3	0.0	0.0	0.0	0.0	0.0
6	30.5	61.4	270	0.	80.9	0.0	0.0	0.0	0.0	0.0
7	30.5	68.1	0	1.	81.0	2.1E-23	1.6E-07	1.1E-04	8.9E-04	2.2E-03
7	30.5	68.1	90	1.	46.9	3.6E-30	3.2E-09	1.9E-05	3.3E-04	1.2E-03
7	30.5	68.1	180	0.	58.3	0.0	0.0	0.0	0.0	0.0
7	30.5	68.1	270	0.	80.9	0.0	0.0	0.0	0.0	0.0
Spare	30.5	63.4	0	1.	81.0	2.5E-23	1.9E-07	1.2E-04	1.0E-03	2.5E-03
Spare	30.5	63.4	90	1.	46.9	4.2E-30	3.7E-09	2.2E-05	3.9E-04	1.3E-03
Spare	30.5	63.4	180	0.	58.3	0.0	0.0	0.0	0.0	0.0
Spare	30.5	63.4	270	0.	80.9	0.0	0.0	0.0	0.0	0.0

^aElevation (E), port numbers, and source-to-receptor distance (R) values were taken from plant specifications and architectural drawings.

^bWind direction.

^cThe reference direction for wind velocity specification was assumed aligned along the axis of the reactor complex, with the wash building extended in the 180 degree direction (see Fig. 1). The wind direction factor, WDF, is defined by WDF = 1 if the air inlet port lies in the downwind 180-degree sector from the release point, and otherwise, by WDF = 0.

^dValues of RF were taken from Table 2.

It would also be valuable to examine the effects of low-speed and variable-direction winds using a plume trajectory model, in order to develop a more accurate prediction of expected intake port concentrations. Simultaneous consideration of momentum-driven plume rise, building wake effects, and density-driven plume rise would yield more realistic results than treating these competing processes sequentially, as was done in this work. Finally, it would be useful to consider the effects of sodium aerosol particle growth and agglomeration (Miller, Fields, and Wiseman, 1982). While it is unlikely that predicted concentrations would be greatly changed by considering the production of larger particles with greater fall velocities, any conclusions drawn about the expected intake port concentrations for low wind speeds would be much more defensible.

REFERENCES

- Briggs, G. A. 1974. Diffusion Estimation for Small Emissions, ATDL Annual Report, ATDL-106, Atmospheric Turbulence and Diffusion Laboratory, Oak Ridge, Tennessee.
- Fields, D. E. and C. W. Miller. 1980. User's Manual for DWNWIND - An Interactive Gaussian Plume Atmospheric Transport Model with Eight Dispersion Parameter Options, ORNL/TM-6874, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Hosker, R. 1984. Private communication, Atmospheric Turbulence Diffusion Laboratory.
- Miller, C. W., D. E. Fields, and P. J. Wiseman. 1982. "Comparison of Observed and Predicted Sodium Air and Ground Concentrations," Trans. Am. Nucl. Soc. 43:81-82.
- Ramsdell, J.V. 1983. Evaluation of the Split-H Approach to Modeling Non-Buoyant Releases from Vent Stacks, NUREG/CR-3016, U.S. Nuclear Regulatory Commission Report.
- Van der Hoven, I. 1968. "Deposition of Particles and Gases," ed. by D. H. Slade, Meteorology and Atomic Energy, TID-24190, U.S. Atomic Energy Commission, pp. 202-208.
- Wilson, D. J. and R. E. Britter. 1982. "Estimates of Building Surface Concentrations from Nearby Point Sources," Atmos. Environ. 16(11):2631-2646.

INTERNAL DISTRIBUTION

1. C. F. Baes III	22. F. R. O'Donnell
2. R. O. Chester	23. C. R. Richmond
3. A. C. Cooper	24. R. D. Sharp
4. C. J. Emerson	25. R. W. Sharpe
5-9. D. E. Fields	26. J. L. Wantland
10. W. O. Harms	27. Biology Division Library
11. J. T. Holdeman	28. DABTS Library
12. S. V. Kaye	29-30. Central Research Library
13. G. D. Kerr	31. Document Reference
14. D. C. Kocher	Section Y-12
15. F. Kornegay	32. Laboratory Records
16-20. C. W. Miller	33. Laboratory Records - RC
21. B. D. Murphy	34. ORNL Patent Section

EXTERNAL DISTRIBUTION

35. J. Brunnings, Atomics International, Rocketdyne Division, Rockwell International, 6633 Canoga Ave., Canoga Park, CA 91304
36. C. R. Dickson, National Oceanic and Atmospheric Administration, 550 Second Street, Idaho Falls, ID 83401
37. D. R. Ferguson, Argonne National Laboratory, 9700 S. Cass Ave., Argonne, IL 60439
38. Bruce Hicks, Atmospheric Turbulence and Diffusion Laboratory, 465 S. Illinois, Oak Ridge, TN 37830
39. Ray Hosker, Atmospheric Turbulence and Diffusion Laboratory, 465 S. Illinois, Oak Ridge, TN 37830
40. R. T. Lancet, Atomics International, Rocketdyne Division, Rockwell International, 6633 Canoga Ave., Canoga Park, CA 91304
41. J. C. Mills, Atomics International, Rocketdyne Division, Rockwell International, 6633 Canoga Ave., Canoga Park, CA 91304
42. J. Otter, Atomics International, Rocketdyne Division, Rockwell International, 6633 Canoga Ave., Canoga Park, CA 91304
43. W. R. Pendergrass, Atmospheric Turbulence and Diffusion Laboratory, 465 S. Illinois, Oak Ridge, TN 37830
44. J. Schwibach, Bundesgesundheitsamt, Ingolstadter Landstrasse 1, D-8042 Neuherberg, Federal Republic of Germany
45. G. L. Sherwood, MS B107, Office of Nuclear Energy, U.S. Department of Energy, Washington, DC 20545
46. I. Winkelmann, Bundesgesundheitsamt, Ingolstadter Landstrasse 1, D-8042 Neuherberg, Federal Republic of Germany
47. Office of Assistant Manager, Energy Research and Development, DOE-ORO, Oak Ridge, TN 37831
- 49-50. Technical Information Center, Oak Ridge, TN 37831