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A Simplified Model of Aerosol Removal by Containment Sprays

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Abstract

Spray systems in nuclear reactor containments are described. The scrubbing of aerosols from containment atmospheres by spray droplets is discussed. Uncertainties are identified in the prediction of spray performance when the sprays are used as a means for decontaminating containment atmospheres. A mechanistic model based on current knowledge of the physical phenomena involved in spray performance is developed. With this model, a quantitative uncertainty analysis of spray performance is conducted using a Monte Carlo method to sample 20 uncertain quantities related to phenomena of spray droplet behavior as well as the initial and boundary conditions expected to be associated with severe reactor accidents. Results of the uncertainty analysis are used to construct simplified expressions for spray decontamination coefficients. Two variables that affect aerosol capture by water droplets are not treated as uncertain; they are (1) `Q´, spray water flux into the containment, and (2) `H´, the total fall distance of spray droplets. The choice of values of these variables is left to the user since they are plant and accident specific. Also, they can usually be ascertained with some degree of certainty. The spray decontamination coefficients are found to be sufficiently dependent on the extent of decontamination that the fraction of the initial aerosol remaining in the atmosphere, m_f, is explicitly treated in the simplified expressions. The simplified expressions for the spray decontamination coefficient are:

$$\lambda(\mathrm{hr}^{-1}) = \lambda(m_f = 0.9)\,[\lambda(m_f)/\lambda(m_f = 0.9)]$$

where

$$\ln \lambda(m_f = 0.9) = A + B \ln Q + CH + DQ^2H + EQH^2 + FQ$$

$$\lambda(m_f)/\lambda(m_f = 0.9) = [a + b \log_{10} Q] \left[1 - \left(\frac{m_f}{0.9}\right)^c\right] + \left(\frac{m_f}{0.9}\right)^c$$

Parametric values for these expressions are found for median, 10 percentile and 90 percentile values in the uncertainty distribution for the spray decontamination coefficient. Examples are given to illustrate the utility of the simplified expressions to predict spray decontamination of an aerosol-laden atmosphere.

Contents

Contents (Concluded)

Figures

Figures (Continued)

Tables

Tables (Concluded)

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I. Introduction

Containment sprays have been an important feature of the containments of some pressurized water reactors for many years [1-4]. Drywell sprays, too, have been important engineered safety systems in boiling water reactors [5]. These systems have been installed in reactors as part of the systems to suppress steam pressurization during design basis loss-of-coolant accidents. That is, the systems are intended to supply enormous amounts of water to condense steam quite promptly after a hypothesized rupture of a large pipe in the reactor coolant system.

There has always been some consideration of the source term reduction capabilities of sprays in reactor containments. This attention has focused on the ability of spray droplets to dissolve molecular iodine from the containment atmosphere [1-4,6]. More recently, much greater attention has been given to the capabilities of containment sprays to remove aerosol particles from the atmosphere. Explicit accounting of these aerosol removal processes is taken in many modern severe accident analysis codes such as the Source Term Code Package [7] and CONTAIN [8].

Systematic consideration of the possible steps that could be taken to terminate or at least mitigate severe reactor accidents, so-called "accident management" strategies, have attached great significance to spray systems in reactor containments or drywells [9,10]. These systems can be used to cool the containment atmosphere and to reduce the possibility of long-term overpressurization. The spray systems would be used rather differently for accident management than was envisaged for mitigation of design basis accidents. Water flow rates needed for long-term cooling of the containment atmosphere would be much less than flows used to condense steam pressurization in a design-basis accident. Indeed, the spray systems might be used only intermittently following a severe reactor accident. The spray system could also be used to cleanse the containment atmosphere of radioactive particulate. Thus, even if rupture of the containment in a severe accident could not be prevented, the spray system could reduce substantially the consequences of the accident.

Spray systems have become of enough interest that there is a need for computational tools to analyze spray performance under severe accident conditions. Indeed, such models are found in systems-level accident analysis codes. These models are, however, inaccessible for routine use in engineering evaluations and regulatory decision making. A simplified equation that could be employed to make quick assessments of spray performance for source term attenuation would be of more use.

The formal differential equation that describes decontamination of an atmosphere by spray droplets is:

$$\frac{dM}{dt} = -\lambda M + \frac{dS}{dt} + \frac{dR}{dt}$$

where

M = mass of aerosol suspended in the containment atmosphere

Introduction

$\frac{dS}{dt}$ = rate at which aerosols are injected into the containment atmosphere

$\frac{dR}{dt}$ = rate at which aerosols are removed from the atmosphere by processes other than those brought on by the sprays

λ = rate constant for aerosol removal by sprays.

As will become more apparent in the discussions below, the rate of aerosol removal from the containment atmosphere by sprays is so much greater than the rates of removal by other processes in the steady state situations of interest here that dR/dt can be neglected. Similarly, the agglomeration of aerosol particles can be neglected. Removal rates by sprays are so much larger than the rates of agglomeration that the changes in the aerosol size distribution caused by agglomeration can often be neglected in comparison to the apparent changes in the size distribution brought about by spray removal of particles.

Source rates of aerosols into the containment, dS/dt, are strong functions of time. They vary, often dramatically, from accident-to-accident and plant-to-plant. For most purposes to which a simplified model of spray decontamination would be applied, sources of aerosols to the containment atmosphere would be assumed to be small or zero. That is, a typical issue to be addressed would involve the hypothesis that aerosol material has been injected into the containment atmosphere. It might then be asked how long a spray of some type must operate to achieve a specified decontamination level. This question is answered by:

$$DF = \exp(+\lambda t)$$

where

DF = the aerosol mass initially in the containment atmosphere divided by the aerosol mass present after spray operation for a time t

DF is usually called the "decontamination factor" and λ is often called the "decontamination coefficient."

The time of spray operation required to achieve a specified decontamination factor is given by $t = (1/\lambda) \ln(DF)$.

A long term, low-level aerosol source rate to the containment atmosphere is also of interest for some purposes. The steady-state aerosol mass in the containment atmosphere if a spray is operating is given by:

$$M(\text{steady-state}) = (1/\lambda)\ dS/dt$$

Clearly, the rate constant for aerosol removal from an atmosphere by a spray, λ, is a critical quantity. This rate constant will be shown to be a complicated function of the aerosol particle size distribution, the characteristics of the spray and the geometry of the containment. A simplified model of λ provides a simplified model of decontamination by sprays. The purpose of this report is to describe such a simplified model that can be used to estimate aerosol removal by sprays without the necessity of using detailed systems codes such as CONTAIN. It is emphasized that the simplified model of aerosol removal by containment sprays developed in this report is not intended to supplant the truly mechanistic models. Rather, the simplified model is intended to provide more readily available estimates of aerosol decontamination along with statistically based uncertainty bounds and confidence limits.

The formulation of a simplified model of decontamination by sprays done here follows a procedure previously used to formulate a simplified model of decontamination by water pools overlying core debris interacting with concrete [11]. A fairly detailed model based on the physical processes involved in decontamination by sprays is first developed. These physical phenomena and processes are discussed in the next chapter of this document. Uncertain features of the model are identified and a Monte-Carlo uncertainty analysis of decontamination by sprays is then conducted. The uncertainties in the model, the ranges of values the influential parameters have, and the distributions of these values are discussed in Chapter III. The Monte Carlo uncertainty analysis of the model predictions is discussed in Chapter IV. The results of the Monte-Carlo analyses are analyzed using non-parametric order statistics. These analyses yield a quantitatively characterized uncertainty distribution for the decontamination that can be achieved by sprays in a volume with a specified height and water flow. Results of analyses for various heights and water flows are used to develop simple expressions for the rate constant for aerosol removal in the fifth chapter of this report.

II. Phenomena and Processes Involved in Decontamination by Sprays

In this chapter, the phenomena and processes pertinent to spray decontamination are described. An important objective of this chapter is to identify models and quantities in the quantitative descriptions of these phenomena and processes that are uncertain. Uncertainties identified here are used to develop the probability distributions for decontamination by sprays presented in Chapter IV.

A. Spray Characteristics

A comprehensive survey of the sprays used in U.S. commercial nuclear power plants has not been attempted for this work. Two types of sprays--one type found especially in pressurized water reactors and one type found in some boiling water reactors--are described here to illustrate the nature of the spray systems in nuclear power plants.

A configuration typical for the containment of a pressurized water reactor is to locate spray nozzles on ring headers near the top of the containment. A particular configuration for a four-ring header system is:

Header	Radius (m)	Elevation (m)
A	2.48	40.5
B	7.72	39.0
C	12.87	37.3
D	18.13	36.0

A configuration found in a Mark III containment of a boiling water reactor is:

Header	Radius (m)	Elevation (m)
B	5.87	25.91
D	12.11	22.56
F	16.48	16.76

Some plants have only two headers. In most pressurized water reactors, either two or three pumps are available to supply water to the headers. Each pump will typically supply 157-189 liters/second. Design flow rates are as high as 330 liters/second. In the Mark III containment, usually, two pumps are available. A single pump can supply about 356 liters/second. With both pumps operating 713 liters/second could be supplied.

More than 300 spray nozzles are mounted on the headers. A Sprayco Model 1713-A or Model 1713 nozzle is widely used. Lists of plants using these nozzles are shown in Tables 1 and 2. The vendor for this nozzle is now Lechler Corporation. The designation for the nozzle is "373.084.xx.BN hollow core, ramp bottom, standard angle spray nozzle." A schematic diagram of the spray nozzle is shown in Figure 1. Also shown in this figure is a schematic diagram of the spray pattern produced by the nozzle when it is pointed downward. In this configuration, droplets emerge from

Table 1 Plants that use the Type 1713-A spray nozzle

Arkansas Units 1 and 2	Millstone
Bellefonte Units 1 and 2	Palisades
Braidwood Units 1 and 2	Prairie Island Units 1 and 2
Byron Units 1 and 2	Perry Units 1 and 2
Calvert Cliffs Units 1 and 2	Rancho Seco
Catawba Units 1 and 2	River Bend Units 1 and 2
Clinton Units 1 and 2	Salem Units 1 and 2
Comanche Peak Unit 1	San Onofre Units 2 and 3
Crystal River	Seabrook
D. C. Cook Units 1 and 2	Sequoyah Units 1 and 2
Davis Besse Unit 1	South Texas Project 1
Diablo Canyon Units 1 and 2	Susquehana Units 1 and 2
Indian Point Units 2 and 3	Three Mile Island Units 1 and 2
Kewaunee	Watts Bar Units 1 and 2
LaSalle County Units 1 and 2	WPPSS Unit 1
Foreign	
Takahama (Japan)	
Ringhals Unit 2 (Sweden)	
Almaraz Units 1 and 2 (Spain)	

Table 2 Plants that use the Type 1713 spray nozzle

Robinson Unit 2
Point Beach Units 1 and 2
Turkey Point Unit 3
Zion Units 1 and 2

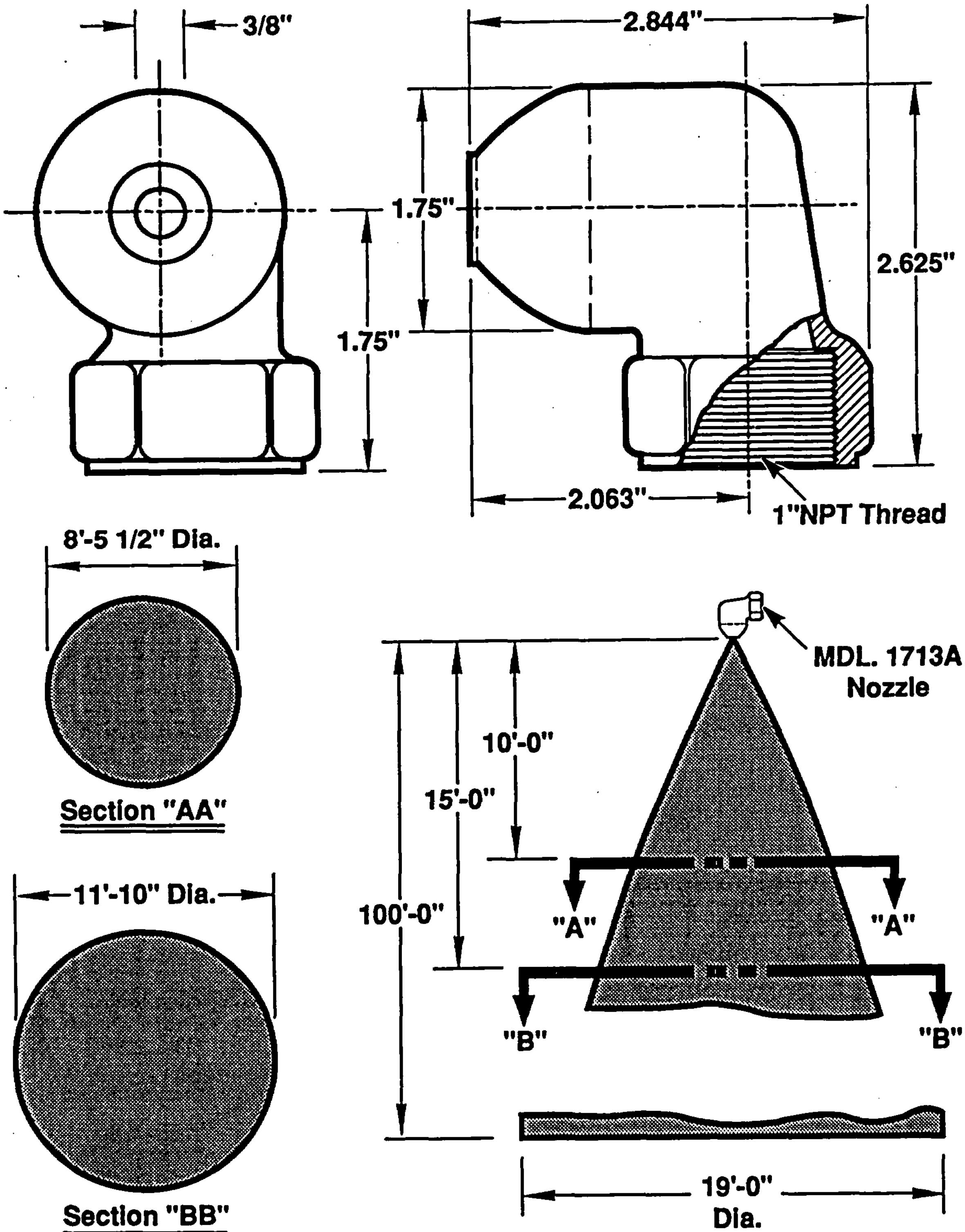

Figure 1 Diagram of the Model 1713-A spray nozzle and schematic diagram of the spray pattern

the nozzle within a conical envelope with a half angle of 30°. This angle varies by less than two degrees as the water pressure varies from 0.34 to 2.7 atmospheres. This is the configuration of the nozzle that is usually analyzed for spray performance. It is not, however, the only nozzle configuration used in spray systems. Other configurations are examined below in the discussion of droplet trajectories.

Water flow rate through the Model 1713-A nozzle as a function of water pressure is shown in Figure 2. Water droplets are initially within an annular conical region. Little of the flow is directly downward from the nozzle. As drag reduces the horizontal components of the droplet velocities, the unsprayed central region of the conical pattern begins to be occupied by falling droplets. The spatial variations in the flow claimed by the manufacturer are shown in Figure 3.

As will be discussed at length below, the distribution of droplet sizes varies with distance from the nozzle. The number-weighted size distribution of droplets at a particular location below a spray nozzle is shown in Figure 4. This distribution is distinctly log-normal in nature. Fit of the data shown in Figure 4 to a log-normal distribution yields:

$$Pr(D_d(e) < D) = 0.5(1 + erf(z))$$

where

$Pr(D_d(e) < D)$ = cumulative probability that the volume equivalent spherical diameter of a droplet, $D_d(e)$, is less than D

$erf(z)$ = error function of z = $\frac{2}{\sqrt{\pi}} \int_0^z \exp(-y^2)\, dy$

$z = \ln(D/\mu) / (\sqrt{(2)}\ \ln \sigma)$

μ = mean droplet size = 234 μm

σ = geometric standard deviation = 2.196

For the purposes of comparison, the size distribution of droplets produced by a similar though not identical nozzle also used in reactor containments (Whirljet Spray Nozzle 15215-1C-304SS-6.3) is shown in Figure 5. This droplet size distribution has a much more distinctly bimodal character than does the distribution of droplet sizes for the Model 1713-A nozzle.

The size distributions shown in Figures 4 and 5 are number distributions. It is not usual to specify spray nozzles for reactor containments in terms of such distributions. It is more common to specify that either the surface-area weighted mean or the volume weighted mean droplet size to be less than some minimum--usually less than 1000 μm. Surface area weighted and volume weighted distributions derived from the data in Figure 4 are shown in Figures 6 and 7, respectively. Note that these distributions sharply de-emphasize the contributions made to the distributions by the small

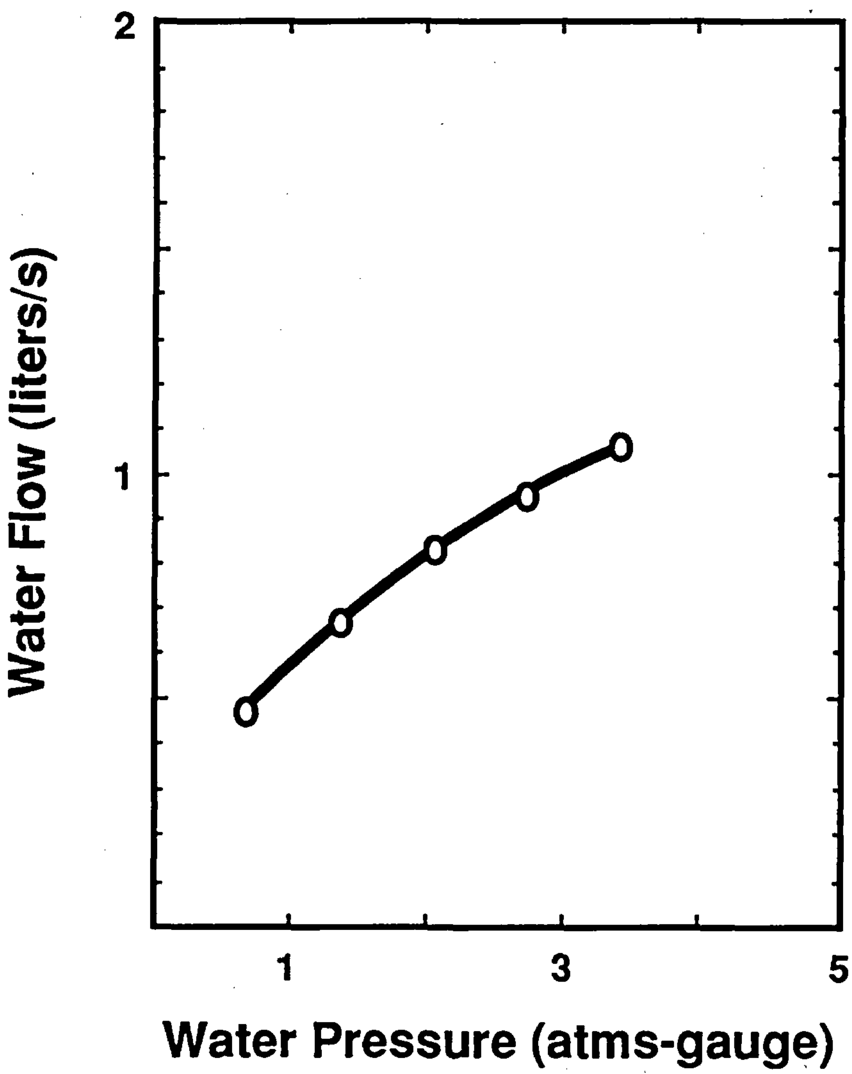

Figure 2 Volumetric flow rate of water through the Model 1713-A spray nozzle as a function of water pressure

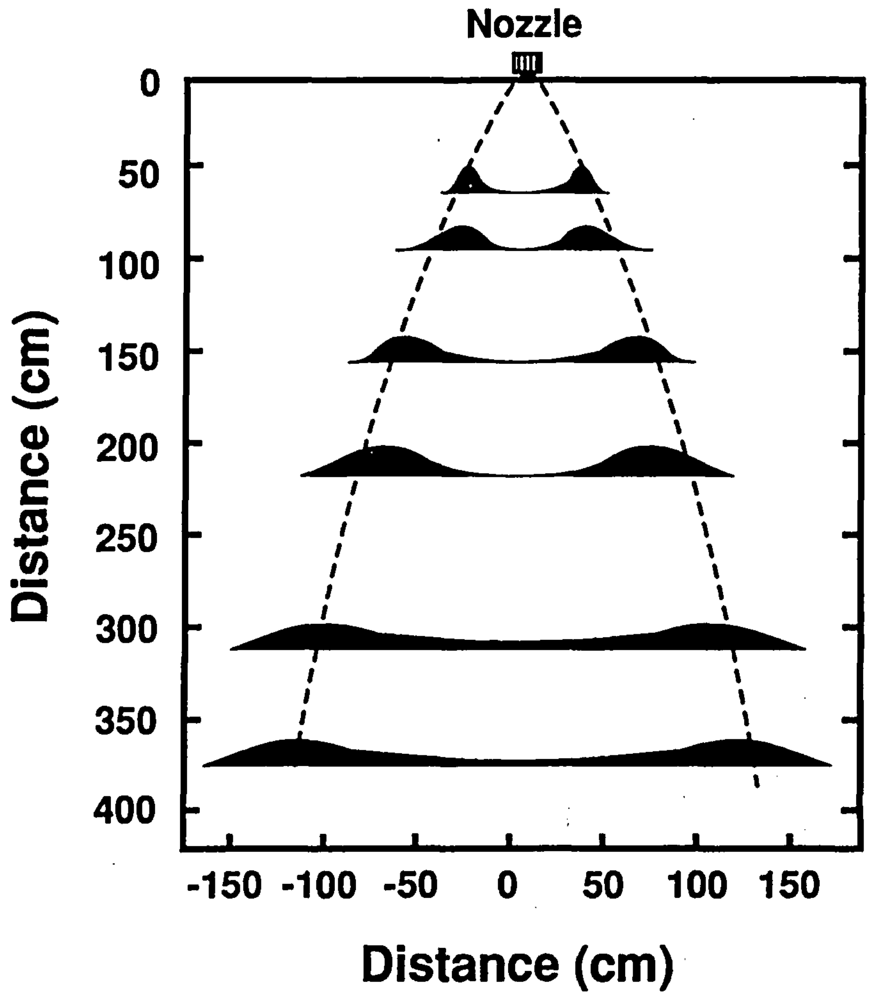

Figure 3 Spatial variation in water flow from a Model 1713-A spray nozzle

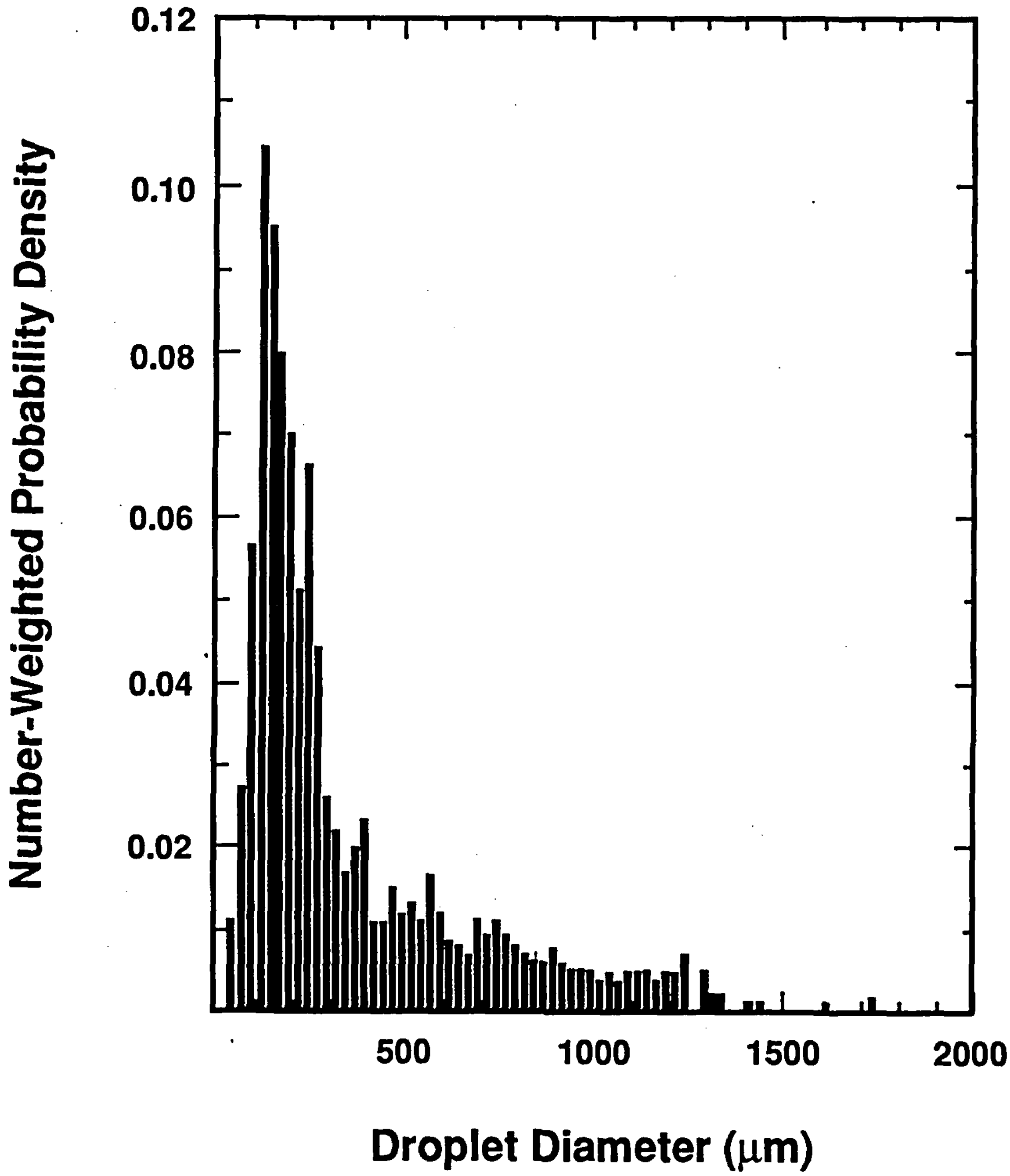

Figure 4 Size distribution of water droplets from a Model 1713-A spray nozzle

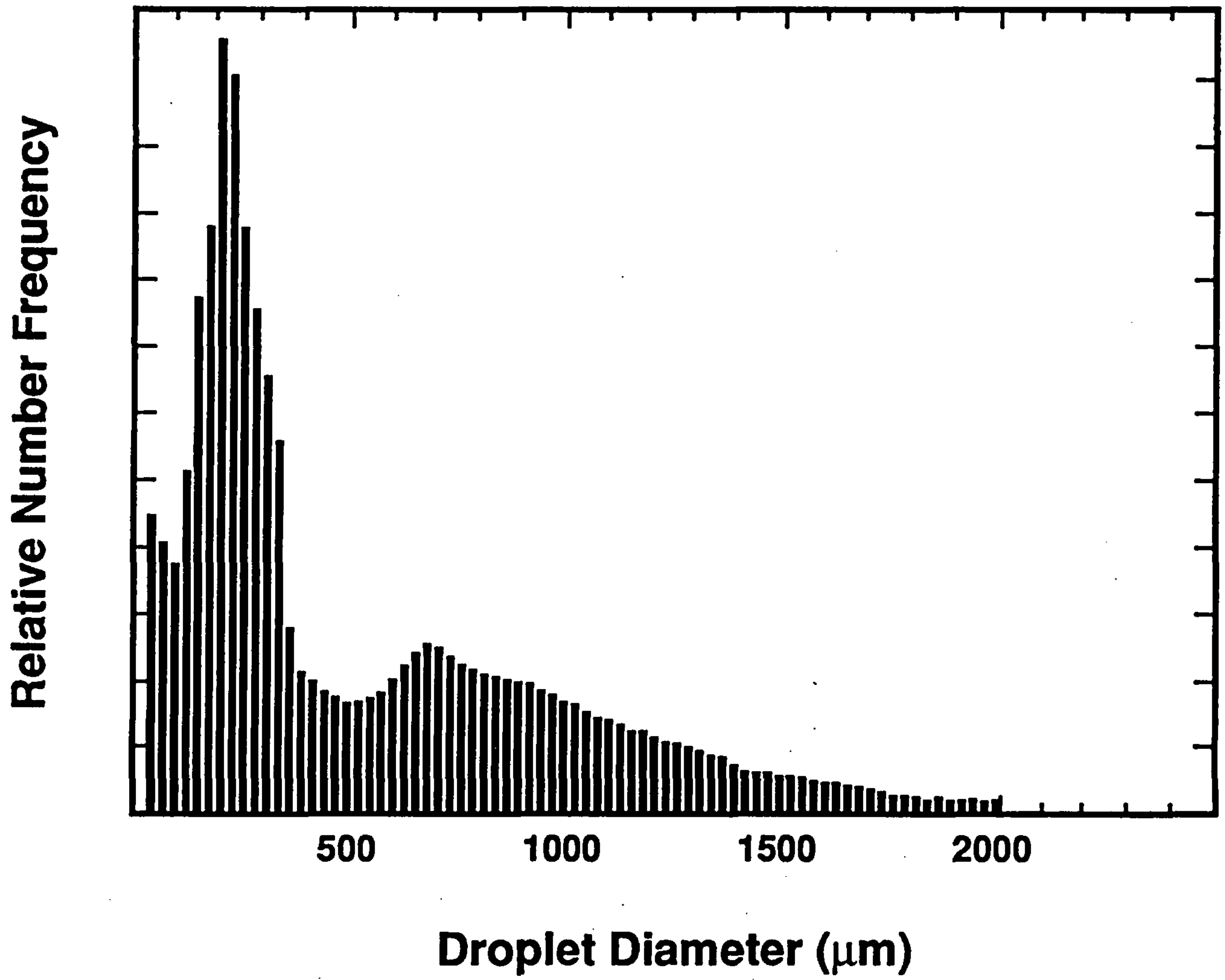

Figure 5 Size distribution of water droplets produced by a Whirljet Spray Nozzle Model 15215-1C-304SS-6.3

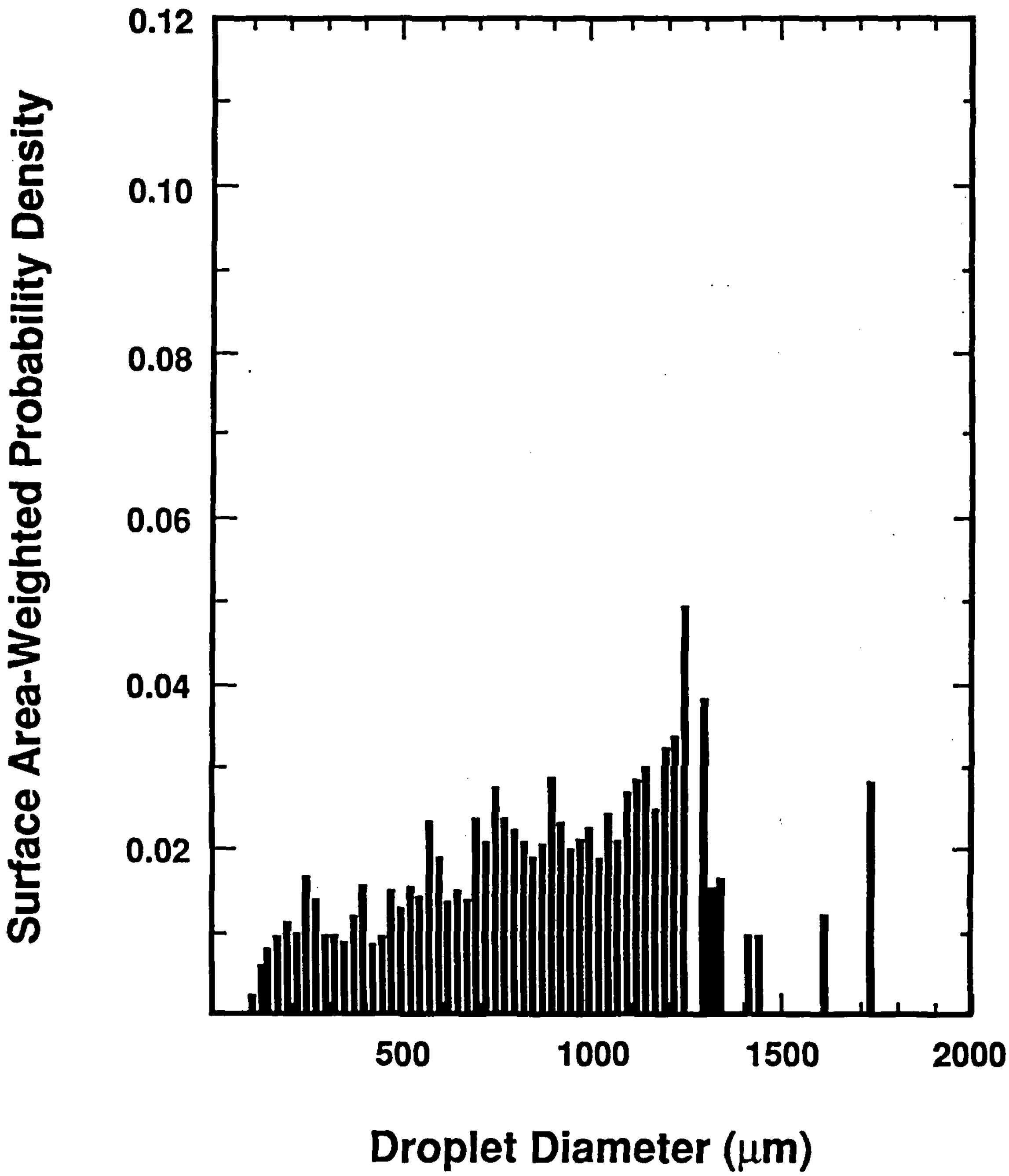

Figure 6 Surface area-weighted size distribution of water droplets from a Model 1713-A spray nozzle

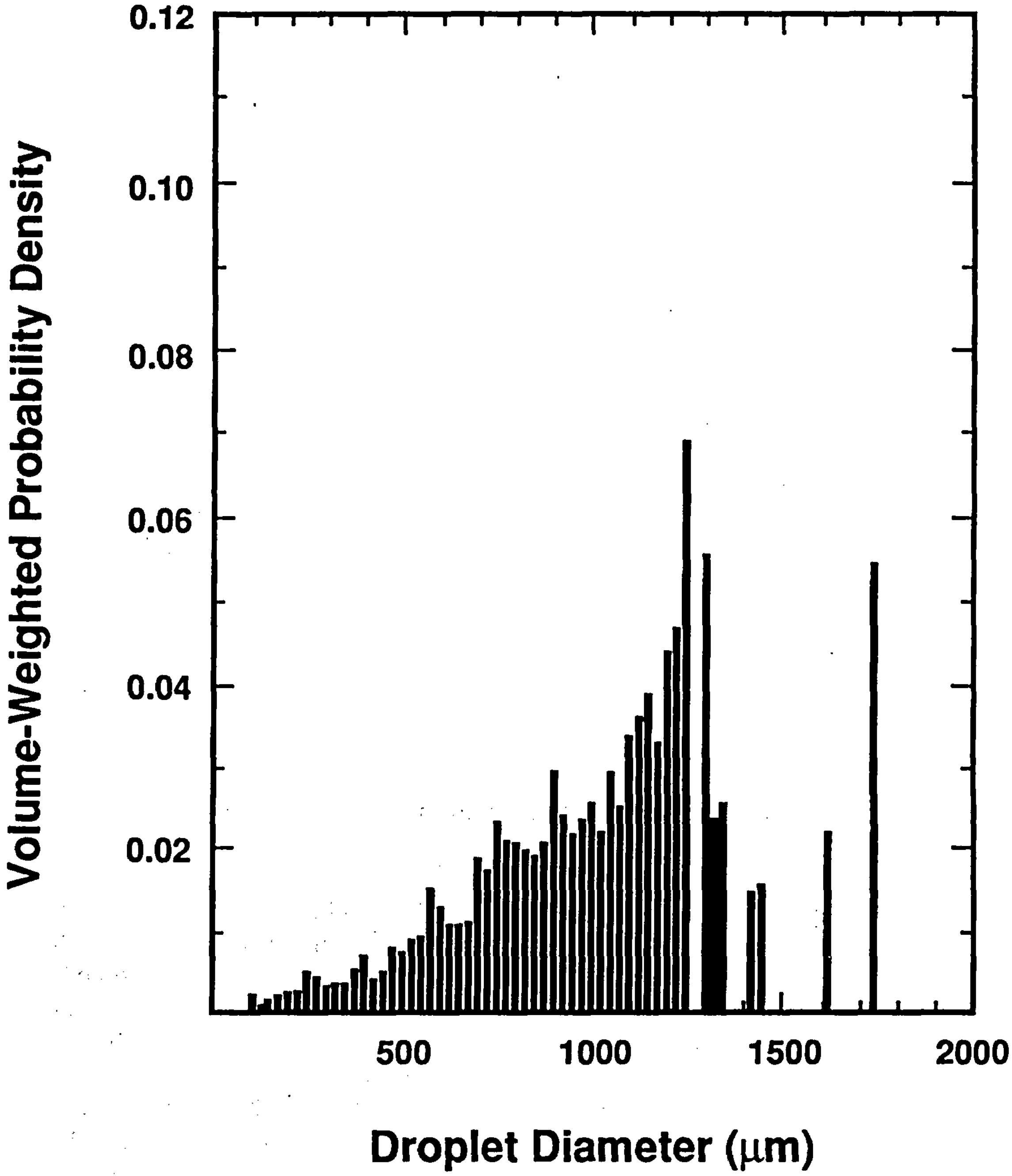

Figure 7 Volume-weighted size distribution of water droplets produced by a Model 1713-A spray nozzle

droplets. Small droplets, however, are important because, as will be described, they can be more efficient than large droplets at trapping aerosol particles.

The distribution shown in Figure 4 was obtained by the manufacturer using a photographic method. Powers and Reid [26] have criticized this method. They adopted a technique in which spray droplets were frozen in liquid nitrogen. The frozen droplets were then size classified with sieves. They found that the spray contained many more small droplets than would be indicated by results of the photographic method. A comparison of the number distribution calculated from their results and the number distribution obtained by photographic methods is shown in Figure 8. Powers and Reid attributed the differences between the distribution obtained with their freeze-and-sieve technique and the distribution obtained by the photographic technique to the inability to resolve small droplets in photographic images and the small sample size used in studies done with the photographic technique.

The freeze-and-sieve technique is, however, not without flaws. A most common source of error that may have affected results is that the sieving process can break particles [27]. This is especially likely to occur if the sieves are very heavily loaded with particulate as they apparently were in the investigations reported by Powers and Reid [26]. No evidence that the usual precautions were taken against particle breakage appears in the documentation of the work.

A remarkable finding of the studies of the 1713-A nozzle using the freeze-and-sieve method is that droplet distributions obtained with a boric acid-sodium hydroxide solution (3000 ppm boron; pH = 9.5) were much coarser than distributions obtained with tap water. Mass fraction distributions obtained in replicate experiments with the two liquids are shown in Table 3 and in Figure 9. Powers and Reid [26] could not offer a ready explanation for the differences in the droplet size distributions. Obvious differences in the properties of the two liquids (density, surface tension, viscosity etc.) seem too small to be responsible for such large differences in the droplet size distributions.

Discrepancies between droplet size distributions obtained by different measurement techniques and the apparent sensitivity of the droplet size distribution to some kinds of water contamination raise uncertainties in the droplet size distributions to be used in the analysis of spray decontamination of containment atmospheres.

A different type of spray nozzle (Spray Systems Co. Model 1-7G25) is shown in Figure 10. This is the type of spray nozzle used in the drywells of some Mark I boiling water reactors. Others use the rather similar Model 1-7G3 nozzle. This type of spray nozzle seems to be better suited than the 1713 or 1713-A nozzle for applications where the droplet fall distances are small. A fairly uniform spatial distribution of droplets is achieved after only a small fall distance. (In the Brown's Ferry Mark I boiling water reactors, headers for the spray nozzles are located 15.84 and 8.53 meters above the drywell floor.) The spray patterns for the nozzles are also shown in Figure 10. About 65 percent of the total water flow from a nozzle is within a central core 3.35 meters (11 feet) in diameter at a point 3.35 meters (11 feet) below the nozzle. The remaining 35 percent of the flow is in an annular region which has an outside diameter of 5.2 meters (17 feet) at 3.35 meters (11 feet) below the nozzle.

Flow rates through individual Model 1-7G25 and Model 1-7G3 nozzles as functions of the water pressure are shown in Figure 11. Total spray flow into the Mark I drywell is 517 liters/second in

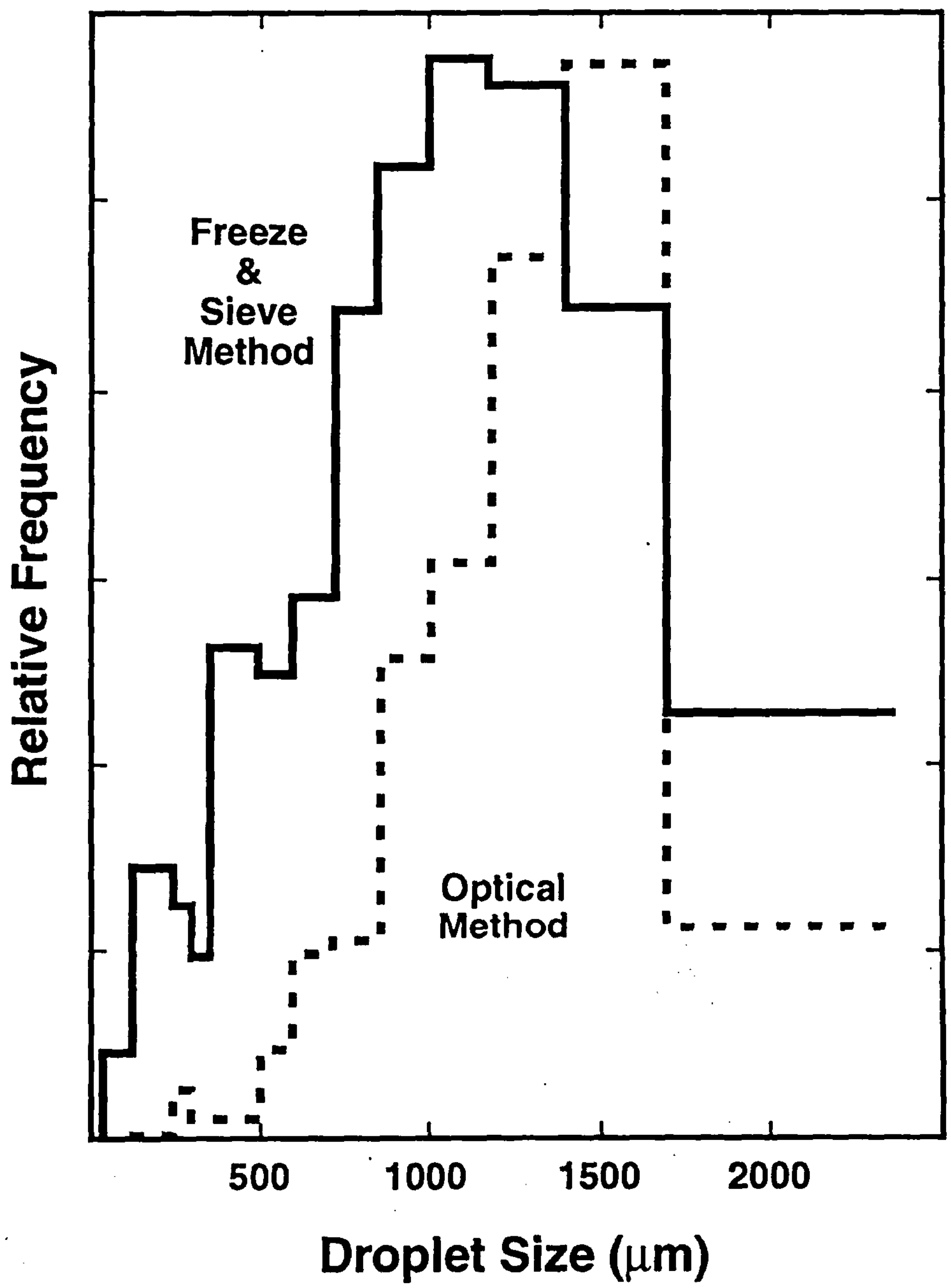

Figure 8 Comparison of mass-weighted distribution data obtained by the freeze-and-sieve technique and by the photographic technique for the Model 1713-A spray nozzle

Table 3 Droplet size data obtained by the freeze-and-sieve method [26] mass on screen (g)*

Nozzle	Test 1a 1713-A	Test 1b 1713-A	Test 2a 1713-A	Test 2b 1713-A	Test 3a 1-7G3	Test 3b 1-7G3	Test 4a 1-7G3	Test 4b 1-7G3
Solution	tap water	tap water	boric acid -NaOH	boric acid -NaOH	tap water	tap water	boric acid -NaOH	boric acid -NaOH
Screen Opening (μm)								
2360	154.3	231.5	231.5	540.1				
1700	2546.0	3857.5	3857.5	6403.5			154.3	0
1400	4937.6	6172.0	6094.9	8177.9			154.3	77.2
1180	6249.2	6712.1	5400.5	6789.2	77.2		231.5	77.2
1000	6403.5	6326.3	4328.4	5477.7	77.2	77.2	77.2	77.2
850	5786.3	5323.4	3086.0	4089.0	231.5	154.3	231.5	231.5
710	4937.6	4011.8	1851.6	2546.0	231.5	77.2	540.1	540.1
600	3240.3	4011.8	1003.0	1465.9	385.8	231.5	925.8	848.7
500	2777.4	2546.0	694.4	1080.1	540.1	462.9	1311.6	1388.7
355	2931.7	2160.2	462.9	848.7	1080.1	1234.4	2468.8	3008.9
300	1080.1	771.5	154.3	308.6	462.9	617.2	1080.1	1234.4
250	1388.7	1003.0	231.5	385.8	462.9	462.9	462.9	462.9
125	1620.2	1234.4	154.3	308.6	231.5	154.3	462.9	771.5
pan	540.1	385.8	77.2	308.6	308.6	231.5	231.5	308.6
μ**	899	941	1295	1214	426	399	469	-
σ_g**	2.192	1.928	1.637	1.710	1.654	1.490	1.577	-

*Taken at a location 86 cm radially displaced from the axis of the nozzle and 305 cm below the nozzle.
**mean, μ, and geometric standard deviation obtained by a least squares fit to a log-normal distribution.

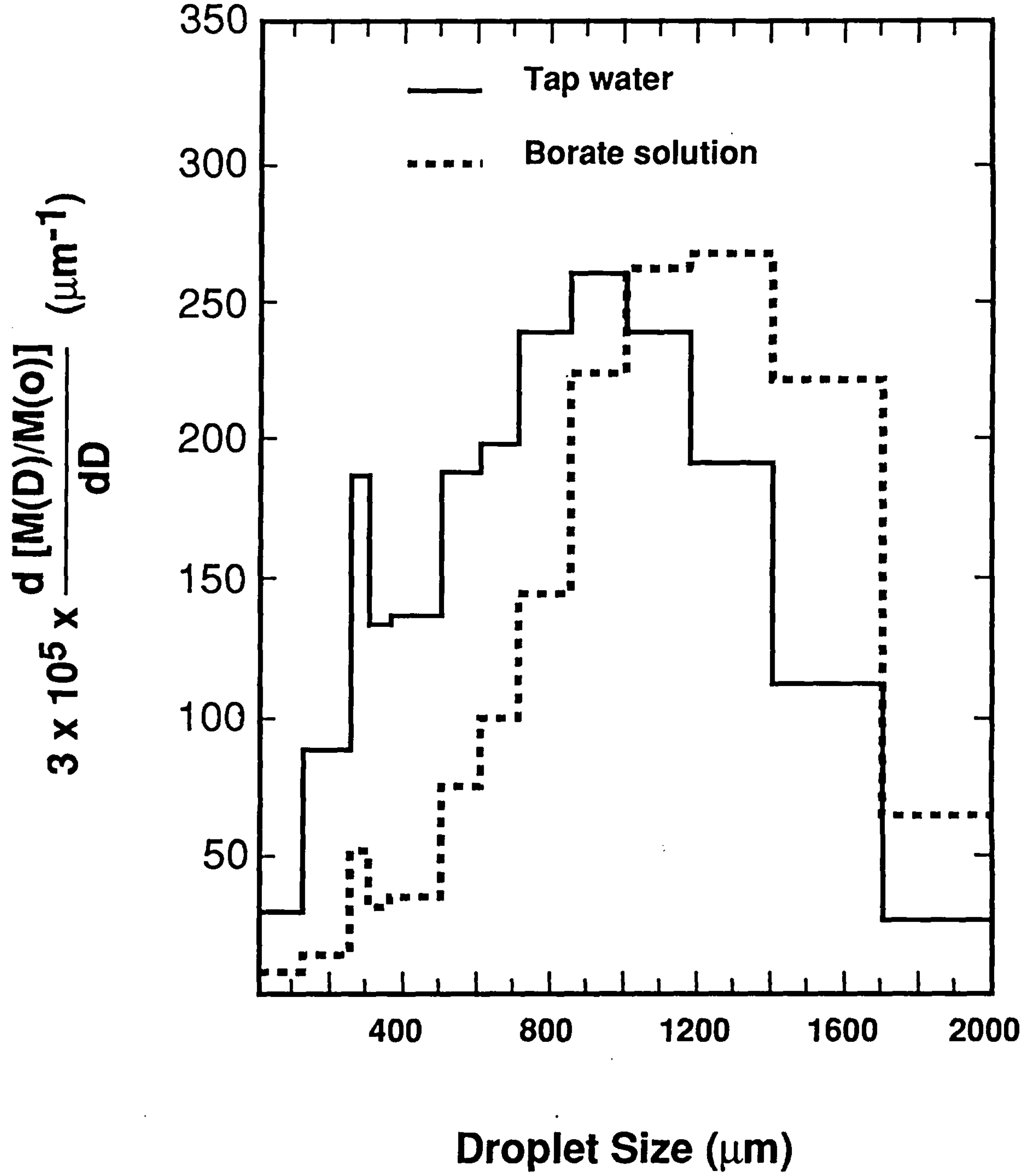

Figure 9 Comparison of mass distribution data obtained by the freeze-and-sieve technique for the Model 1713-A spray nozzle using tap water and a boric acid-sodium hydroxide solution

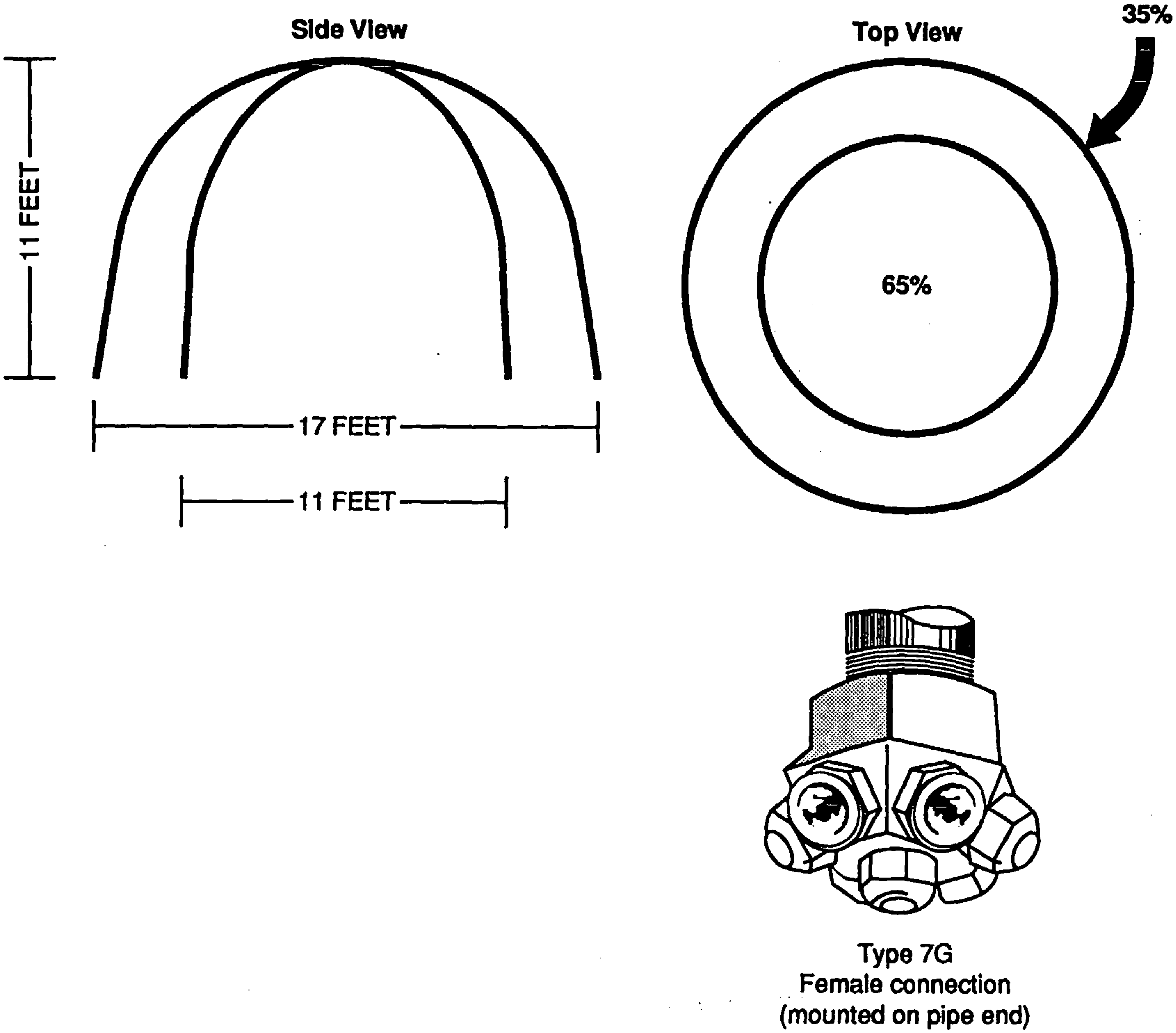

Figure 10 Schematic diagram of the Model 1-7G25 spray nozzle and the spray pattern it produces

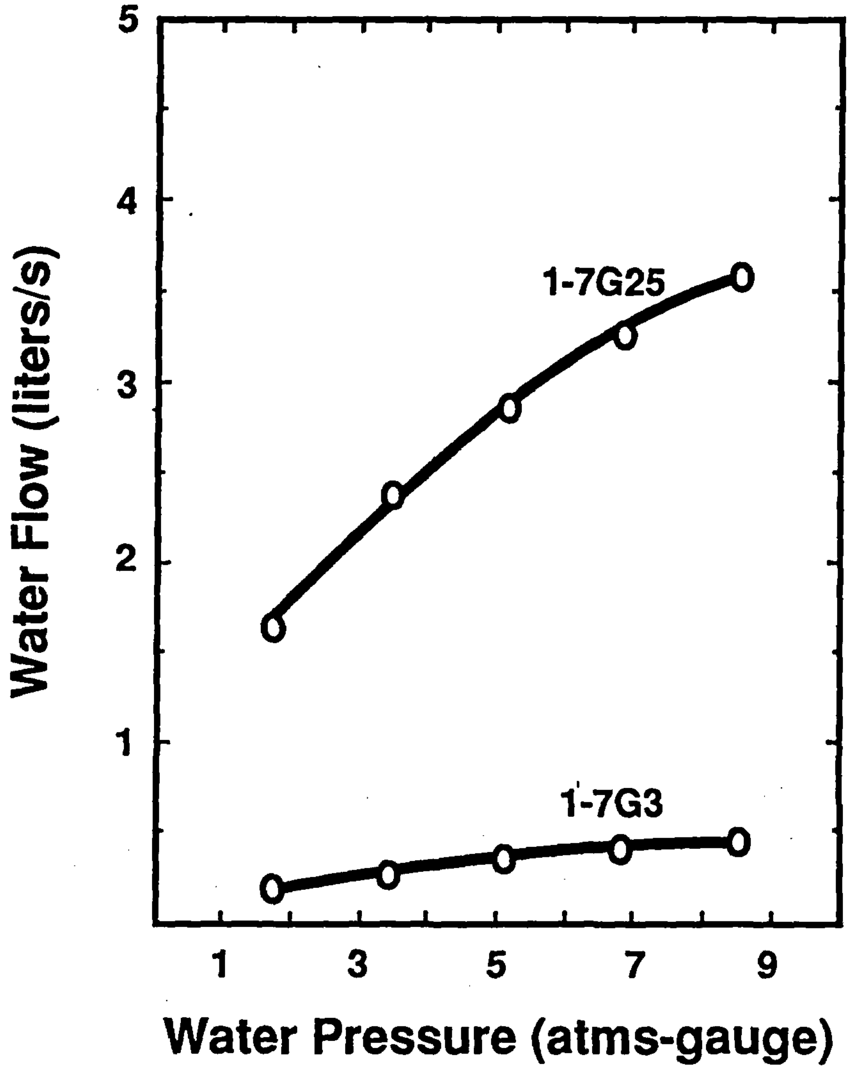

Figure 11 Volumetric flow as a function of water pressure for the Model 1-7G25 and the Model 1-7G3 spray nozzles

Units 1 and 2 at Brown's Ferry and 577 liters/second in Unit 3. These flow rates are not, however, typical for all Mark I drywells. Some plants have reduced the available flow to as low as 57 liters/second to reduce the risk of underpressurization of the drywell. At Brown's Ferry, interlocks prevent actuation of the drywell sprays if the drywell is not at a positive pressure or the core is not at least 2/3 covered with water. Note also that, to the author's knowledge, sprays cannot operate in a Mark I boiling water reactor if off-site electrical power is not available.

The volume-weighted mean droplet size produced by the Model 1-7G25 nozzle as functions of water pressure are shown in Figure 12. Also shown in this figure is the volume weighted mean droplet size produced by the similar, though smaller, Model 1-7G3 nozzle which is also of interest [26,28]. Detailed droplet size data are not available for the Model 1-7G25 spray nozzle. Droplet size data for the Model 1-7G3 nozzle obtained by the freeze-and-sieve method [26] are shown in Table 3 and in Figure 13. Note that the droplets are somewhat smaller for Model 1-7G3 nozzle than for the Model 1713-A nozzle. Again, note that the boric acid-sodium hydroxide solution yielded somewhat larger droplets than did tap water. The effect is, however, not as large as it is for the Model 1713-A spray nozzle.

The distributions of droplet sizes are not readily described in terms of conventional lognormal distributions. In summary, it is evident that the knowledge of these droplet size distributions is not thorough. There is at least some evidence that the size distributions are sensitive to contamination of the liquid. Certainly, when sprays are used to decontaminate containment atmospheres the water will become contaminated with a variety of materials and at concentrations that could be higher than the concentration of the boric acid-sodium hydroxide solution used in the experiments by Powers and Reid. Moreover, in most spray systems, contaminated water is recirculated from a sump in the containment through the spray headers. The effects of contaminants in sump waters on droplets sizes are, of course, not known.

B. Droplet Shapes

Water droplets falling through a gaseous atmosphere do not adopt a tear-drop shape. If big-enough, the drops can, as a first approximation, be considered to be oblate ellipsoids with semi-major axis a and semi-minor axis b. Pruppacher and Beard [12] have proposed the correlation for droplet eccentricity at atmospheric pressure:

$$1/E = b/a = \begin{cases} 1.030 - 0.62\, D_d(e) & \text{for } 0.1 \le D_d(e) \le 0.9 \text{ cm} \\ 1.00 & \text{for } D_d(e) < 0.1 \text{ cm} \end{cases}$$

where

E = a/b = eccentricity

$D_d(e)$ = diameter (cm) of the spherical droplet that would have the same volume

$= 2\, a / E^{1/3}$

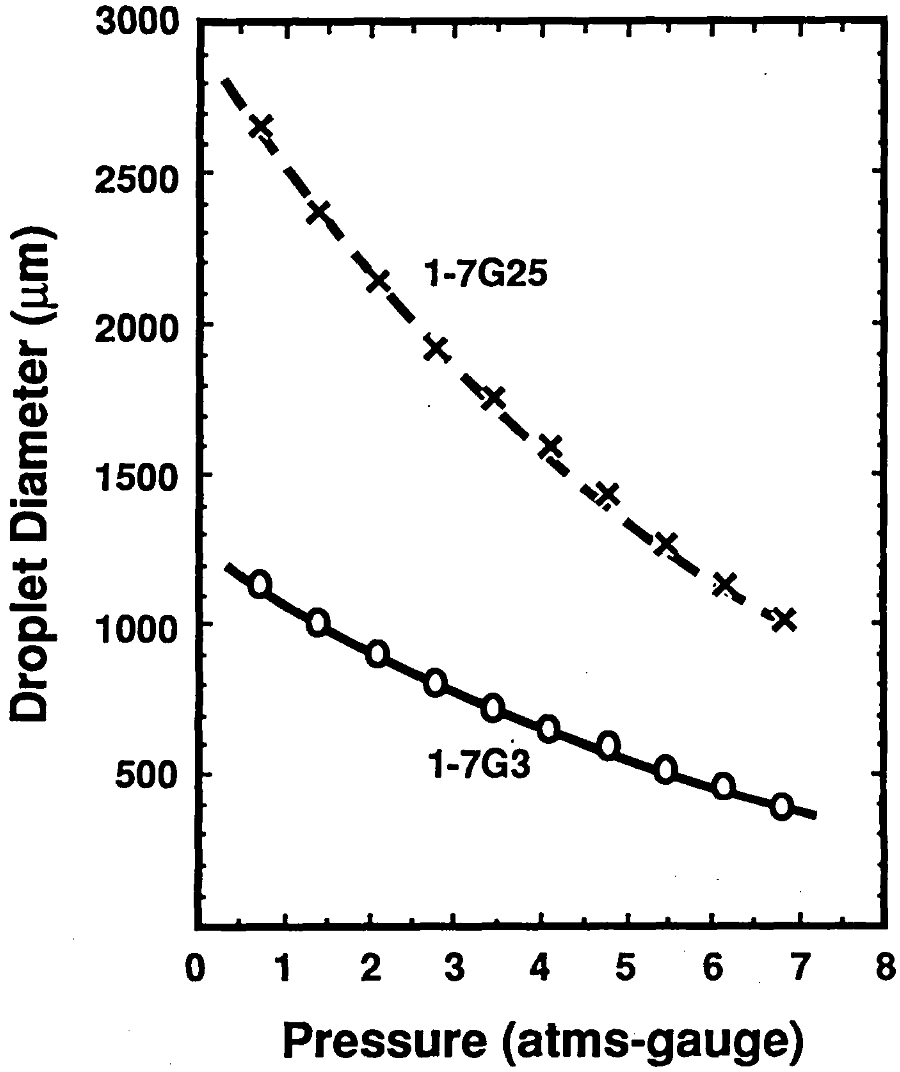

Figure 12 Volume weighted mean droplet sizes produced by the Model 1-7G25 and Model 1-7G3 spray nozzles as functions of water pressure

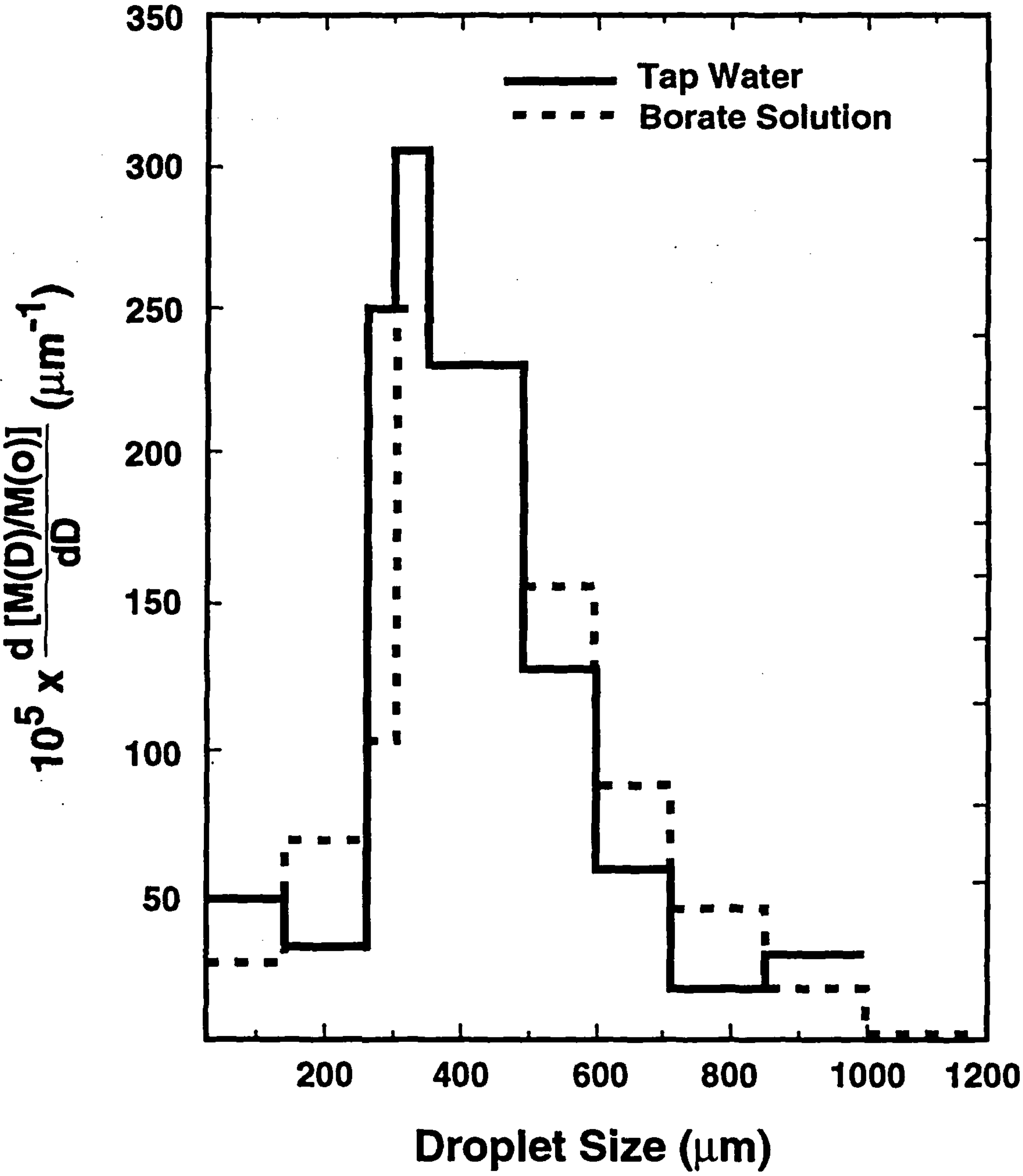

Figure 13 Mass distribution data obtained by the freeze-and-sieve method for the Model 1-7G3 spray nozzle using tap water and a boric acid-sodium hydroxide solution

The surface area of the oblate ellipsoid is:

$$A = 2\pi a^2 + \pi \left\{ \frac{ab}{\sqrt{E^2 - 1}} \ln \left[\frac{E + \sqrt{E^2 - 1}}{E - \sqrt{E^2 - 1}} \right] \right\}$$

This area can be compared to the area of the volume-equivalent sphere which is $4\pi a^2/E^{2/3} = \pi D_d^2(e)$.

With the Pruppacher and Beard correlation it is calculated that only the largest droplets produced by reactor sprays are distorted significantly from spherical. Unfortunately, there is no data base to validate this conclusion for conditions different than air at one atmosphere.

A somewhat better approximation for drop shape is to consider the droplet to be formed by two hemi-ellipsoids with semi-minor axes b_1 and b_2 and a common semi-major axis a as shown in Figure 14. Correlations for the droplet dimensions are [13]:

$$(b_1 + b_2) / 2a = \begin{cases} \sim 1.0 & \text{for } E_o \leq 0.4 \\ 1.0 / \left(1.0 + 0.18(E_o - 0.4)^{0.8}\right) & \text{for } 0.4 < E_o \leq 8 \end{cases}$$

$$b_1 / (b_1 + b_2) = \begin{cases} 0.5 & \text{for } E_o \leq 0.5 \\ 0.5 / \left(1.0 + 0.12(E_o - 0.4)^{0.8}\right) & \text{for } 0.5 < E_o \leq 8 \end{cases}$$

where

E_o = Eotvos number = $g(\rho_\ell - \rho_g)D_d(e) / \sigma_\ell$

g = acceleration due to gravity

ρ_ℓ = density of droplet liquid

ρ_g = density of the gas phase

σ_ℓ = surface tension of the droplet liquid

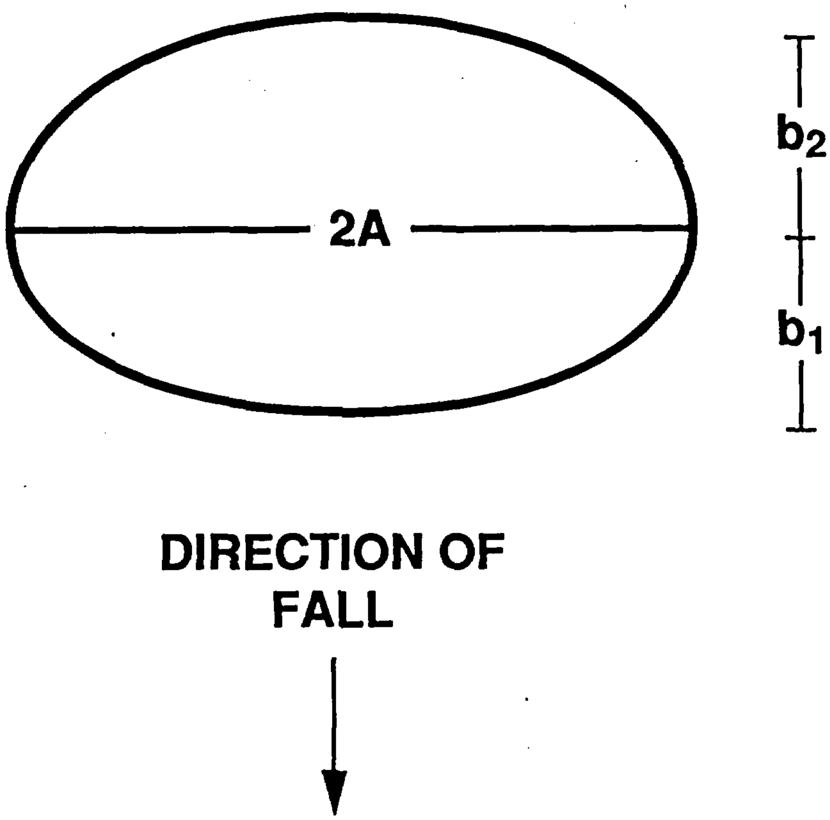

Figure 14 Schematic diagram of a two hemi-ellipsoid approximation for droplet shape

$$D_d(e) = 2a / E'^{1/3}$$

$$E' = \text{effective eccentricity} = \left[(b_1 + b_2) / 2a\right]$$

The surface area of a two hemi-ellipsoid droplet is given by:

$$A = 2\pi a^2 + \frac{\pi}{2}\left\{(b_1{}^2 / e_1) \ln\left[\frac{1 + e_1}{1 - e_1}\right] + (b_2{}^2 / e_2) \ln\left[\frac{1 + e_2}{1 - e_2}\right]\right\}$$

where

$$e_1 = \left[1 - b_1{}^2 / a^2\right]^{1/2}$$

$$e_2 = \left[1 - b_2{}^2 / a^2\right]^{1/2}$$

The surface area of the volume-equivalent sphere is $4\pi a^2/E'^{2/3}$.

Surface areas and eccentricities predicted with the two correlations are shown as functions of the diameter of the spherical droplet with the equivalent volume in Figure 15. Again, it is apparent that at atmospheric pressure, droplets of pure water produced by containment sprays distort little. Contamination of the water by species that affect surface tension is predicted to cause more significant distortion of the droplets.

C. Droplet Terminal Velocities

Clift, Grace and Weber [13] note that the data base for terminal velocities of water droplets is not large. Most of the available data are for raindrops in air. There appear to be no data for water drops falling through atmospheres of the type expected to exist in nuclear reactor containments during severe accidents. Three correlations of the terminal velocities of water drops are:

- Model A: [14]

$$Re_T = \exp\left[-3.126 + 1.01 \ln N_D - 0.01912 (\ln N_D)^2\right]$$
$$\text{for } 2.4 < N_D < 10^7;\ 0.1 < Re_T < 3550$$

where

$$Re_T = \text{terminal Reynolds number} = U_T\, \rho_g\, D_d(e) / \mu_g$$

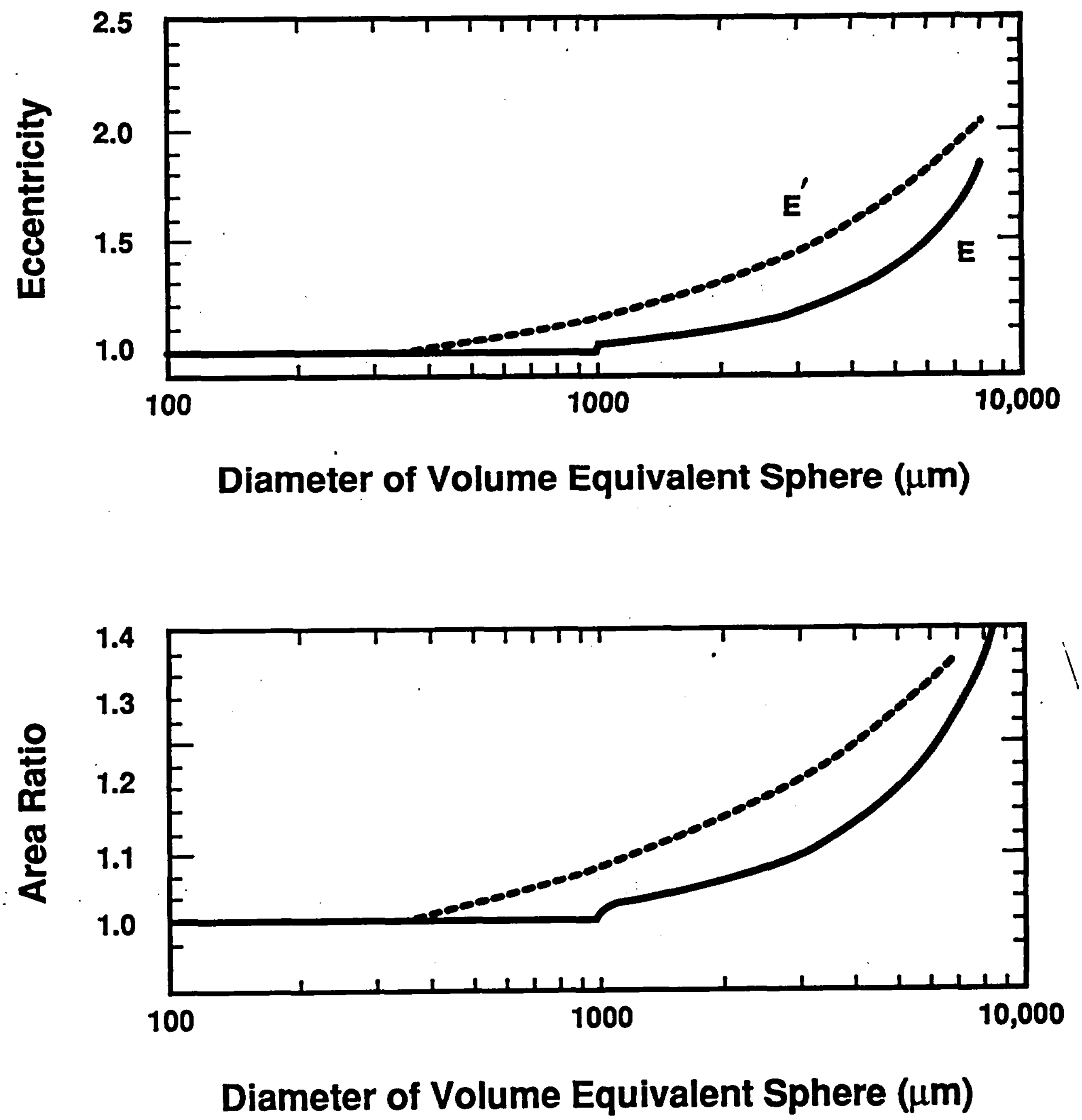

Figure 15 Comparison of eccentricities E and E′ and the ratios of the ellipsoidal surface areas to the area of the volume-equivalent sphere for two models of droplet shape

U_T = terminal velocity

μ_g = viscosity of the gas phase

N_D = Best number = $4\,\rho_g\,(\rho_\ell - \rho_g) g\, D_d(e)^3 / 3\,\mu_g^2$

C_D = drag coefficient = N_D / Re_T^2

- **Model B**: [13]

$$Re_T = \begin{cases} 1.62\ E_o^{0.755}\ M^{-0.25} & \text{for } 0.5 < E_o \leq 1.84 \\ 1.83\ E_o^{0.555}\ M^{-0.25} & \text{for } 1.84 < E_o \leq 5.0 \\ 2.00\ E_o^{0.5}\ M^{-0.25} & \text{for } E_o > 5.0 \end{cases}$$

and for $E_o < 0.5$

$$Re_T = N_D / 24 - 1.7569 \times 10^{-4}\ N_D^2 + 6.9252 \times 10^{-7}\ N_D^3 + -2.3027 \times 10^{-10}\ N_D^4$$

for $N_D < 73$ and $Re_T < 2.37$

$$\log_{10} Re_T = -1.7095 + 1.33438 \log_{10} N_D - 0.11591(\log_{10} N_D)^2$$

for $73 < N_D < 580$

$$\log_{10} Re_T = -1.81391 + 1.34671 \log_{10} N_D - 0.12427(\log_{10} N_D)^2 + 0.006344\ (\log_{10} N_D)^3$$

for $N_D > 580$

where

M = Morton number = $g\,\mu_g^4\,(\rho_\ell - \rho_g) / \rho_g^2\,\sigma_\ell^3$

C_D = $4\rho_g\,(\rho_\ell - \rho_g)\,g\,D_d(e)^3 / 3\mu_g^2\,Re_T^2$

• <u>Model C</u>: [13]

$$Re_T = \begin{cases} 0.766\ E_o^{0.66}\ M^{-028} & \text{for } E_o \leq 164M^{1/6} \\ 1.37\ E_o^{0.55}\ M^{-0.26} & \text{for } E_o > 164M^{1/6} \end{cases}$$

where, again:

$$C_D = 4\rho_g\,(\rho_\ell - \rho_g)\,g\,D_d(e)^3\,/\,3\mu_g^2\,Re_T^2$$

Terminal velocities calculated from these models for water droplets falling through air at 1 atmosphere pressure and 298 K are shown in Figure 16. Physical properties of air and water used in these calculations are shown in Table 4. The essential result shown by these models is that droplets of different sizes fall at different velocities. As a result, spray droplets not only sweep aerosols from the atmosphere, they also sweep other spray droplets from the atmosphere. Most importantly, the smallest droplets, which will be shown below to be most efficient at the capture of aerosol particles, are swept out by larger droplets as the spray droplets fall. Thus, the ability of a spray to cleanse a containment of particulate decreases with increasing fall distances.

D. Aerosol Capture by Water Droplets

In the most general situation hypothesized to develop in a severe reactor accident, the containment or drywell spray would be actuated at a time when the containment atmosphere was very hot and rich in steam. Evaporation of the initial drops expelled by the spray would reduce any superheating of the atmosphere. Steam would then begin to condense on the droplets. The flux of steam condensing on the droplets would carry aerosol particles into the droplets. There would be, also initially, a thermophoretic force that would drive particles into the droplets. These highly dynamic conditions would be of short duration. A steady-state situation in which the atmosphere composition and temperature come close to equilibrium with the droplets of the spray would be established rather quickly. This is the situation that is of interest here. Under these quasi steady-state conditions the predominant modes of aerosol capture are:

- impaction,

- interception, and

- diffusion.

Impaction and interception of aerosol particles are affected by the atmosphere hydrodynamics. As a droplet falls through the atmosphere, a flow field develops around the droplet. This flow field will carry along aerosol particles. The flow field will, ideally, carry the aerosols around falling droplets. Some aerosols will, however, be too massive to respond to the sudden accelerations in the gas flow in the vicinity of the falling droplet. Inertia will carry these particles across streamlines of the flow so that the particles impact on the droplet surface. It is assumed here that contact between a droplet

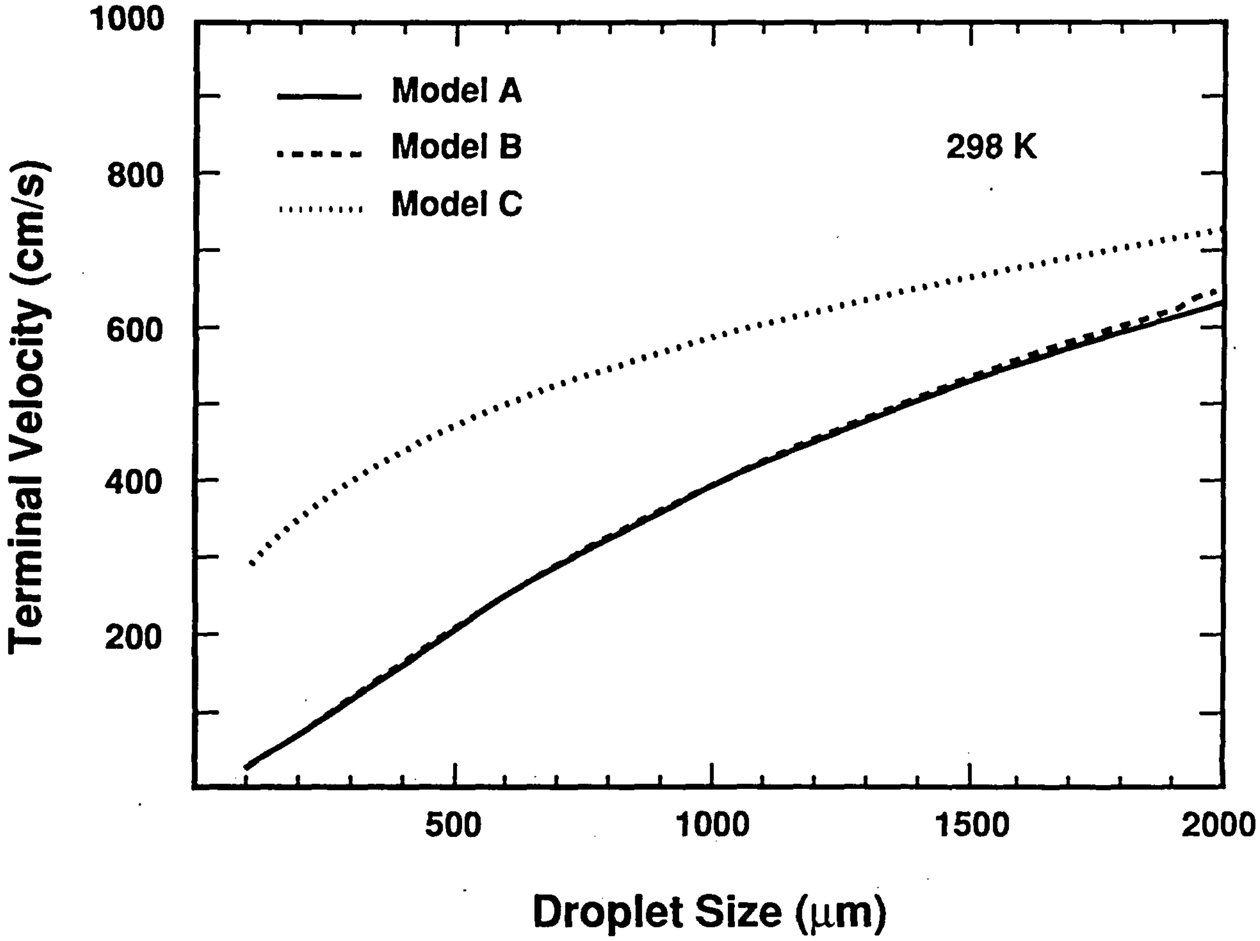

Figure 16 Terminal velocities for falling water droplets

Table 4 Physical properties of air and water

Water Density (g/cm^3)

$$\rho_\ell = 1 / \left(1.236866 - 1.828945 \times 10^{-3}\, T(K) + 3.509325 \times 10^{-6}\, T(K)^2\right)$$

Water Surface Tension (dyne/cm)

$$\sigma_\ell = 34.6\, (T(K) / 704)^{-0.8373}$$

Water Viscosity (Poise)

$$\log_{10} (\mu_\ell) = \log_{10} (0.01002) + \left[\frac{1.3272(293 - T(K)) - 1.52 \times 10^{-3}\, (T(K) - 293)^2}{(T(K) - 168)}\right]$$

Air Density (g/cm^3)

$$\rho_g(\text{air}) = 28.91\, P(\text{atms}) / 82.06\, T(K)$$

Air Viscosity (Poise)

$$\mu_g(\text{air}) = 2.3013 \times 10^{-6}\, T(K)^{0.768}$$

Saturation Pressure of Water Vapor (atms):

$$\log_{10} \frac{P(\text{atms})}{218.167} = \frac{-x}{T(K)} \left[\frac{3.2437814 + 5.86826 \times 10^{-3} x + 1.1702379 \times 10^{-8} x^3}{1 + 2.1878462 \times 10^3 x}\right]$$

$$x = 647.27 - T(K)$$

and a particle is sufficient to cause capture of the aerosol particle. Surface tension and Van der Waals forces are sufficient to keep the particle in contact with the droplet even if the material that makes up the particle is not soluble in the droplet.

If the center of mass of an aerosol particle can follow the streamlines of the flow field around a falling droplet, the finite size of the aerosol particle may lead, nevertheless, to contact between the droplet and the particle. This interception mechanism is quite important for non-spherical aerosol particles. Again, contact with the droplet is probably sufficient to assure capture of the particle because of the surface tension and Van der Waals forces.

Very small particles are more able to follow the streamlines of the flow field around a droplet and are, therefore, less susceptible to capture by impaction or interception. But, these very small particles respond to the stochastic impulses of collisions with gas molecules. Because these impulses are not perfectly balanced on the time scales of interest during the passage of a droplet, there is an apparent diffusion of aerosol particles that can carry the aerosols across streamlines of the flow, leading to aerosol contact with the droplet and, consequently, aerosol capture. Convection of the gas can enhance this diffusive flux of particles into the droplet.

The diffusive flux of particles into the droplets is complicated by the vaporization of water from the falling droplet. Even if the atmosphere is nominally in equilibrium with water, it will not be in equilibrium with a droplet. The curvature of the droplet surface means that it will have a slightly higher vapor pressure than does a large body of water. The vapor pressure over a surface with a radius of curvature r relative to the vapor pressure over a flat surface is given by:

$$\ln \frac{P(r)}{P(\infty)} = \frac{2M\sigma_\ell}{RT\rho_\ell r}$$

where M is the molecular weight of the vapor. Thus, the vapor pressure of the droplets increases with decreasing size. There will be, then, a tendency for small droplets to evaporate and large droplets to grow in a cloud of droplets even if the atmosphere is nominally saturated. For droplets of the size of interest here (>100 μm) the effect is not large. It is ameliorated further by the tendency of the evaporating droplet to cool slightly [29]. Any effect of the vapor flux coming off small droplets on the ability of the droplet to capture particles is probably overwhelmed by local turbulence effects. Therefore, the effect is ignored here.

It is possible for aerosol particles and water droplets to become electrostatically charged. The relatively powerful electrostatic forces could greatly accentuate or reduce the trapping of aerosols by droplets depending on whether charges on the droplets and the particles were different or were the same. Radiation fields can efficiently discharge both droplets and particles. It is assumed here that electrostatic effects can be neglected. There is no entirely satisfactory proof that this assumption is valid (but, see Reference 25). The difficulty is that even if particles are neutral, overall fluctuations in the charge densities or non-zero variances in charge density could affect the trapping process.

For the purposes of this work, only the three steady-state aerosol capture mechanisms discussed above--impaction, interception, and diffusion--are considered. The quantitative descriptions of these particle-capture processes presented below are based on analyses for isolated spherical droplets.

Phenomena

From the discussions above, it is apparent that the droplets will not always be spherical and they are never isolated. This introduces some uncertainty in the prediction of decontamination of containment atmospheres by sprays.

Consider a sphere of diameter $D_d(e)$ falling through space. After falling a distance X, the sphere will sweep out a volume of gas given by:

$$\text{Volume} = \frac{\pi}{4} D_d(e)^2 X$$

If the gas contains a concentration of n(i) particles of diameter $d_p(i)$, then in the absence of hydrodynamic phenomena, the falling sphere would sweep out:

$$\frac{\pi}{4} D_d(e)^2 X \, n(i)$$

of the particles. A convenient definition of the particle capture efficiency is the ratio of the actual number of particles of size $d_p(i)$ captured to the number captured in the hypothetical situation:

$$\in\left(D_d(e),\ d_p(i)\right) = 4\Delta N(i)/\pi D_d(e)^2\ n(i)X$$

where

$\in(D_d(e), d_p(i))$ = efficiency with which a drop of diameter $D_d(e)$ captures particles of diameter $d_p(i)$

$\Delta N(i)$ = actual number of particles of diameter $d_p(i)$ captured in a fall of distance X

Hydrodynamic effects cannot be neglected in the analysis of aerosol capture by falling water droplets. The efficiency with which droplets capture aerosol particles depends on the nature of flow around the droplet. Analytic results are, however, available only for the limiting flow regimes of viscous flow ($Re \rightarrow 0$) and of potential flow ($Re \rightarrow \infty$). Pemberton [14] has argued that in view of the substantial size differences between aerosols of interest (diameters less than 10 μm) and droplets of interest (diameters greater than 100 μm), flow around the droplets is well approximated by potential flow. Others [8,15] have felt it necessary to consider some means for interpolating between viscous and potential flow to predict real decontamination rates. Not everyone has agreed with the interpolation methods that have been described in the literature [16].

Widely used expressions for the efficiency of aerosol collection as a result of impaction are:

a. Potential Flow Regime

$$\in(\text{imp, pot}) = 0 \qquad \text{for Stk} \le 0.0833$$

$$\in(\text{imp, pot}) = [\text{Stk}/(\text{Stk} + \delta)]^2 \qquad \text{for Stk} \ge 0.2$$

$$\in(\text{imp, pot}) = 8.57[\text{Stk}/(\text{Stk} + \delta)]^2\,(\text{Stk} - 0.083336) \qquad \text{for } 0.08333 < \text{Stk} < 0.2$$

b. Viscous Flow Regime

$$\in(\text{imp, visc}) = 0 \qquad \text{for Stk} \le 1.214$$

$$\in(\text{imp, visc}) = \left[1 + \frac{0.75\,\ln(2\,\text{Stk})}{(\text{Stk} - 1.214)}\right]^{-2} \qquad \text{for Stk} > 1.214$$

c. Transition Flow Regime

$$\in(\text{imp, trans}) = \frac{\in(\text{imp, visc}) + Re_d \in(\text{imp, pot}) / 60}{1 + Re_d / 60}$$

where

$$\text{Stk} = d_p^2\, \rho_g\, U_T / 9\, \mu_g\, D_d(e)\, \chi$$

$$Re_d = U_T\, \rho_g\, D_d(e)/\mu_g$$

χ = dynamic shape factor for the particles

δ = uncertain constant cited to have values between 0.25 and 0.75

Note there are really two models here. All real flows are in the transition regime. One model is based on the assumption that real flows are similar to potential flows so the impaction efficiency is given by $\in$(imp, pot). The other model uses $\in$(imp, trans) for the impaction efficiency. Plots of $\in$(imp, pot) and $\in$(imp, trans) against aerosol particle size are shown in Figure 17 for droplets of various sizes falling through air at 298 K and 1 atmosphere pressure.

Expressions for the efficiency of aerosol capture by interception are:

a. Potential Flow Regime

$$\in(\text{int, pot}) = 3\,\gamma\, d_p / D_d(e)$$

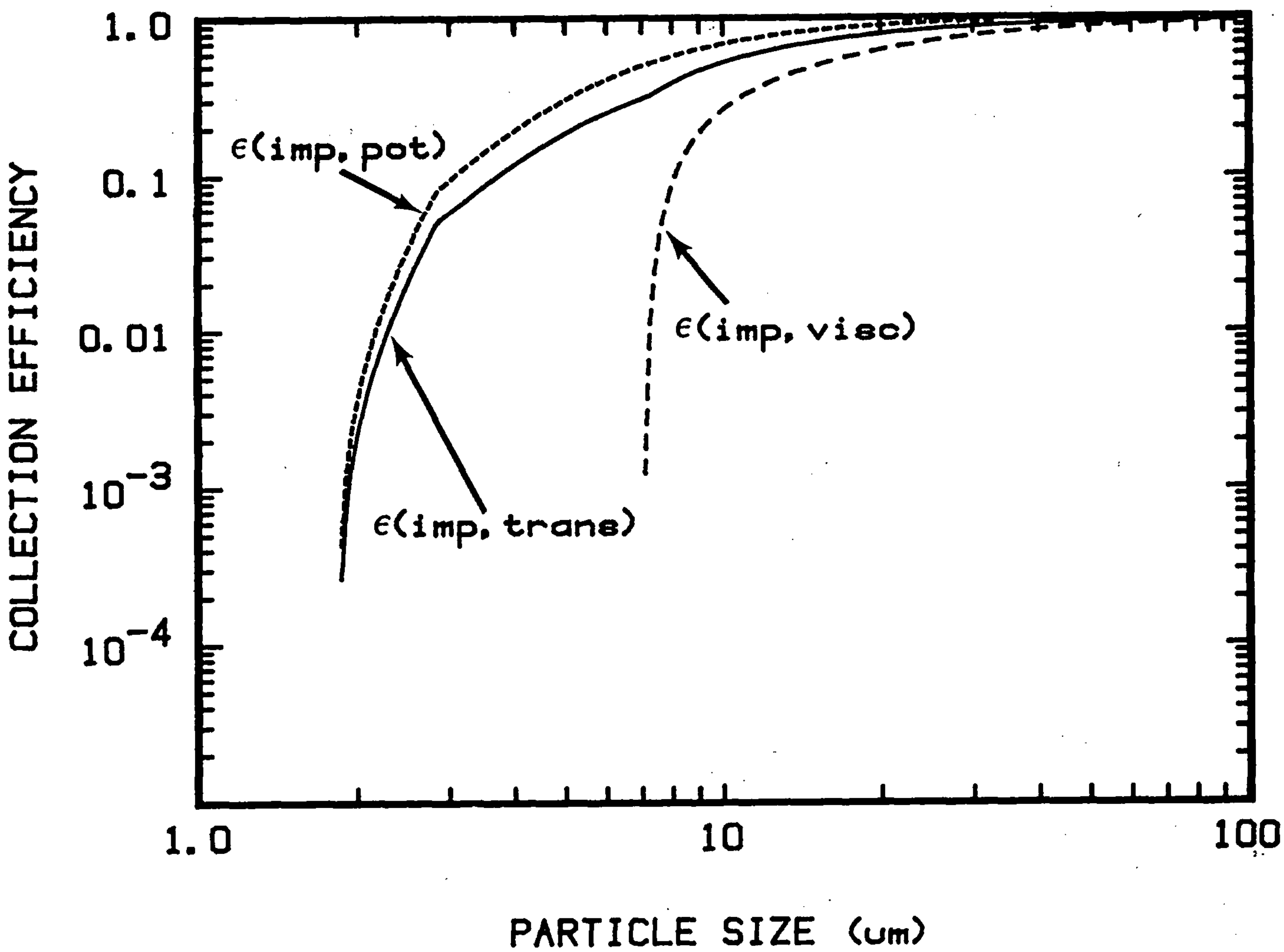

Figure 17 ϵ(imp, trans) and ϵ(imp, pot) as functions of aerosol particle size for a 600 μm drop

b. Viscous Flow Regime

$$\in(\text{int, visc}) = 1.5(\gamma\, d_p / D_d(e))^2 / (1 + \gamma\, d_p / D_d(e))^{1/3}$$

c. Transition Flow Regime

$$\in(\text{int, trans}) = \frac{\in(\text{int, visc}) + Re_d \in(\text{int, pot}) / 60}{1 + Re_d / 60}$$

where γ is the collision shape factor for the aerosol particles.

The capture efficiency for the viscous flow regime deserves comment. Lee and Gieseke [21] have reviewed the various approximations for interception efficiency. Under Stokes-flow conditions, the efficiency is given by:

$$\in(\text{int, visc}) = (1 + I)^2 \left[1 - 1.5 / (1 + I) + 0.5 / (1 + I)^2\right]$$

where

$$I = \gamma\, d_p / D_d'(e)$$

Lee and Gieseke note the following approximations that have been made to this expression:

- $1.5\, I^2 - 0.25\, I^3 / (1 + I)$
- $1.45\, I^2$
- $1.5\, I^2$
- $1.5\, I^2 / (1 + I)^m + \frac{(3m - 1)}{4} \left[\frac{I^3}{(1 + I)^{m+1}}\right]$

Lee and Gieseke [21] recommended the last of these approximations with $m = 1/3$ as the better approximation to the actual Stokes flow efficiency. They also note that the presence of many collectors affects the collection efficiency. For an array of collectors occupying a volume fraction α, they cite as the collection efficiency:

$$\in(\text{int, visc}) = (1 / K_s) \left[(1 + I)^2 - 1.5(1 + I) + 0.5 / (1 + I) + f(\alpha)\right]$$

where

$$K_s = 1 - (9/5)\, \alpha^{1/3} + \alpha - 0.2\, \alpha^2$$

$$f(\alpha) = \alpha\left[0.2 / (1 + I) + 0.5 (1 + I)^2 - 0.3 (1 + I)^4\right]$$

Plots of the interception efficiency calculated with various models are shown in Figure 18.

Aerosol capture by diffusion processes presents some conceptual problems involving the treatment of convection. Some of the expressions available for the efficiency of aerosol capture by diffusion are:

$$\in(\text{dif}) = 2.18\ Pe^{-1/2} \quad \text{for } d_p / D_d(e) < 0.3Pe^{-1/2}$$

$$\in(\text{dif}) = \left[2\ Pe\ D_d(e)\right]^{-1/2}$$

$$\in(\text{dif}) = 3.18\ Pe^{-2/3}$$

$$\in(\text{dif}) = (4/Pe)\left(2 + 0.557\ Re_d^{1/2}\ Sc^{3/8}\right)$$

where

Pe = Peclet number = $Re_d\ Sc$

Sc = Schmidt number - $\mu_g/\rho_g \tilde{\mathcal{D}}_p$

$\tilde{\mathcal{D}}_p$ = diffusion coefficient of particles

= $\bar{c}\ kT/3\pi\ \mu_g\ d_g$

k = Boltzmann's constant = 1.38×10^{-16} ergs/K

$\bar{c}$ = Cunningham slip correction

$$= 1 + \left(\frac{2\lambda}{d_p}\right)\left[1.257 + 0.4 \exp\left(-0.55\ d_p / \lambda\right)\right]$$

λ(cm) = mean free path in the gas phase $\cong 2.3 \times 10^{-8}$ T(K) / P(atm)

Great confidence cannot be placed in any of these expressions. The expressions are based on isolated spheres. There is, however, substantial evidence that in an array of spheres mass transport to one of the spheres is less than to an isolated sphere in the same flow conditions [22, 23]. Detailed results are available only for cases involving two equal size spheres [22-24]. At the limit of $Pe \rightarrow 0$ where the Sherwood number for an isolated sphere is 2, the Sherwood number for a paired sphere as a function of the separation is [24]:

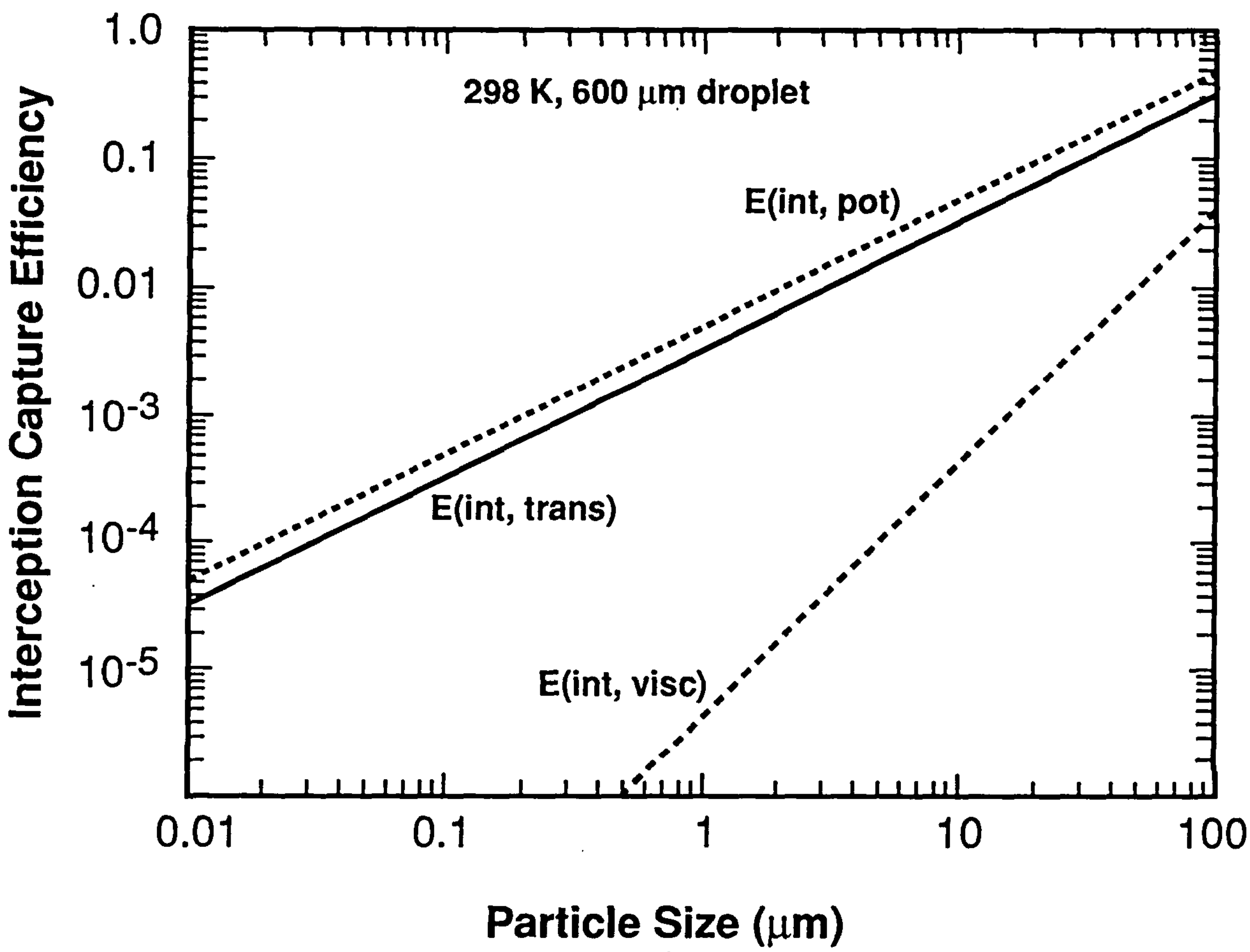

Figure 18 ∈(int, trans) and ∈(int, pot) as functions of aerosol particle size and water drop size

Separation Divided by Sphere Radius	Sherwood Number
∞	2.00
20.14	1.9056
8.288	1.7852
3.0862	1.5232
2.0402	1.3920

Where the Sherwood number is $k_m D_d(e)/\mathscr{D}$ and k_m is the mass transport coefficient.

Thus, the deviation increases as the spheres become closer. The obvious limit of 1.0 for the spheres is not reached until the two spheres are combined. The presence of the adjacent sphere drastically affects the angular distribution of the local Sherwood number around the sphere.

Useful results for randomly dispersed spheres with varying diameters do not appear to be available. The issue is troublesome because it can be anticipated that the wakes of large fast falling droplets could disturb the trajectories and the aerosol capture efficiencies of smaller droplets which are the most efficient at decontaminating the atmosphere.

The problem of combining the effects of all three aerosol capture mechanisms must also be addressed. Traditionally, it would be assumed that the three mechanisms would be completely independent. Then,

$$\in(\text{total}) = \in(\text{imp}) + \in(\text{int}) + \in(\text{dif})$$

It is manifestly apparent that the three aerosol capture mechanisms are not entirely independent. An alternate expression for the overall efficiency of aerosol capture is [17]:

$$\in'(\text{total}) = 1 - (1 - \in(\text{imp}))\,(1 - \in(\text{int}))\,(1 - \in(\text{dif}))$$

Plots of $\in'$(total) and $\in$(total) against aerosol particle size for water drops 200, 400, 1000 and 2500 μm in diameter are shown in Figure 19. Note that there is a minimum in the overall efficiency of aerosol capture when plotted against aerosol particle size. At this minimum, aerosol particles are too big to be affected significantly by Brownian motion which is responsible for aerosol capture by diffusion. Yet, the aerosol particles are still small enough to have a high probability of eluding capture by impaction or interception.

A great deal of significance has been attached to this minimum in the aerosol capture efficiency. Though sprays may be effective agents for cleansing an atmosphere of general aerosols, they may be less effective at removing aerosols with sizes in the vicinity of the minimum. This minimum size, not coincidentally, is the aerosol size most likely to be injected into the containment atmosphere by sources previously subjected to other decontamination processes such as decontamination by an

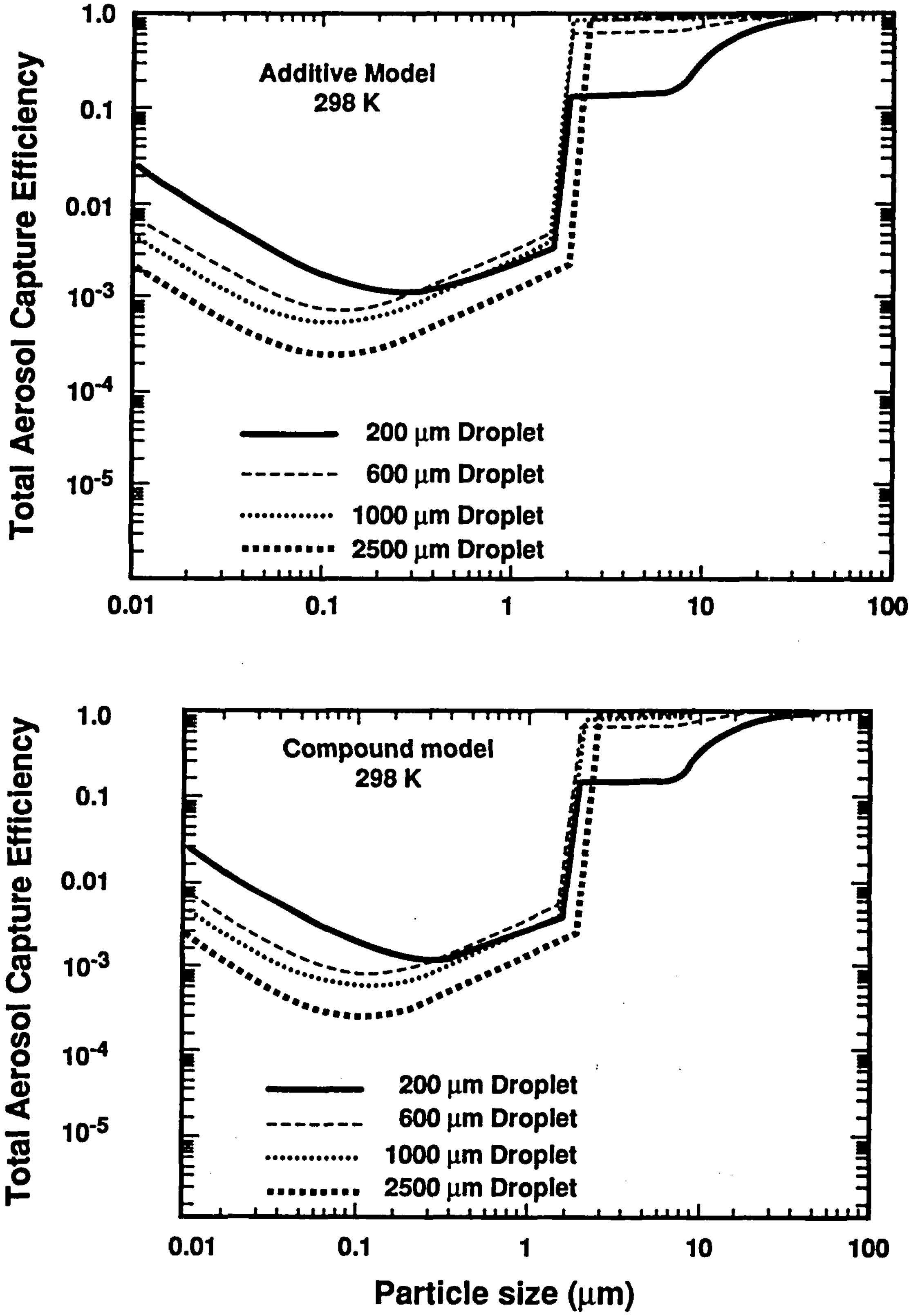

Figure 19 ∈′(total), the compound model, and ∈(total), the additive model, as functions of aerosol particle size and water drop size overlying water pool or aerosol deposition during transport through the reactor coolant system. It is also the most likely aerosol particle size to be expected when vapors produced by revaporization in the reactor coolant system condense upon entering the cooler containment atmosphere.

Note, however, that the minimum in the overall efficiency curve is dependent on droplet size. The minimum in the overall efficiency curve for 200 μm droplets is shifted substantially from the minima in the efficiency curves for larger droplets. Much of the concern that some aerosols may be resistent to capture by sprays arises from analyses with models that describe sprays in terms of a single monodisperse droplet size [8]. Were these models to use a more realistic description of the spray in terms of a distribution of droplet sizes including droplets of about 200 μm diameter, much of the concern would disappear.

The discussions of aerosol capture efficiency also show that spray performance will depend very strongly on the size distribution of aerosols in the containment. Both the mean size and the breadth of the aerosol size distribution will affect the predicted performance of the containment spray. Further, the spray will alter the size distribution because very large and very small particles will be removed more efficiently than are particles near the size of minimum capture efficiency. The effectiveness of the spray will decrease as decontamination progresses.

Though the aerosol size distribution will significantly affect spray performance, the discussion of this uncertainty is deferred to Chapter III of this report. Suffice it here to say that two classes of aerosol size distributions need to be considered. The first class includes those aerosols injected into the containment from the original source without any significant modification by some aerosol attenuation system. The second class of aerosols are those injected into containment after first passing through some aerosol attenuation system such as a water pool or a filter system.

E. Droplet Trajectories

Analyses of decontamination of containment atmospheres by spray droplets usually consider the droplet motion to be strictly downward and at the droplet terminal velocity. Certainly after a long fall distance, the droplet motions will be well-represented by this simple description. Before reaching this steady-state situation, the droplet motions are a good deal more complex. The first source of the complexity is that the nozzles need not be mounted so that they point directly downward. Indeed, the Model 1713-A (or Model 1713) nozzles are frequently mounted so that the centerlines of the nozzles point in a variety of directions to achieve more complete coverage of the containment cross-sectional area. Consequently, initial motions of the drops follow ballistic arcs.

The classic differential equations of droplet motions are [22]:

$$\frac{d\ U(x)}{dx} = -0.75\rho_g\ |U|\ C_D\ U(x)\ /\ \rho_\ell\ D_d(e)$$

$$\frac{d\ U(y)}{dt} = g(\rho_\ell - \rho_g)\ /\ \rho_\ell\ -0.75\rho_g |U|\ C_D\ U(y)\ /\ \rho_\ell\ D_d(e)$$

$$\frac{dx}{dt} = U(x)$$

$$\frac{dy}{dt} = U(y)$$

where

C_D = drag coefficient

g = acceleration due to gravity = 980 cm/s^2

U(x) = radial component of droplet velocity

U(y) = axial component of droplet velocity

|U| = droplet speed = $\sqrt{(U(x)^2 + U(y)^2)}$

x = radial position relative to the nozzle

y = axial position relative to the nozzle

The initial conditions for the differential equations for position are:

$$x(t=0) = 0$$

$$y(t=0) = 0$$

The initial conditions for the velocity equations are not as obvious. In principle, the initial speeds of the droplets are given by:

$$|U| = Q / A_h C$$

where

Q = volumetric flow rate ≅ 956 cm^3/s

A_h = nozzle flow area ≅ 0.713 cm^2

C = discharge coefficient.

The discharge coefficients for the nozzles might be between 0.6 and 1. A discharge coefficient of about 0.75 has apparently been used in the study of spray trajectories reported in Reference 22. The observed pattern of the sprays can, in principle, be used to back-calculate a discharge coefficient. Available data on the spray patterns are, however, quite limited. Back-calculation of the discharge coefficient is somewhat sensitive to the droplet size used to define the spray pattern. Here, a discharge coefficient of 0.6 is assumed for the Model 1713-A and Model 1713 spray nozzles [59].

Droplet trajectories for droplets with diameters of 200 to 1000 μm are shown in Figures 20-22. Trajectories for a nozzle with its axis pointed directly downward are shown in Figure 20. Droplets larger than about 600 μm follow trajectories that conform well to the manufacturer's indicated spray pattern. Drag forces cause smaller droplets to lose quickly their horizontal components of motion. These smaller droplets follow trajectories that "fill-in" the hollow cone area of the initial spray envelope. Were a single, isolated spray nozzle of interest, it is evident that the droplet size distribution would be calculated to vary radically across the cross-section of the spray pattern. The trajectories of the small droplets separate the small droplets from larger droplets. Sweepout of small droplets by larger droplets could occur only in a small region of space.

Trajectories for water droplets of various sizes produced by a Model 1713-A nozzle with its axis pointed horizontally are shown in Figure 21. The envelope of the spray pattern is not defined by droplets of a particular size. Larger droplets travel for extended horizontal distances. Small droplets quickly lose their horizontal motion and fall across the trajectories of the larger droplets. The opportunities for collisions between small and large droplets are greater in this situation than in the situation with the nozzle pointed downward.

An even more complicated set of trajectories for droplets formed by a nozzle with its axis pointed at an angle 45° above horizontal is shown in Figure 22.

The spray patterns for droplets produced by individual spray nozzles are not simple especially when nozzles can have orientations that are different than simply downward. Spray patterns and the opportunities for droplets to interact become even more complicated to analyze when the overlaps of the spray patterns produced by adjacent spray nozzles are considered. The elliptical cross-sections of spray envelopes defined by 800 μm droplets in horizontal planes about 3 m below nozzles on various headers in a particular spray system are shown in Figures 23 to 25. Patterns produced by only 13 of the nozzles on a header are shown in these figures. Inclusion of patterns from all nozzles on a header would produce an indecipherable figure. Overlaps of the patterns have been

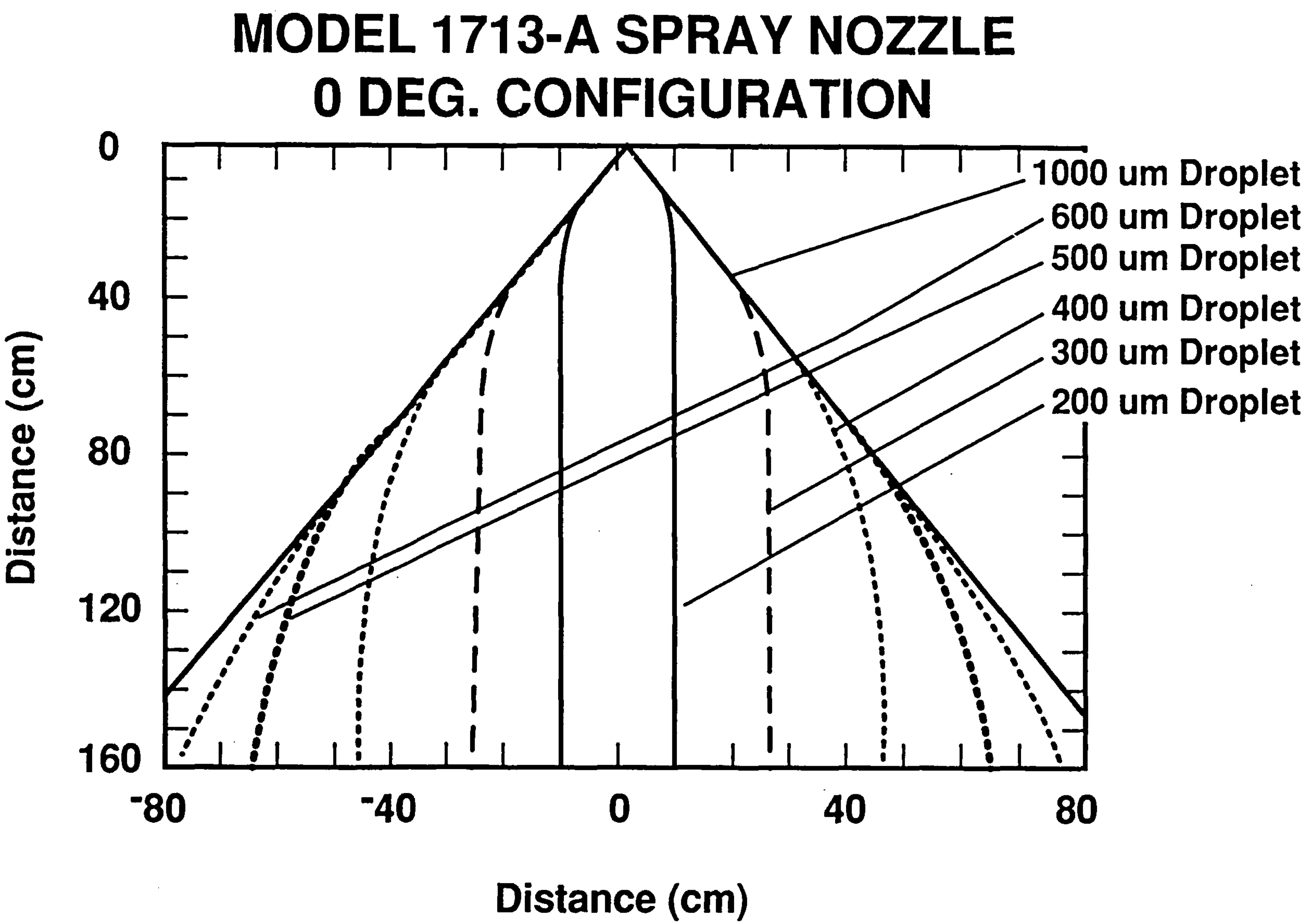

Figure 20 Trajectories of droplets of various sizes from a Model 1713-A spray nozzle pointed downward. Trajectories were calculated for droplets in air at 1 atmosphere pressure and 298 K.

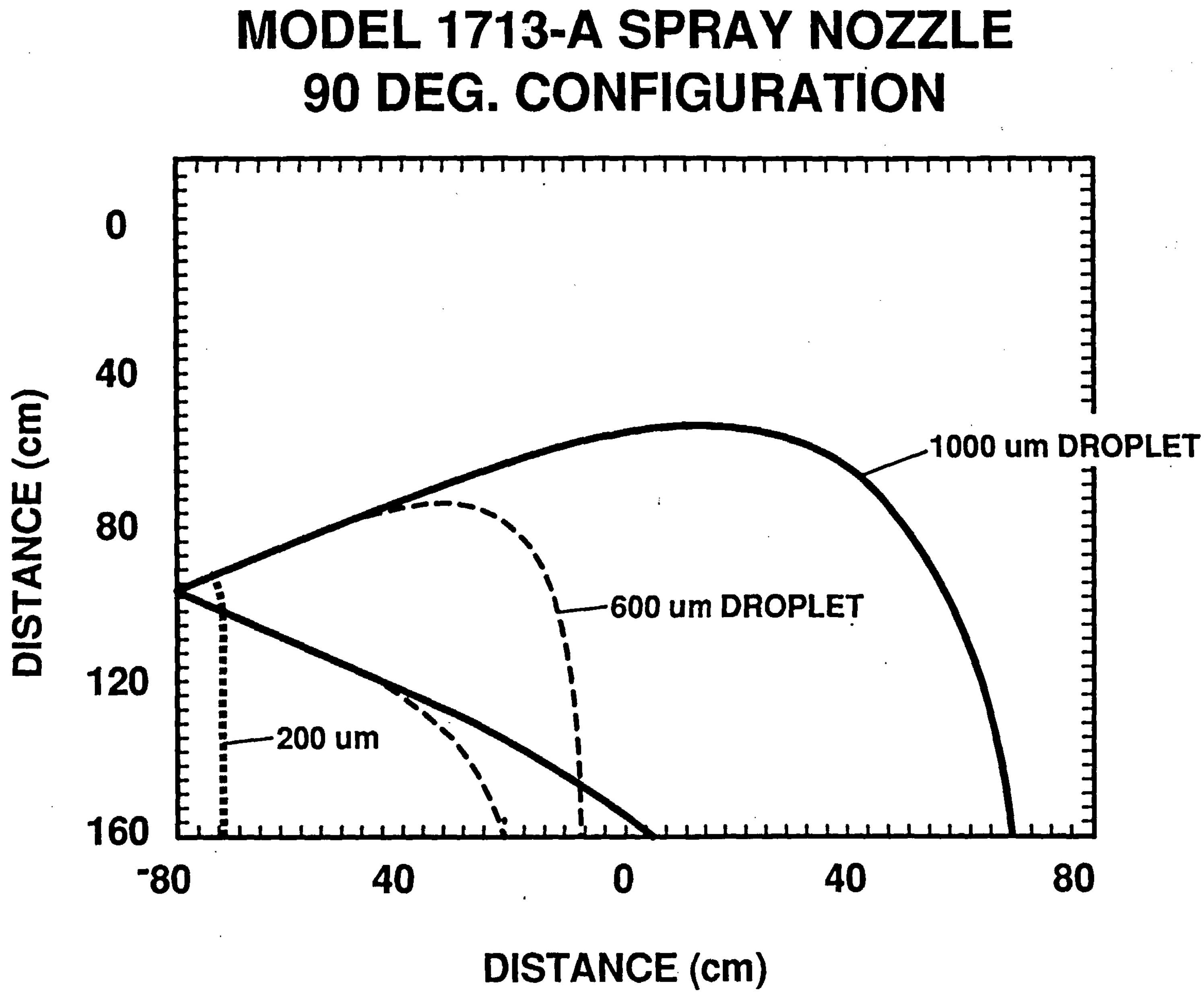

Figure 21 Trajectories of droplets of various sizes from a Model 1713-A spray nozzle pointed horizontally. Trajectories were calculated for droplets in air at 1 atmosphere pressure and 298 K.

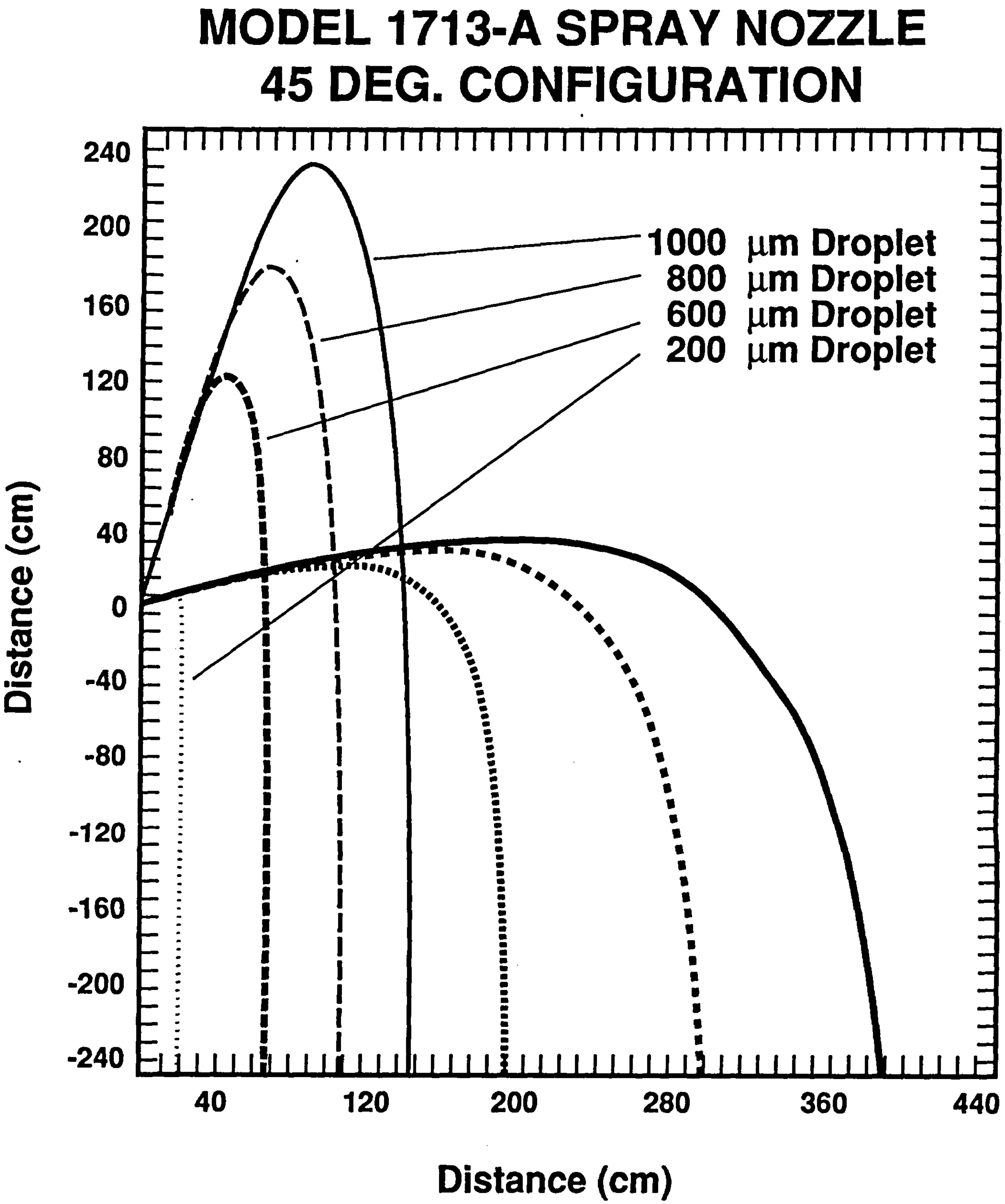

Figure 22 Trajectories of droplets of various sizes from a Model 1713-A spray nozzle pointed upward at a 45° angle. Trajectories were calculated for droplets in air at 1 atmosphere pressure and 298 K.

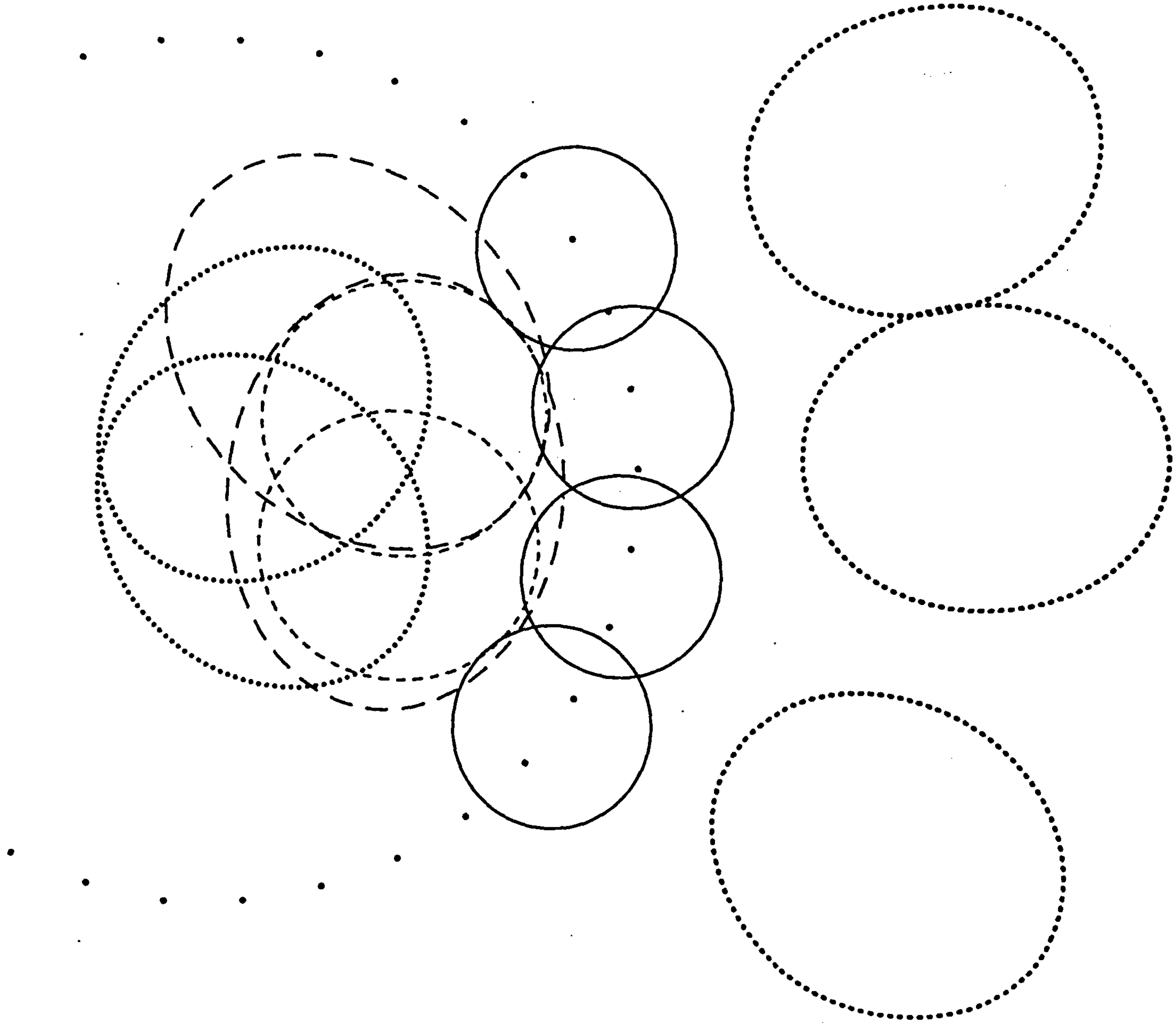

Figure 23 Cross-sections for spray patterns produced by 13 nozzles on Header B in a particular containment spray system. Cross-sections are for a plane 3 m below the nozzles.

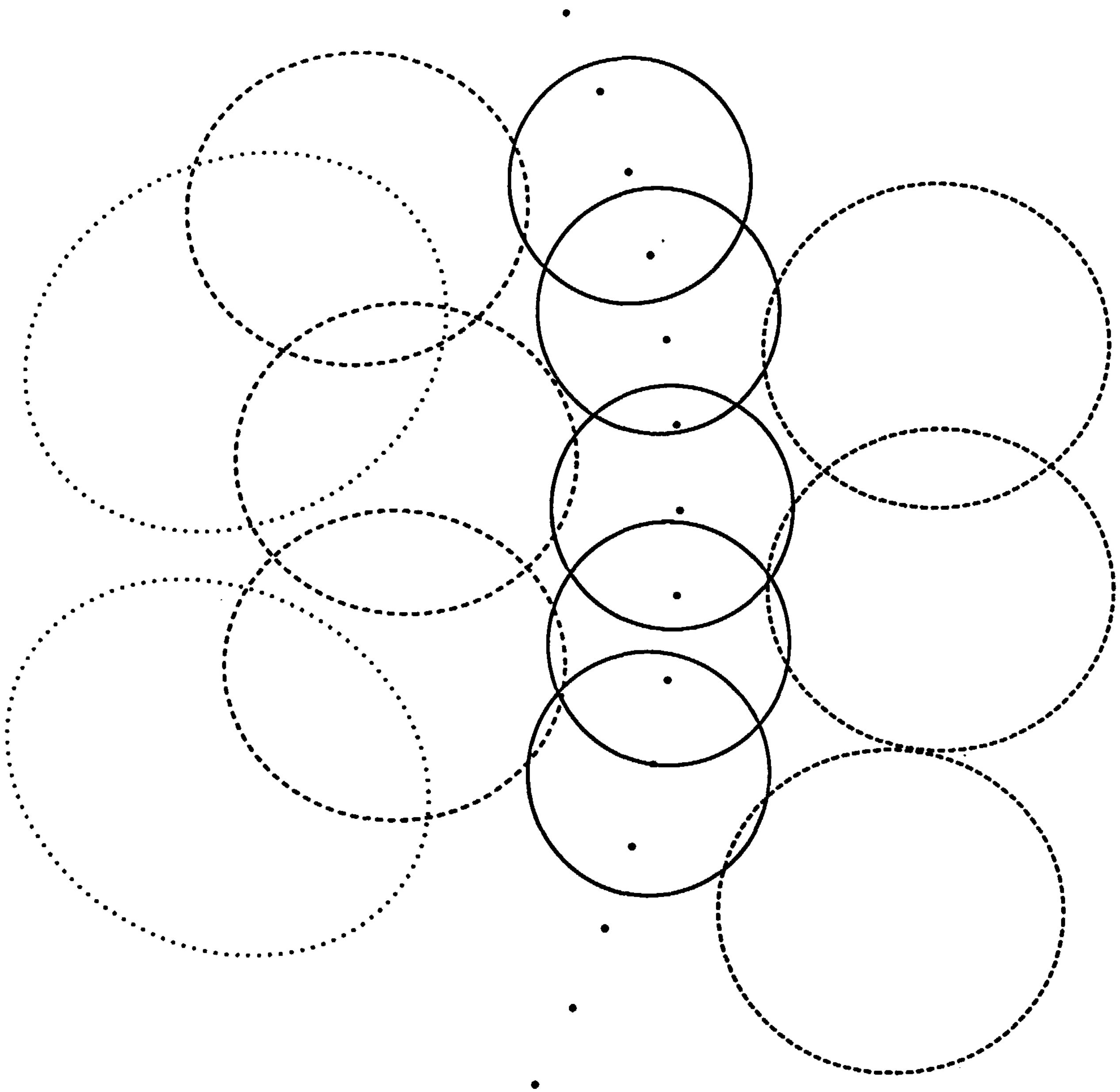

Figure 24 Cross-sections for spray patterns produced by 13 nozzles on Header D in a particular containment spray system. Cross-sections are for a plane 3 m below the nozzles.

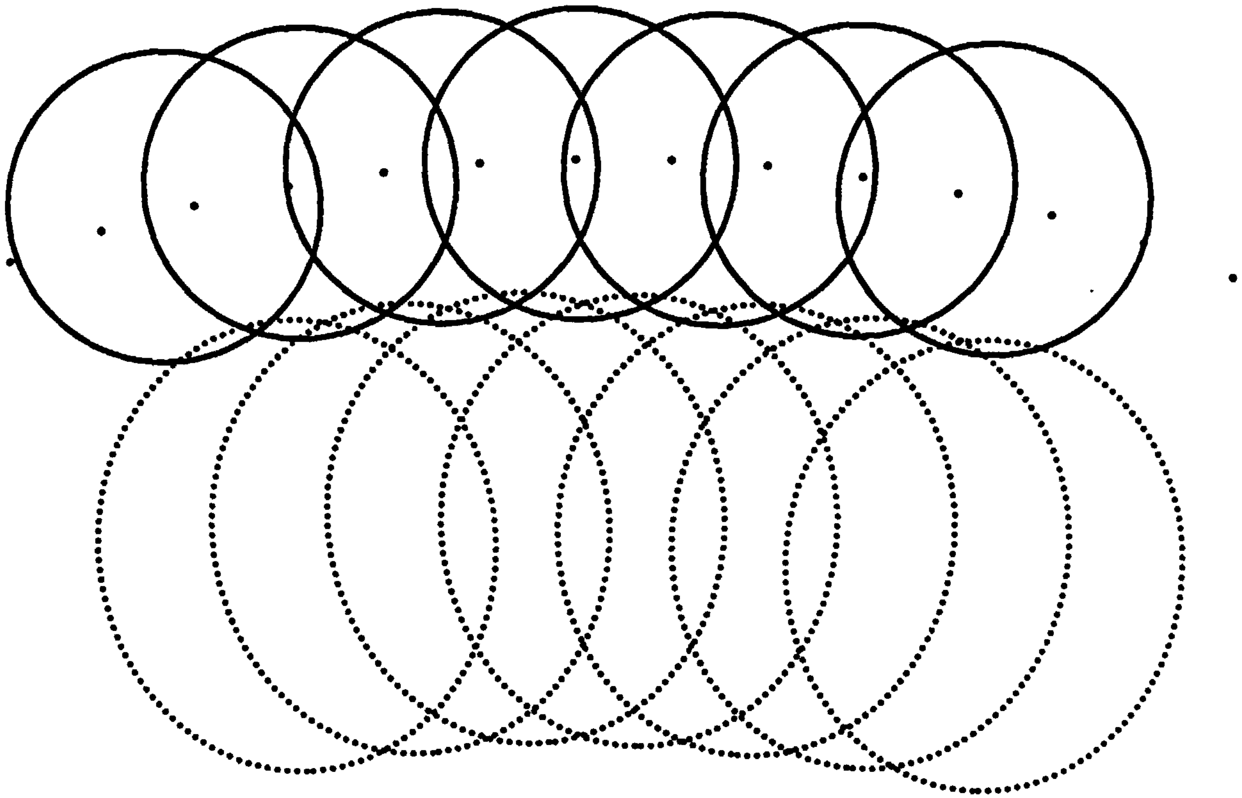

Figure 25 **Cross-sections for spray patterns produced by 13 nozzles on Header F in a particular containment spray system. Cross-sections are for a plane 3 m below the nozzles.**

deliberately designed into the spray system. Projections of the cross-sections of all 3 header systems are shown in Figure 26.

The various headers in the spray system considered in making these figures are located at different elevations. Droplets produced by nozzles on one header would have lost much if not all of their horizontal motions by the time they arrive at the elevation of the next header. There is, then, an additional complication in the analysis of droplet trajectories and the opportunities for spray droplets to interact. Droplets produced by nozzles on higher headers will fall through the developing spray patterns produced by nozzles on headers at lower elevations. Again, complicated opportunities for droplet collisions would develop in regions immediately below the lower header.

Some efforts to mechanistically model spray droplet behavior have been undertaken [33]. These analyses include hydrodynamic effects of the reverse flow of gas caused by droplets falling through the atmosphere. This reverse flow can disturb the droplet trajectories from the simple ballistic trajectories discussed here. The gas flow is, however, affected by structures in the containment. Gas and droplet motions are also strongly coupled near the spray nozzles where droplet concentrations are high. Coupling of the gas and droplet motions could be expected to affect the efficiency of sweepout of smaller droplets by larger droplets. The detailed analysis of this hydrodynamic problem is, however, not yet entirely feasible and is not attempted here.

F. Droplet Agglomeration

Because of drag and the overlap of spray patterns there is relative motion among droplets. This creates the opportunity for droplet collisions. Analyses of droplet collisions often portray the process as involving simple sweepout of slowly falling smaller droplets by larger, faster moving droplets. The discussion of droplet trajectories above make it evident that the interactions of droplets, at least in the vicinity of the spray nozzles, is not so simple. Collisions of droplets can take place because of differences in their horizontal components of velocity as well as differences in their vertical velocity components.

For this work, collisions of droplets in the regions where droplets have significant horizontal components of motion are neglected. It is regrettable that this approximation has to be made. But, the details of droplet motions and the interactions among droplets in this region appear to constitute a problem too difficult to address in this work. Solution of this problem would be peculiar to the spray system in question and very difficult to generalize on an overall basis. The effects of droplet-droplet interactions in the vicinity of spray nozzles and in the regions of pattern overlaps would distort the droplet size distribution from that observed to be produced by a single, isolated spray nozzle. As discussed above, the size distribution of spray droplets produced by even a single nozzle is uncertain. Droplet-droplet interactions in multiple nozzle systems add further to this uncertainty. The uncertainty is in the contributions to the distribution made by smaller droplets--those with diameters less than 200 μm. Coalescence of droplets removes these fine droplets from the size spectrum. But, high velocity collisions of droplets can also generate such fine droplets [51, 55]. Here the effects of droplet trajectories are considered only as implicit contributors to the uncertainty in the initial size distribution of droplets.

Analyses of the evolution of the droplet size distribution are restricted to an idealized situation in which all of the droplets are falling vertically at terminal velocities. Once below the region of

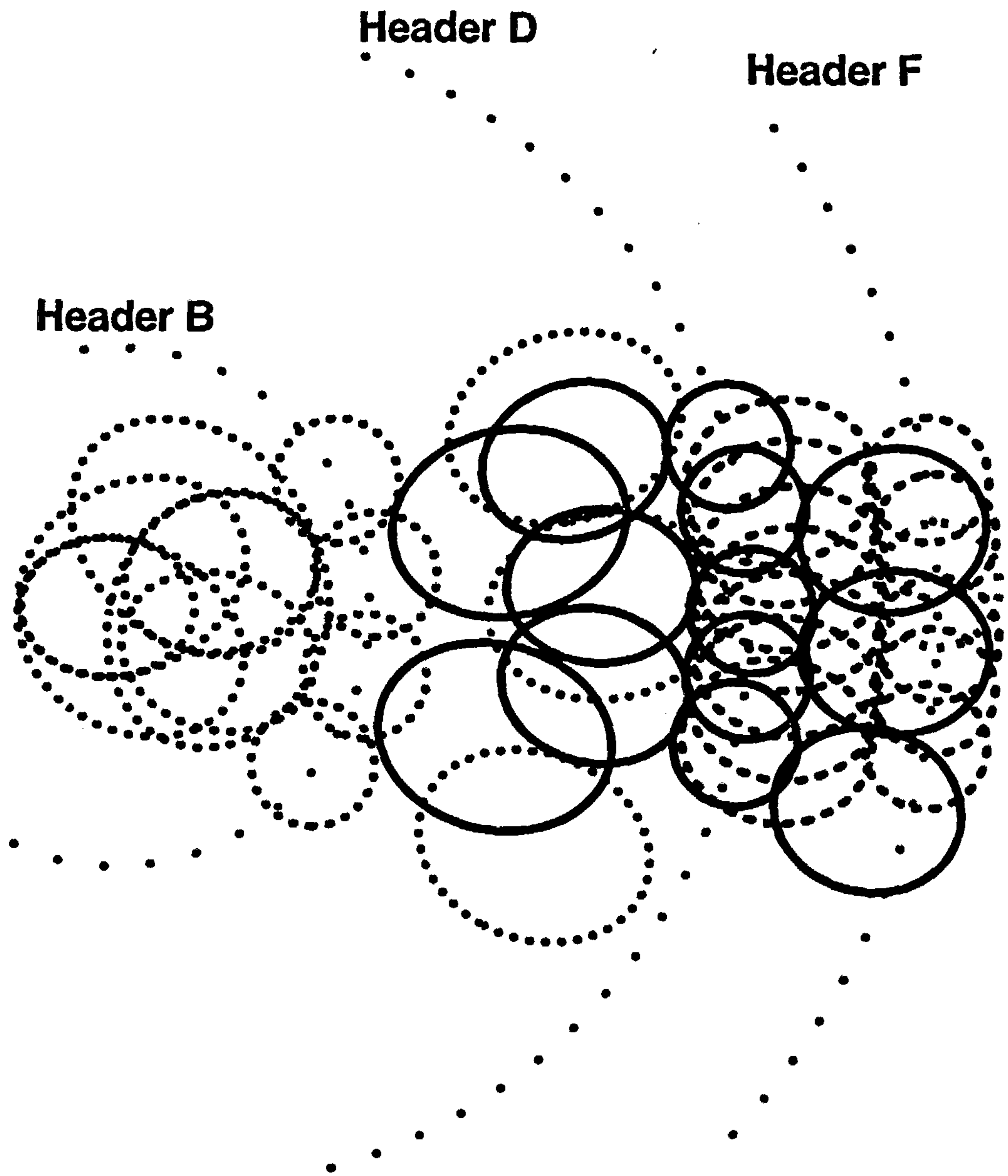

Figure 26 Projection of the spray pattern cross-sections of all three headers. Note that patterns are shown for only a subset of adjacent nozzles on each header.

dynamic, transient droplet motion, which is the first few meters below the nozzle, droplet motions are just in the downward direction. During the fall of droplets through the containment atmosphere, larger droplets will sweep out smaller droplets. A steady-state droplet size distribution will develop in the containment atmosphere. Consider N_o droplets with a distribution in sizes such that there are $N(i) = f(i)N_o$ droplets with diameters between $D_d(i)$ and $D_d(i + 1)$. For calculational purposes, it is convenient to assume initially that all droplets in size class i, that is, droplets with diameters between $D_d(i)$ and $D_d(i + 1)$ have the same diameter. The droplet size distribution will change as droplets fall and collide with each other. The sizes of droplets within a given size class will become distributed rather than constant because of coalescence of droplets of various sizes. Assume that the aerodynamic properties of all droplets in a size class i are well represented by a droplet with radius R(i). In general, the volumetric properties of droplets in the i^{th} size class will not be represented well by a droplet of this size. These volumetric properties are therefore taken to be represented by a different droplet of radius, S(i). Initially R(i) and S(i) are nearly equal. As the fall of the droplets progresses and droplet collisions resulting in coalescence occur, these representative droplet radii will change.

Since it has been assumed that all horizontal motions of the droplets have ceased, at least over some suitable time average, the containment and droplet fall can be treated one dimensionally. Mass balance requires that at a horizontal plane in the containment atmosphere:

$$\sum_{i=1}^{N} n(i)\ V(i)\ \frac{4}{3}\ \pi\ S(i)^3 = Q$$

where

N = number of droplet size classes

n(i) = number concentration of droplets in class i

V(i) = terminal velocity of a droplet of radius R(i)

S(i) = volume characteristic droplet radius for size class i

Q = volume flux of water into the containment produced by sprays.

A cross-sectional area for size class i is defined by

$$A(i) = \sum_{i=1}^{N} n(i)\ \pi\ R(i)^2$$

Phenomena

Consider a subvolume defined by two horizontal planes at x and x + dx. A number balance of droplets of size class j in this region is:

Number of j class droplets that enter the volume in time dt		Number of j class droplets that leave the volume in time dt	=	Number of j class droplets removed by agglomeration in time dt	-	Number of j class droplets created by agglomeration in time dt

or

$$[n(j,x) - n(j,x + dx)]\, V(j)A\, dt = \Delta N(j) - \psi(j)$$

where

$n(j,x)$ = number concentration of j class droplets at plane x

$V(j)$ = terminal velocity of j class droplets

$\Delta N(j)$ = number of j class droplets removed by agglomeration in time dt

$\psi(j)$ = number of j class droplets created by agglomeration in time dt

A single droplet of size class i such that $R(i) > R(j)$ falling a distance dx will encounter $\Delta n(i,j)$ droplets of size class j given by:

$$\Delta n(i,j) = \pi\left(R(i) + R(j)\right)^2 n(j,x) \frac{V(i) - V(j)}{V(i)} dx$$

During the period dt the number of i class droplets that enters the volume is given by:

$$n(i,x)\, V(i)A\, dt$$

If the efficiency with which a collision of i and j class droplets results in agglomeration is $\in(i,j)$, then from the above it is found that the number of j class droplets lost by sweepout by the larger i class droplets is:

$$\Delta N(i > j) = \sum_{i=j+1}^{N} \in(i,j)\, \pi\left[R(i) + R(j)\right]^2 n(j,x)\, n(i,x)\left[V(i) - V(j)\right] A\, dt\, dx$$

By analogous arguments the number of j class droplets lost by collisions with smaller droplets is:

$$\Delta N(j > k) = \sum_{k=1}^{j-1} \in'(j,k)\ \pi\ [R(j) + R(k)]^2\ n(j,x)\ n(k,x)[V(j) - V(k)]\ A\ dt\ dx$$

where $\in'(j,k)$ includes an additional term that indicates whether the agglomeration of a j class droplet and a k class droplet creates a droplet that is outside the range of sizes for the j class.

Were all the droplets within a size class to have exactly the same diameter, then, under the idealized assumptions for this analysis, there would be no collisions of droplets from the same size class. Because droplets within a class are not all the same size, and because rather large size ranges are used to define the boundaries of a size class, there can be collisions of droplets within the same size class. Coalescence of two droplets within a size class may yield a droplet that is outside the size range for the class. This type of collision reduces the population of the size class by 2. On the other hand, depending on the upper and lower boundaries defining a size class, collisions of two droplets within the same size class may only yield a slightly larger droplet that is still within the size class. The population of the size class is then reduced by one.

Considering the limits for a size class, the expression of the loss of j class droplets by collisions with other j class droplets can be constructed by analogy with expressions for collisions between droplets of different size classes. Recognizing that a collision can remove two droplets from the size class yields:

$$\Delta N(j=j) = \in''(j,j)\ \frac{\pi}{2}\ [D_d(j+1) + D_d(j)]^2\ n(j,x)^2\ \Delta V(j)\ A\ dx\ dt$$

where

$$\Delta V = V(D_d(j+i) - V(D_d(j))$$

$$V(D_d(j)) = \text{terminal velocity of a droplet of diameter } D_d(j)$$

The efficiency term, $\in''(j,j)$, includes an expression for the probability that a collision results in coalescence and a term that indicates if the droplet produced by coalescence is outside the specified size limits for the j^{th} size class.

Then, the total number of j class droplets lost by collision in the spatial interval x to x + dx is:

$$\Delta N(j) = \Delta N(i>k) + \Delta N(j>k) + \Delta N(j=j)$$

Formation of j class droplets by collisions of droplets in size classes k and l such that $j > k > l$ can be analyzed in a similar fashion to yield:

$$\psi(j) = \sum_{k=2}^{j-1} \sum_{\ell=1}^{k-1} \in'(k,\ell)\ \pi\ [R(k) + R(\ell)]^2\ n(k,x)\ n(\ell,x)[V(k) - V(\ell)]A\ dt\ dx$$

$$+\sum_{k=1}^{j-1} \in'(k,k)\ \frac{\pi}{4}\ [D_d(k+1) + D_d(k)]^2\ n(k,x)^2 \Delta V(k) A\ dt\ dx$$

Formation of j class droplets by collisions of two k class droplets can be estimated as was done for the loss of j class droplets by collisions of two j class droplets. Then, from a number balance on droplets of size class j:

$$\frac{-dn(j,x)}{dx} = \sum_{i=j+1}^{N} \in(i,j)\ \pi\ [R(i) + R(j)]^2\ n(j,x)\ n(i,x)\ \frac{[V(i) - V(j)]}{V(j)}$$

$$+ \sum_{k=1}^{j-1} \in(j,k)\ \pi\ [R(j) + R(k)]^2\ n(k,x)\ n(j,x)\ \frac{[V(j) - V(k)]}{V(j)}$$

$$+ \in'(j,j)\ \frac{\pi}{2}\ [D_d(j+1) + D_d(j)]^2\ \ n(j,x)^2\ \frac{\Delta V(j)}{V(j)}$$

$$- \sum_{k=2}^{j-1} \sum_{\ell=1}^{k-1} \in'(k,\ell)\ \pi\ [R(k) + R(\ell)]^2\ n(\ell,x)\ n(k,x)\ \frac{[V(k) - V(\ell)]}{V(j)}$$

$$- \sum_{k=1}^{j-1} \in'(k,k)\ \frac{\pi}{4}\ [D_d\ (k+1) + D_d(k)]^2\ n(k,x)^2\ \frac{\Delta V(k)}{V(j)}$$

Differential equations of this type for j = 1 to N were solved by an explicit, Eulerian method to obtain the spatial distribution in droplet sizes. Term-by-term examinations were necessary to account for the changes in the water volume and total cross-sectional area in a size class. Values of R(j) and S(j) for each size class were adjusted at the end of each spatial step to reflect these changes. Mass balance was maintained by adjusting N_o such that

$$\frac{N_0' \sum_{j=1}^{N} n(j,x)\ V(j)\ \frac{4}{3}\ \pi S(j)^3}{\Omega} = Q$$

where

$$\Omega = \sum_{i=1}^{N} n(i,x)$$

Values of n(j,x) for the next spatial step were calculated from

$$n(j,x + dx) = N_0\ n(j,x) \ /\ \Omega$$

Plots of the various terms in the differential equation are shown in Figure 27 for an example distribution with essentially a constant number density of particles across the size spectrum (see Figure 28). Sweepout of droplets by larger droplets is the largest term in the equation for droplets smaller than about 1000 μm. The next largest terms for this example are losses and gains of droplets in a class by agglomeration with smaller droplets. These terms become the dominant terms for the largest droplets in the distribution. Agglomeration processes within a droplet size class do make contributions to the evolution of the size distribution of droplets. These contributions are, however, about one order of magnitude less than other contributions.

The evolution of an example droplet size distribution during free fall is shown in Figure 28. This figure is a plot of the quantity

$$\left[f_i(N) \ /\ \log_{10} \Delta D\right]$$

where

$f_i(N)$ = fraction of the total number of droplets in the size class i

ΔD = D(i+1) / D(i)

against the characteristic diameter of droplets in the i^{th} size class. For the example, an initial distribution was selected such that the plotted quantity was the same for all size classes. Dramatic changes in the distribution occur in the first 50 cm of free fall as the larger droplets sweep out smaller droplets. Evolution in the distribution of droplet sizes slows once droplets smaller than about 100 μm have been removed. After free fall of about 1050 cm, nearly all droplets smaller than 200 μm have been eliminated from the distribution.

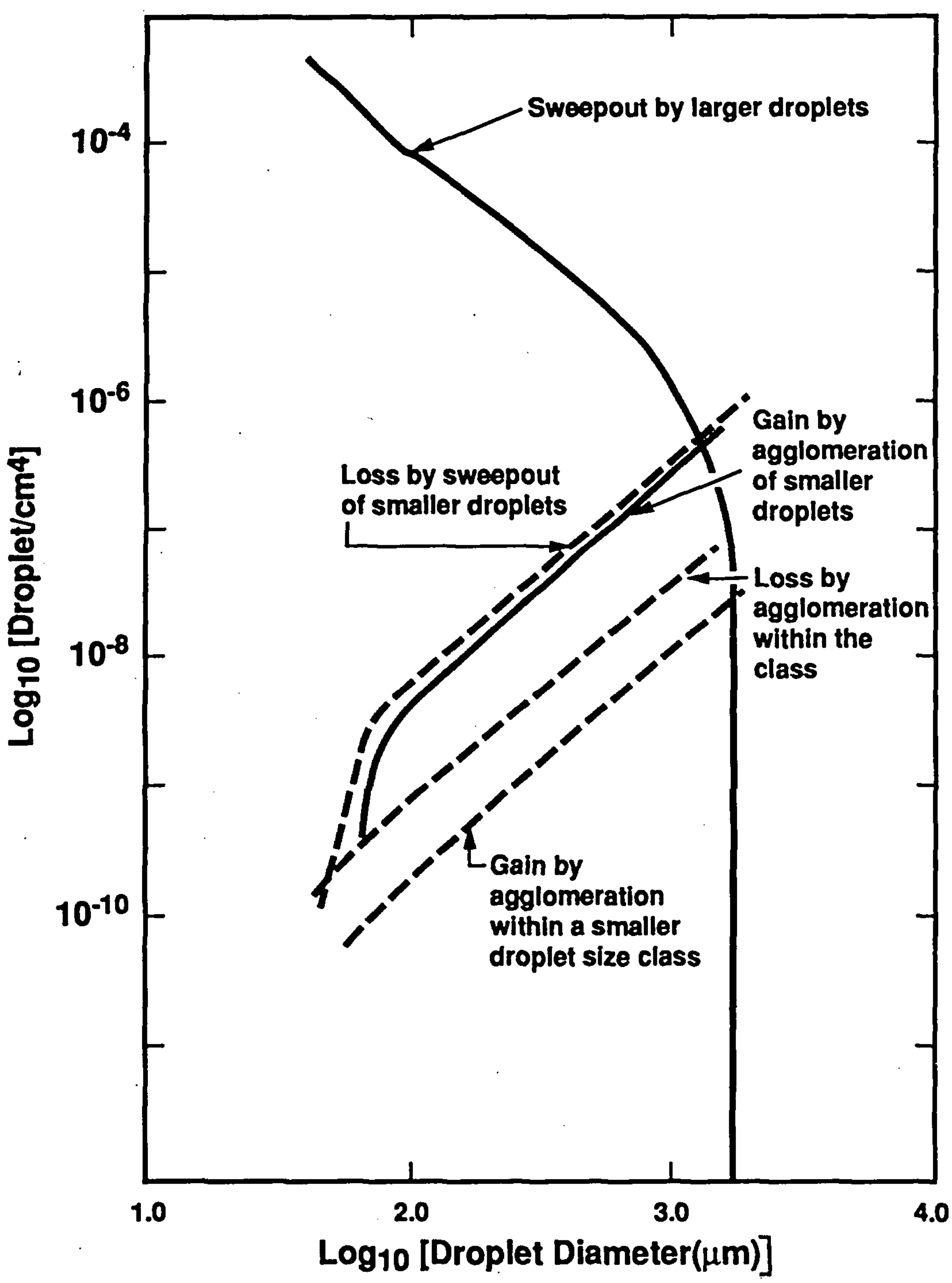

Figure 27 Terms in the differential equation for the steady state number distribution of droplets in containment. These terms are calculated for the initial size distribution shown in Figure 28.

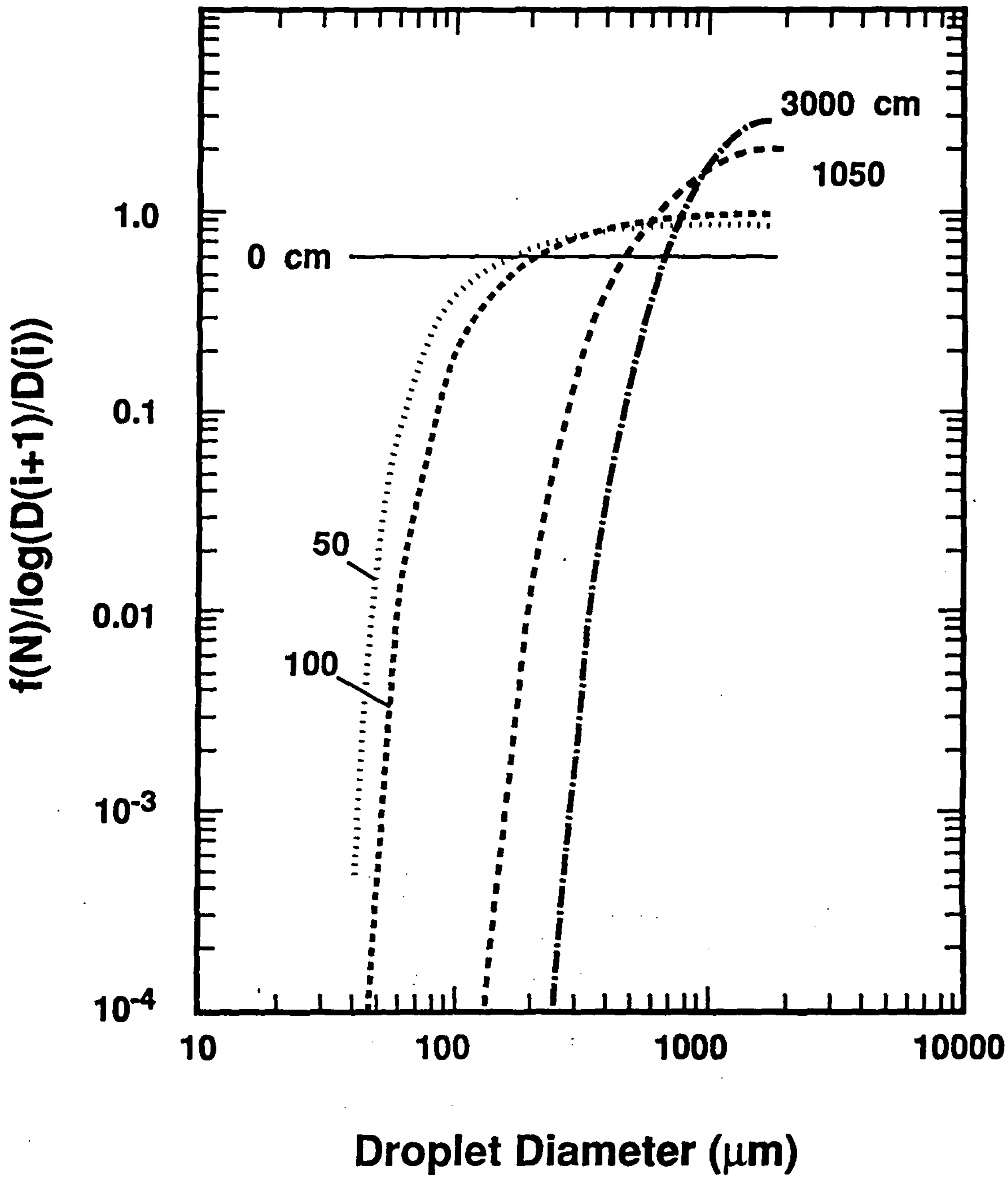

Figure 28 Evolution of a droplet size distribution during free fall. The vertical axis is the logarithm of the fraction of the total number of droplets in a size bin, f(N), divided by the logarithm of the ratio of the droplet sizes defining the bin limits. Curves are labelled by the distance from the start of free fall.

The evolution of a more realistic droplet size distribution is shown in Figure 29. The initial number distribution was formulated from a hypothesized log-normal mass distribution:

$$f(M) = 0.5(1 + \mathrm{erf}(p))$$

where

$f(M)$ = fraction of the mass of droplets with sizes less than D

$p = \ln (D/\mu) / \sqrt{(2)} \ln \sigma$

μ = mean droplet size = 426 μm

σ = geometric standard deviation = 1.654

$$\mathrm{erf}(p) = \text{error function of } p = \frac{2}{\sqrt{\pi}} \int_0^p \exp(-y^2)\, dy$$

It is evident from these results why there might be difficulty in obtaining reliable droplet size data from single spray nozzles. In the region of 0-3 meters below the nozzle, the distribution is undergoing very significant changes as a result of droplet-droplet interactions. Measurements of droplet size distributions in this region will be complicated because spatial variations in the distribution are so large. In particular, the contributions to the distribution made by droplets 200 μm and less in size vary dramatically in this region. Needless to say, it is precisely in this region that most attempts to measure the droplet size have been made.

G. Efficiency of Droplet-Droplet Interactions

Simple contact between water droplets does not necessarily result in the coalescence of the droplets. Colliding water droplets may recoil, splatter or otherwise be disrupted as well as coalescing [53]. Droplet-droplet collisions that are not head-on collisions are likely not to coalesce even at low, terminal velocities [47-52]. The greatest diversity of behavior occurs for droplets of nearly equal size. A criterion for coalescence of droplets is that the collision energy be less than 15 ergs [54]. At terminal velocities of interest here, the collisions nearly always satisfy this criterion. The same could not be said for droplet collisions in the immediate vicinity of the spray nozzle. Even when the energy criterion is satisfied, the efficiency with which collision of droplets results in coalescence is not unity. A commonly cited efficiency for coalescence during water droplet collisions is [47]:

$$\in(i,j) = \frac{R(i)^2}{[R(i) + R(j)]^2} \quad \text{for } R(i) > R(j)$$

The evolution in the size distributions of droplets discussed in the previous subsection were computed using this expression for the efficiency with which droplet-droplet interactions result in

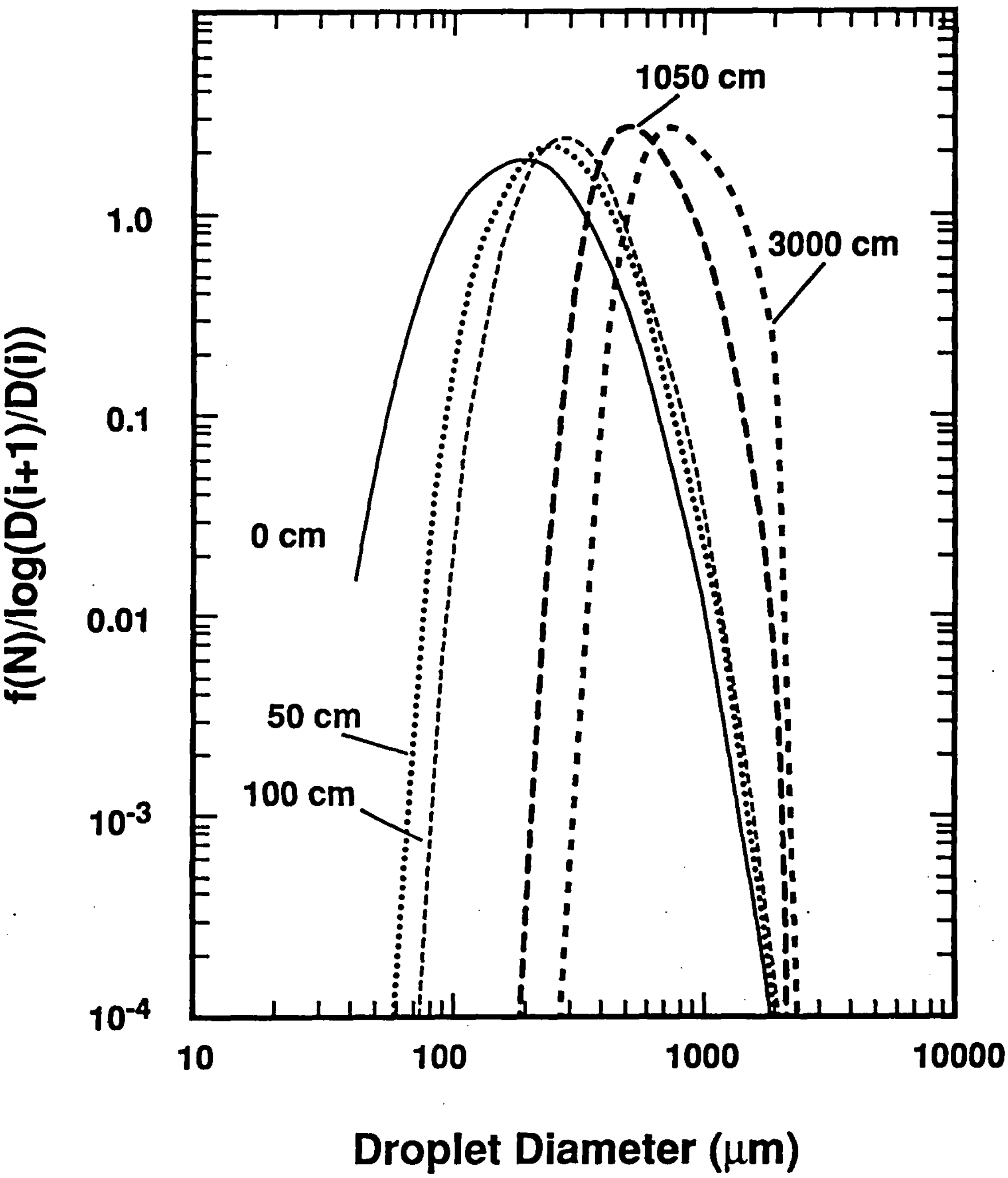

Figure 29 Evolution of a realistic spray droplet size distribution using for the efficiency of droplet-droplet interactions $\in(i,j) = 1 / (1 + R(j) / R(i))^2$

coalescence. This expression for the efficiency of collisions yielding coalescence indicates that the minimum efficiency is 0.25. Experimental evidence indicates that lower efficiencies can occur [48]. Efficiencies calculated based on theoretical arguments [48] and supported by the limited data that are available are compared in Figure 30 to the efficiencies calculated with the usual expression. As droplets become of similar size, the efficiency of collisions falls below that calculated with the simple expression above. An alternate bound on the efficiencies shown in the figure is given by:

$$\in(i,j) = \begin{cases} 1 - 8\, R(j) / R(i) & \text{for } R(j) / R(i) < 0.125 \\ 0 & \text{otherwise} \end{cases}$$

The evolution of the initial droplet size distribution shown in Figure 31 is based on this efficiency. In comparison to the case calculated with the usual description of the coalescence of colliding droplets, this case of a lower bound efficiency yields much less change in the droplet size distribution. Still, this alternate description of collision efficiency indicates that droplets smaller than 100 μm in diameter are removed from the distribution quite quickly.

H. Droplet-Structure Interactions

Reactor containment buildings are not simple, open volumes. Immediately below spray headers there is often a substantial open space. But, eventually, falling drops begin to encounter equipment, structures and operating floor of the reactor. The drywells of Mark I containments are well-known for the congestion that can interfere in the free fall of water droplets.

The flooring in many reactor containments is grating or so-called "expanded sheet metal." Below the flooring are large volumes which, in a severe reactor accident, would hold aerosol-contaminated gas. It is of interest to know, then, if spray droplets, after hitting structures and the open flooring, would continue to sweep aerosols from the containment atmosphere. Certainly, in the case of the design basis analysis of iodine removal from containment atmospheres, it has been traditional to assume droplets are ineffective once they have hit a structure or the flooring.

Baker et al. [42] have reviewed the observed behaviors of droplets of all sorts when they contact surfaces. The behaviors observed are of three types:

- droplets can bounce off the structure,

- droplets can spread on the surface, or

- droplets can splash.

Droplets bounce because of an "air cushion" that forms as they interact with the solid surface. Spreading and coalescence of droplets on surfaces of interest for the analysis of spray performance would lead, eventually, to the reformation of droplets as the liquid film formed by the droplets drained off the structure surface. Splashing of droplets can lead to the formation of more, smaller drops.

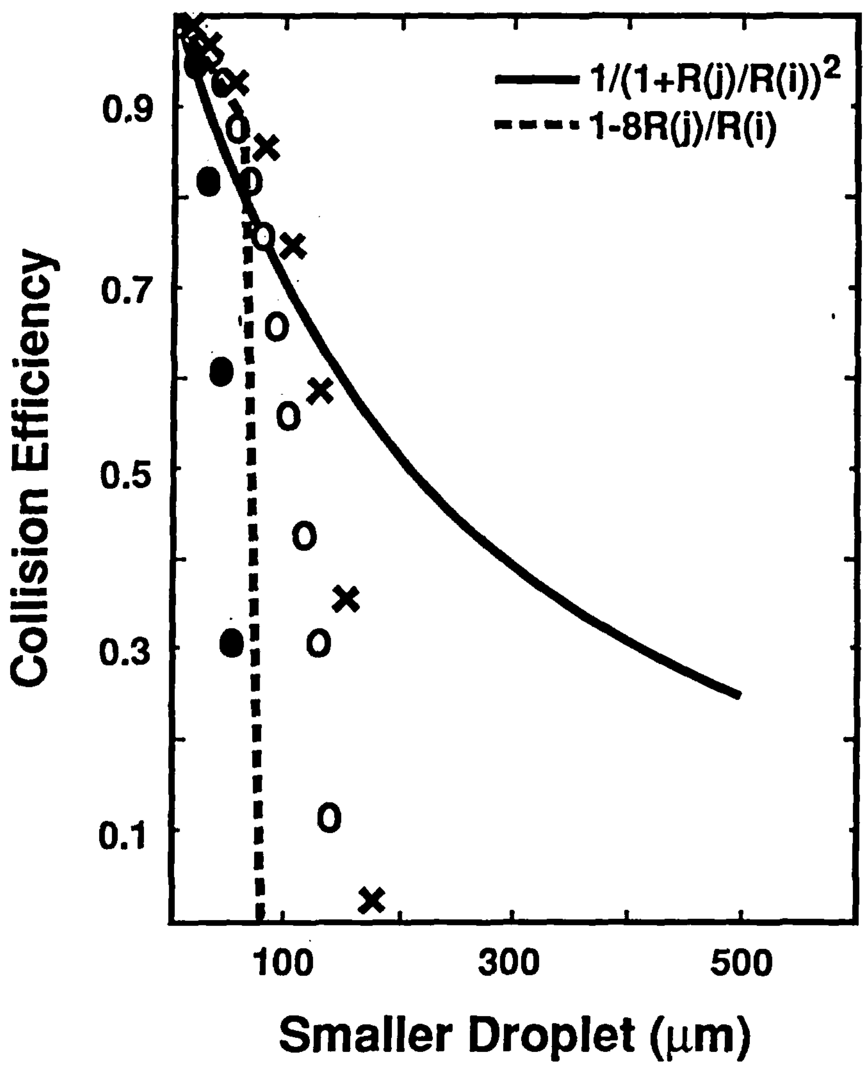

Figure 30 Comparison of the usual collision efficiency (bold line) to theoretical analyses of the collision efficiency of a 500 μm droplet (symbols) and the alternate model $\in$ = 1 - 8 R(j) / R(i) (dashed line)

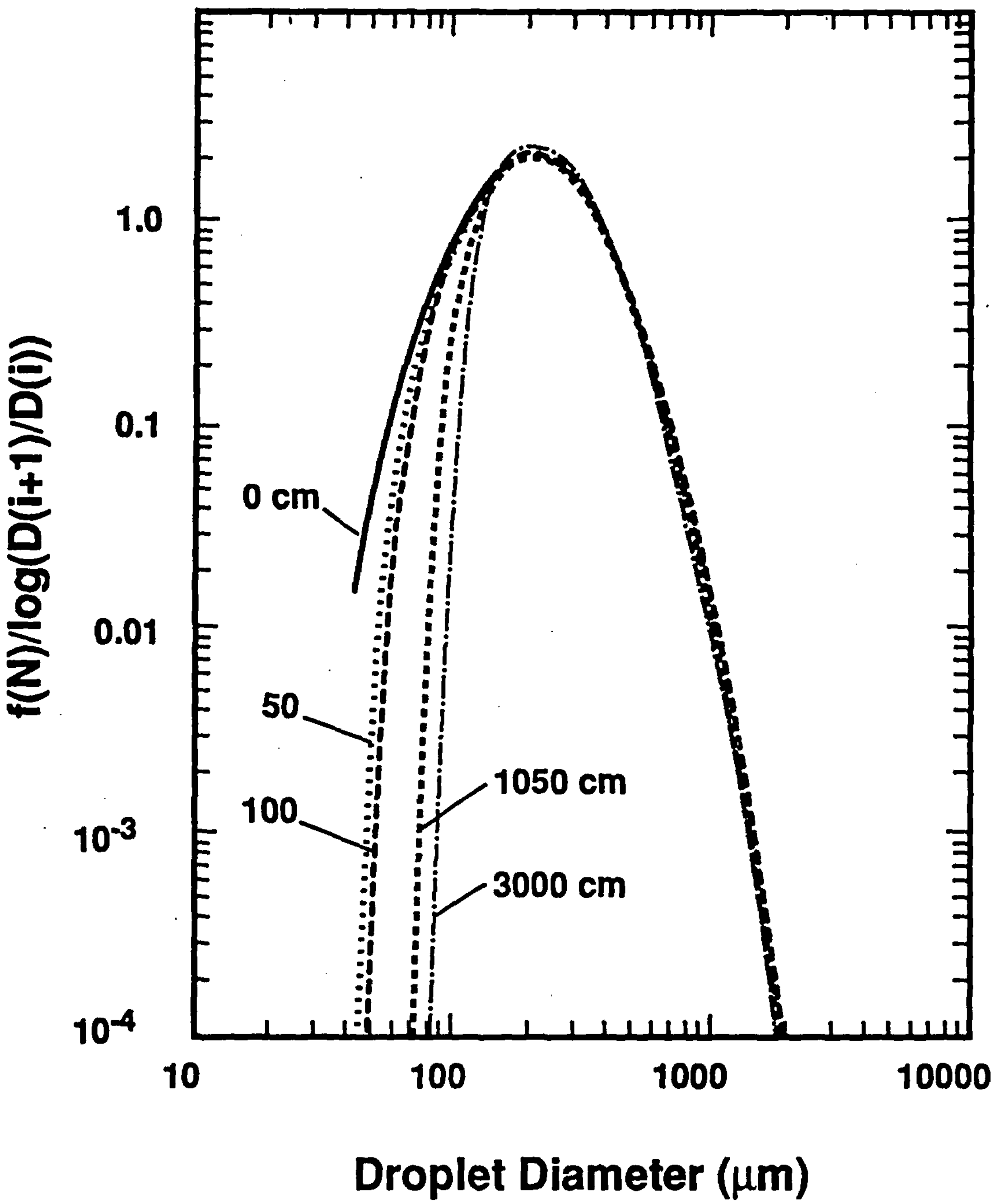

Figure 31 Evolution of droplet size distribution calculated using as the efficiency of droplet coalescence $\in(i,j) = 1 - 8\ R(j)\ /\ R(i)$ for $R(j)\ /\ R(i) < 0.125$. The evolution shown in this figure should be compared to that in Figure 29.

The behaviors of water droplets when they encounter solid surfaces can be categorized into regimes according to the Weber number of the drop, We, given by:

$$We = D_d(e)\rho_\ell\ U_T^2\ /\ \sigma_\ell$$

An example of categorization is shown in Figure 32. For low Weber numbers, typically We < 5, droplets bounce when they hit structures [43]. The droplets retain only about 6 percent of their incident kinetic energy when they bounce off structures [44]. At higher Weber numbers, the droplets coalesce with the water film. Water that coalesces to form a film on surfaces is lost for decontamination purposes unless it can contribute to drips off the surface. Baker et al. [42] indicate the drops formed by dripping have a diameter calculated from Taylor instability given by:

$$D_d(e) = 3\sqrt{\frac{\sigma}{\rho_\ell g}}$$

Such drops are huge in comparison to the drops formed by spray nozzles and would be ineffective at removing aerosols. Baker et al. noted, however, that when these drops detach from the surface, four or five smaller droplets are formed as the liquid filaments rupture. These smaller drops might be more effective at decontamination.

At Weber numbers of about 65, water droplets striking wet surfaces begin to splash. About 50 percent of the incident water droplet mass is splashed [44, 45, 46] in droplets with median diameters of about 0.1 to 0.05 cm at Weber numbers of about 1500. At a Weber number of 3000 essentially 100 percent of the incident water volume is splashed. The splashed water droplets would be effective at removing aerosols, but few spray droplets would have such high Weber numbers at their terminal velocities.

Clearly, there are opportunities for water to continue to be effective at atmosphere decontamination even after the water in the form of droplets has encountered a structure. Because of the wide diversity of reactor containments and the structures housed within these containments, no attempt has been made in this work to include analyses of droplet interactions with structures.

I. Summary of the Uncertainties in the Spray Decontamination Process

The subsections above describe the essential physical processes that lead to aerosol removal from a containment atmosphere by spray droplets. The processes depend on the number and size distribution of the spray droplets, the size distribution of the aerosols and the distance the droplets fall within a containment atmosphere. There is sufficient understanding of the many physical phenomena involved in aerosol removal by sprays, that a detailed, mechanistic model of the process can be formulated. The major modeling difficulties arise in describing the interactions among droplets and the complex droplet trajectories in the immediate vicinity of spray nozzles.

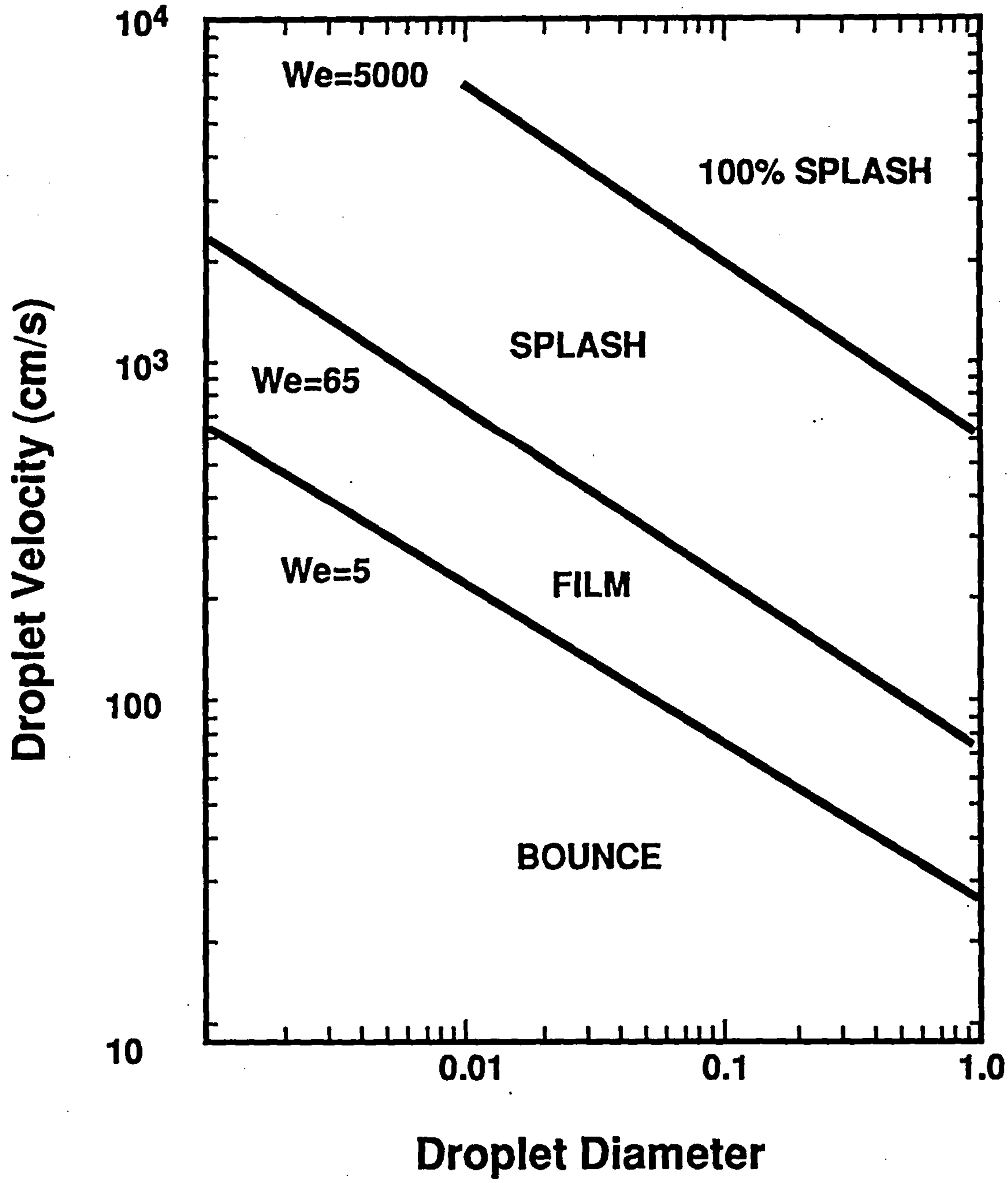

Figure 32 Regimes of droplet behavior on impact with surfaces

Predictions of the efficiency of spray removal of aerosol obtained with the detailed mechanistic model would, however, still be uncertain. The uncertainty arises from several sources. There is, of course, omnipresent uncertainty about the atmosphere conditions that will exist in reactor containments during severe reactor accidents. Containment temperatures, pressures, and the amount of water available to drive the sprays depend on details of both the reactor and the reactor accident. The exact size distribution of the aerosols suspended in the containment is another uncertainty that depends on the details of the rector accidents that are known only to within fairly large, uncertainty limits. Definitive measurements of the size distribution of spray droplets have not been made.

There are also phenomenological uncertainties. The proper model to describe aerosol capture by processes such as interception is not known. The summation of the efficiencies of various aerosol capture processes is not known. The efficiency with which two colliding droplets will coalesce to form a larger droplet is not well known.

These and the other uncertainties that afflict the prediction of spray performance are summarized in Table 5. In the next chapter of this report, a quantitative analysis of the uncertainty in predictions of spray performance is described.

Some phenomena that lead to aerosol capture have been neglected. Notably, the diffusiophoretic deposition of particles on droplets as steam produced by decay heat condenses on droplets has been neglected. Steam produced late in an accident condenses on both structures and spray droplets. The relative importance of deposition on droplets depends on the details of the accident and the extent to which the structures have been heated during the accident. Analysis of the diffusiophoretic deposition of particles late in an accident is too dependent on the specific design of the reactor to be considered here. In any event, the contribution of this diffusiophoretic deposition late in the accident is thought to be small.

Table 5 Summary of uncertain quantities

Symbols	Description	Range	Probability density function
a	Parameter to change the mix of fine and coarse droplets in the initial size distribution of the water droplets	0 - 1	uniform
P	Total pressure in containment (atms)	1.1 - 9.0	uniform
$P(H_2O)$	Partial pressure of steam in the containment atmosphere (atms)	0.1 - 7.9	uniform
$\delta(H)$	$[P(CO) + P(CO_2)] / P(H_2)$ in the containment atmosphere	0.02 to 3	log-uniform
$\delta(C)$	$P(CO)/P(CO_2)$ in the containment atmosphere	10^{-4} - 1	log-uniform
μ_p	Mean size of aerosols in the containment atmosphere		
Case 1		1.5 - 5.5	uniform
Case 2		0.15 - 0.65	uniform
σ_p	Geometric standard deviation of aerosols in the containment atmosphere		
Case 1		1.6 - 3.7	uniform
Case 2		1.1 - 1.6	correlated to the mean
χ	Dynamic shape factor for aerosols	1 - 4	log-normal $\mu = 0.3$ $\sigma = 3.04$
γ	Collision shape factor for aerosols		
$\delta\sigma_\ell$	Uncertainty in the surface tension of water	-0.1 to 0.1	uniform
$\delta\rho_\ell$	Uncertainty in the density of water	0 to 0.05	uniform

Table 5 Summary of uncertain quantities (Concluded)

Symbols	Description	Range	Probability density function
$\delta\mu_g$	Uncertainty in the estimated viscosity of the containment gases	-0.04 to 0.04	uniform
$\epsilon(1)$	Uncertainty in the model of droplet shape	0 - 1	uniform
$\epsilon(2)$	Uncertainty in the terminal velocities of droplets	0 - 1	uniform
$\delta(i)$	Uncertainty in the applicable flows regime model for aerosol capture by impaction and interception	0 - 1	uniform
$\delta(t)$	Uncertainty in the interpolation between viscous and potential flow regimes		log-normal $\mu = 60$ $\sigma = 4$
δ	Uncertain parameter in impaction efficiency model	0.25 - 0.75	uniform
$\delta(dif)$	Uncertainty in the model for aerosol capture by diffusion	0 - 1	uniform
$\delta(sum)$	Uncertainty in the summation of aerosol capture efficiencies by impaction, interception and diffusion	0 - 1	uniform
$\delta(drop)$	Uncertainty in the efficiency with which droplet-droplet interactions result in coalescence of the drops	0 - 1	uniform

III. Uncertainty Analysis

A. Overview of the Approach to Uncertainty

The discussions presented in Chapter II show that there are many uncertainties in the modeling of aerosol capture by spray droplets. In addition to the phenomenological uncertainties, there are, of course, also uncertainties in the boundary and initial conditions. These uncertainties in the boundary and initial conditions originate in the analyses of accident scenarios and are propagated into the analysis of spray performance. These accident-dependent uncertainties include such things as the pressure in the containment or the drywell and the availability of pumps to drive the sprays.

The "expert opinion" approach to uncertainty has been avoided here. Instead, an approach to develop quantitative uncertainty analysis first articulated by Theofanous [31] and pursued by Powers [32] has been adopted. The approach involves six steps.

The first two steps in this approach are:

1) develop a mechanistic description of the phenomenon or process of interest, and

2) identify uncertain parameters or submodels in this description of the phenomenon or process.

These first two steps for the analysis of uncertainties in the prediction of spray decontamination of an aerosol-laden containment atmosphere are described in the previous chapter (Chapter II) of this report.

The next two steps in the uncertainty analysis process are:

3) define ranges for the uncertain parameters in the model, and

4) develop probability density functions for the values of uncertain parameters within these ranges.

These two steps are described for the spray decontamination process in this chapter (Chapter III).

The final two steps in the uncertainty analysis are:

5) conduct multiple evaluations of the phenomenon or process with the mechanistic model (described in Step 1) while sampling from the distributions to obtain parameter values used in each calculation, and

6) accumulate the results of the model predictions to develop a quantitative description of the uncertainty.

These last two steps are described for spray decontamination in Chapter IV of this report.

Some of the mechanical details of this uncertainty analysis are described elsewhere [11]. The approach does not completely avoid expert opinion. Expert opinion is, in fact, essential in the development of a mechanistic model and in the definition of ranges for uncertain parameter values and the definition of alternate models for critical phenomena contributing to the issue of interest. This use of expert opinion is inherently different than the use of expert opinion in more traditional approaches to uncertainty. Expert opinion is here focused on detailed phenomenological issues for which there are data and, consequently, real expertise can be developed. Often, questions requiring the opinions of experts can be of sufficient detail that the "opinions" can be drawn from the scientific literature as they have been, in the main, here.

This chapter presents a summary of the uncertainties that arise in the prediction of aerosol removal by sprays. The uncertainties that are examined include phenomenological uncertainties discussed in Chapter II and uncertainties in boundary or initial conditions. Ranges for the uncertain quantities are defined based on literature data or limitations imposed by physical laws. Finally, probability density functions are developed for values of the uncertain quantities within their respective ranges. These probability density functions are used in the Monte Carlo uncertainty analysis described in the next chapter of this report.

Many of the uncertain features of spray performance are readily ascribed to individual parameters with uncertain values. It is, however, also important to recognize uncertainty in the predictions of spray performance that arise because of uncertainties concerning which model to use to describe processes and phenomena that affect spray performance. To incorporate this type of uncertainty into the Monte Carlo uncertainty analyses discussed in Chapter IV, it is convenient to define a parameter that reflects uncertainty in the applicable model. This is done here in one of two ways. The first of these is a weighted averaging of model predictions. This averaging method is applied when there are two or more available models that could be used to describe the same phenomena or process but the models have different parameterization or different functional dependencies. A typical example might be different correlations of the convective enhancement of diffusive mass transport to a sphere. Denote the prediction of the models to be used in the evaluation of spray performance as π. Let the value predicted by model A to be $\pi(A)$ and the value predicted by model B be $\pi(B)$. Then, a parameter ξ is defined to have values uniformly distributed over the range of 0 to 1 and the value of the model predictions used in the analysis is given by:

$$\pi = \xi\ \pi(A) + (1 - \xi)\ \pi(B)$$

The second method used to account for model uncertainty is applied when the competing models are based on different views of the physical processes responsible for the predicted quantities. Again, define the predictions of models A and B to be $\pi(A)$ and $\pi(B)$, respectively. Then, a parameter δ is defined to have values uniformly distributed between 0 and 1. The value of the quantity of interest used in an analysis of spray performance is given by:

$$\pi = \begin{cases} \pi(A) & \text{for } 0 < \delta \leq 0.5 \\ \pi(B) & \text{for } 0.5 < \delta \leq 1.0 \end{cases}$$

Definition of probability density functions to be used for uncertain quantities is a subjective process. The authors know of no algorithm or non-controversial way to do this. There have been attempts reported in the literature to define optimal approaches to the definition of these probability density functions [34]. A rule-based approach is adopted here. All parameters used here are non-negative. Three possible types of probability density functions are considered:

- the uniform distribution,
- the log-uniform distribution, and
- the log-normal distribution.

The uniform distribution has a constant probability density within the range of values defined for the parameter of interest. The log-uniform distribution has a constant probability density for the logarithm of the parameter of interest within its specified range. The probability densities for the uniform and log-uniform distributions are, of course, zero for values of the parameters outside their respective ranges. The third distribution used here is the log-normal function. For a parametric quantity, Z, the probability density is given by:

$$f(Z) = \frac{1}{\ln\sigma\,\sqrt{(2\pi)}}\ \exp\left[-\ \frac{(\ln\ (Z/\mu))^2}{2(\ln\sigma)^2}\right]$$

where

μ = mean of the distribution

σ = geometric standard deviation

The log-normal distribution specifies finite probability densities for all positive values of the parametric quantity even if the values are outside the probable ranges for values discussed above. Here, the lower limit of the specified range is taken to be the 1 percentile of the cumulative distribution and the upper limit is taken to be the 99 percentile value when the distribution function is log-normal. Thus, the upper limit, x(u), and the lower limit, x(L), of the range of parametric values specify the mean and standard deviation of the distribution:

$$\ln\mu = (1/2)\ (\ln x\ (u) + \ln x(L))$$

$$\ln\sigma = \ln\ (x(u)\ /\ x(L))\ /\ 4.65269$$

The three probability density functions used here are shown schematically in Figure 33. Note that the log-uniform density function would, if plotted against the logarithms of the parameter values, be a constant. When plotted against the actual parameter values, the probability density varies with the reciprocal of the parameter value.

The "rules" adopted here for the selection of the distribution functions are as follows:

1. The log-normal distribution is selected for those parameters for which values are known well enough that means and standard deviations can be meaningfully calculated.

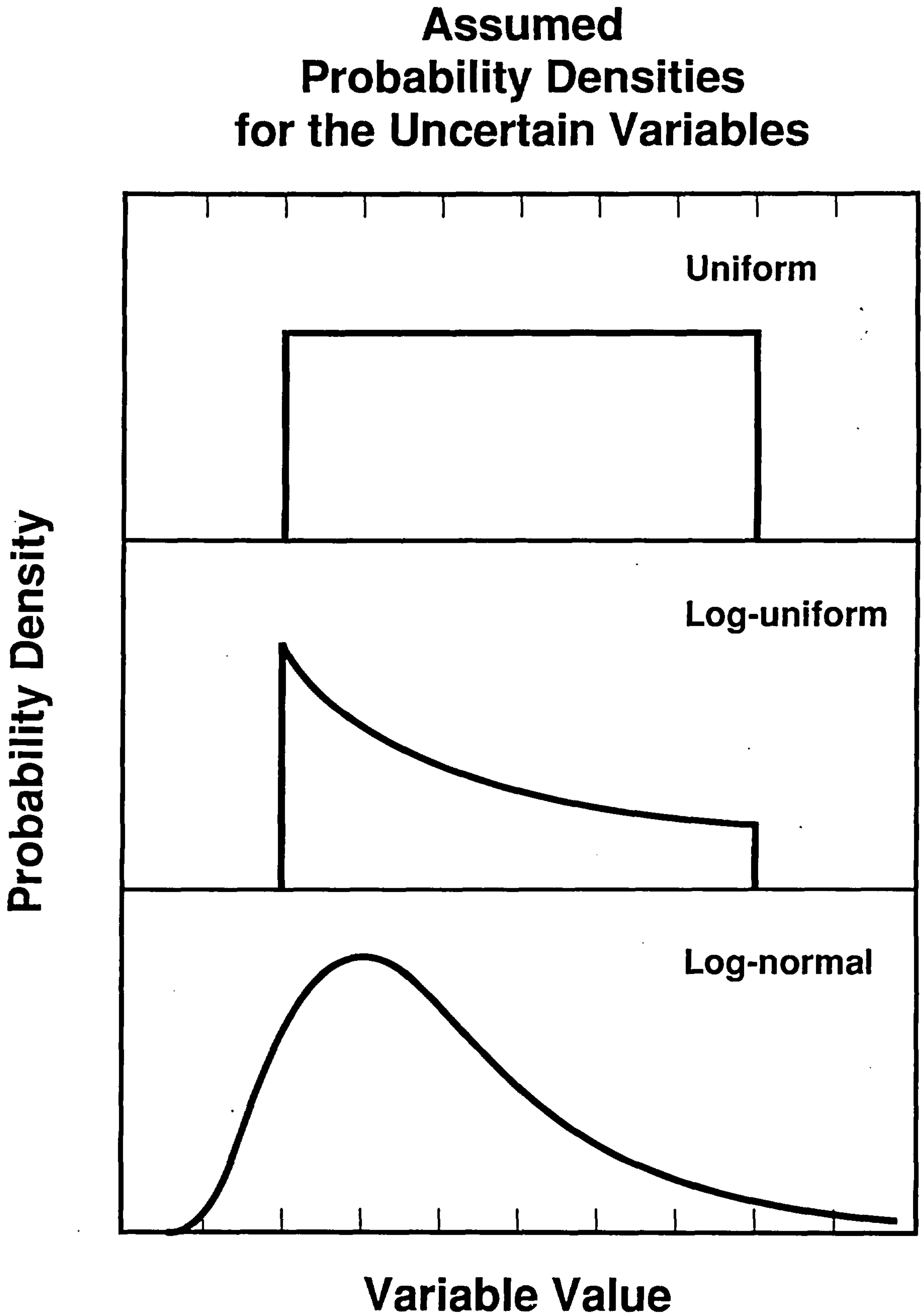

Figure 33 Schematic illustrations of the probability density functions used for the uncertainty analyses

2. Uniform distributions are used for uncertain parameters whose meaningful values span a range of less than one order of magnitude.

3. The log-uniform distribution is used when meaningful values of the parameter span more than one order of magnitude.

The various parameters and quantities considered to be uncertain in the analyses presented here are summarized in Table 5. Allowable ranges for the values of these quantities and the probability density functions assumed for the values within the ranges are also indicated in the table. Some effort has been made to decompose issues sufficiently that the uncertainties are uncorrelated. Where it has not been possible to entirely avoid correlations among uncertain quantities, the necessary modifications to the density functions are described below as part of the discussions of each of the individual uncertain quantities.

B. Discussion of Individual Uncertainties

Fourteen areas of uncertainty involving 20 uncertain quantities have been identified as possibly affecting predictions of spray performance. In the subsections below, each of the uncertainties considered in the analysis of spray performance is discussed. The principal objectives of the discussions are to define the ranges of values the uncertain quantities can assume along with the probability density functions defined for values within the ranges. The bases for the ranges of values have often been defined in the discussion of phenomena and processes in Chapter II. Only when some elaboration is thought necessary is there further discussion of the bases for the ranges.

1. Uncertainty in the Initial Droplet Size

The complexities and uncertainties in the initial droplet size of the spray have been discussed at length in Chapter II. In summary, these uncertainties arise because:

- different measurement techniques yield different spray droplet size distributions,

- the size distributions are, apparently, sensitive to the purity of the water, and

- overlap of spray patterns of adjacent nozzles provides the opportunity for larger droplets to sweep out smaller droplets.

The primary uncertainty is the contribution to the spray made by small droplets. The question is, are droplets less than 200 μm in diameter as numerous as is indicated by spray size distributions obtained by the freeze-and-sieve technique with tap water or are they less abundant as indicated by results obtained with boric acid-sodium hydroxide solution? To reflect this uncertainty, it is assumed here that the spray droplet size distribution can be resolved into two modified log-normal components. The mix between these components is taken to be uncertain. The modifications made to the log-normal distributions are to truncate the components at lower and upper limits to the sizes of droplets that can initially be present. The upper limit is taken to be 3000 μm. This is a limit drawn simply from the empirical evidence presented in Chapter II that there appear to be few droplets larger than this. The lower limit is taken to be 39 μm based on the experience that it takes special effort to form droplets smaller than about this size.

The two component distributions are taken to have means of 125 μm and 650 μm, respectively, and geometric standard deviations of 2.0. These parameters are admittedly somewhat arbitrary. At best they are based on a qualitative inspection of the data on spray size distributions shown in Chapter II. It is possible to consider these parameters as uncertain. But, a sufficient account of the uncertainty concerning the initial size distribution of water droplets is probably provided by varying the contributions the two components make to the overall distribution.

The cumulative number distribution of spray droplets is then given by:

$$F\left(D_d(e) < D\right) = \frac{aN_1}{2}\left\{0.90712 + \mathrm{erf}(Z_1)\right\} + \frac{(1-a)N_2}{2}\left\{0.99996 + \mathrm{erf}(Z_2)\right\}$$

where

a = uncertain parameter uniformly distributed between 0 and 1

N_1 = normalization factor to account for the cutoff of the distribution at 39 and 3000 μm = 1.0487

N_2 = normalization factor to account for the cutoff of the distribution at 39 and 3000 μm = 1.0139

$Z_1 = \ln(D / 125) / \sqrt{2}\ \ln 2$

$Z_2 = \ln(D / 650) / \sqrt{2}\ \ln 2$

D = critical droplet size in μm.

$$\mathrm{erf}(Z) = \text{error function of } Z = \frac{2}{\sqrt{\pi}} \int_0^Z \exp(-y^2)\, dy$$

Plots of the number distribution against droplet size for various values of the parameter a are shown in Figure 34. As the parameter varies from 0 to 1 the importance of fine droplets in the distribution increases.

2. Uncertainty in the Droplet Shape

Only the largest water droplets of interest here distort significantly from spherical during fall through the containment atmosphere. Typically, at atmospheric pressure, only droplets larger than 0.1 cm distort. Two models for the distortion are described in Chapter II. A simple model developed by Pruppacher and Beard [12] considers distortion of droplets larger than 0.1. This model can be designated model A. A more complicated model that considers distortions when the Eotvos

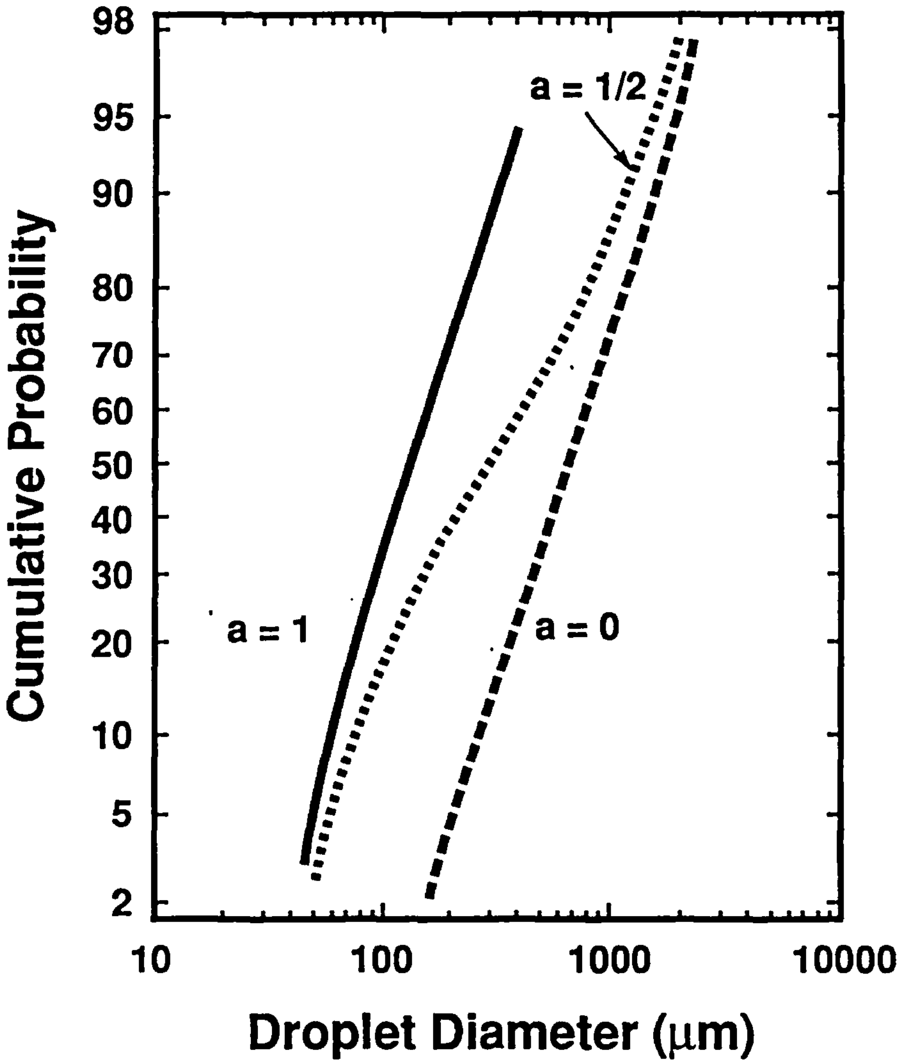

Figure 34 Variations in the droplet size distribution with variations in the uncertain parameter a. Cumulative probability is in percent.

number, E_o, is greater than 0.4 is designated model B. An uncertain parameter, $\in(1)$, which is uniformly distributed over the range of 0 to 1, is used to select between these models. Model A is used when $\in(1) < 0.5$ and Model B is used otherwise. Note that the distorted geometry of the droplets is not used in the computations of the terminal velocities. The droplet distortions are implicitly considered in the correlations for terminal velocities.

3. Uncertainty in the Droplet Terminal Velocities

There is a limited data base for the terminal velocities of water droplets for conditions more extreme than those encountered in weather systems. That is, the elevated temperatures and pressures in reactor containment atmospheres under severe accident conditions have not been considered in the development of the data base for the terminal velocities of water droplets. Three models for the terminal velocities of water droplets are described in Chapter II of this report. Model C in these discussions is really restricted in its applications to droplets that are larger than those of interest here. Consequently, Model C is not considered here. Model A is the best fit model for terminal velocities of water droplets in air and Model B has been used by others to extrapolate the data base[13]:

- Model A:

$$Re_T^{(A)} = \exp\left[-3.126 + 1.013 \ln N_D - 0.01912 (\ln N_D)^2\right]$$

- Model B:

$$Re_T^{(B)} = \begin{cases} 1.62\, E_o^{0.755}\, M^{-0.25} & \text{for } 0.5 < E_o \le 1.84 \\ 1.83\, E_o^{0.555}\, M^{-0.25} & \text{for } 1.84 < E_o \le 5.0 \\ 2.0\, E_o^{0.5}\, M^{-0.25} & \text{for } E_o > 5 \end{cases}$$

$$Re_T^{(B)} = N_D / 24 - 1.7569 \times 10^{-4} N_D^2 + 6.9252 \times 10^{-7} N_D^3$$

$$- 2.3027 \times 10^{-10} N_D^4 \qquad \text{for } N_D < 73;\ E_o \le 0.5;\ Re_T < 2.37$$

Uncertainty

$$\log_{10} Re_T^{(B)} = -1.7095 + 1.33438 \log_{10} N_D - 0.11591 (\log_{10} N_D)^2$$

$$\text{for } 73 < N_D < 580; E_o \leq 0.5; 2.37 < Re_T < 12.2$$

$$\log_{10} Re_T^{(B)} = -1.81391 + 1.34671 \log_{10} N_D - 0.12427 (\log_{10} N_D)^2 + 0.006344 (\log_{10} N_D)^3$$

$$\text{for } N_D > 580; E_o \leq 0.5; 12.2 < Re_T < 6350$$

To account for the uncertainty in the extrapolation of water droplet terminal velocities, an uncertain parameter $\in(2)$ which is uniformly distributed over the range 0 to 1 is defined. The terminal velocity is then calculated from:

$$Re_T = \in(2)\, Re_T^{(A)} + [1 - \in(2)]\, Re_T^{(B)}$$

4. Uncertainty in the Surface Tension of Water

The surface tension of water in the droplets affects the deformation and consequently the drag on the droplets as they fall through the atmosphere. Surface tension effects may be responsible for the changes in the water droplet size distributions when boric acid-sodium hydroxide solutions are used rather than tap water in sprays (see Chapter II).

The surface tension of pure water at temperatures of interest here is quite well known. The effects of additives such as boric acid, sodium hydroxide and the like as well as the effects of contaminants that accumulate in the waters during spray operation are the sources of uncertainty in the surface tension of water. None of the additives or contaminants usually considered to be in the spray waters is a particularly strong surface-active agent. Rather, the effects of these species, when dissolved in water, are milder bulk chemistry effects. As discussed elsewhere [11], dissolved species can either increase or decrease the surface tension of water. At the concentrations expected to arise in spray waters, the magnitude of the effect ought not be greater than a 10 percent increase or reduction in the surface tension of pure water. Here the surface tension of the spray water is taken to be:

$$\sigma_\ell = \sigma(w)\,(1 + \delta\sigma_\ell)$$

where

$\sigma(w)$ = surface tension of pure water

$\delta\sigma_\ell$ = uncertain parameter uniformly distributed over the range of 0.1 to -0.1.

5. Uncertainty in the Density of Water

The density of pure water is, of course, very well known. The temperature-dependent density of pure water is shown in Table 4. But, water used in sprays is likely to contain additives such as boric acid at concentrations of up to 4000 ppm. In most reactor systems, the containment sprays operate in a recirculation mode. As decontamination progresses, the water used for the sprays becomes more heavily contaminated with dissolved and suspended materials. Consequently, the water density is taken here to be given by:

$$\rho(\ell) = \rho\ (\text{pure water})\ [1 + \delta\rho_\ell]$$

where $\delta\rho_\ell$ is an uncertain variable with values uniformly distributed over the range of 0 to 0.05.

6. Uncertainty in the Viscosities of Gas Mixtures

The viscosity of the gas phase has a pervasive effect on spray performance. Viscosity affects droplet sizes, shapes, and terminal velocities. Fairly complicated gas mixtures of air, steam, and the gaseous products of concrete decomposition can develop in reactor containments under severe accident conditions. The viscosities of individual constituents of the gas phase have been measured with reasonable accuracy. The viscosities of the mixtures thought to be possible during severe accidents have not been studied. To estimate the viscosities of mixtures the Herning-Zipperer formula is used

$$\mu_g\ (\text{mixture}) = \frac{\sum_i\ (P(i)\ /\ P)\mu_g(i)\ \sqrt{(Mw(i))}}{\sum_i\ (P(i)\ /\ P)\ \sqrt{(Mw(i))}}$$

where the summations are over the constituents of the mixture (taking air as a constituent species) and Mw(i) is the molecular weight of the i^{th} gas species. This estimation formula has proven to give results accurate to about 2 percent for CO-H_2 gas mixtures at 298 K [36]. Another test of the estimation formula is to compare its predictions for air-steam mixtures to the more involved formula suggested by Knudsen [35]:

$$\mu\ (\text{mixture}) = \frac{\mu(\text{air})}{1 + P(\text{steam})\phi\ /\ P(\text{air})} + \frac{\mu\ (\text{steam})}{1 + P(\text{air})\psi\ /\ P\ (\text{steam})}$$

Uncertainty

where

$$\mu\,(\text{air}) = 2.3013 \times 10^{-6}\, T^{0.768} \text{ poises}$$

$$\mu\,(\text{steam}) = 9.75 \times 10^{-7}\, T / (1 + 207/T) \text{ poises}$$

$$\phi = \frac{\left\{1 + \left[\dfrac{\mu(\text{air})}{\mu(\text{steam})}\right]^{1/2} 0.884\right\}^2}{4.56525}$$

$$\psi = \frac{\left\{1 + \left[\dfrac{\mu(\text{steam})}{\mu(\text{air})}\right]^{1/2} 1.134\right\}^2}{3.60331}$$

Results obtained in this comparison are shown in Table 6. Again, it is found that the Herning-Zipperer formula produces predictions that agree to within about 4 percent with predictions obtained with the presumedly more accurate correlation developed by Knudsen specifically for air-steam mixtures.

Predictions of the Herning-Zipperer formula are uniformly higher than those of the Knudsen Model. It is, however, not apparent that this systematic difference will occur for all mixtures. To account for uncertainty in the estimates of gas mixture viscosities, estimates of viscosity obtained from the Herning-Zipperer formula are considered uncertain by ± 4 percent of the estimated value. The uncertainty is considered to be uniformly distributed over this range.

Viscosities of CO, CO_2, and H_2 used in the Herning-Zipperer formula are:

$$\mu_g(CO) = 14.151 \times 10^{-6}\, T^{0.502012} / (1 + 117.178/T) \text{ poise}$$

$$\mu_g(CO_2) = 15.957 \times 10^{-6}\, T^{0.457212} / (1 + 246.744/T) \text{ poise}$$

$$\mu_g(H_2) = 1.5765 \times 10^{-6}\, T^{0.705712} / (1 - 3.378/T) \text{ poise}$$

7. Uncertainty in Droplet-Droplet Interactions

Sweepout of small water droplets by larger water droplets is an important factor in the prediction of the performance of containment sprays. Simple contact between two droplets does not necessarily lead to coalescence of the droplets. Two limiting models of the efficiency with which droplet collisions result in coalescence are described in Chapter II:

Table 6 Comparison of predictions of the viscosities of air/steam mixtures

T(K)	Total pressure (atms)	Steam partial pressure (atms)	Gas viscosity from Herning-Zipperer model (Poise)	Gas viscosity from Knudsen model (Poise)	Percent difference
298	1.031	0.031	1.807×10^{-4}	1.798×10^{-4}	0.5
310	1.061	0.061	1.842×10^{-4}	1.826×10^{-4}	0.9
320	1.104	0.104	1.861×10^{-4}	1.837×10^{-4}	1.3
330	1.170	0.170	1.866×10^{-4}	1.832×10^{-4}	1.8
340	1.268	0.268	1.858×10^{-4}	1.813×10^{-4}	2.4
350	1.411	0.411	1.836×10^{-4}	1.781×10^{-4}	3.0
360	1.613	0.613	1.802×10^{-4}	1.740×10^{-4}	3.5
370	1.892	0.892	1.761×10^{-4}	1.697×10^{-4}	3.7
380	2.270	1.270	1.720×10^{-4}	1.657×10^{-4}	3.7
390	2.771	1.771	1.682×10^{-4}	1.624×10^{-4}	3.5
400	3.424	2.424	1.652×10^{-4}	1.601×10^{-4}	3.1
410	4.259	3.259	1.632×10^{-4}	1.588×10^{-4}	2.7
420	5.313	4.313	1.622×10^{-4}	1.585×10^{-4}	2.3
430	6.625	5.625	1.621×10^{-4}	1.590×10^{-4}	1.9
440	8.236	7.236	1.628×10^{-4}	1.603×10^{-4}	0.4
450	10.194	9.194	1.641×10^{-4}	1.621×10^{-4}	1.2

Uncertainty

$$\in(A) = \frac{R(i)^2}{(R(i) + R(j))^2}$$

and

$$\in(B) = \begin{cases} 1 - 8 \frac{R(j)}{R(i)} & \text{for } R(j) / R(i) < 0.125 \\ 0 & \text{for } R(j) / R(i) \geq 0.125 \end{cases}$$

An uncertain parameter, δ(drop), is defined here to have values uniformly distributed over the range of 0 to 1. This parameter is used to evaluate the efficiency of droplet coalescence in collisions from

$$\in = \delta(\text{drop}) \in(A) + [1 - \delta(\text{drop})] \in(B)$$

8. Uncertainty in Containment Pressure and Temperature

The pressure and the temperature in reactor containments is affected by operation of the sprays. The sprays can, of course, cool the atmosphere and condense steam. How much reduction in the pressure and temperature can be achieved with containment sprays depends on other aspects of the accident. In particular, the non-condensible gases generated during the accident are important and for this analysis they are considered uncertain. For this analysis, it is clear that pressures above the containment failure pressure are not of interest. The difficulties of estimating the ultimate failure pressures of reactor containments are well beyond the scope of this work. It is clear that few containments are capable of withstanding pressures in excess of 9 atmospheres. Even if global analyses of a containment structure indicate higher pressure capabilities, it is likely that flaws or errors in construction would restrict pressure capabilities to less than 9 atmospheres.

Pressure in the reactor containment is determined by the amount of air originally in the containment, the vapor pressure of water, and the amount of non-condensible gas produced during core degradation and during core debris interactions with concrete. The concentrations of steam and non-condensible gas in the containment atmosphere vary markedly over the range of severe accidents that are hypothesized to occur at the various types of reactor containments found in the country. Prediction of these concentrations is still the subject of debate within the reactor safety community.

To account for the uncertainty in the pressure and composition of the containment atmosphere during spray operation, the following steps are taken:

1. the total pressure, P, in the containment is taken to be uncertain over the range of 1.1 to 9.0 atmospheres,

2. the partial pressure of steam is taken to be uncertain over the range of 0.1 to 7.8 atmospheres but is always less than the total pressure minus one atmosphere to account for the original air in containment,

3. the temperature of the atmosphere during spray operation is taken to be that temperature which yields the selected value of the steam partial pressure,

4. the partial pressures of hydrogen, carbon monoxide and carbon dioxide produced during core degradation complete the description of the composition of the containment atmosphere.

Note that the containment atmosphere is assumed to be saturated during spray operations. The transient period when sprays just begin to operate and to condense steam from the atmosphere is neglected in this work. It is assumed that the atmosphere can become quite hot to sustain steam partial pressures of up to 7.9 atmospheres because containment sprays do operate in a recirculation mode especially if they are used to attenuate the potential source term in the long-term phase of a severe accident. Sprays can draw water from sumps containing large inventories of radionuclides that heat the water by radioactive decay. The temperature of the containment atmosphere is calculated from a simple correlation of vapor pressure data for water:

$$\ln P(H_2O) = -7.938.16/T + 88.912 - 12.1215 \ln(T) + 0.011079T$$

where $P(H_2O)$ is the partial pressure of water vapor in atmospheres.

Hydrogen is produced during severe reactor accidents predominantly by metal-water reactions as the core degrades within the reactor coolant system or as the core debris interacts with concrete. Metal-water reactions during steam explosions [56] or during other energetic events such as direct containment heating [57] can also produce hydrogen in the containment atmosphere. Radiolysis and corrosion of metals in the containment are negligible sources of hydrogen in severe reactor accidents [58]. Carbon monoxide and carbon dioxide in the containment atmosphere are thought to come from the interaction of core debris with concrete. Some carbon monoxide and carbon dioxide may also come from pyrolysis of organic materials in the containment under severe reactor accident conditions. The authors are not aware of any detailed analysis of this possible source of carbonaceous gases but suspect that this source is small in comparison to the production of carbon monoxide and carbon dioxide during core debris interactions with concrete.

The sum of the partial pressures of carbon monoxide and carbon dioxide relative to the partial pressure of hydrogen is affected by the extent to which hydrogen is produced during core degradation as well as by the composition of concrete used to construct the reactor. Concretes that use siliceous materials as the aggregate contain only about 1 weight percent carbon dioxide in the form of carbonates. Concretes that use calcareous aggregate can contain as much as 36 weight percent carbon dioxide in the form of carbonates that will decompose during interactions with high temperature core debris.

Carbon dioxide liberated from the concrete sparges through and reacts with core debris. The reactions produce carbon monoxide. Core debris of depths greater than 5-10 cm is capable of reacting with evolved carbon dioxide to the point that essentially an equilibrium mixture of carbon monoxide and carbon dioxide is formed. The partial pressure ratio of carbon monoxide and carbon dioxide in this equilibrium mixture depends on the reactivity of metals in the core debris. When metallic zirconium is present in the core debris interacting with the concrete, reactions of carbon dioxide to form carbon monoxide are nearly complete. The equilibrium partial pressure ratio is quite large:

$$\frac{1}{\delta(C)} = \frac{P(CO)}{P(CO_2)} \cong 10^4$$

If chemical reactions have depleted the core debris of reactive metals such as zirconium and chromium so that iron is the most reactive metal remaining in the core debris, the reaction of carbon dioxide to form carbon monoxide is much less complete:

$$\frac{1}{\delta(C)} = \frac{P(CO)}{P(CO_2)} \cong 1$$

The water content of concrete depends on the humidity of the atmosphere to which the concrete is exposed during operation of the reactor. Typically structural concretes in nuclear reactors are found to contain 5 to 8 weight percent water. When core debris interacts with concrete, this water is vaporized, sparges through the core debris and reacts to form hydrogen. Again, the extent of reaction of water vapor released from the concrete to form hydrogen depends on the reactivity of the core debris. Nearly complete reduction of water vapor occurs when metallic zirconium is present. Only about 2/3 of the evolved water vapor is converted to hydrogen when iron is the most reactive constituent of core debris.

If core debris interactions with concrete were the only sources of hydrogen, carbon monoxide and carbon dioxide to the containment atmosphere, the partial pressure ratio

$$[P(CO_2) + P(CO)] \,/\, P(H_2)$$

could be as high as 3 in the case of calcareous aggregate concrete. In the case of siliceous aggregate concrete, the ratio might be as low as 0.05. Consideration of other sources of hydrogen production during severe reactor accidents leads to the conclusion that this ratio might be even lower.

Based on these considerations, the contributions to the atmospheric composition that are made by hydrogen, carbon monoxide and carbon dioxide are found from the following equations:

$$P(H_2) = \Delta \,/\, (1 + \delta(H))$$

$$P(CO) = \delta(H)\Delta \,/\, [(1 + \delta(H))\ (1 + \delta(C))]$$

$$P(CO_2) = \delta(C)\delta(H)\Delta \,/\, [(1 + \delta(H))\ (1 + \delta(C))]$$

where

$$\Delta = P - \frac{T}{298} - P(H_2O)$$

P = total pressure in the containment

$P(H_2O)$ = partial pressure of steam

$$\delta(H) = \left(P(CO) + P(CO_2)\right) / P(H_2)$$

= uncertain parameter with a log-uniform distribution over the interval from 0.02 to 3

$$\delta(C) = P(CO_2) / P(CO)$$

= uncertain parameter with a log-uniform distribution over the range from 1 to 10^{-4}

One of the biggest safety concerns that has been raised over spray operations during severe reactor accidents deals with the issue of hydrogen combustion. Sprays condense steam and can eliminate the so-called "steam-inerting" of containment atmospheres which increases the likelihood of hydrogen combustion [58]. The effect of hydrogen combustion events is to reduce the contributions made by oxygen and hydrogen to the containment atmosphere since, by postulate, hydrogen combustion events are assumed not to rupture containment. Relative to other factors that might affect the composition of the atmosphere, the changes that a hydrogen combustion event might have on the atmospheric composition during steady state spray operation are thought to be negligible.

9. Uncertainty in the Aerosol Size

Aerosols in the containment atmosphere can come from a variety of sources such as:

- in-vessel core degradation
- ex-vessel core debris interactions
- revaporization of volatile materials from the reactor coolant system.

Within the containment, the size spectrum of the aerosols will evolve as smaller particles agglomerate and larger particles deposit from the atmosphere. A number of computer codes have been developed to predict the evolution in aerosol particle sizes [37-41]. Where it has been possible to compare predictions to data, the evidence is that these codes are quite accurate at least for the purposes of reactor safety analyses. With continuing sources of aerosols to the reactor containment that are not too intense, a stable distribution of particle sizes is established in the containment atmosphere. While the distributions of aerosol sizes are not precisely log-normal, they are usually rather well approximated by such a distribution.

Some example size distributions for aerosols in containments during severe reactor accidents calculated with the Source Term Code Package are shown in Figure 35. The distributions indicate the aerosols in containment to be relatively large. Based on these results and results from the QUEST study [61], the aerosol size distributions present in containment are assumed here to be log-normally distributed in size with uncertain means and geometric standard deviations. The mass mean aerosol size is taken to be uniformly distributed over the size range of 1.5 to 5.5 μm. The geometric standard deviation is taken to be uniformly distributed over the range of 1.6 to 3.7.

It might be expected that the geometric standard deviation and the mass mean size are correlated. No evidence to support this suspicion could be found. Breadth in the size distribution as indicated by a large geometric standard deviation is more readily correlated with a continuing source of aerosol material to the containment atmosphere.

Dedicated attempts to mitigate the consequences of a severe reactor accident will affect the total mass suspended in the reactor containment atmosphere as well as the particle sizes of the containment aerosol. For instance, a water pool overlying core debris that is interacting with concrete will significantly reduce the total amount of aerosol that is lofted into the containment atmosphere by these ex-vessel interactions. The aerosol mass that is lofted will, however, be shifted to a particle size, $\sim 0.3 \pm 0.15$ μm, that resists additional filtration or removal. That is, the aerosol that emerges from a water pool can be highly persistent in the atmosphere. Further, the aerosol will have a very narrow distribution in sizes--geometric standard deviations of 1.1 to 1.6 depending on such factors as the depth of the water pool and the sub-cooling of the pool. The nearly monodisperse nature of the aerosol as well as its low concentration greatly slows agglomeration of the particles to sizes that can be easily removed from the atmosphere by natural and engineered processes. One of the principal interests in the performance of containment spray systems is, in fact, ability of spray systems to remove persistent, low concentration aerosols.

Consequently, a second "case" is defined here for the size distribution of aerosols in the containment atmosphere. This fine-particle case is based on considering the mean aerosol particle size to be uncertain within the range of 0.15 to 0.65 μm and the geometric standard deviation to be uncertain within the range of 1.4 and 3.2. The geometric standard deviation is taken to be linearly correlated with the mean size:

$$\sigma = 0.860 + 3.6\,\mu$$

where the mean particle size, μ, is given in micrometers.

10. Uncertainty in Aerosol Shape Factors

The physical phenomena that lead to decontamination of an atmosphere by spray droplets have been described in Chapter II. The models presented in that chapter have been derived under the assumption that aerosol particles are spheres. It is unlikely that aerosols in the reactor containment under severe accident conditions will be spheres. The traditional and rather

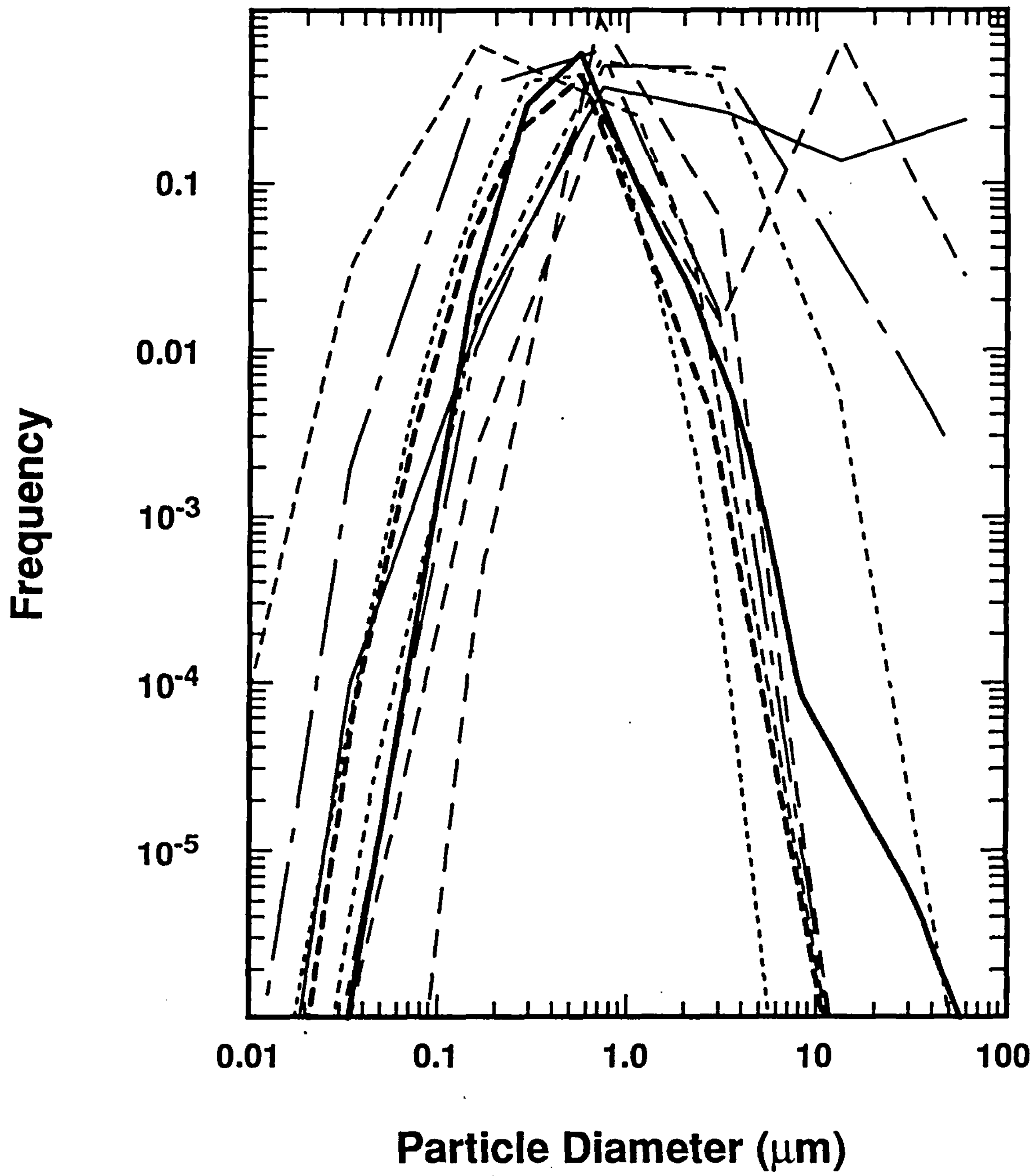

Figure 35 Some examples of aerosol size distribution calculated to exist in containment atmospheres during severe reactor accidents

approximate approach adopted in aerosol science to correct for the fact aerosols are not necessarily spheres is to introduce shape factors [16]. Two shape factors are pertinent to the discussions here:

- the dynamic shape factor = χ, and
- the collision shape factor = γ.

These shape factors are defined by:

$$\chi = \rho_p d_p^{\,2}(m) \,/\, \rho_o d_p(ae)^2$$

$$\gamma = d_p(c) \,/\, d_p(m)$$

where

$d_p(m)$ = diameter of the nonporous spherical particle having the same mass as the particle of interest

$d_p(ae)$ = diameter of the unit density spherical particle with the same aerodynamic characteristics as the particle of interest

$d_p(c)$ = diameter of the spherical particle that would have the same collision characteristics as the particle of interest

ρ_o = 1 g/cm^3

Brockman [19] has reviewed the data available on dynamic shape factors for aerosols of the type expected in reactor containments under severe accident conditions. Values of χ from nearly 1 to 9 have been observed. There have been no measurements of the collision shape factors for aerosols of the type of interest here. Values of the collision shape factor have been estimated based on the rates of agglomeration and settling of aerosols. Values as high as 10 have been suggested.

Very large values of the dynamic and collision shape factors are obtained only under dry conditions. Under high humidity conditions that are of interest here, water vapor can condense in the concave interstices created by the agglomeration of aerosol particles. The surface tension of the condensed water tends to compact the particles into spheres. Shape factors, then, reflect the packing density that can be achieved in agglomerated particles. Based on tests with U_3O_8 and Fe_2O_3 aerosols [20], Kress [19] has suggested that under high humidity conditions an upper bound for both χ and γ is 3. Further, under these high humidity conditions $\chi = \gamma$. Values of the shape factors are especially likely to approach the theoretical packing limit for spheres [19] or about 1.1 in aerosols that are hygroscopic or deliquescent. The hygroscopicity of the aerosolized materials in a reactor containment is expected to be highly variable and is definitely uncertain [20].

The preponderance of data cited by Brockmann [19] indicates that the dynamic and the collision shape factors will be equal under conditions of high humidity. Then, here, it is assumed:

$$\chi = \gamma$$

Further, the high humidity limits the range of values the shape factors can assume. Typically values will not be greatly different from 1. Brockmann suggests the range of values is 1 to 4 [19], but notes large values are unusual. Here the dynamic and collision shape factors are assumed to have uncertain values log-normally distributed with means of 1.3 and geometric standard deviations of 3.04 so $\chi = \gamma = 4$ is the 99th percentile of the cumulative distribution. Then,

$$\chi = \gamma = 1 + \delta(s)$$

where $\delta(s)$ is lognormally distributed with a mean of 0.3 and a standard deviation of 3.04.

11. Uncertainty in the Collection Efficiency by Impaction and Interception

In the discussions of aerosol capture by impaction and interception in Chapter II, it is noted that correlations are known only for viscous and potential flow. Some have argued that because of the size disparity between droplets and the aerosol particles, potential flow results are adequate to describe the efficiency of aerosol capture by impaction and interception under real flow conditions. Others have argued some interpolation, which is itself uncertain as discussed below, between viscous and potential flow efficiencies is needed for real flow conditions.

To account for this uncertainty in the use of potential or transition flow approximations for aerosol capture efficiency, a parameter $\delta(i)$ is defined and taken to be uniformly distributed over the range of 0 to 1. The impaction and interception efficiencies are then taken to be:

$$\in(\text{imp}) = \begin{cases} \in(\text{imp,pot}) & \text{for } \delta(i) \le 0.5 \\ \in(\text{imp,trans}) & \text{for } 0.5 < \delta(i) \le 1.0 \end{cases}$$

$$\in(\text{int}) = \begin{cases} \in(\text{int,pot}) & \text{for } \delta(i) \le 0.5 \\ \in(\text{int,trans}) & \text{for } 0.5 < \delta(i) \le 1.0 \end{cases}$$

Note that the selections of impaction and interception models are completely correlated. The uncertainty being described here is the applicability of potential flow as a descriptor of real flow conditions. The collection efficiencies are then determined by the decision on the applicability of the flow model. Note that the expression for $\in$(imp,pot) includes another uncertain parameter δ discussed in Chapter II.

12. Uncertainty in the Collection Efficiencies in the Transition Flow Regime

The Langmuir interpolation [15] between results for the viscous flow regime and results for the potential flow regime is used in models for the efficiency of impaction and the efficiency of interception. The efficiencies of these processes for flows in the transition regime are given by:

$$\in(\text{transition}) = \frac{\in(\text{viscous}) + \in(\text{potential})\, Re_d / \delta(t)}{1 + Re_d / \delta(t)}$$

where

$\in$(transition) = efficiency of impaction or interception at real Reynolds numbers

$\in$(viscous) = efficiency of impaction or interception at Reynolds numbers approaching zero

$\in$(potential) = efficiency of impaction or interception at Reynolds numbers approaching infinity

$Re_d = U_T D_d(e) \rho_g / \mu_g$ = Reynolds number

In the Langmuir interpolation, $\delta(t) = 60$. There is, however, no particular virtue to this selection. Here $\delta(t)$ is taken to be an uncertain parameter log-normally distributed with a mean value of 60 and a geometric standard deviation of 4.

13. Uncertainty in the Collection Efficiency by Diffusion

Several possible models of aerosol collection by water droplets as a result of particle diffusion are described in Chapter II. Diffusion is by far the most uncertain of the aerosol capture processes. Yet, diffusion is an important mechanism for the removal of very small, low concentration aerosols. To account for uncertainty in the diffusion, a parameter, δ(dif), is defined and is considered to be uncertain over the range of 0 - 1. The efficiency of aerosol capture by diffusion is then taken to be:

$$\in(\text{dif}) = \left[2Pe\, D_d(e)\right]^{-1/2} \quad \text{for } 0 < \delta(\text{dif}) \leq 2/3$$

$$\in(\text{dif}) = 3.18\, Pe^{-2/3} \quad \text{for } 1/3 < \delta(\text{dif}) \leq 2/3$$

$$\in(\text{dif}) = (4/Pe)\left(2 + 0.557\, Re_d^{1/2}\, Sc^{3/8}\right) \quad \text{for } 2/3 < \delta(\text{dif}) \leq 1.0$$

Note that the term $0.557\, Re_d^{1/2}\, Sc^{3/8}$ in the third model of diffusion efficiency is, itself, uncertain. This uncertainty in the convective enhancement of diffusion is thought to be accounted for by the consideration of other models for diffusion efficiency.

14. Uncertainty in the Summation of Efficiencies

The uncertainty in summing aerosol collection efficiencies by diffusion, impaction and interception is whether these processes are adequately approximated as independently acting processes. To account for this uncertainty, two models are considered. The choice between these models is based on the value of the uncertain parameter δ(sum) which is uniformly distributed over the range of 0-1:

$$\in(\text{total}) = \begin{cases} \in(\text{dif}) + \in(\text{imp}) + \in(\text{int}) & \text{for } 0 < \delta(\text{sum}) \leq 0.5 \\ 1 - (1 - \in(\text{dif}))\,(1 - \in(\text{imp}))\,(1 - \in(\text{int})) & \text{for } 0.5 < \delta(\text{sum}) \leq 1.0 \end{cases}$$

C. Summary Concerning Individual Uncertainties

The fourteen areas of uncertainty discussed above are represented by 20 uncertain quantities. Nine of these uncertain quantities stem from uncertainties in the details of the accident or the design of the plant in question:

1. containment pressure, P
2. steam partial pressure, $P(H_2O)$
3. ratio of partial pressures of carbonaceous gases to hydrogen in the containment atmosphere, δ(H)
4. ratio of carbon monoxide partial pressure to the carbon dioxide partial pressure in the containment atmosphere, δ(C)
5. the mean of the aerosol particle size distribution, μ_p
6. the geometric standard deviation of the aerosol particle size distribution, σ_p
7. the dynamic shape factor of the aerosol, χ
8. the collision shape factor of the aerosol, γ, and
9. the distribution of spray droplets between fine and coarse modes, a.

Three of the uncertain quantities have to do with properties of water and gas:

10. uncertainty in the surface tension of contaminated water, $\delta\sigma_\ell$
11. uncertainty in the density of contaminated water, $\delta\rho_\ell$, and
12. uncertainty in the predicted viscosity of a gas mixture, $\delta\mu_g$.

Uncertainty

Eight of the uncertain quantities have to do with the phenomena of droplet behavior and droplet aerosol interactions:

13. uncertainty in the appropriate model of droplet shape, $\in(\ell)$
14. uncertainty in the appropriate model for predicting terminal velocities of water droplets under severe accident conditions, $\in(2)$
15. uncertainty in the applicable flow regime for droplet particle interactions, δ(i)
16. uncertainty in the interpolation of impaction and interception efficiencies in the transition flow regime, δ(t)
17. uncertainty in the impaction efficiency model, δ
18. uncertainty in the efficiency of droplet-particle interaction by diffusion, δ(diff)
19. uncertainty in the summation of efficiencies of droplet-particle interactions by impaction, interception and diffusion, δ(sum), and
20. uncertainty in the efficiency of droplet-droplet interactions, δ(drop).

Justifiable ranges for the values of these uncertain quantities and probability density functions for values within the ranges are summarized in Table 5. Exept for the treatment of aerosol size distribution parameters in Case 2 (see below), the uncertain parameters are assumed to be uncorrelated. These uncertain quantities are considered in the Monte Carlo analysis of uncertainty in spray performance described in the next chapter of this report.

IV. Results of the Monte Carlo Uncertainty Analysis

The first objective of this report is to review the technical bases for the mechanistic calculation of aerosol removal from reactor containment atmospheres by sprays. This first objective has been addressed in Chapters II and III. Physical phenomena involved in the capture of aerosol particles by falling water drops were discussed at length in Chapter II. As part of these discussions, uncertain parameters and variables that will affect predictions of the aerosol removal process were identified. In Chapter III, realistic ranges for the values of these uncertain parameters and variables were determined and probability density functions for values within these ranges were defined. The uncertain parameters, the credible ranges for their values and the associated probability density functions are summarized in Table 5.

The second objective of this work is to apply a mechanistic model of spray removal of aerosols to a wide range of reactor accident conditions to obtain a meaningful sampling of atmosphere decontamination that can be achieved by sprays. The mechanistic model of spray removal of aerosols is described in this chapter (Chapter IV).

In Chapter V analyses of spray performance are discussed. The results of these analyses are used to construct cumulative probability distributions from which spray decontamination of containment atmospheres can be estimated with specified conservatism at known confidence levels.

The extent to which sprays will decontaminate an aerosol-laden atmosphere depends, of course, on the number of spray droplets falling through the atmosphere and the distance the water droplets fall. The water droplet flux into the containment atmosphere is under the control of the plant operators. The fall distance of water droplets is dependent on the particular containment design. These two variables which so strongly affect spray performance--water flux and fall distance--are not treated as uncertain variables. To facilitate applications of results obtained here, calculations are done for a variety of specific water fluxes and fall distances.

Calculations are done for three values of the volumetric water flux Q, i.e., Q = 0.25, 0.01, and 0.001 cm^3 H_2O/cm^2-s. Typical spray systems in pressurized water reactors produce water fluxes in the range of 0.01 to 0.06 cm^3 H_2O/cm^2-s. The lowest value of Q used in the calculations, Q = 0.001 cm^3 H_2O/cm^2-s, was taken to be indicative of the performance of a degraded spray system or one whose water discharge rate had been reduced as part of a strategy to manage severe accidents. The highest value of Q used in the calculations, Q = 0.25 cm^3 H_2O/cm^2-s, is an upper bound on the capacity of spray systems in nuclear reactor containments known to the authors.

For each of the selected water fluxes, analyses were done for eight fall distances H, i.e., H = 500, 853, 1000, 1584, 2000, 3000, 4000 and 5000 cm. These values of the fall distances are believed to span the range of fall distances open to spray droplets in commercial nuclear power plants.

The mechanistic model of aerosol removal by sprays is built upon the knowledge of how a single droplet falling through an aerosol-laden containment atmosphere would scavenge particles. The scavenging process depends on (1) the properties and behavior of the water droplet, (2) the properties of the aerosol, and (3) the nature and properties of the containment atmosphere under accident conditions. Many of these things that affect the scavenging process are not now predictable to high accuracy for reactor accident conditions. There is, then, some uncertainty in predictions of spray performance for specified values of the water flux, Q, and the droplet fall distance, H. To account for these uncertainties, a large number (400) of calculations were done with the mechanistic model for specific values of Q and H and varying values of the uncertain parameters. For each calculation, a set of parameter values was selected from the prescribed ranges weighted according to the probability density functions summarized in Table 5. Each result of a calculation is a sample of the uncertainty distribution for spray performance at the specified values of Q and H. Results of the many calculations were accumulated to develop an estimate of the uncertainty distribution for spray performance at specific values of the water flux and fall distance. It was found in the analyses that spray performance is also dependent on the extent of atmosphere decontamination. Analyses were done, then, for six specific values of the extent of atmosphere decontamination. Altogether, 144 uncertainty distributions for spray removal of aerosols from a containment atmosphere were developed. An additional 48 uncertainty distributions for spray performance in conjunction with water pools overlying core debris were derived.

The uncertainty distributions produced in these analyses are then used in Chapter V of this report to develop simplified models of spray removal of aerosols. These simplified models permit interpolation of the results of calculations with the mechanistic model to other values of water flux, fall distance and the extent of decontamination. Because the simplified models are based on quantitative uncertainty distributions for spray performance obtained with the detailed mechanistic model, they can be used to provide estimates of spray performance at specified levels of conservatism.

A. Model Description

The mechanistic model of aerosol removal by sprays used for the uncertainty analysis is based on the phenomena and correlations presented in Chapter II.

A number of simplifying assumptions have been made to make the analyses of spray removal of aerosols more tractable. It is assumed that in the spatial region of the containment where spray decontamination is occurring, all droplets have lost any horizontal components of their motions and are falling vertically downward at their terminal velocities. Droplet position, x, is measured downward from a horizontal plane of origin to the containment floor at position H. It is assumed that the aerosol suspended in the containment atmosphere is homogeneously distributed so that the size distribution of the aerosol is independent of location in the sprayed region. Aerosol agglomeration and aerosol removal by processes other than the action of spray (such as settling, diffusiophoresis to the walls, etc.) is neglected.

Major steps in the calculation of spray performance are:

- select, randomly, the values of uncertain quantities,

- calculate the steady-state population and size distribution of water droplets throughout the containment atmosphere,

- evaluate the rates of capture of aerosol particles in various size classes by water droplets, and

- accumulate the results in terms of an overall rate of aerosol removal.

This analysis sequence is done for each of the 24 combinations of fall distance and water flux described above. As will be discussed further below, the efficiency of spray removal of aerosol particles from the atmosphere depends on the extent to which the aerosol size distribution has been altered by the actions of spray droplets earlier. Analyses were done for six levels of decontamination, DF = 1.1, 2, 3.3, 10, 100, and 1000.

Uncertain parameters and models that affect predictions of spray performance are discussed at length in Chapter II of this report. Values of the uncertain parameters used in each calculation were selected according to the probability density function hypothesized for each parameter. The selection was done by solving the equation below for X_o:

$$\text{rnd } \# = \Pr(x < X_o)$$

where

rnd # = random number between 0 and 1.0

x = value of the uncertain quantity

X_o = selected value of the uncertain quantity

$\Pr(x < X_o)$ = cumulative probability that x is less than or equal to X_o

The inversion needed to obtain the selected parameter values from this equation was done with a Newton-Raphson root-solving routine. The random numbers needed in the selection process were obtained with a congruent, sequential random number generator. Numbers produced by this generator were "shuffled" randomly to avoid any periodicity in the generator's characteristics [62].

As described in Chapter II, the number density and size distribution of water droplets change with distance from the origin plane. These changes affect the efficiency with which the spray removes aerosol particles. Because large spray droplets collide with smaller droplets, the spray becomes less efficient with increasing fall distance. The steady-state, spatial, size distribution of water droplets was calculated at horizontal planes in the sprayed volume using an explicit, Eulerian, differential equation solver. The initial droplet size distribution was divided into 18 "bins" or size intervals. The limits on these bins are listed in Table 7. The volumetric properties of droplets within a bin were taken to be represented initially by a droplet whose diameter is given by

$$D_d(v) = \left\{\left[D(i)^3 + D(i+1)^3\right]/2\right\}^{1/3}$$

where D(i) and D(i + 1) are the upper and lower limits of the size bin. The hydrodynamic and aerosol capture properties of droplets in a particular bin were taken to be represented initially by a droplet whose diameter is given by:

Table 7 Droplet size "bins"

Bin number	Size range (μm)
1	2000 - 3000
2	1587 - 2000
3	1260 - 1587
4	1000 - 1260
5	794 - 1000
6	630 - 794
7	500 - 630
8	397 - 500
9	315 - 397
10	250 - 315
11	198 - 250
12	157 - 198
13	125 - 157
14	99 - 125
15	79 - 99
16	62 - 79
17	50 - 62
18	39 - 50

$$D_d(h) = \left\{\left[D(i)^2 + D(i+1)^2\right]/2\right\}^{1/2}$$

Values of $D_d(v)$ and $D_d(h)$ were adjusted as droplets were added to or removed from the bin during the fall through the sprayed volume. Calculations of the size distributions were done at spatial intervals selected so that the population of any bin did not change by more than 25 percent. Spatial intervals were limited, however, to be smaller than 20 cm and larger than 1 cm. Some numerical tests showed that the size distributions calculated to be present at distances greater than 500 cm below the starting point of droplet fall were not significantly sensitive to the details of these limits on the changes in the droplet size distribution. Care was taken throughout the calculation of the droplet size distribution to assure water volume was conserved.

Capture of aerosol particulate by falling water droplets was also done using an explicit Eulerian solver. The calculations of aerosol capture were done for the same spatial intervals used in the calculation of the droplet size distribution. For these calculations, the droplet size distribution calculated for the bottom of the spatial interval was assumed to exist over the entire interval. Calculations using the droplet size distribution present at the top of the spatial interval did not yield significantly different results.

For the analysis of aerosol capture, the aerosol size distributions were divided into 20 size bins. The limits on these size bins were selected so that initially each bin contained 5 percent of the aerosol mass. The properties of particles within each bin were assumed to be represented by a particle with the mass average diameter of particles in the bin.

Capture rates were computed for aerosols in each size bin by droplets of each size class. The results were then summed to determine the overall rate of aerosol removal. That is, the decontamination coefficient for aerosols in the j^{th} size class is defined by

$$-\frac{1}{M(j)}\frac{d\,M(j)}{dt} = \lambda(j)$$

where M(j) is the mass concentration of aerosols in the j^{th} size class. The value of $\lambda(j)$ is determined by the capture efficiencies of droplets in all size classes and the fall distance:

$$\lambda(j) = \sum_{i=1}^{18} \sum_{k} \frac{\Delta x(k)}{H}\, \pi R(i)^2\, n(i,x)\, V(i,x)\, \in(i,j)$$

where

$\Delta x(k)$ = length of the k^{th} spatial step

$n(i,x)$ = number concentration of droplets in the i^{th} size class in the k^{th} spatial node

V(i,x) = terminal velocity of the droplets in the i^{th} size class in the k^{th} spatial node

$$x = \sum_{j=1}^{k} \Delta x(j)$$

$$R(i) = D_d(h)/2$$

$$H = \text{total fall distance available} = \sum_{k} \Delta x(k)$$

It has been assumed here that the aerosols are well mixed so that the droplet velocity term in the above equation need not be adjusted by the settling velocities of the aerosols with respect to the terminal velocities of the droplets. The overall decontamination coefficient is calculated from:

$$\frac{dM}{dt} = -\lambda(\text{overall})\ M = -\sum_{j=1}^{20} \lambda(j)\ M(j)$$

where

$$M = \sum_{j=1}^{20} M(j)$$

Calculations were done for fixed amounts of aerosol in the containment volume and assuming any unsprayed volume was negligible. Discussion of the results presented below indicates how the calculated results may be used when either of these assumptions is invalid.

B. Some Representative Results

The decontamination factors produced by sprays for three particular cases are shown in Figure 36. These three cases were chosen simply to illustrate the magnitude of decontamination that can be achieved by sprays. The cases shown in the figure are not statistically representative of all the results. Decontamination is initially quite rapid. As decontamination progresses, the rate of aerosol removal slows. The reasons for this are readily apparent when the size distribution of the aerosol remaining suspended in the atmosphere is examined. The size distributions of the remaining aerosol after decontamination factors of 10, 100, and 1000 have been reached are shown in Figure 37. The amount of mass in any size bin falls as decontamination progresses. The rate of removal of aerosol mass is greater for very large and very small aerosol particles. Removal of aerosol particles with diameters of 0.1 to 0.4 μm is slower than removal of larger or smaller particles. Therefore, as decontamination of the atmosphere by a spray progresses, the size distribution of the aerosol remaining in the atmosphere changes. The mean size of the remaining aerosol shifts toward the particle size that is removed most slowly. The breadth of the aerosol size distribution is also

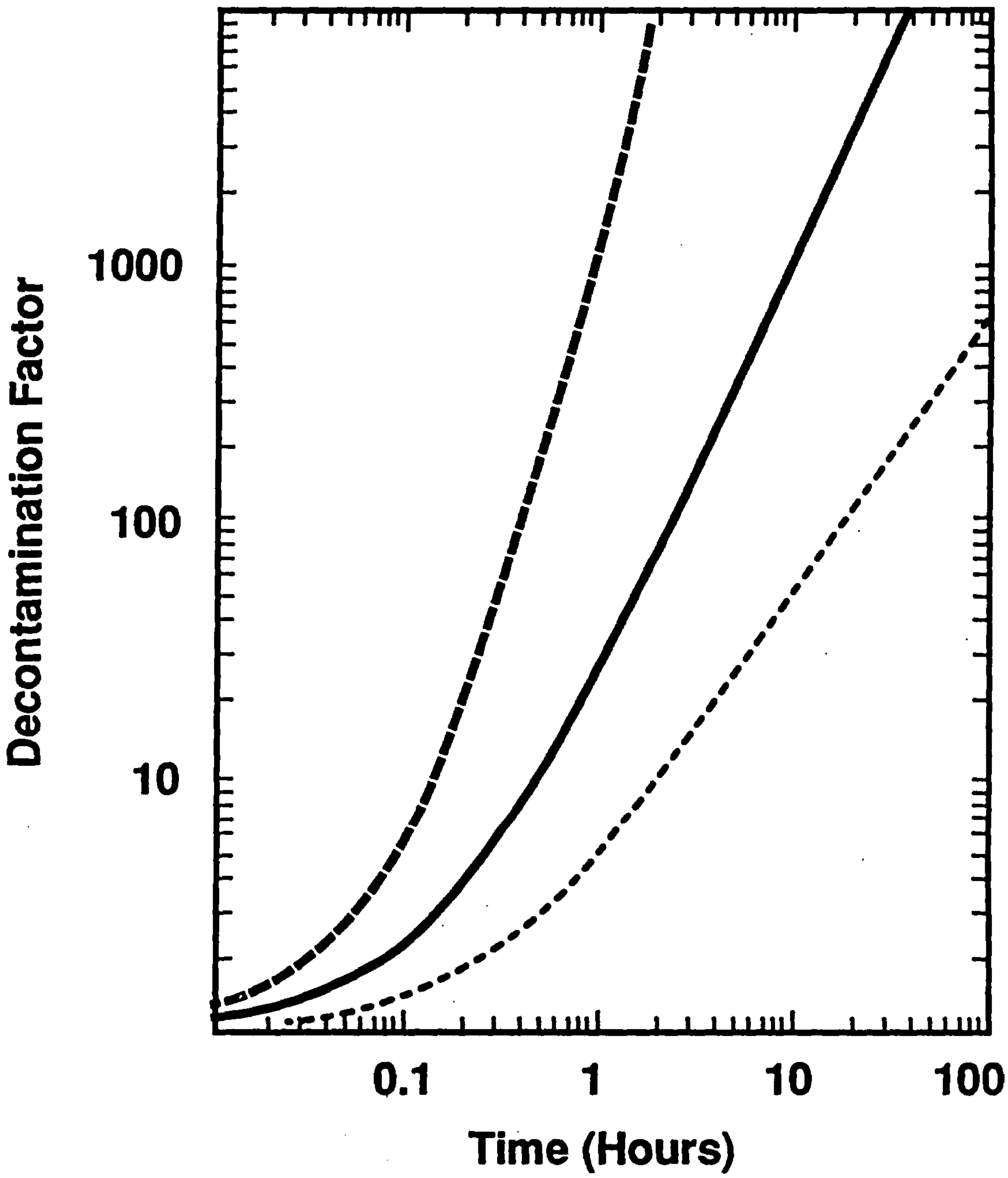

Figure 36 Three examples of the predicted decontamination by a spray for H = 3000 cm, $Q = 0.01\ cm^3/cm^2$-s

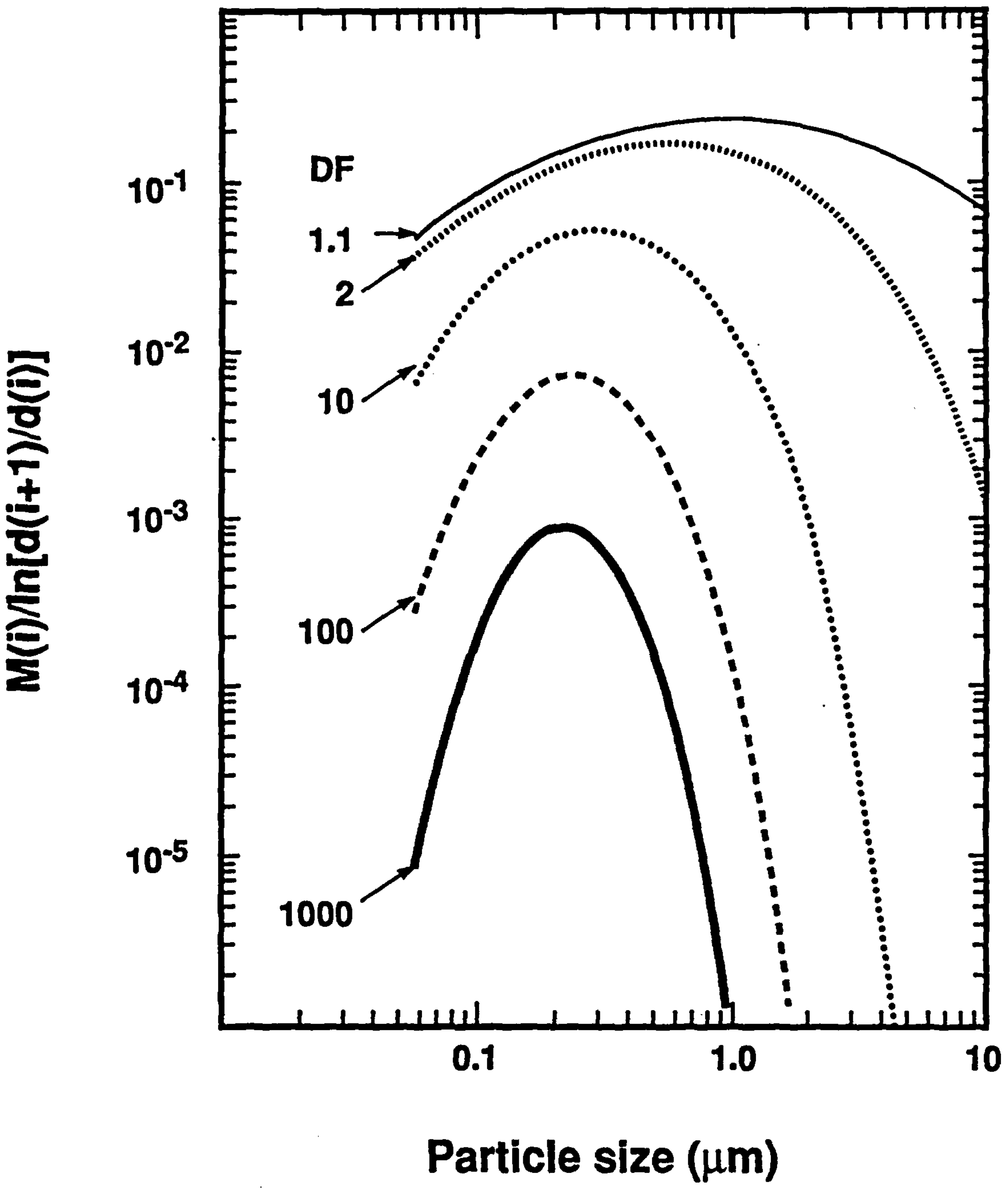

Figure 37 Evolution of the aerosol size distribution as decontamination progresses

narrowed. As the easily removed aerosol particles are captured, the remaining aerosol becomes progressively more difficult to remove.

Continued operation of a spray can, given sufficient time, produce any desired level of decontamination. For the purposes of this work, it is not useful to speak in terms of the decontamination factor that can be achieved with a spray. It is more useful to discuss the rate of decontamination characterized by the decontamination coefficient, λ. The values of λ that were used to calculate decontamination for the three cases shown in Figure 36 are plotted in Figure 38.* The decontamination coefficient λ varies with the fraction of aerosol mass remaining in the containment, m_f. λ decreases approximately linearly with m_f for values of m_f greater than about 0.1. For smaller values of m_f, λ approaches a constant value. The changes in λ with m_f are simply the result of changes in size distribution of aerosol remaining in the atmosphere as decontamination progresses.

Detailed results are presented below for m_f = 0.9, 0.5, 0.3, 0.1, 0.01, and 10^{-3}. The value of λ at m_f = 0.9 is taken to be indicative of the initial rate of decontamination when aerosol is first exposed to the action of a spray. This is the value of λ that would be applied to the analysis of the decontamination of a steady source of aerosols to the containment atmosphere which is one of the principal issues addressed in Chapter I of this report. Values of λ at m_f = 0.5, 0.1, 0.01 and 10^{-3} correspond to values at decontamination factors of 2, 10, 100, and 1000.

The decontamination coefficient at a fixed level of decontamination (or, equivalently, a fixed value of m_f) decreases with increasing fall distance. Some examples of the variations in λ with fall

*Throughout this document λ is given in units of reciprocal hours. It is useful to remember in examining the values of λ presented here that 1/λ is the time (in hours) required to reduce the aerosol concentration by a factor of e ≈ 2.72

Regulatory descriptions of λ use the definition [63]:

$$\lambda = \frac{1.5\ HF}{V}\left[\frac{E}{D}\right]$$

where

F = total water flow rate

H = fall distance

V = containment volume

$\frac{E}{D}$ = capture efficiency divided by the droplet diameter

For droplets 1000 μm in diameter a value of E/D = 10 m^{-1} has been recommended [63]. This value is further recommended to be reduced to 1 m^{-1} once the mass fraction of aerosol remaining in the containment has been reduced to 0.02. Values of λ cited here in units of hr^{-1} may be converted to E/D ratios in units of m^{-1} by:

$$\frac{E}{D}(m^{-1}) = \frac{\lambda(hr^{-1})\ 0.01852}{Q(cm^3/cm^2\text{-}s)}$$

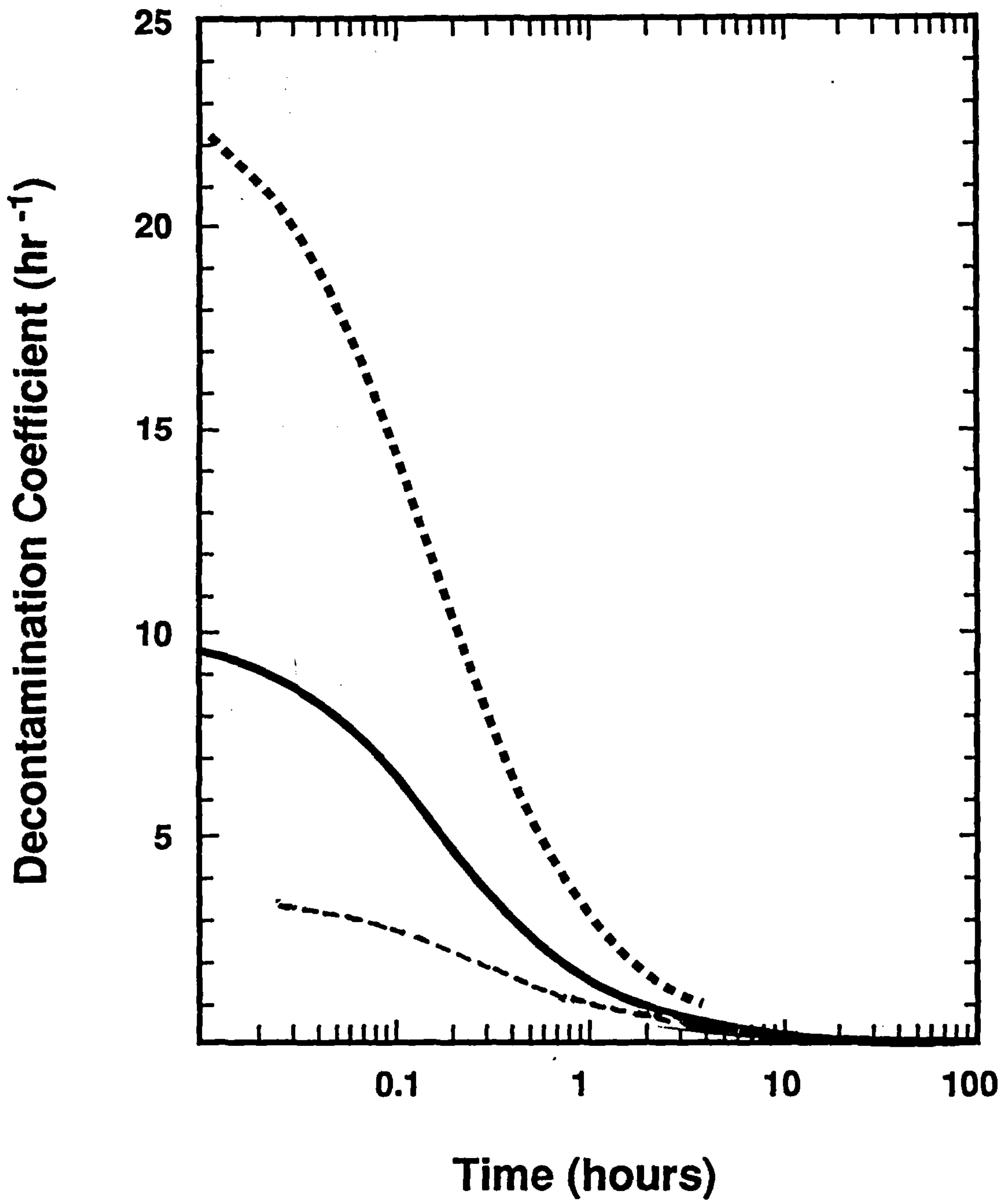

Figure 38 Variations of the decontamination coefficients as decontamination progresses for three cases

distance, H, are shown in Figures 39 and 40 for $m_f = 0.9$ and $m_f = 0.01$, respectively. Again, these examples were chosen simply to be illustrative of the range of variation of λ with m_f. In some cases, λ changes fairly significantly as the fall distance goes from 500 cm to 5000 cm. In other cases, the change is not so great though λ still decreases as the fall distance increases. The decrease in λ with increasing fall distance comes about because the droplet size distribution becomes increasingly coarse with distance from the spray nozzle. Larger droplets less efficiently trap aerosols than do smaller droplets. The variability in the sensitivity of λ to fall distance comes about because of the uncertainty in the efficiency with which large droplets sweep out small droplets during the fall through the containment atmosphere.

The decontamination coefficient, λ, also varies with the volumetric water flux, Q. All this sensitivity of λ presents a challenge in presenting the results of the calculations done for the uncertainty analysis. Quite a lot of results must be examined to understand how λ varies with the known quantities, Q and H as well as m_f.

C. Detailed Results of the Uncertainty Analysis

About 400 calculations of λ were done for each of the three values of water flux, Q, the eight values of fall distance, H, and for $m_f = 0.9, 0.5, 0.3, 0.1, 0.01$, and 10^{-3}. The sets of values of λ for fixed values of Q, H, and m_f were analyzed to formulate uncertainty distributions for $\lambda(Q, H, m_f)$ using a non-parametric, order statistics method. This method of analysis has been described in detail elsewhere [11]. The Monte Carlo method samples the distribution of values of $\lambda(Q, H, m_f)$. Because only a finite number of samples is selected at given values of Q, H, and m_f, the actual distribution of $\lambda(Q, H, m_f)$ is known only to a selected confidence level. Here, attentions are focused on the confidence levels of 50, 90, and 95 percent. Enough information is provided in the Tables in Appendix A to compute quantities of interest at other confidence levels.

The non-parametric, order statistics used to analyze the results of the Monte Carlo calculation yields cumulative probability distributions for $\lambda(Q, H, m_f)$. A range of values of λ define each percentile of the cumulative distribution. The range is indicative of the stochastic uncertainty that exists because of the finite sample used to estimate the uncertainty distribution of λ.* The cumulative distribution is the result of phenomenological uncertainty and uncertainty in initial and boundary conditions in spray operations. One of the most desirable features of the order statistical analysis procedure is that it separates stochastic uncertainty from the phenomenological, initial condition and boundary condition uncertainty. An example of the product of this analysis for $Q = 0.01\ cm^3/cm^2$-s, H = 3000 cm, and $m_f = 0.9$ is shown in Table 8. Other tables for other values of Q, H, and m_f are collected in Appendix A.

Some example distributions of λ are shown in Figures 41 to 44. The first of these figures shows the variations in the distributions with the extent of decontamination. Note that percentile levels in the cumulative probability plot are shown in the figure for confidence levels of 50 percent (bars) and 95 percent (dashed lines). The next figure illustrates the dependence of the distributions of λ on fall

*The ranges defining percentile levels can be reduced by taking a larger number of samples. The ranges narrow with the square root of the number of samples. For this work, sample sizes were selected so that it was at least 95 percent certain that 95 percent of the range of values of λ had been sampled. See Appendix A of Reference 11 for further discussion of this point.

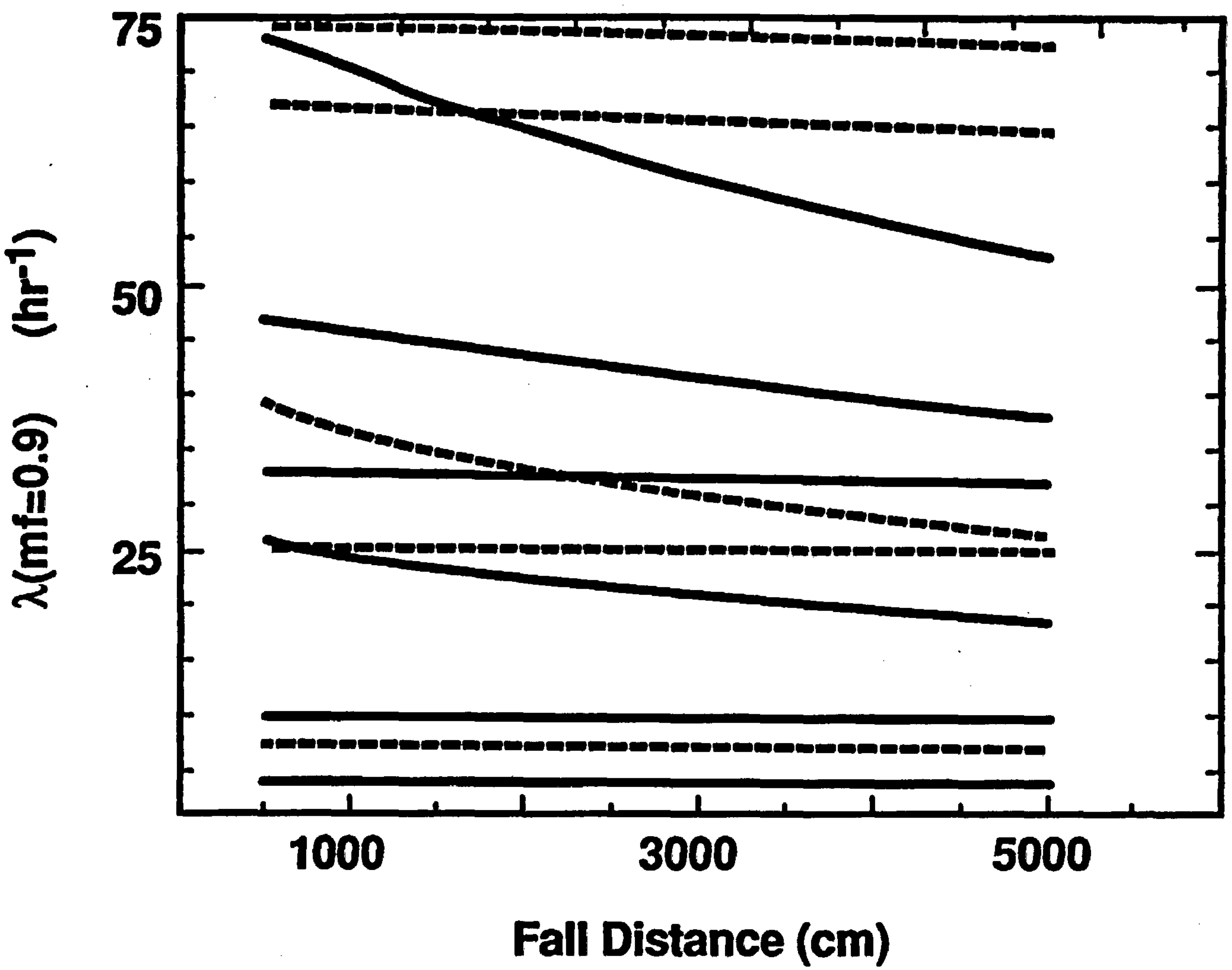

Figure 39 Some examples of the calculated variations in the decontamination coefficient with fall distance for Q = 0.01 cm^3/cm^2-s and m_f = 0.9

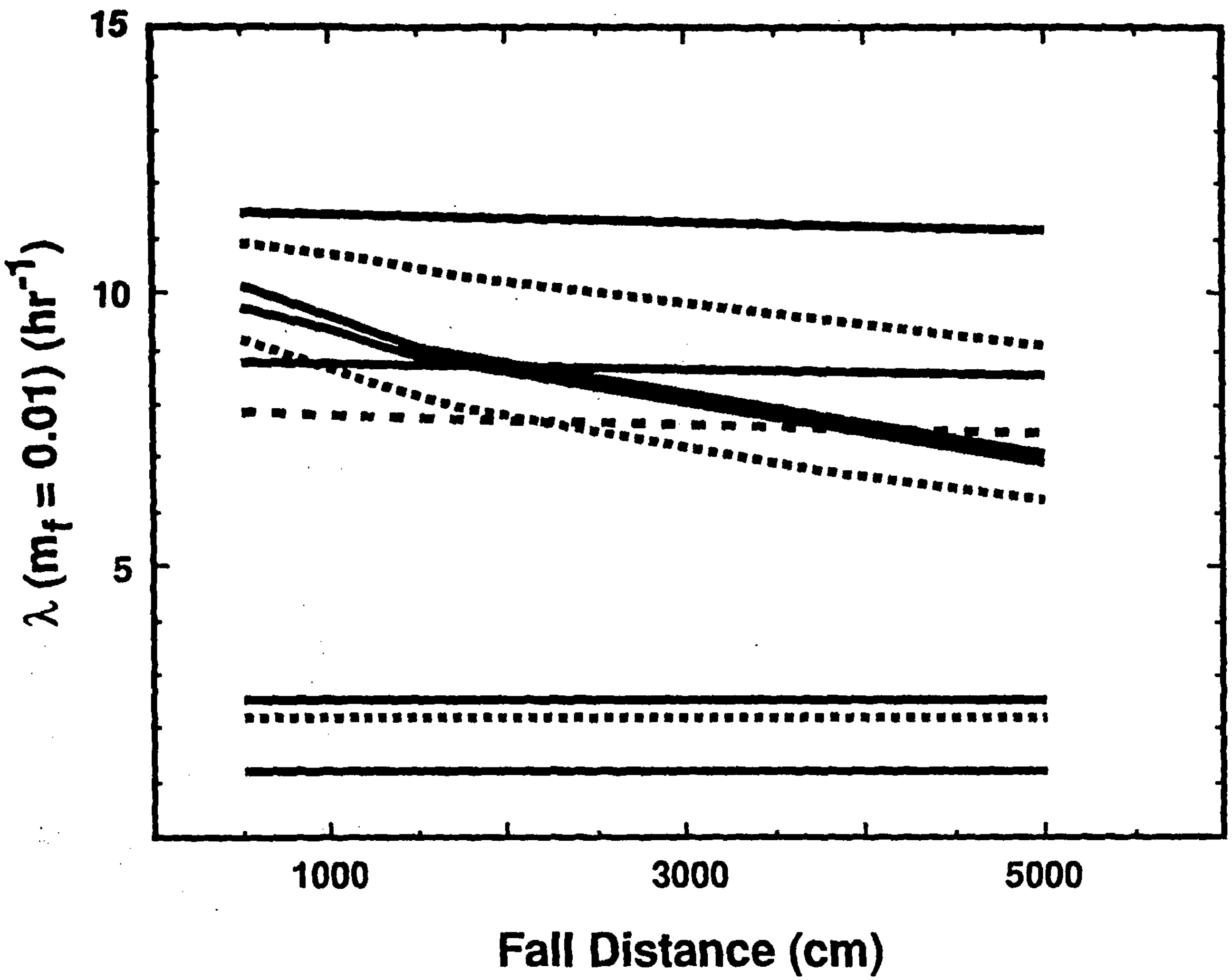

Figure 40 Some examples of the calculated variations in the decontamination coefficient with fall distance for $Q = 0.01\ cm^3/cm^2\text{-}s$ and $m_f = 0.01$

Table 8 Cumulative uncertainty distribution for $\lambda(Q, H, m_f)$ for $Q = 0.01\ cm^3/cm^2\text{-}s$, $H = 3000$, and $m_f = 0.9$ for confidence levels of 95, 90 and 50 percent

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of 95%	90%	50%	
Mean = 9.740	5	2.087 - 2.760	2.172 - 2.739	2.492 - 2.672	Water Flux = $0.01\ cm^3/s\text{-}cm^2$
	10	2.755 - 3.713	2.782 - 3.487	2.990 - 3.290	
	15	3.359 - 4.307	3.400 - 4.286	3.837 - 4.152	
	20	4.150 - 5.174	4.202 - 5.042	4.310 - 4.609	
	25	4.554 - 5.761	4.650 - 5.711	5.080 - 5.452	
Std. Dev. = 7.537	30	5.377 - 6.403	5.434 - 6.330	5.687 - 6.182	Fall Distance = 3000 cm
	35	5.986 - 6.985	6.092 - 6.886	6.310 - 6.661	
	40	6.467 - 7.698	6.605 - 7.661	6.807 - 7.182	
	45	7.021 - 8.200	7.141 - 8.040	7.519 - 7.796	
	50	7.746 - 8.952	7.775 - 8.760	7.922 - 8.394	
Sample Size = 400	55	8.223 - 9.794	8.316 - 9.704	8.668 - 9.256	Aerosol Mass Fraction Remaining = 0.9
	60	9.052 - 10.510	9.244 - 10.388	9.533 - 10.116	
	65	9.816 - 11.363	9.930 - 10.995	10.354 - 10.676	
	70	10.586 - 12.327	10.641 - 12.086	10.930 - 11.722	
	75	11.583 - 13.053	11.692 - 12.893	12.019 - 12.673	
	80	12.612 - 14.230	12.689 - 14.111	12.897 - 13.564	
	85	13.566 - 15.957	13.605 - 15.702	14.220 - 15.060	
	90	15.321 - 18.215	15.626 - 18.039	16.291 - 17.459	
	95	18.197 - 24.898	18.288 - 24.150	20.524 - 22.776	

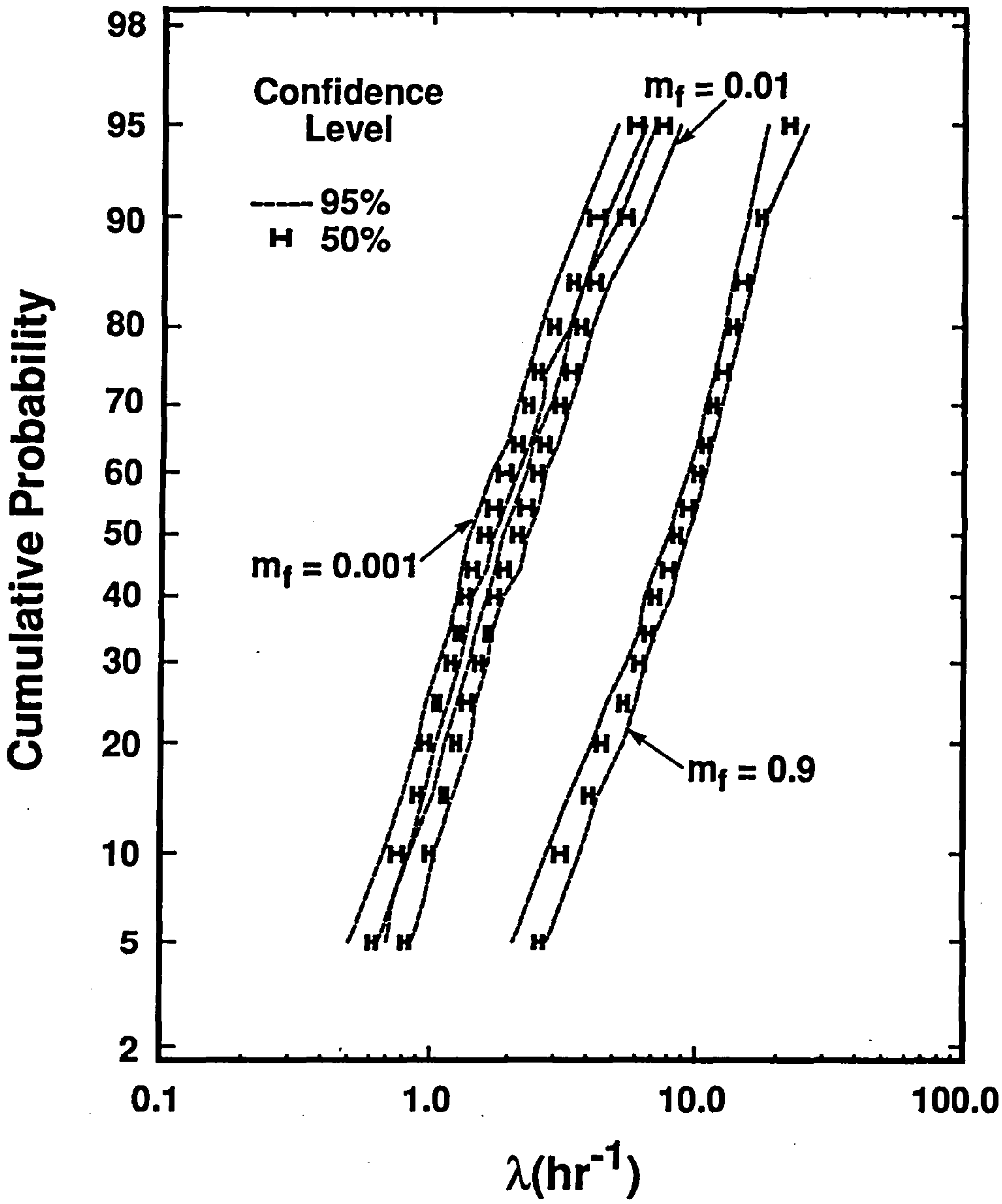

Figure 41 Cumulative distributions of λ for Q = 0.01 cm^3/cm^2-s, H = 3000 cm and m_f = 0.9, 0.01, and 0.001 Note that the cumulative probability is given in percent.

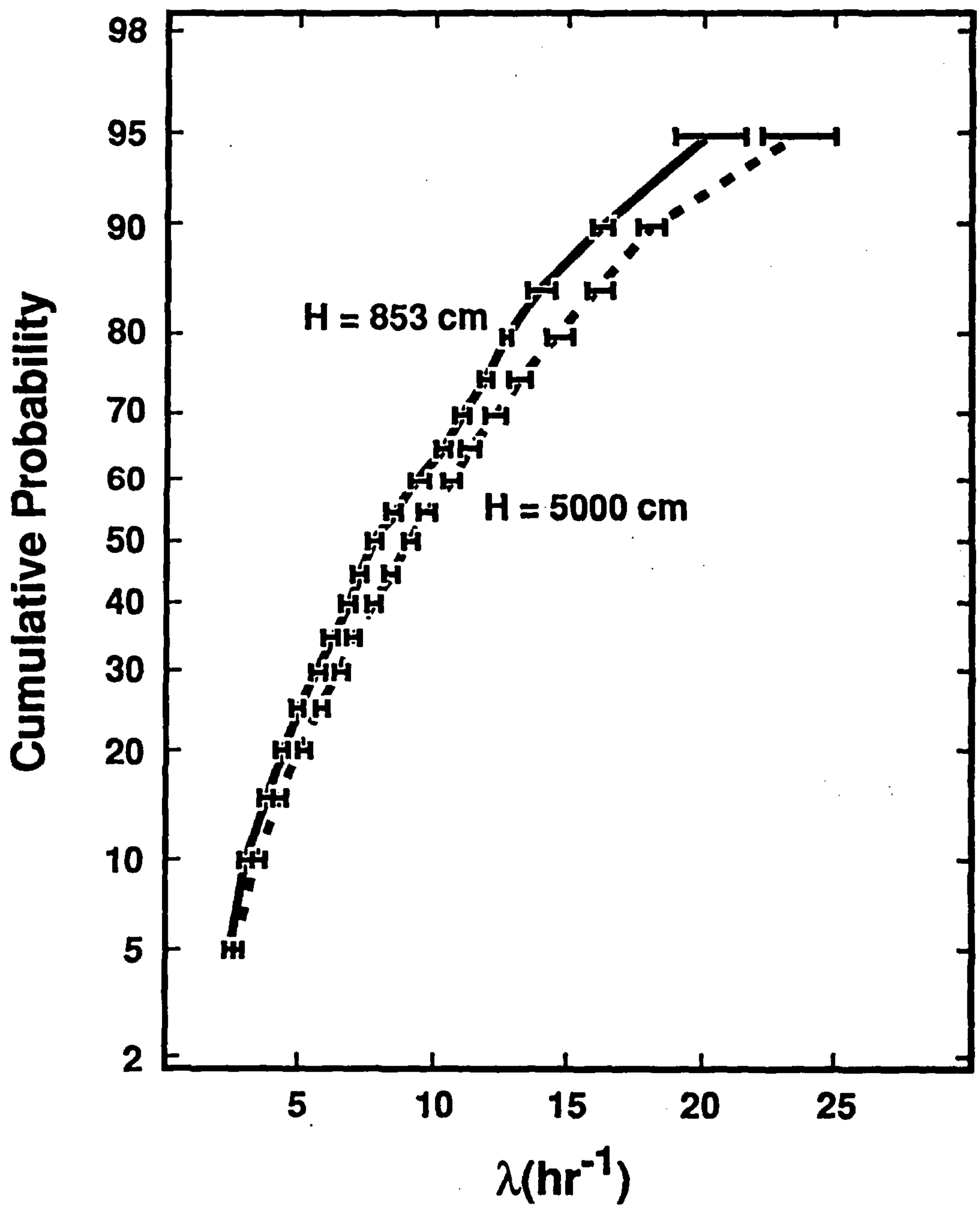

Figure 42 Cumulative distributions of λ for Q = 0.01 cm^3/cm^2-s, m_f = 0.9 and H = 853 and 5000 cm. Bars indicate 50 percent confidence intervals for λ. Cumulative probability is given in percent.

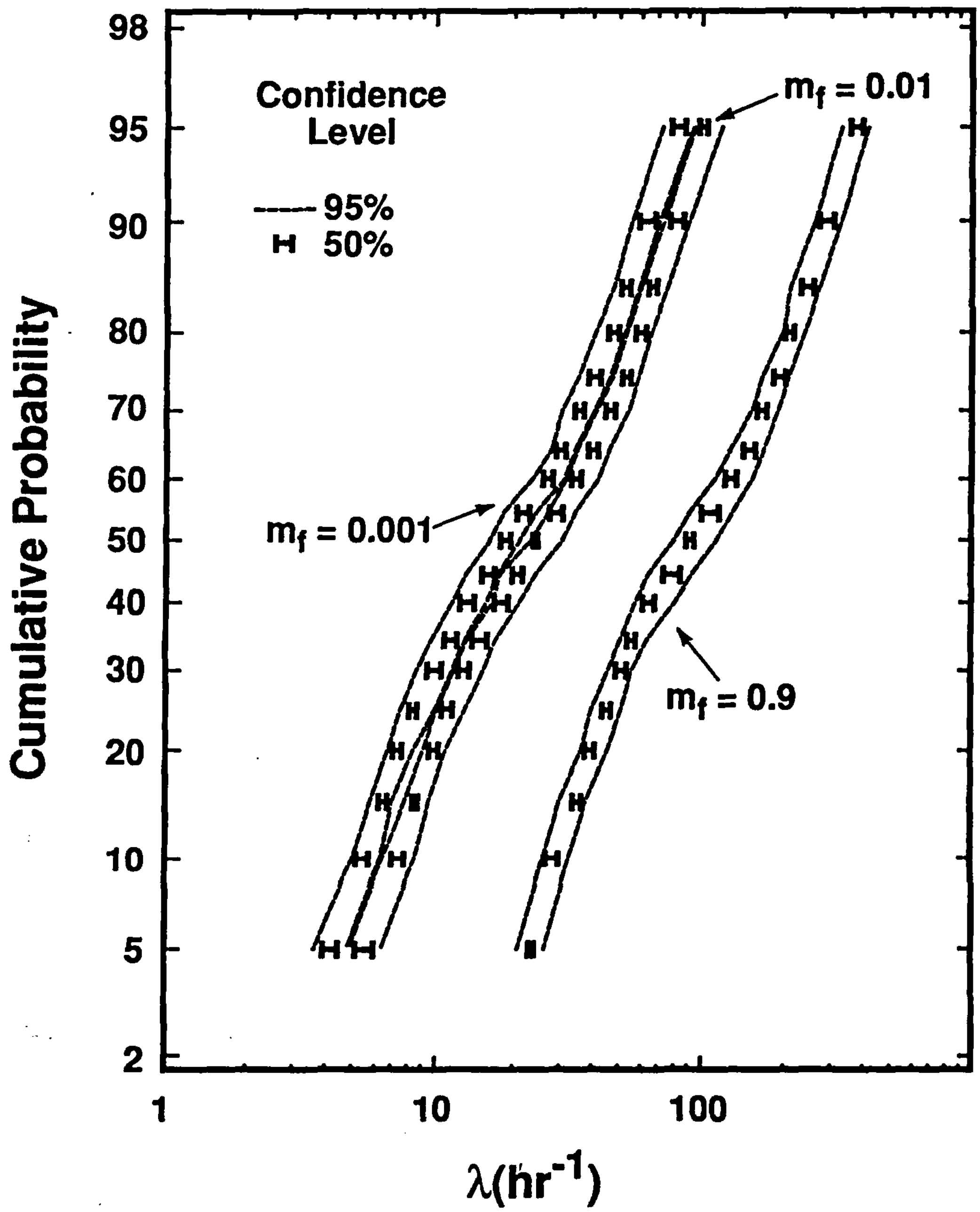

Figure 43 Cumulative distribution of λ for $Q = 0.25\ cm^3/cm^2$-s, $H = 3000$ cm and $m_f = 0.9$, 0.01, and 0.001. Cumulative probability is given in percent.

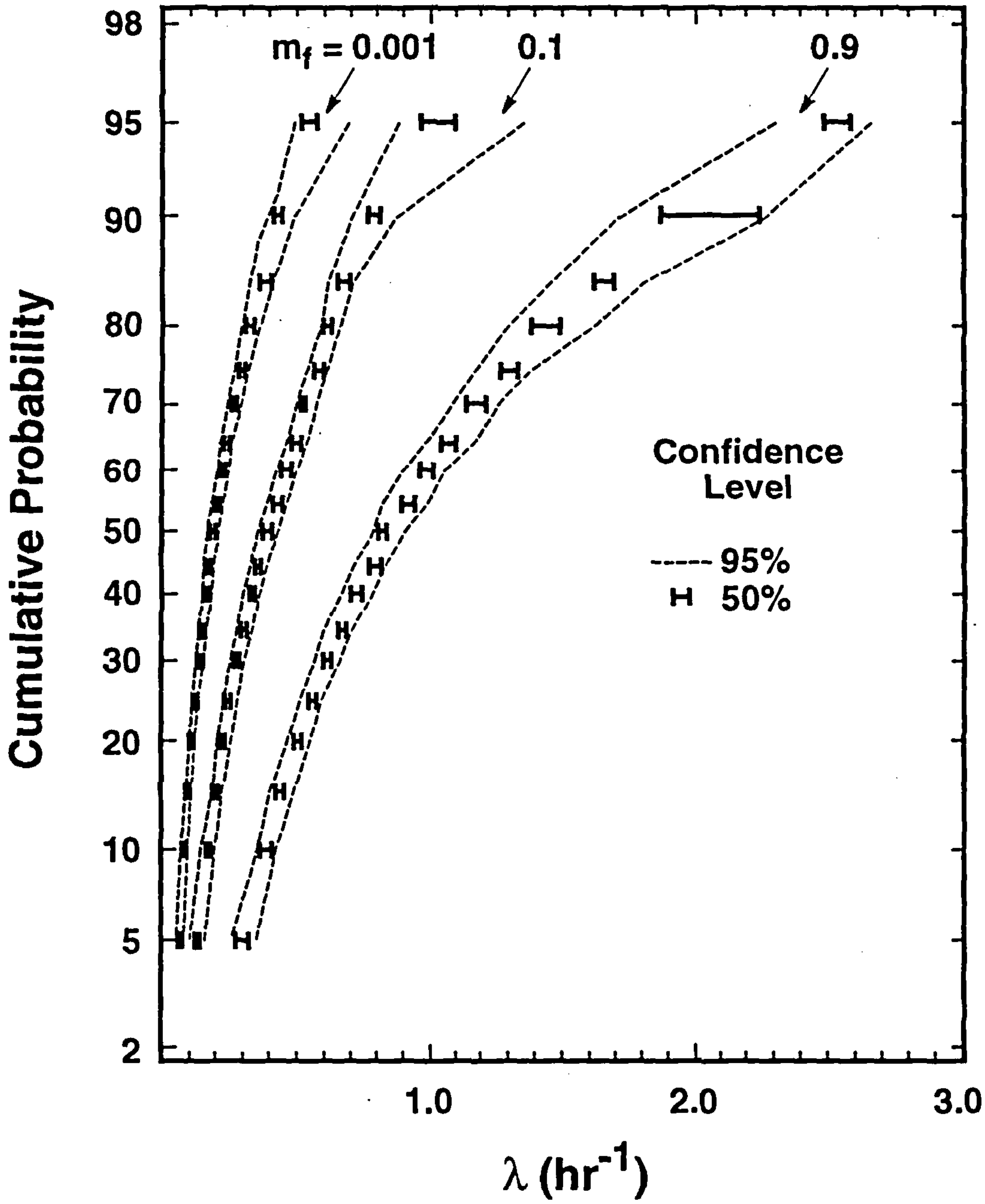

Figure 44 Cumulative distribution of λ for Q = 0.001 cm^3/cm^2-s, H = 3000 cm and m_f = 0.9, 0.1, and 0.001. Cumulative probability is given in percent.

distance. The next two figures show the sensitivity of the distribution to water flux. Were the distributions shown in the figures log-normal distributions, the percentile levels would fall on straight lines. Clearly, the distributions for the spray decontamination coefficients found here are more complicated than the well-known log-normal distribution.

Introduction of confidence level to which the uncertainty distributions are known as well as the distributions themselves creates challenges in the succinct presentation of the results of the analyses done here. The distributions for λ at various values of water flux, fall distance and the mass fraction of aerosol remaining in the atmosphere can be quite broad because of uncertainties in quantities that affect spray performance. Notably the size distribution of the aerosol initially present in the atmosphere, the initial size distribution of the spray droplets and the efficiency with which droplets collisions result in coalescence of droplets are uncertainties that contribute significantly to the breadth of the distribution of predicted values of the spray decontamination coefficient, λ. Attentions are restricted in the rest of the discussion presented here to only certain percentiles of the distributions. It is thought by the authors that of most immediate interest is the median or 50 percentile of the distributions.* It is assumed by the authors that analyses done using the medians of the uncertainty distributions for λ would not have especially stringent demands with regard to confidence level. Therefore, the medians at only 50 percent confidence level [50 percent confidence that the true median lies within the indicated range] are discussed below.. For other purposes, the extremes of the distribution for λ may be more appropriate. It might be, for instance, that conservative predictions of the aerosol removal are appropriate to use. Then, the lower percentiles of the distributions might be of greater interest than the median. If, on the other hand, the intended use of results presented here is to develop a conservative estimate of the amount of radioactivity in containment sump waters, then higher percentiles of the distributions for λ might be of interest. For the purposes of the remainder of the discussions, the authors have selected the 10 and 90 percentiles of the distributions as reasonable lower and upper bounds, respectively, of the values of λ for particular conditions. It has been assumed that when extremes of the distributions are of interest there are also demands for high levels of confidence. The 10 and 90 percentiles at 90 percent confidence [90 percent confidence that the true values of the 10 and 90 percentiles lie within the indicated range] are discussed here.

Sufficient information is presented in Appendix A for the interested reader to examine other percentiles of the distributions at other confidence levels.

Summaries of the ranges of $\lambda(Q, H, m_f)$ corresponding to

- the median at 50 percent confidence level,
- the 10 percentile or reasonable lower bound at 90 percent confidence level, and
- the 90 percentile or reasonable upper bound at 90 percent confidence level

*Means and standard deviations of the distributions are also presented in the tables in Appendix A. Because the uncertainty distributions for λ are not simple, normal or log-normal distributions, means and standard deviations are not especially significant.

are shown in Tables 9 to 17. Again, information on other quantiles at other confidence levels can be derived from tables assembled in Appendix A of this report.

The median values of $\lambda(Q, H)$ for $m_f = 0.9$ and for $m_f = 0.01$ are shown as functions of fall distance H and water flux Q in Figures 45 and 46. Note that the decontamination coefficients do decrease with increasing fall distance. The sensitivity of λ to fall distance increases with increasing water flux. As the concentration of water droplets increases, the rates at which the water droplets collide and coalesce increase during the fall of these droplets through the containment atmosphere. At water flux of 0.001 cm^3/cm^2-s, λ is practically insensitive to fall distance.

The sensitivity of the 90 percentile values of λ to fall distance is only slightly greater than the sensitivity of the median values of λ. The 10 percentile values of λ are less sensitive than the median values to fall distance.

A plot of values of λ at $m_f = 0.9$ for a fall distance of 3000 cm distance against water flux, Q, is shown in Figure 47. The values of λ vary essentially linearly with water flux from Q = 0.001 to Q = 0.01 cm^3/cm^2-s. At water fluxes of 0.25 cm^3/cm^2-s some non-linear effects appear. The efficiency of aerosol removal is reduced from what would be expected based on linear extrapolation. This reduction in the efficiency of capture occurs because of changes in the water droplet size distribution during free fall through the containment atmosphere. The coalescence of water droplets proceeds at a rate that is approximately proportional to the square of droplet concentration whereas aerosol capture proceeds at a rate proportional to the droplet concentration. At the highest concentrations studied here, extensive coalescence of droplets occurs to form larger droplets that are less efficient at aerosol capture.

Plots of the median values of λ for various values of fall distance and water flux against the mass fraction of the aerosol remaining in the atmosphere are shown in Figures 48 to 50. These plots show that λ decreases as decontamination progresses. These plots must, however, be carefully interpreted. There is a correlation among sampled values of λ with m_f at fixed Q and H. That is, for circumstances in which λ with $m_f = 0.9$ is large, there is a high probability that λ at other values of m_f will also be relatively large. This correlation among values of λ for fixed water flux and fall height but varying values of m_f is demonstrated in the plot of $\lambda(m_f = 0.01)$ against $\lambda(m_f = 0.9)$ for Q = 0.01 cm^3/cm^2-s and H = 3000 cm shown in Figure 51. Some of the correlation can be eliminated by considering the ratio $\lambda(m_f)/\lambda(m_f = 0.9)$. The lower correlation between $\lambda(m_f)/\lambda(m_f = 0.9)$ and $\lambda(m_f = 0.9)$ can be seen by the plot of sampled values shown in Figure 52. Distributions of the ratios $\lambda(m_f)/\lambda(m_f = 0.9)$ are more nearly independent than are the distributions of $\lambda(m_f)$. Results of the Monte Carlo sampling were reanalyzed in terms of the ratios $\lambda(m_f)/\lambda(m_f = 0.9)$ for m_f = 0.5, 0.3, 0.1, 0.01, and 0.001. Results of the analyses are summarized in Tables 18 to 26. Note that the ratios are dependent on m_f and Q but are essentially independent of the fall distance, H. Cumulative probability plots of $\lambda(m_f)/\lambda(m_f = 0.9)$ are shown in Figures 53 to 55.

Table 9 Median decontamination coefficient, $\lambda(hr^{-1})$, at 50 percent confidence level for a water flux of 0.01 cm^3/cm^2-s

Fall distance (cm)	Mass fraction of aerosol remaining in the containment atmosphere					
	0.9	0.5	0.3	0.1	0.01	0.001
500	8.862 - 9.264	6.464 - 7.064	5.412 - 5.799	3.765 - 3.930	2.141 - 2.261	1.640 - 1.740
853	8.731 - 9.170	6.428 - 6.887	5.350 - 5.648	3.705 - 3.850	2.112 - 2.210	1.630 - 1.696
1000	8.710 - 9.164	6.379 - 6.802	5.338 - 5.656	3.665 - 3.823	2.120 - 2.233	1.631 - 1.702
1584	8.446 - 8.874	6.342 - 6.651	5.222 - 5.495	3.594 - 3.744	2.083 - 2.182	1.582 - 1.642
2000	8.311 - 8.755	6.264 - 6.593	5.138 - 5.364	3.527 - 3.691	2.069 - 2.149	1.552 - 1.632
3000	7.922 - 8.394	6.032 - 6.294	4.953 - 5.247	3.348 - 3.545	1.985 - 2.102	1.494 - 1.599
4000	7.698 - 8.148	5.914 - 6.229	4.757 - 5.060	3.236 - 3.469	1.922 - 2.045	1.484 - 1.577
5000	7.500 - 7.892	5.671 - 6.042	4.687 - 4.936	3.131 - 3.292	1.872 - 2.007	1.428 - 1.536

Table 10 10 Percentile decontamination coefficient, $\lambda(hr^{-1})$, at 90 percent confidence level for a water flux of 0.01 cm^3/cm^2-s

Fall distance (cm)	Mass fraction of aerosol remaining in the containment atmosphere					
	0.9	0.5	0.3	0.1	0.01	0.001
500	3.138 - 3.990	2.514 - 3.068	2.128 - 2.584	1.596 - 1.832	1.019 - 1.138	0.747 - 0.902
853	3.089 - 3.865	2.467 - 3.023	2.119 - 2.552	1.594 - 1.820	0.982 - 1.117	0.733 - 0.878
1000	3.119 - 3.872	2.439 - 2.964	2.113 - 2.526	1.588 - 1.817	0.982 - 1.124	0.732 - 0.870
1584	3.053 - 3.742	2.395 - 2.879	2.035 - 2.468	1.540 - 1.776	0.965 - 1.105	0.718 - 0.862
2000	2.939 - 3.644	2.337 - 2.851	1.968 - 2.436	1.505 - 1.749	0.938 - 1.094	0.710 - 0.852
3000	2.782 - 3.487	2.277 - 2.746	1.938 - 2.304	1.465 - 1.678	0.898 - 1.050	0.703 - 0.812
4000	2.695 - 3.282	2.227 - 2.720	1.900 - 2.182	1.459 - 1.628	0.877 - 1.014	0.672 - 0.778
5000	2.619 - 3.295	2.171 - 2.615	1.824 - 2.150	1.430 - 1.581	0.850 - 0.995	0.651 - 0.741

Table 11 90 percentile decontamination coefficient, $\lambda(hr^{-1})$, at 90 percent confidence level for a water flux of 0.01 cm^3/cm^2-s

Fall distance (cm)	Mass fraction of aerosol remaining in the containment atmosphere					
	0.9	0.5	0.3	0.1	0.01	0.001
500	16.837 - 20.735	12.294 - 14.242	9.907 - 11.745	7.410 - 8.923	4.708 - 6.311	3.894 - 4.952
853	16.892 - 20.443	12.052 - 14.136	9.688 - 11.655	7.266 - 8.352	4.596 - 6.114	3.880 - 4.864
1000	16.449 - 20.125	11.957 - 14.046	9.648 - 11.628	7.233 - 8.286	4.687 - 6.148	3.937 - 5.301
1584	16.074 - 19.231	11.656 - 13.522	9.354 - 11.224	7.118 - 8.197	4.594 - 5.852	3.814 - 4.787
2000	16.044 - 19.098	11.441 - 13.419	9.323 - 10.930	6.985 - 8.194	4.550 - 5.758	3.754 - 4.745
3000	15.626 - 18.039	10.940 - 12.943	9.208 - 10.664	6.760 - 7.983	4.499 - 5.625	3.681 - 4.605
4000	15.166 - 17.419	10.879 - 12.889	8.980 - 10.431	6.644 - 7.834	4.420 - 5.650	3.515 - 4.586
5000	15.088 - 17.299	10.600 - 12.647	8.868 - 10.371	6.590 - 7.649	4.388 - 5.611	3.404 - 4.565

Table 12 Median decontamination coefficient, $\lambda(hr^{-1})$, at a confidence level of 50 percent for a water flux of 0.25 cm^3/cm^2-s

Fall distance (cm)	Mass fraction of aerosol remaining in the containment atmosphere					
	0.9	0.5	0.3	0.1	0.01	0.001
500	144.302 - 158.520	109.629 - 118.793	89.046 - 93.558	63.361 - 65.174	37.780 - 40.456	29.481 - 30.926
853	128.227 - 138.510	95.617 - 102.228	77.661 - 82.729	53.885 - 57.275	33.343 - 36.243	25.743 - 28.456
1000	121.340 - 136.124	89.496 - 99.013	74.114 - 81.176	50.931 - 55.178	31.844 - 34.513	24.370 - 27.429
1584	108.094 - 118.246	78.832 - 86.987	63.324 - 70.572	43.873 - 49.038	28.567 - 30.560	22.411 - 23.651
2000	96.826 - 110.243	70.160 - 79.865	58.499 - 65.342	41.186 - 45.819	25.847 - 28.431	20.030 - 21.962
3000	83.989 - 91.291	60.442 - 68.414	48.749 - 55.514	36.021 - 38.510	22.498 - 23.609	16.882 - 18.893
4000	73.854 - 84.354	53.575 - 59.184	43.660 - 48.285	31.066 - 36.164	19.421 - 22.569	14.826 - 16.922
5000	65.440 - 76.867	47.699 - 53.529	39.577 - 43.410	28.085 - 33.663	17.208 - 21.212	13.505 - 16.358

Table 13 10 percentile decontamination coefficient, $\lambda(hr^{-1})$, at a 90 percent confidence level for a water flux of 0.25 cm^3/cm^2-s

Fall distance (cm)	Mass fraction of aerosol remaining in the containment atmosphere					
	0.9	0.5	0.3	0.1	0.01	0.001
500	54.533 - 61.904	42.350 - 50.506	35.565 - 40.670	23.445 - 29.328	13.461 - 17.325	10.162 - 13.121
853	46.143 - 52.854	35.891 - 41.298	29.871 - 33.451	19.691 - 24.171	11.026 - 14.579	8.336 - 11.343
1000	43.322 - 52.706	34.253 - 38.542	27.953 - 31.513	18.439 - 22.685	10.412 - 13.886	7.894 - 10.632
1584	35.167 - 43.669	27.952 - 31.652	22.889 - 25.700	16.026 - 18.175	8.383 - 10.961	6.758 - 8.490
2000	30.898 - 38.743	24.718 - 27.847	19.975 - 23.439	14.256 - 16.199	7.663 - 9.965	5.914 - 7.548
3000	25.222 - 30.337	19.983 - 21.942	16.038 - 18.707	11.376 - 13.019	6.333 - 8.045	4.868 - 5.990
4000	21.484 - 26.221	17.068 - 18.748	13.606 - 15.787	9.753 - 10.985	5.628 - 6.798	4.152 - 5.050
5000	18.934 - 23.316	14.957 - 16.499	11.835 - 13.796	8.521 - 9.652	4.903 - 5.924	3.623 - 4.409

Table 14 90 percentile decontamination coefficient, $\lambda(hr^{-1})$, at a 90 percent confidence level for a water flux of 0.25 cm^3/cm^2-s

Fall distance (cm)	Mass fraction of aerosol remaining in the containment atmosphere					
	0.9	0.5	0.3	0.1	0.01	0.001
500	318.316 - 366.868	218.596 - 258.747	182.084 - 207.701	130.062 - 156.260	80.724 - 98.823	63.224 - 78.441
853	296.267 - 348.861	207.498 - 249.353	175.959 - 199.056	121.338 - 148.608	77.239 - 95.992	60.560 - 75.928
1000	287.074 - 346.965	205.097 - 244.232	173.763 - 196.900	120.046 - 146.943	76.400 - 95.113	59.776 - 75.256
1584	272.434 - 336.391	194.375 - 237.302	167.435 - 188.991	115.276 - 139.034	73.762 - 92.430	57.034 - 72.418
2000	267.688 - 334.389	189.821 - 231.738	164.554 - 185.425	112.953 - 136.156	70.545 - 89.629	54.451 - 70.048
3000	252.802 - 313.652	182.912 - 223.418	157.956 - 175.482	105.802 - 130.606	67.533 - 87.285	52.521 - 68.300
4000	248.930 - 309.229	180.940 - 216.779	154.402 - 171.409	101.459 - 127.837	66.120 - 85.082	51.447 - 66.678
5000	246.726 - 305.904	177.006 - 212.539	151.242 - 168.371	99.381 - 124.472	66.520 - 83.500	51.393 - 64.798

Table 15 Median decontamination coefficient, $\lambda(hr^{-1})$, at 50 percent confidence level for a water flux of 0.001 cm^3/cm^2-s

Fall distance (cm)	Mass fraction of aerosol remaining in the containment atmosphere					
	0.9	0.5	0.3	0.1	0.01	0.001
500	0.834 - 0.859	0.644 - 0.694	0.539 - 0.559	0.379 - 0.412	0.235 - 0.252	0.181 - 0.193
853	0.832 - 0.856	0.644 - 0.693	0.537 - 0.559	0.378 - 0.411	0.234 - 0.251	0.180 - 0.193
1000	0.831 - 0.855	0.643 - 0.693	0.536 - 0.559	0.377 - 0.411	0.234 - 0.251	0.180 - 0.193
1584	0.828 - 0.854	0.643 - 0.691	0.533 - 0.556	0.373 - 0.411	0.234 - 0.250	0.179 - 0.192
2000	0.826 - 0.854	0.643 - 0.688	0.531 - 0.554	0.372 - 0.411	0.233 - 0.248	0.178 - 0.192
3000	0.822 - 0.853	0.643 - 0.685	0.528 - 0.549	0.369 - 0.411	0.231 - 0.247	0.177 - 0.190
4000	0.818 - 0.844	0.640 - 0.677	0.527 - 0.548	0.368 - 0.409	0.231 - 0.244	0.177 - 0.190
5000	0.815 - 0.832	0.636 - 0.669	0.519 - 0.545	0.365 - 0.406	0.231 - 0.241	0.177 - 0.190

Table 16 10 percentile decontamination coefficient, $\lambda(hr^{-1})$, at 90 percent confidence level for a water flux of 0.001 cm^3/cm^2-s

Fall distance (cm)	Mass fraction of aerosol remaining in the containment atmosphere					
	0.9	0.5	0.3	0.1	0.01	0.001
500	0.355 - 0.424	0.296 - 0.327	0.240 - 0.279	0.162 - 0.195	0.097 - 0.116	0.072 - 0.087
853	0.353 - 0.424	0.295 - 0.326	0.239 - 0.278	0.162 - 0.195	0.097 - 0.116	0.071 - 0.086
1000	0.353 - 0.424	0.294 - 0.326	0.238 - 0.278	0.162 - 0.195	0.097 - 0.116	0.071 - 0.086
1584	0.352 - 0.424	0.293 - 0.325	0.237 - 0.277	0.162 - 0.194	0.097 - 0.116	0.071 - 0.086
2000	0.352 - 0.424	0.291 - 0.325	0.236 - 0.276	0.162 - 0.194	0.097 - 0.115	0.071 - 0.086
3000	0.349 - 0.424	0.289 - 0.324	0.234 - 0.275	0.162 - 0.192	0.097 - 0.114	0.070 - 0.086
4000	0.349 - 0.424	0.288 - 0.322	0.230 - 0.274	0.160 - 0.190	0.097 - 0.112	0.070 - 0.084
5000	0.351 - 0.423	0.286 - 0.321	0.228 - 0.273	0.159 - 0.189	0.093 - 0.111	0.069 - 0.084

Table 17 90 percentile decontamination coefficient, $\lambda(hr^{-1})$, at 90 percent confidence level for a water flux of 0.001 cm^3/cm^2-s

Fall distance (cm)	Mass fraction of aerosol remaining in the containment atmosphere					
	0.9	0.5	0.3	0.1	0.01	0.001
500	1.788 - 2.364	1.227 - 1.552	0.997 - 1.196	0.719 - 0.904	0.508 - 0.596	0.411 - 0.489
853	1.788 - 2.356	1.225 - 1.550	0.992 - 1.196	0.718 - 0.901	0.507 - 0.596	0.411 - 0.489
1000	1.788 - 2.352	1.224 - 1.550	0.991 - 1.196	0.717 - 0.900	0.506 - 0.596	0.411 - 0.489
1584	1.785 - 2.339	1.221 - 1.548	0.987 - 1.195	0.715 - 0.896	0.503 - 0.596	0.409 - 0.488
2000	1.780 - 2.329	1.218 - 1.542	0.983 - 1.195	0.715 - 0.893	0.500 - 0.595	0.409 - 0.488
3000	1.768 - 2.304	1.212 - 1.527	0.975 - 1.194	0.712 - 0.885	0.491 - 0.594	0.407 - 0.486
4000	1.755 - 2.281	1.206 - 1.512	0.969 - 1.192	0.707 - 0.878	0.486 - 0.594	0.406 - 0.482
5000	1.747 - 2.257	1.203 - 1.496	0.966 - 1.190	0.705 - 0.871	0.482 - 0.594	0.404 - 0.478

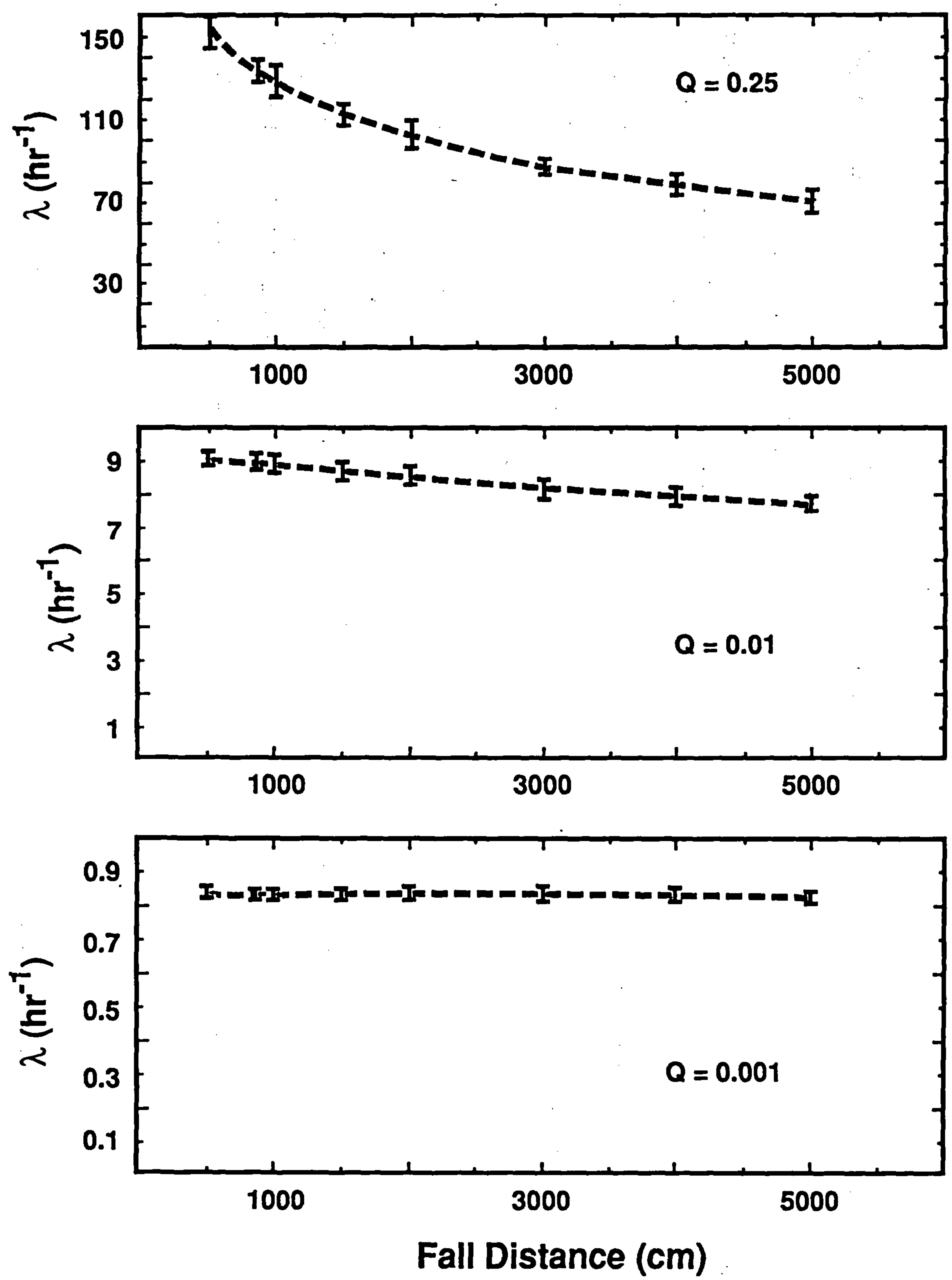

Figure 45 Median (50 percentile) λ at 50 percent confidence level for $m_f = 0.9$ as a function of water flux, Q, and fall distance, H

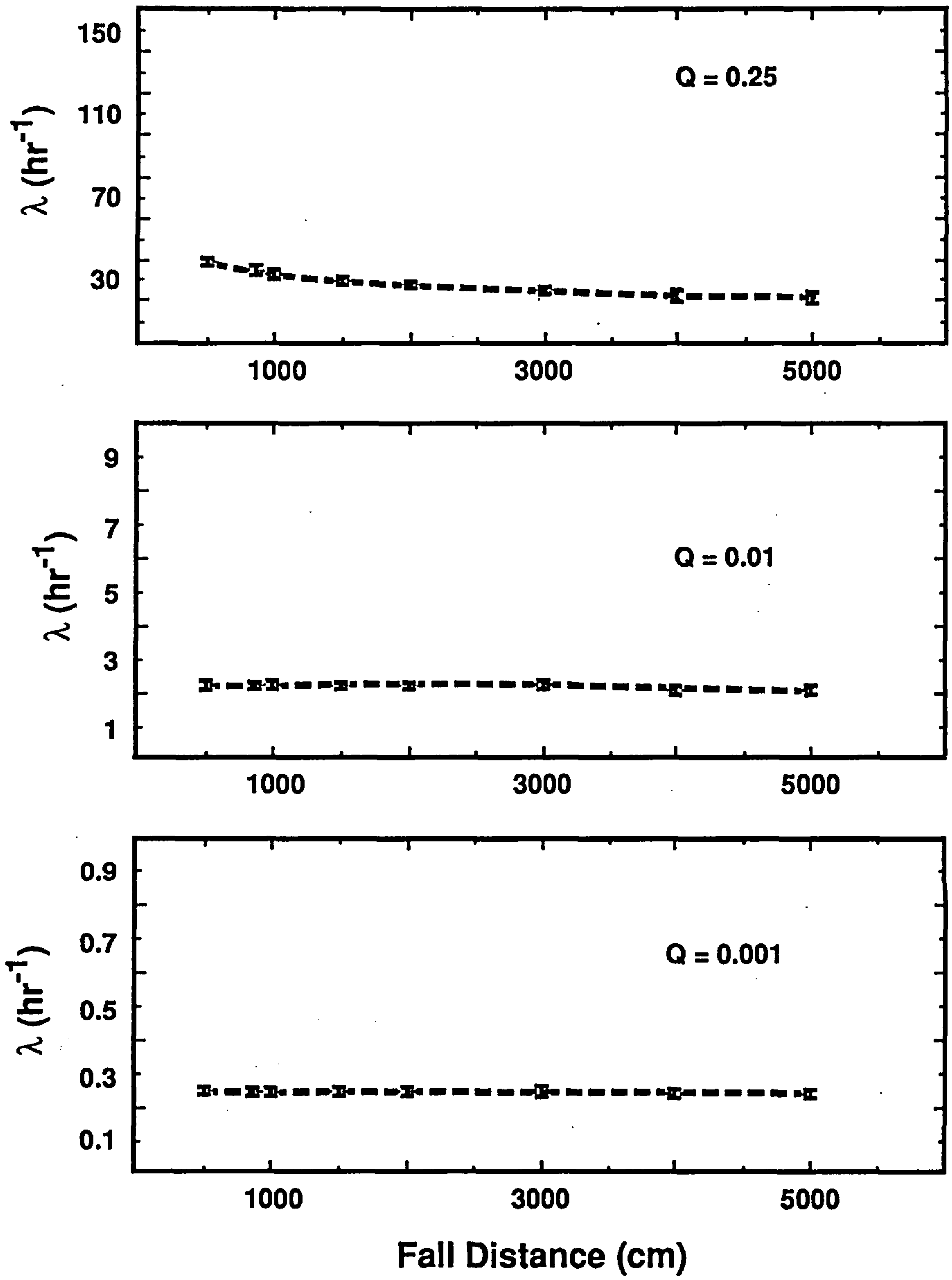

Figure 46 Median (50 percentile) λ at 50 percent confidence level for $m_f = 0.01$ as a function of water flux, Q, and fall distance, H

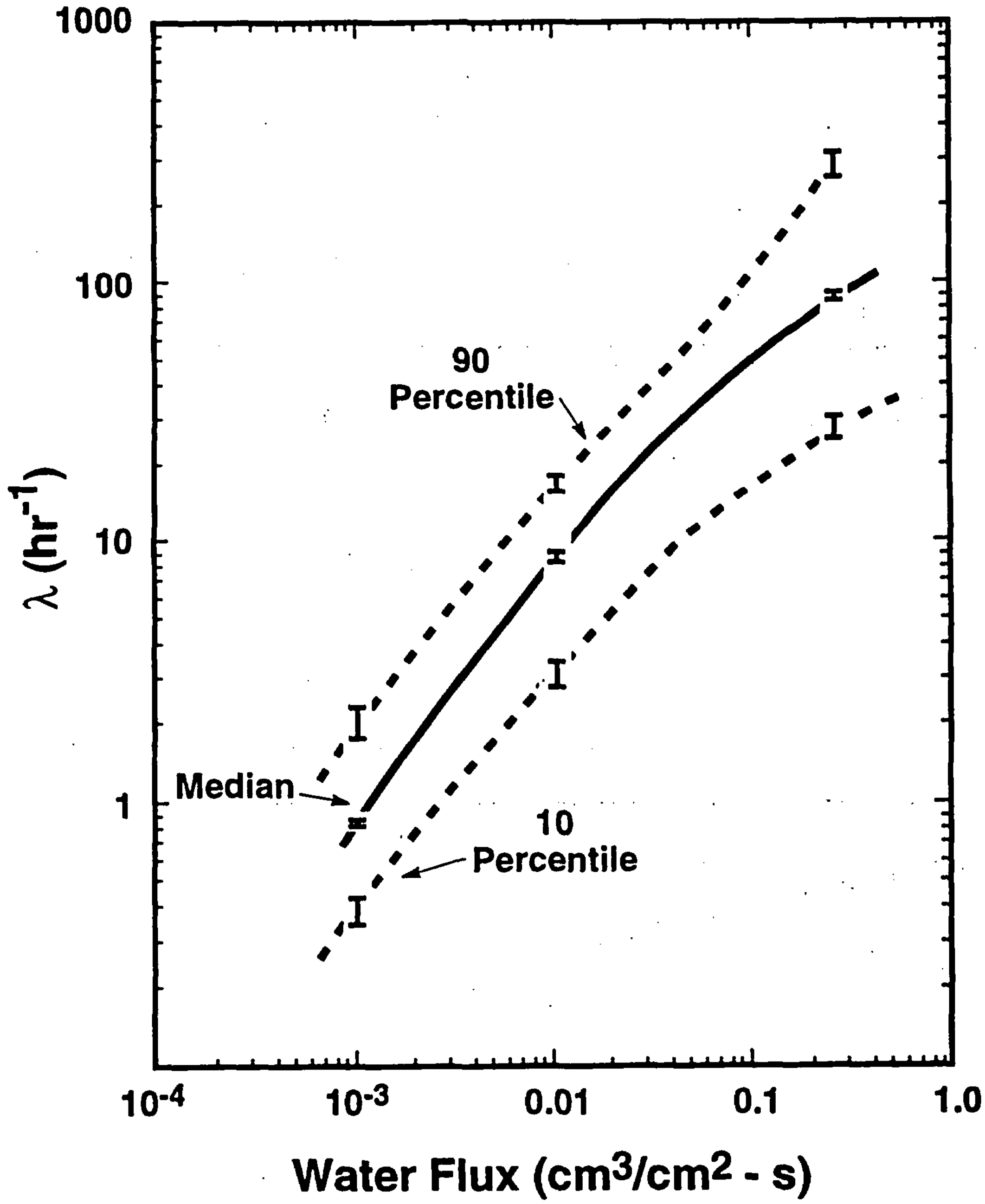

Figure 47 Median (50 percentile), 10 percentile and 90 percentile values of λ for $m_f = 0.9$ as functions of water flux, Q, for H = 3000 cm

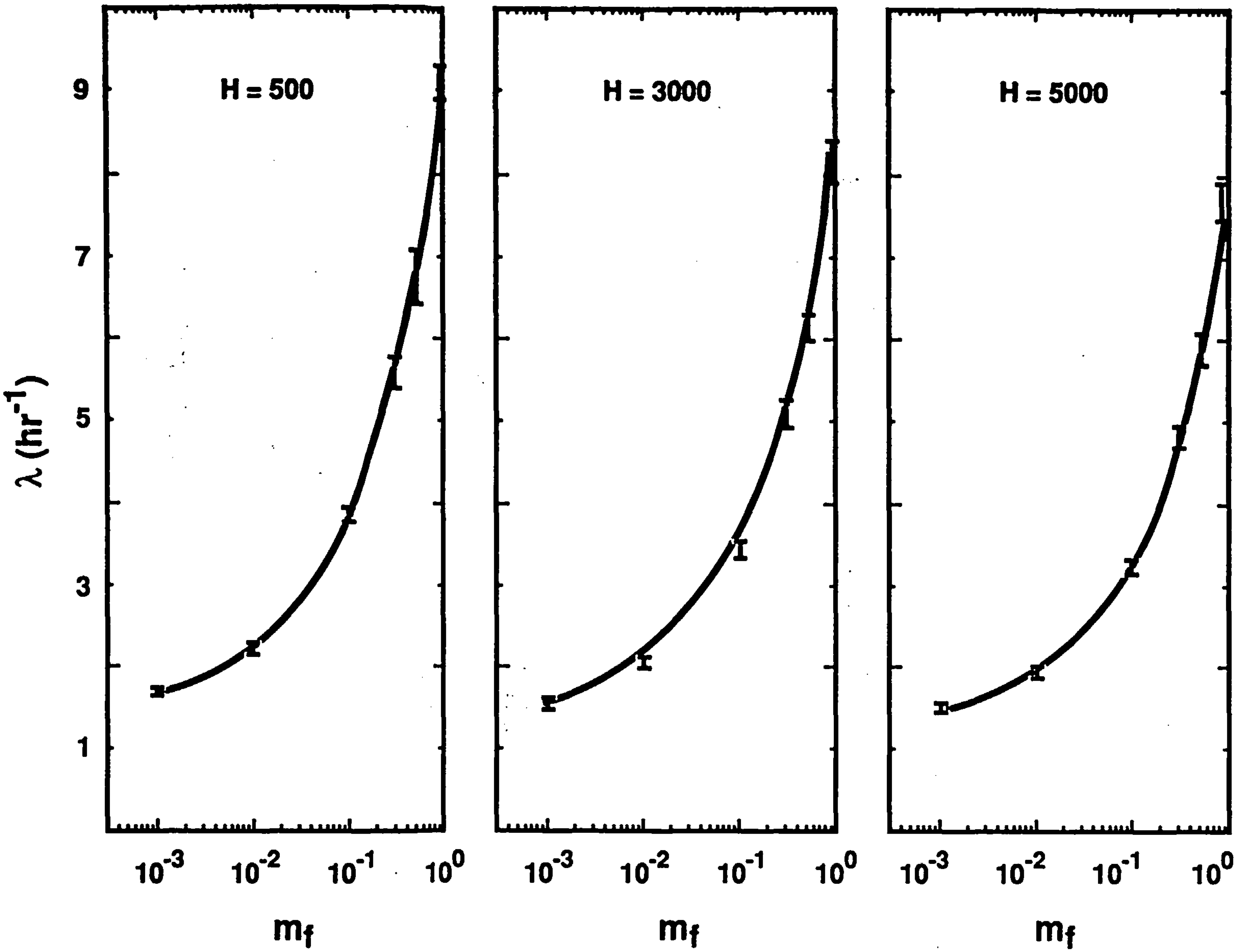

Figure 48 Median (50 percentile) λ for Q = 0.01 cm^3/cm^2-s as a function of the mass fraction of aerosol remaining in the atmosphere

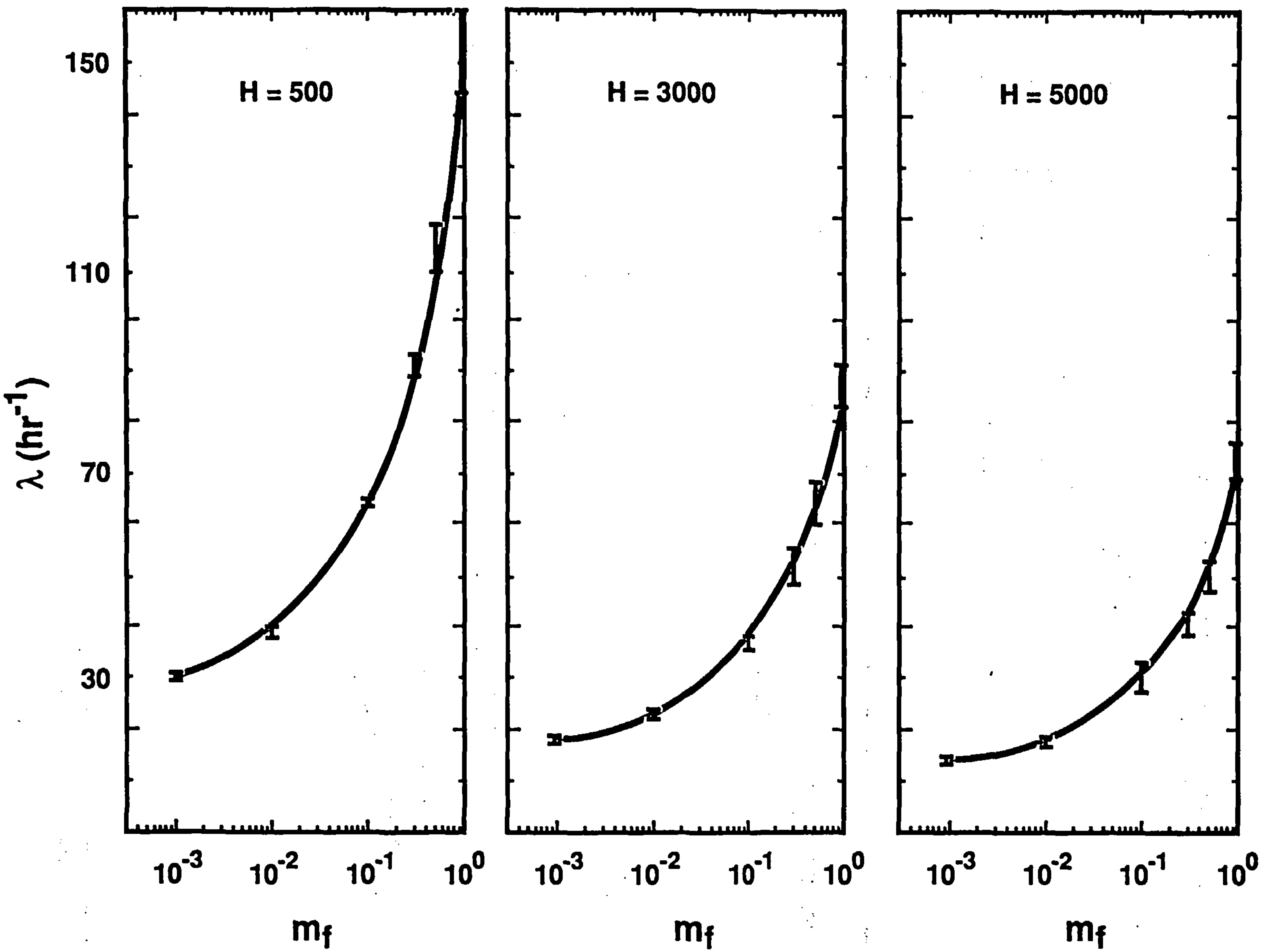

Figure 49 Median (50 percentile) λ for Q = 0.25 cm^3/cm^2-s as a function of the mass fraction of aerosol remaining in the atmosphere

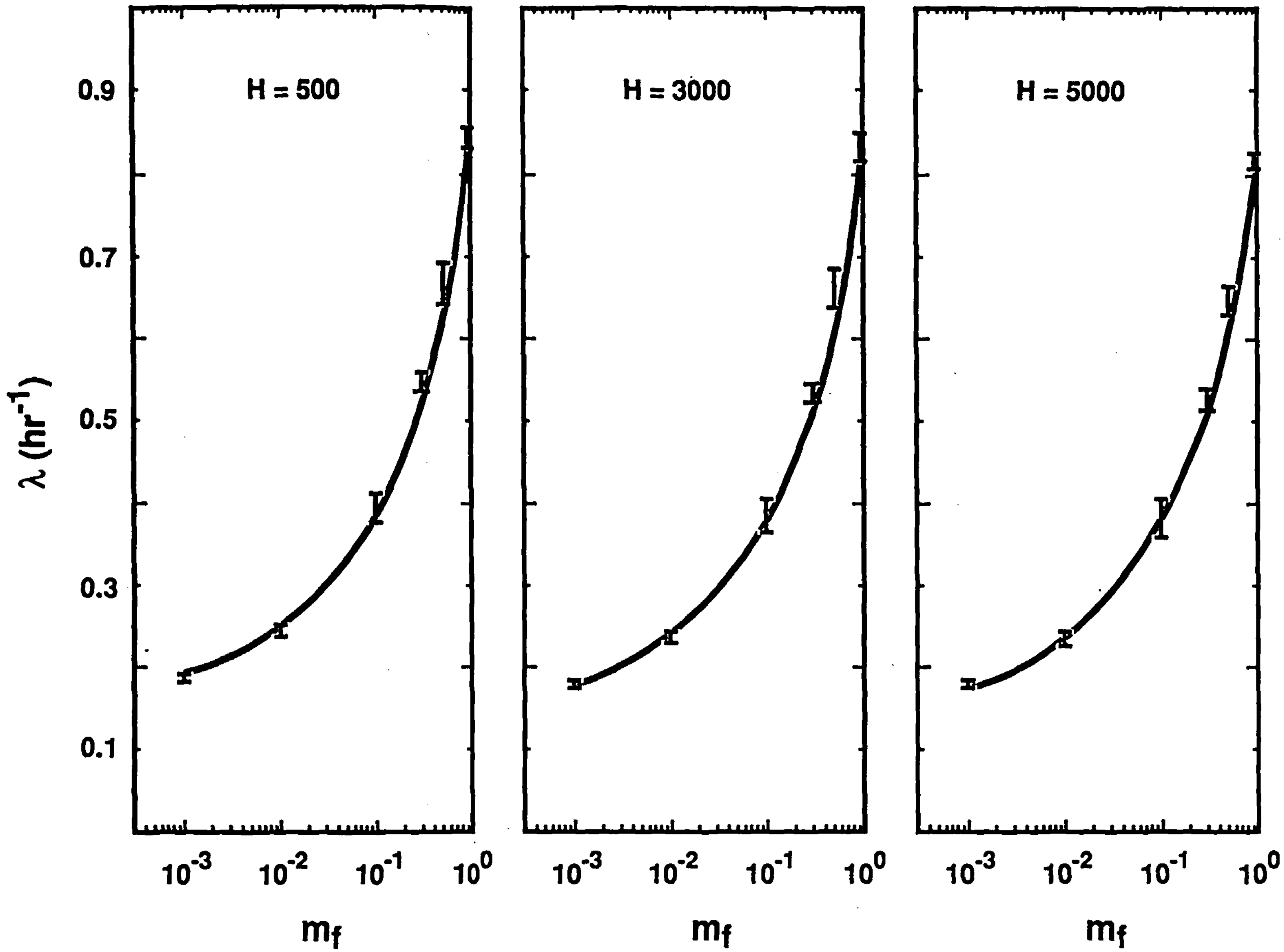

Figure 50 Median (50 percentile) λ for Q = 0.001 cm^3/cm^2-s as a function of the mass fraction of aerosol remaining in the atmosphere

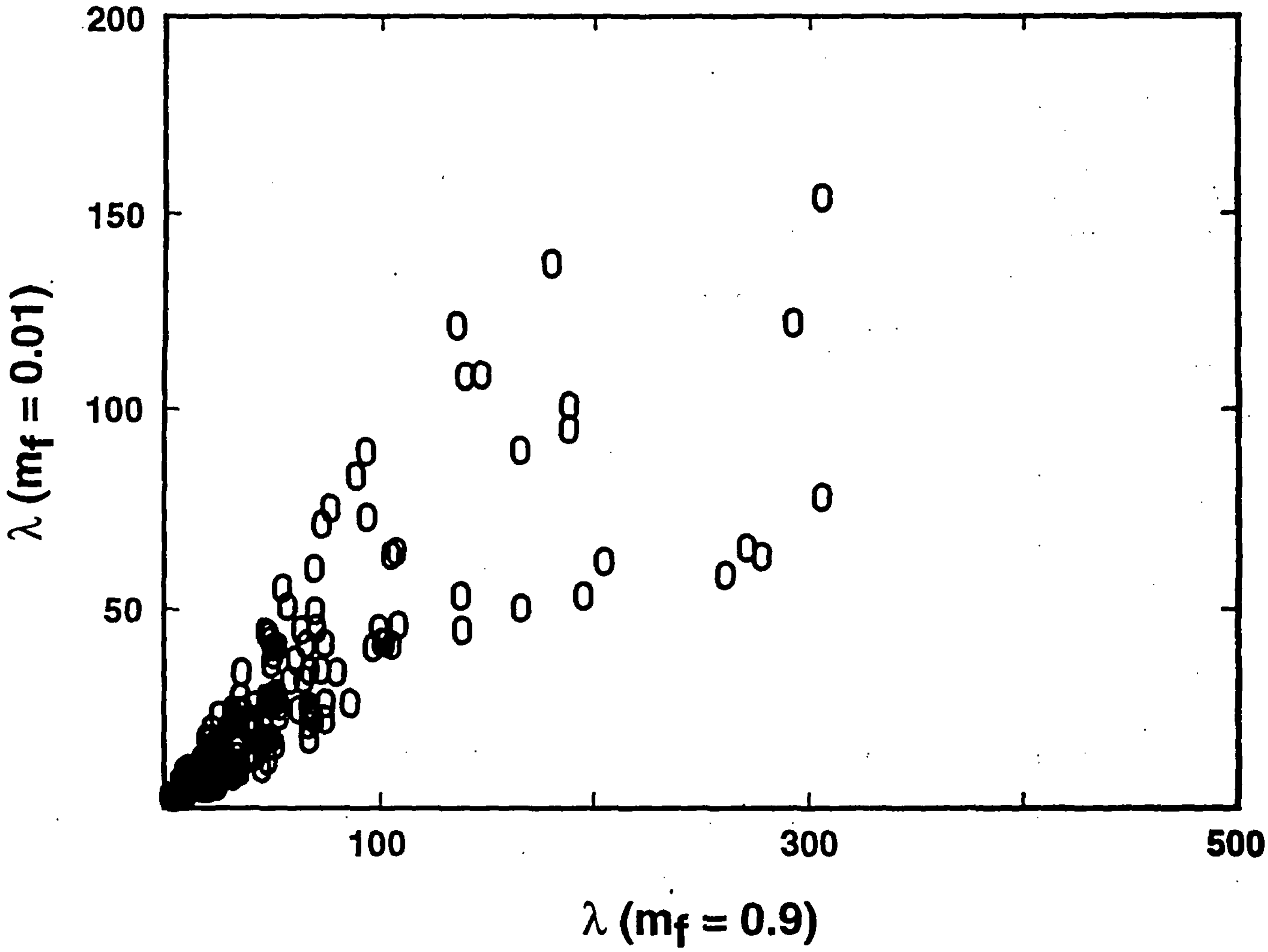

Figure 51 Correlation between values of $\lambda(m_f = 0.01)$ and values of $\lambda(m_f = 0.9)$ for $Q = 0.01$ cm^3/cm^2-s and $H = 3000$ cm

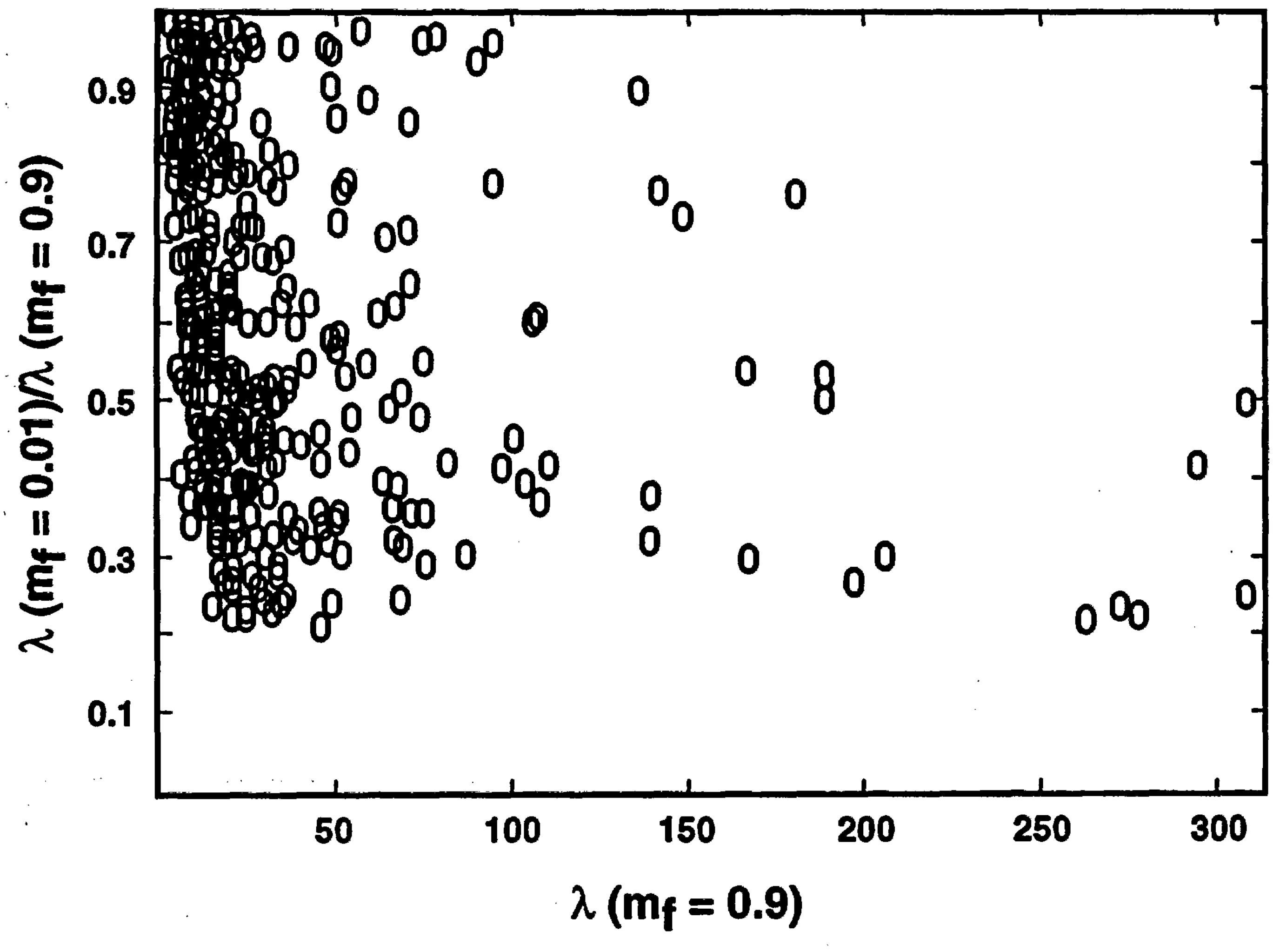

Figure 52 Values of $\lambda(m_f = 0.01)/\lambda(m_f = 0.9)$ plotted against values of $\lambda(m_f = 0.9)$ for $Q = 0.01\ cm^3/cm^2\text{-s}$ and $H = 3000$ cm

Table 18 Median (50 percentile) values of $\lambda(m_f)/\lambda(m_f = 0.9)$ at 50 percent confidence for $Q = 0.01\ cm^3/cm^2$-s

Fall distance (cm)	$\lambda(m_f)/\lambda(m_f = 0.9)$*				
	$m_f = 0.5$	$m_f = 0.3$	$m_f = 0.1$	$m_f = 0.01$	$m_f = 0.001$
500	0.743 - 0.758	0.600 - 0.621	0.421 - 0.443	0.265 - 0.274	0.202 - 0.214
853	0.743 - 0.758	0.600 - 0.621	0.421 - 0.443	0.264 - 0.273	0.202 - 0.214
1000	0.743 - 0.758	0.600 - 0.621	0.421 - 0.443	0.264 - 0.273	0.202 - 0.214
1584	0.745 - 0.760	0.601 - 0.622	0.422 - 0.443	0.261 - 0.273	0.202 - 0.212
2000	0.744 - 0.759	0.600 - 0.621	0.421 - 0.443	0.261 - 0.273	0.202 - 0.212
3000	0.742 - 0.759	0.601 - 0.621	0.421 - 0.442	0.261 - 0.273	0.202 - 0.210
4000	0.744 - 0.759	0.601 - 0.622	0.423 - 0.442	0.261 - 0.273	0.202 - 0.210
5000	0.744 - 0.759	0.601 - 0.622	0.421 - 0.442	0.261 - 0.272	0.201 - 0.211

*Equivalent to $\frac{E}{D}(m_f)/\frac{E}{D}(m_f = 0.9)$

Table 19 10 percentile value of $\lambda(m_f)/\lambda(m_f = 0.9)$ at 90 percent confidence for $Q = 0.01\ cm^3/cm^2\text{-}s$

Fall distance (cm)	$\lambda(m_f)/\lambda(m_f = 0.9)$*				
	$m_f = 0.5$	$m_f = 0.3$	$m_f = 0.1$	$m_f = 0.01$	$m_f = 0.001$
500	0.600 - 0.620	0.435 - 0.455	0.259 - 0.277	0.125 - 0.143	0.088 - 0.103
853	0.600 - 0.620	0.434 - 0.455	0.259 - 0.275	0.125 - 0.143	0.088 - 0.103
1000	0.599 - 0.619	0.435 - 0.455	0.259 - 0.274	0.125 - 0.143	0.088 - 0.103
1584	0.600 - 0.620	0.435 - 0.457	0.259 - 0.277	0.125 - 0.144	0.088 - 0.103
2000	0.600 - 0.620	0.433 - 0.455	0.259 - 0.275	0.125 - 0.143	0.088 - 0.103
3000	0.599 - 0.620	0.435 - 0.456	0.259 - 0.275	0.125 - 0.143	0.088 - 0.103
4000	0.599 - 0.620	0.433 - 0.455	0.259 - 0.274	0.125 - 0.143	0.088 - 0.103
5000	0.600 - 0.621	0.435 - 0.456	0.259 - 0.274	0.125 - 0.143	0.088 - 0.103

*Equivalent to $\frac{E}{D}(m_f)/\frac{E}{D}(m_f = 0.9)$

Table 20 90 percentile value of $\lambda(m_f)/\lambda(m_f = 0.9)$ at 90 percent confidence for $Q = 0.01\ cm^3/cm^2\text{-}s$

Fall distance (cm)	$\lambda(m_f)/\lambda(m_f = 0.9)$*				
	$m_f = 0.5$	$m_f = 0.3$	$m_f = 0.1$	$m_f = 0.01$	$m_f = 0.001$
500	0.895 - 0.914	0.818 - 0.849	0.692 - 0.737	0.521 - 0.580	0.433 - 0.489
853	0.896 - 0.914	0.820 - 0.850	0.691 - 0.737	0.521 - 0.580	0.433 - 0.489
1000	0.895 - 0.914	0.818 - 0.849	0.690 - 0.737	0.521 - 0.580	0.433 - 0.489
1584	0.896 - 0.914	0.819 - 0.849	0.689 - 0.737	0.521 - 0.580	0.433 - 0.489
2000	0.896 - 0.914	0.819 - 0.849	0.689 - 0.737	0.521 - 0.580	0.433 - 0.490
3000	0.896 - 0.914	0.819 - 0.849	0.689 - 0.737	0.521 - 0.580	0.432 - 0.490
4000	0.896 - 0.914	0.819 - 0.849	0.689 - 0.737	0.521 - 0.580	0.432 - 0.490
5000	0.896 - 0.914	0.819 - 0.849	0.689 - 0.737	0.521 - 0.580	0.432 - 0.490

*Equivalent to $\frac{E}{D}(m_f)/\frac{E}{D}(m_f = 0.9)$

Table 21 Median (50 percentile) values of $\lambda(m_f)/\lambda(m_f = 0.9)$ at 50 percent confidence for $Q = 0.25\ cm^3/cm^2\text{-}s$

Fall distance (cm)	$\lambda(m_f)/\lambda(m_f = 0.9)$* $m_f = 0.5$	$m_f = 0.3$	$m_f = 0.1$	$m_f = 0.01$	$m_f = 0.001$
500	0.741 - 0.751	0.600 - 0.615	0.419 - 0.437	0.247 - 0.262	0.191 - 0.202
853	0.742 - 0.754	0.602 - 0.617	0.420 - 0.437	0.250 - 0.262	0.191 - 0.201
1000	0.741 - 0.752	0.601 - 0.617	0.421 - 0.438	0.249 - 0.264	0.192 - 0.200
1584	0.745 - 0.757	0.602 - 0.617	0.420 - 0.436	0.252 - 0.264	0.191 - 0.199
2000	0.744 - 0.754	0.601 - 0.618	0.422 - 0.439	0.251 - 0.264	0.190 - 0.199
3000	0.749 - 0.756	0.601 - 0.618	0.423 - 0.438	0.252 - 0.263	0.191 - 0.199
4000	0.748 - 0.756	0.602 - 0.618	0.423 - 0.438	0.253 - 0.263	0.191 - 0.199
5000	0.742 - 0.754	0.600 - 0.616	0.422 - 0.436	0.252 - 0.264	0.190 - 0.199

*Equivalent to $\frac{E}{D}(m_f)/\frac{E}{D}(m_f = 0.9)$

Table 22 10 percentile values of $\lambda(m_f)/\lambda(m_f = 0.9)$ at 90 percent confidence for $Q = 0.25\ cm^3/cm^2$-s

Fall distance (cm)	$\lambda(m_f)/\lambda(m_f = 0.9)$*				
	$m_f = 0.5$	$m_f = 0.3$	$m_f = 0.1$	$m_f = 0.01$	$m_f = 0.001$
500	0.591 - 0.622	0.429 - 0.459	0.258 - 0.274	0.128 - 0.138	0.092 - 0.101
853	0.595 - 0.621	0.430 - 0.459	0.258 - 0.274	0.128 - 0.139	0.091 - 0.101
1000	0.596 - 0.619	0.431 - 0.459	0.258 - 0.274	0.128 - 0.139	0.091 - 0.101
1584	0.597 - 0.618	0.432 - 0.458	0.257 - 0.274	0.128 - 0.139	0.091 - 0.101
2000	0.596 - 0.618	0.432 - 0.457	0.257 - 0.273	0.128 - 0.138	0.091 - 0.101
3000	0.598 - 0.619	0.432 - 0.460	0.257 - 0.275	0.128 - 0.140	0.091 - 0.101
4000	0.598 - 0.619	0.432 - 0.459	0.258 - 0.275	0.128 - 0.140	0.091 - 0.101
5000	0.598 - 0.618	0.432 - 0.454	0.258 - 0.273	0.128 - 0.140	0.091 - 0.101

*Equivalent to $\frac{E}{D}(m_f)/\frac{E}{D}(m_f = 0.9)$

Table 23 90 percentile values of $\lambda(m_f)/\lambda(m_f = 0.9)$ at 90 percent confidence for $Q = 0.25\ cm^3/cm^2\text{-}s$

Fall distance (cm)	$\lambda(m_f)/\lambda(m_f = 0.9)^*$				
	$m_f = 0.5$	$m_f = 0.3$	$m_f = 0.1$	$m_f = 0.01$	$m_f = 0.001$
500	0.890 - 0.906	0.814 - 0.837	0.685 - 0.725	0.527 - 0.571	0.438 - 0.501
853	0.890 - 0.908	0.815 - 0.841	0.692 - 0.733	0.528 - 0.576	0.437 - 0.492
1000	0.893 - 0.908	0.818 - 0.841	0.684 - 0.731	0.527 - 0.576	0.437 - 0.488
1584	0.892 - 0.907	0.815 - 0.841	0.685 - 0.731	0.529 - 0.577	0.439 - 0.489
2000	0.892 - 0.907	0.815 - 0.843	0.685 - 0.732	0.529 - 0.578	0.439 - 0.490
3000	0.891 - 0.906	0.815 - 0.842	0.685 - 0.732	0.530 - 0.577	0.439 - 0.488
4000	0.891 - 0.907	0.818 - 0.844	0.687 - 0.731	0.529 - 0.577	0.440 - 0.487
5000	0.891 - 0.907	0.816 - 0.842	0.687 - 0.731	0.529 - 0.577	0.440 - 0.487

*Equivalent to $\frac{E}{D}(m_f)/\frac{E}{D}(m_f = 0.9)$

Table 24 Median values (50 percentile) of $\lambda(m_f)/\lambda(m_f = 0.9)$ at 50 percent confidence for $Q = 0.001\ cm^3/cm^2\text{-}s$

Fall distance (cm)	$\lambda(m_f)/\lambda(m_f = 0.9)^*$				
	$m_f = 0.5$	$m_f = 0.3$	$m_f = 0.1$	$m_f = 0.01$	$m_f = 0.001$
500	0.749 - 0.776	0.612 - 0.645	0.436 - 0.465	0.276 - 0.291	0.214 - 0.225
853	0.749 - 0.776	0.612 - 0.645	0.436 - 0.465	0.276 - 0.292	0.214 - 0.225
1000	0.749 - 0.776	0.612 - 0.645	0.436 - 0.465	0.276 - 0.292	0.214 - 0.225
1584	0.750 - 0.775	0.612 - 0.645	0.436 - 0.465	0.276 - 0.292	0.214 - 0.225
2000	0.750 - 0.776	0.612 - 0.645	0.437 - 0.465	0.276 - 0.292	0.214 - 0.225
3000	0.750 - 0.775	0.612 - 0.645	0.436 - 0.465	0.276 - 0.292	0.213 - 0.225
4000	0.751 - 0.775	0.612 - 0.644	0.435 - 0.463	0.276 - 0.290	0.212 - 0.223
5000	0.750 - 0.775	0.609 - 0.644	0.432 - 0.463	0.270 - 0.290	0.212 - 0.223

*Equivalent to $\frac{E}{D}(m_f)/\frac{E}{D}(m_f = 0.9)$

Table 25 10 percentile values of $\lambda(m_f)/\lambda(m_f = 0.9)$ at 90 percent confidence for $Q = 0.001\ cm^3/cm^2$-s

Fall distance (cm)	$\lambda(m_f)/\lambda(m_f = 0.9)^*$ $m_f = 0.5$	$m_f = 0.3$	$m_f = 0.1$	$m_f = 0.01$	$m_f = 0.001$
500	0.602 - 0.623	0.438 - 0.458	0.261 - 0.280	0.132 - 0.146	0.095 - 0.105
853	0.602 - 0.623	0.438 - 0.459	0.261 - 0.280	0.132 - 0.146	0.095 - 0.106
1000	0.602 - 0.623	0.438 - 0.459	0.261 - 0.280	0.132 - 0.146	0.095 - 0.106
1584	0.602 - 0.623	0.438 - 0.459	0.261 - 0.280	0.132 - 0.146	0.096 - 0.106
2000	0.602 - 0.622	0.438 - 0.459	0.261 - 0.280	0.132 - 0.146	0.096 - 0.106
3000	0.603 - 0.623	0.438 - 0.459	0.261 - 0.280	0.132 - 0.146	0.095 - 0.106
4000	0.603 - 0.624	0.438 - 0.459	0.261 - 0.280	0.132 - 0.146	0.095 - 0.106
5000	0.603 - 0.624	0.438 - 0.459	0.261 - 0.280	0.132 - 0.146	0.095 - 0.106

*Equivalent to $\frac{E}{D}(m_f)/\frac{E}{D}(m_f = 0.9)$

Table 26 90 percentile values of $\lambda(m_f)/\lambda(m_f = 0.9)$ at 90 percent confidence for $Q = 0.001\ cm^3/cm^2$-s

Fall distance (cm)	$\lambda(m_f)/\lambda(m_f = 0.9)$*				
	$m_f = 0.5$	$m_f = 0.3$	$m_f = 0.1$	$m_f = 0.01$	$m_f = 0.001$
500	0.896 - 0.909	0.820 - 0.839	0.690 - 0.720	0.521 - 0.558	0.431 - 0.467
853	0.896 - 0.909	0.820 - 0.839	0.690 - 0.720	0.521 - 0.556	0.431 - 0.465
1000	0.896 - 0.909	0.819 - 0.839	0.690 - 0.720	0.521 - 0.556	0.431 - 0.465
1584	0.896 - 0.908	0.820 - 0.839	0.690 - 0.720	0.520 - 0.556	0.430 - 0.465
2000	0.896 - 0.908	0.820 - 0.839	0.690 - 0.720	0.520 - 0.556	0.430 - 0.465
3000	0.896 - 0.908	0.820 - 0.839	0.690 - 0.720	0.520 - 0.556	0.429 - 0.466
4000	0.896 - 0.908	0.820 - 0.840	0.690 - 0.720	0.520 - 0.556	0.429 - 0.466
5000	0.896 - 0.908	0.820 - 0.839	0.690 - 0.720	0.520 - 0.556	0.429 - 0.466

*Equivalent to $\frac{E}{D}(m_f)/\frac{E}{D}(m_f = 0.9)$

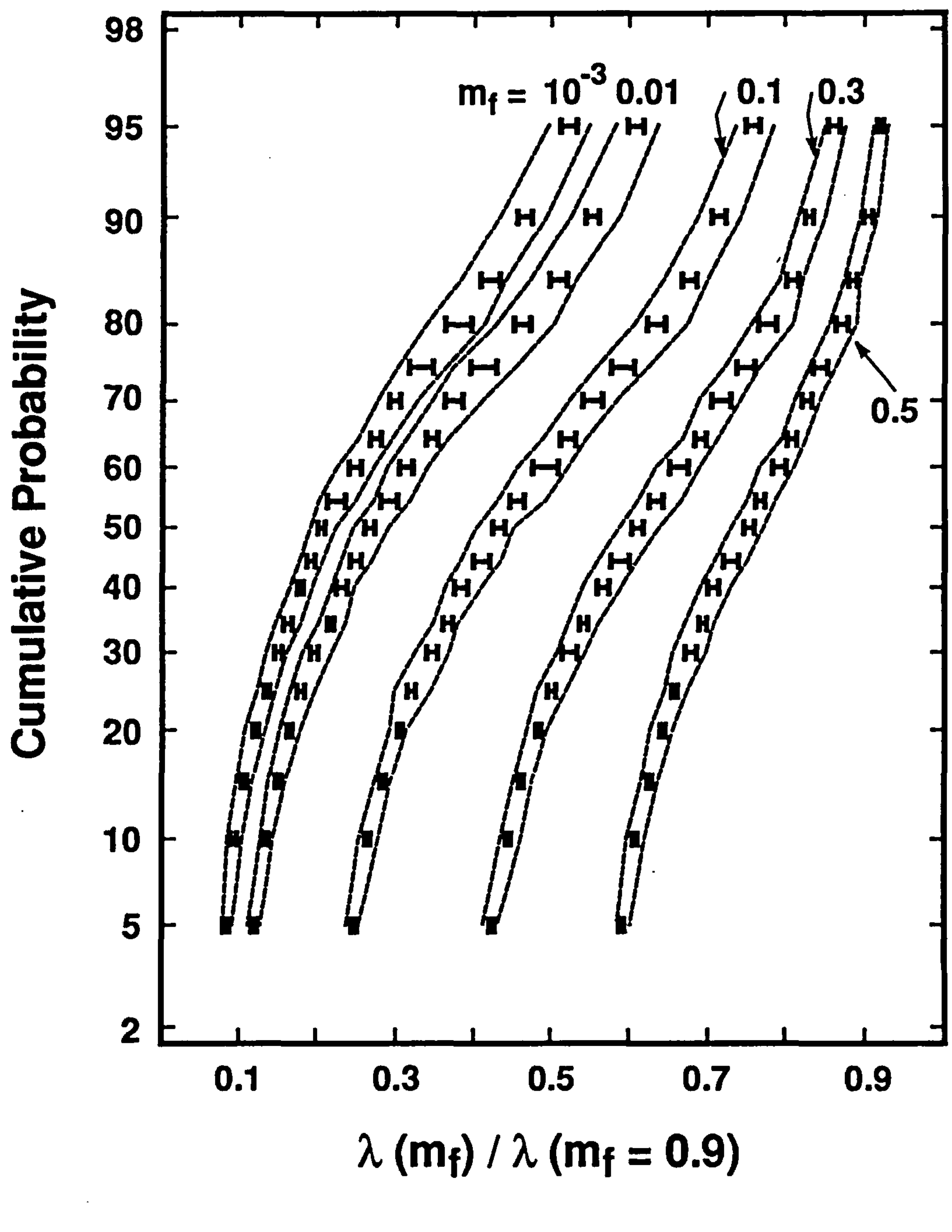

Figure 53 Cumulative probability plots for the distributions of $\lambda(m_f)/\lambda(m_f = 0.9)$ for various values of m_f and a water flux of 0.01 cm^3/cm^2-s. Percentile levels are shown for 50 percent confidence (bars) and 95 percent confidence (dashed lines). These distributions are for the case H = 3000 cm. Distributions for other fall distances are very similar (see Appendix B).

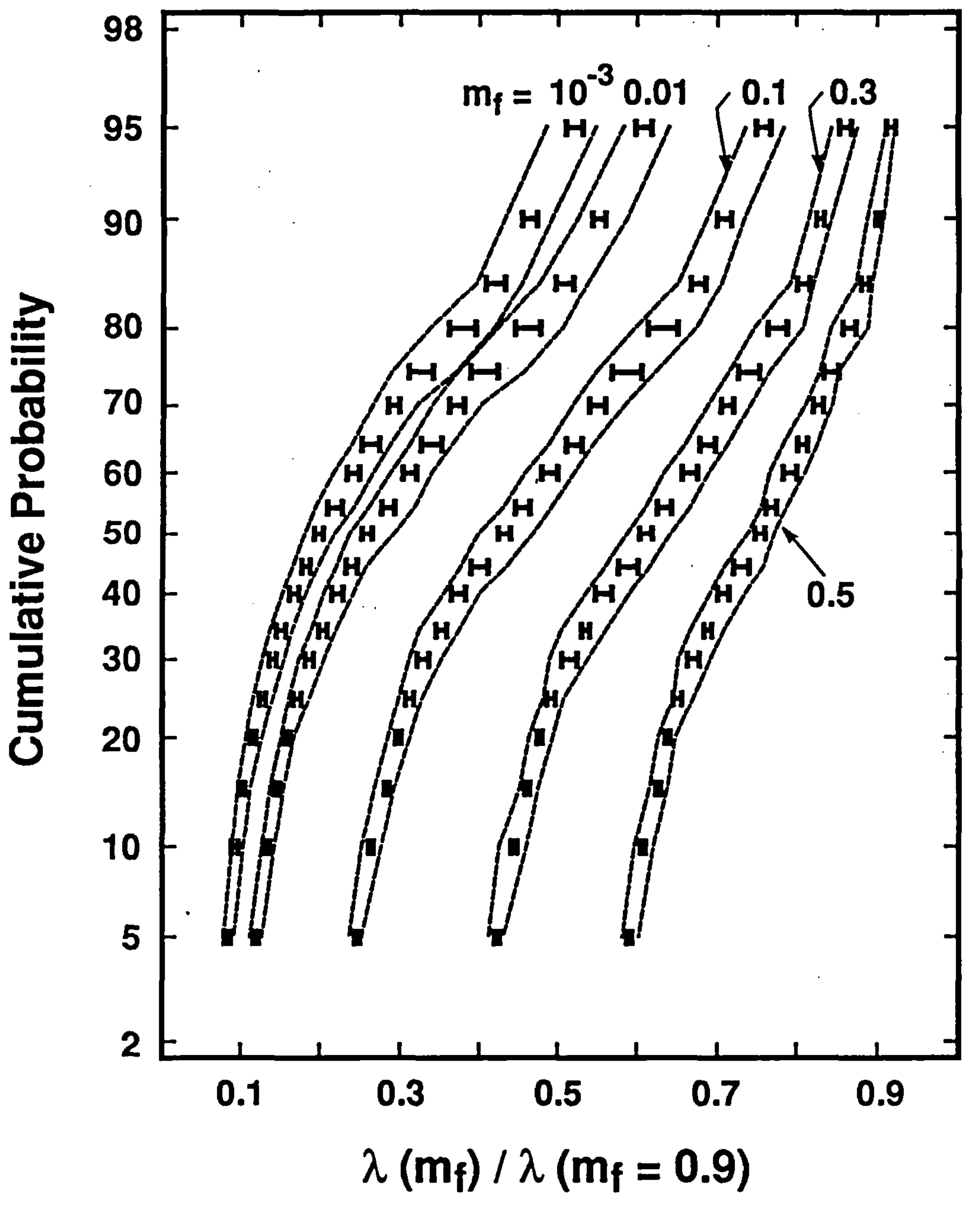

Figure 54 Cumulative probability plots for the distributions of $\lambda(m_f)/\lambda(m_f = 0.9)$ for various values of m_f and a water flux of 0.25 cm^3/cm^2-s. Percentile levels are shown for 50 percent confidence (bars) and 95 percent confidence (dashed lines). These distributions are for the case H = 3000 cm. Distributions for other fall distances are very similar (see Appendix B).

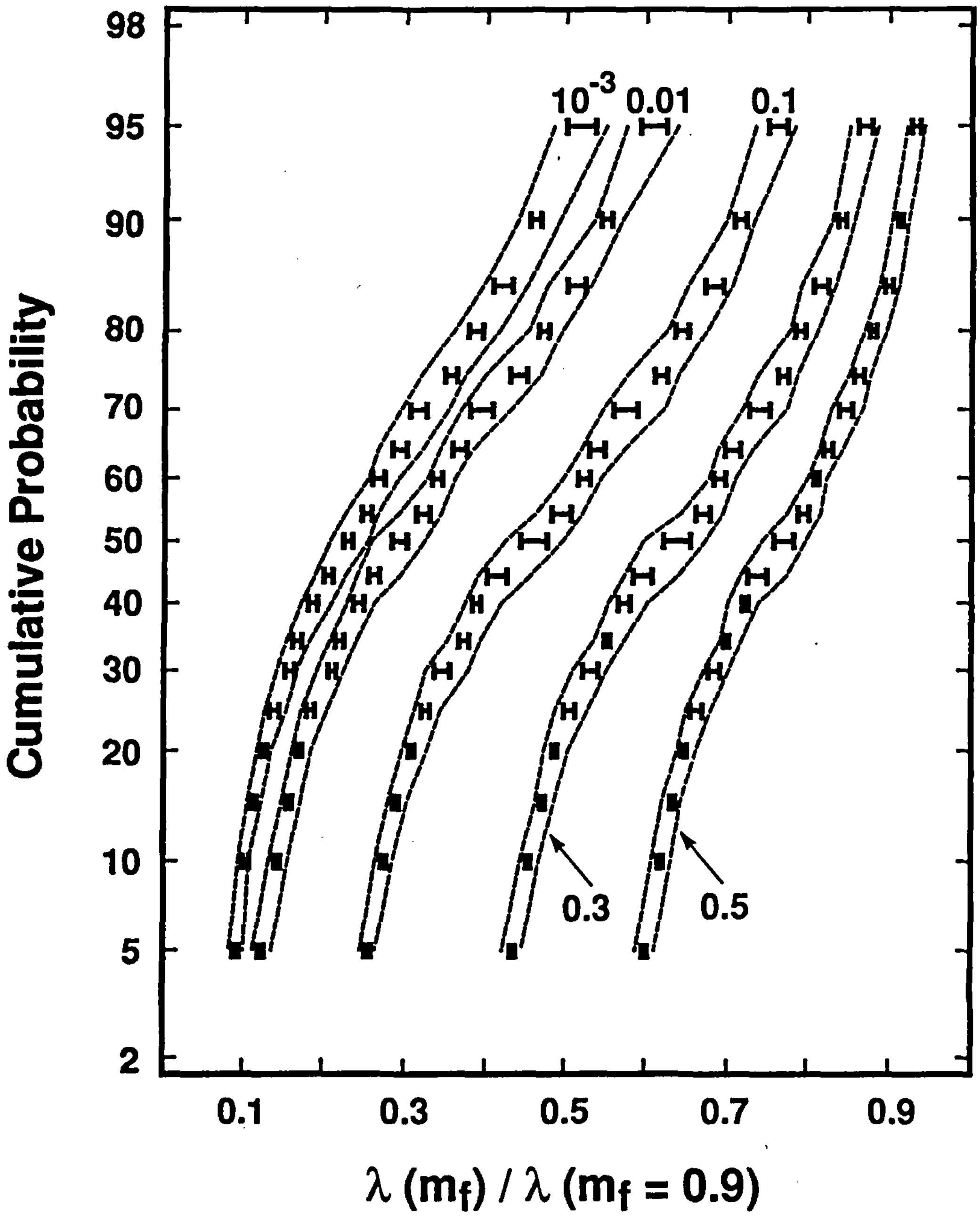

Figure 55 Cumulative probability plots for the distributions of $\lambda(m_f)/\lambda(m_f = 0.9)$ for various values of m_f and a water flux of 0.001 cm^3/cm^2-s. Percentile levels are shown for 50 percent confidence (bars) and 95 percent confidence (dashed lines). These distributions are for the case H = 3000 cm. Distributions for other fall distances are very similar (see Appendix B).

Results

A quantity of regulatory interest is the change in λ between the start of decontamination (here represented by $\lambda(m_f = 0.9)$) and λ when the decontamination factor has reached about 100 (here represented by $\lambda(m_f = 0.01)$). Plots of the distributions of $\lambda(m_f = 0.01)/\lambda(m_f = 0.9)$ for various water fluxes are shown in Figure 56. These distributions in the value of $\lambda(m_f = 0.01)/\lambda(m_f = 0.9)$ can be compared to the fixed value 0.1 that has been recommended [68].

From the discussion above, it is evident that $\lambda(m_f = 0.9)$ is essentially a linear function of fall distance and a quadratic function of water flux. The ratio $\lambda(m_f)/\lambda(0.9)$ is independent of the fall distance. The ratio does depend on the water flux but the dependence is weak. Essentially, the ratio $\lambda(m_f)/\lambda(m_f = 0.9)$ approaches a limiting value dependent on the water flux into the containment atmosphere as the mass fraction of the aerosol remaining in the atmosphere approaches zero. The ratio is quite dependent on the mass fraction of the aerosol remaining in the containment atmosphere especially when the extent of decontamination is small. Once m_f falls below 0.01 (DF = 100) the dependence of the ratio on m_f is small.

These results suggest that a simplified model for spray performance can be devised by developing a correlation for $\lambda(m_f = 0.9)$ in terms of water flux and fall distance and a correlation for $\lambda(m_f)/\lambda(m_f = 0.9)$ in terms of water flux and the mass fraction of aerosol remaining in the containment atmosphere. Such a simplified model is developed in Chapter V.

D. Effect of Unsprayed Volume

The decontamination coefficients have been calculated here assuming that the entire containment volume is exposed to the action of the spray. This, of course, can never be entirely true. Compartments in a reactor below the operating floor will not be exposed to the spray. At best, relatively large droplets produced by liquid films draining from surfaces will fall through atmospheres of the lower compartments. In some reactors there can be unsprayed space above the spray headers (of course, in many reactors the spray nozzles are configured so that some spray droplets go upward to penetrate areas above the spray headers).

The spray does produce a significant amount of gas circulation in the containment atmosphere (see, for example, discussions in Reference 33). The turbulent, circulating atmosphere can penetrate into regions that are not exposed to the spray. If it is assumed that this circulation is rapid in comparison to the decontamination rate, then, the decontamination coefficients for a containment with unsprayed volumes, λ(real) are easily related to the decontamination coefficients calculated here:

$$\lambda(\text{real}) = \lambda(Q, H, m_f) \ / \ (1 + \alpha)$$

where

λ(real) = actual decontamination coefficients for an atmosphere in a containment with unsprayed volumes

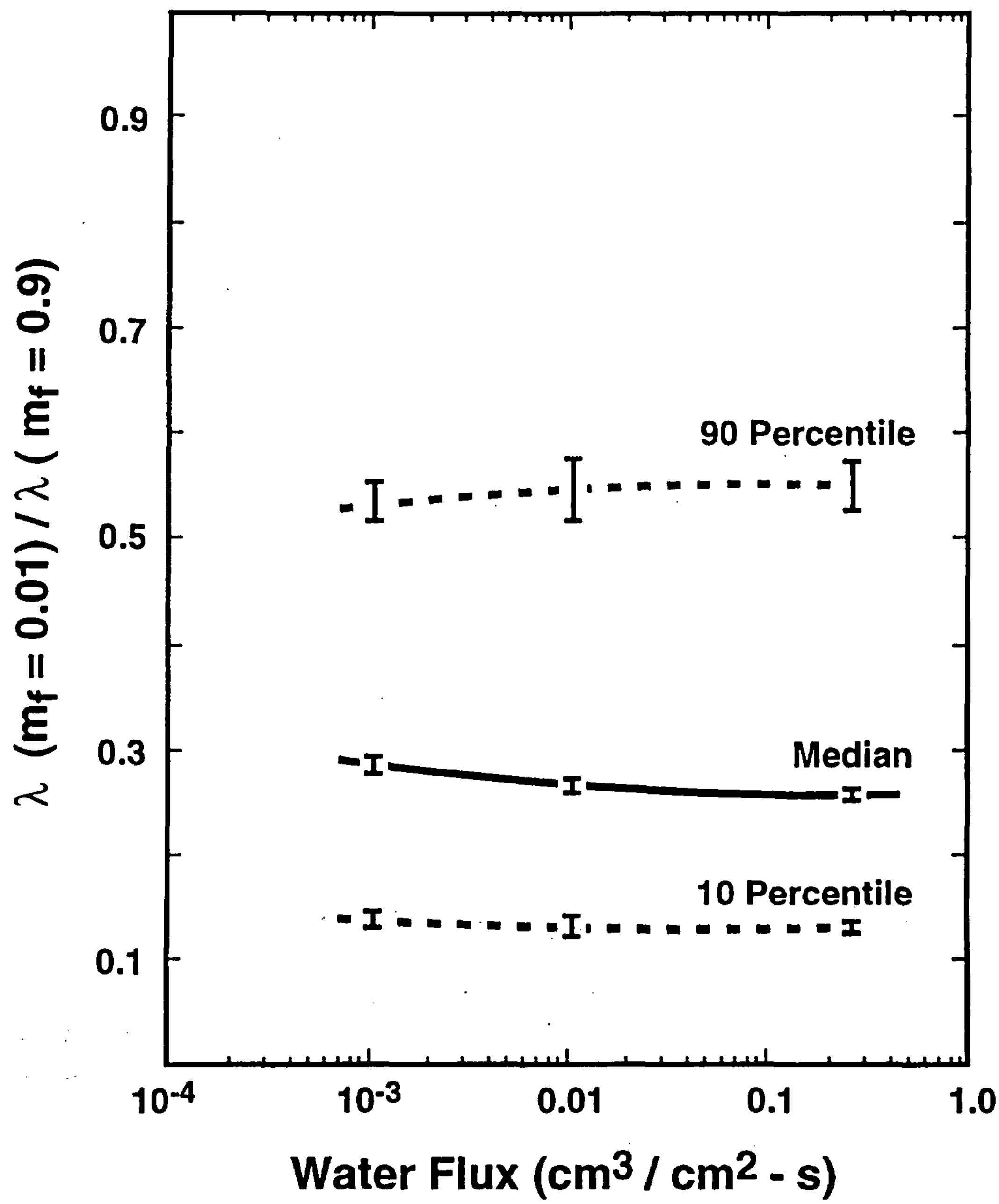

Figure 56 Variation of $\lambda(m_f = 0.01)/\lambda(m_f = 0.9)$ with water flux. The median values of $\lambda(m_f = 0.01)/\lambda(m_f = 0.9)$ are shown at 50 percent confidence. The 90 percentile and 10 percentile values are shown at 90 percent confidence.

Results

$\lambda(Q, H, m_f)$ = decontamination coefficient calculated here

α = v(unsprayed) / v(sprayed)

v(unsprayed) = volume of containment not exposed to the spray

v(sprayed) = volume of containment exposed to the spray

If, on the other hand, circulation of gas from the unsprayed volumes into the volume exposed to the spray is slow relative to rate of decontamination by the spray, then the gas circulation rate determines the overall rate of decontamination of the entire containment. The values of $\lambda(Q, H, m_f)$ computed here can still be used in an analysis of the containment response by treating the slow circulation of gas from unsprayed volumes as a source of aerosol to the sprayed volume.

E. Combined Effects of Water Pools and Sprays

All the calculated results discussed above have been for the removal of rather coarse aerosol subjected only to attenuation by sprays. The aerosols considered thus far have size distributions expected for materials discharged directly to the containment atmosphere from the reactor coolant system or as a result of core debris interactions with concrete in the reactor cavity. Sprays may, however, not be the only system being used to mitigate the amount of radioactivity suspended in the reactor containment atmosphere. Sprays may, in fact, be used to augment the aerosol attenuation achieved by other means. A likely, additional, method to attenuate the potential severe accident source term is to maintain a water pool over core debris that has penetrated the reactor coolant system and is interacting with structural concrete [11].

Water pools overlying core debris interacting with concrete will scrub aerosols from the gases evolved during these interactions. The efficiency of aerosol scrubbing by a water pool depends on the size of the aerosol particles. As a result of this size selective scrubbing, aerosols that emerge into the containment atmosphere from a water pool are expected to be much smaller than the aerosol considered thus far in the analysis of spray performance. The aerosol must also have a narrower distribution of sizes. Since the removal of aerosol particles by sprays is size selective, the decontamination that can be achieved by sprays would be expected to be less when the spray is used in conjunction with a water pool than when a spray is used alone.

To demonstrate this reduction in spray effectiveness at removal of aerosols subjected to the actions of a water pool, a second set of calculations was done for a spray producing a water flux of 0.01 cm^3/cm^2-s. For these calculations, the range of mean aerosol particle sizes was taken to be 0.15 to 0.65 μm (see Case 2 in Table 7). This is the range of mean aerosol particle sizes calculated to emerge from water pools of depths of 30 to 500 cm and subcooling of 0 to 70 K overlying core debris interacting with concrete [11]. The aerosols emerging from the water pool to be subjected to the action of the spray are assumed to be log-normally distributed in size. Because the smaller sizes of these aerosols are the result of size selective scrubbing, it is assumed that the geometric standard deviation of the aerosol size distribution is completely correlated to the mean size. The maximum value of the geometric standard deviation, which corresponds to a mean aerosol particle size of 0.65 μm, is taken to be 3.2. The minimum geometric standard deviation, corresponding to a mean aerosol size of 0.15 μm, is taken to be 1.4. Values of the geometric standard deviation for other mean aerosol particle sizes are calculated from:

$$\sigma_g = 0.86 + 3.6\,\mu$$

where μ is the mean aerosol particle size in units of micrometers.

Calculations of the spray decontamination factor for aerosol previously subjected to the actions of a water pool were done in a manner completely analogous to other uncertainty analyses described in this report. Results of the calculations are summarized in Tables 27 and 28. Values of $\lambda(m_f = 0.9)$ corresponding to 10, 50, and 90th percentiles of the uncertainty distributions at confidence levels of 95, 90, and 50 percent for various fall distances are shown in Table 27. Values of $\lambda(m_f)/\lambda(m_f = 0.9)$ for a fall distance of 3000 cm are shown in Table 28. Values listed in the table are, of course, ranges at confidence levels of 95, 90 and 50 percent corresponding to the 10, 50, and 90th percentile of the distributions for m_f = 0.5, 0.3, 0.1, 0.01, and 0.001 (DF = 2, 3.3, 10, 100, and 1000). Values of $\lambda(m_f)/\lambda\ (m_f = 0.9)$ for other fall distances are nearly identical to those listed in Table 28 for a fall distance of 3000 cm since the ratio of spray decontamination coefficients is insensitive to fall distance.

The values of $\lambda(m_f = 0.9)$ are plotted against fall distances in Figure 57. Values corresponding to the median of the uncertainty distribution (at 50 percent confidence) and the 10 and 90 percentiles of the distribution (at 90 percent confidence) are shown in this figure. Similar values of $\lambda(m_f = 0.9)$ obtained for coarser aerosol injected directly into the containment atmosphere without passing through a water pool are also shown in this figure. Comparison of the values of the $\lambda(m_f = 0.9)$ for the two cases shows that the effectiveness of a spray at particle removal is substantially reduced for particles that have emerged from the water pool. Again, this reduction in spray effectiveness is simply because the particles that do emerge from a water pool have size distributions that are centered near the size of minimum aerosol capture efficiency by falling water droplets.

Values of $\lambda(m_f)/\lambda(m_f = 0.9)$ are plotted against m_f in Figure 58. Values of this ratio obtained in the calculations described above for coarse aerosols injected directly into the containment atmosphere without passing through a water pool are also shown in this figure. The ratios $\lambda(m_f)/\lambda(m_f = 0.9)$ found for aerosols that had been subjected to scrubbing by a water pool are somewhat less sensitive to the extent of atmosphere decontamination than are the ratios for aerosols not subjected to scrubbing. The reason for this relative insensitivity is that scrubbing by a water pool narrows the spread in the particle size distribution. The shape of the distribution is not changed greatly as atmosphere decontamination progresses.

Table 27 Summary of the uncertainty distributions found for $\lambda(m_f = 0.9)$ for the case of aerosols subjected to pool scrubbing and spray decontamination at a water flux of 0.01 cm^3/cm^2-s

Fall distance (cm)	Percentile of distribution	Range of values of λ (m_f = 0.9) (hr^{-1}) at a confidence level of 95%	90%	50%
500	10	0.440 - 0.534	0.445 - 0.522	0.470 - 0.503
	50	1.013 - 1.128	1.026 - 1.125	1.061 - 1.086
	90	2.036 - 2.361	2.055 - 2.313	2.180 - 2.262
853	10	0.435 - 0.523	0.440 - 0.511	0.466 - 0.497
	50	1.000 - 1.117	1.011 - 1.109	1.045 - 1.080
	90	1.991 - 2.299	2.016 - 2.271	2.166 - 2.203
1000	10	0.431 - 0.518	0.438 - 0.507	0.462 - 0.492
	50	0.995 - 1.116	1.002 - 1.101	1.040 - 1.078
	90	1.977 - 2.277	2.010 - 2.264	2.147 - 2.200
1584	10	0.413 - 0.506	0.424 - 0.498	0.450 - 0.477
	50	0.972 - 1.095	0.985 - 1.076	1.008 - 1.059
	90	1.920 - 2.251	1.995 - 2.198	2.050 - 2.166
2000	10	0.401 - 0.495	0.418 - 0.494	0.440 - 0.462
	50	0.967 - 1.082	0.970 - 1.071	0.990 - 1.039
	90	1.913 - 2.242	1.955 - 2.233	2.013 - 2.157
3000	10	0.384 - 0.472	0.388 - 0.467	0.423 - 0.444
	50	0.932 - 1.054	0.941 - 1.049	0.964 - 1.017
	90	1.821 - 2.169	1.853 - 2.161	1.953 - 2.116
4000	10	0.374 - 0.451	0.380 - 0.444	0.399 - 0.432
	50	0.901 - 1.036	0.910 - 1.027	0.947 - 0.987
	90	1.804 - 2.144	1.808 - 2.134	1.887 - 1.441
5000	10	0.366 - 0.438	0.374 - 0.432	0.381 - 0.420
	50	0.866 - 0.999	0.891 - 0.988	0.930 - 0.965
	90	1.754 - 2.118	1.787 - 2.103	1.853 - 1.988

Table 28 Summary of the uncertainty distribution for $\lambda(m_f)/\lambda(m_f = 0.9)$ for the case of aerosols subjected to water pool scrubbing and spray decontamination at a water flux of 0.01 cm^3/cm^2-s and a fall distance of 3000 cm

Percentile of the distribution	Mass fraction of initial aerosol remaining (m_f)	Range of values of $\lambda(m_f)/\lambda(m_f = 0.9)$ at a confidence level of		
		95%	90%	50%
10	0.5	0.727 - 0.750	0.728 - 0.747	0.731 - 0.740
	0.3	0.590 - 0.621	0.592 - 0.620	0.599 - 0.610
	0.1	0.431 - 0.477	0.433 - 0.475	0.445 - 0.462
	0.01	0.304 - 0.357	0.307 - 0.355	0.318 - 0.337
	0.001	0.261 - 0.309	0.261 - 0.305	0.272 - 0.288
50	0.5	0.857 - 0.894	0.861 - 0.892	0.870 - 0.882
	0.3	0.773 - 0.831	0.775 - 0.824	0.795 - 0.810
	0.1	0.666 - 0.734	0.670 - 0.732	0.681 - 0.705
	0.01	0.565 - 0.635	0.567 - 0.618	0.576 - 0.602
	0.001	0.510 - 0.582	0.515 - 0.572	0.532 - 0.556
90	0.5	0.981 - 0.993	0.983 - 0.993	0.987 - 0.990
	0.3	0.968 - 0.987	0.369 - 0.987	0.977 - 0.983
	0.1	0.943 - 0.976	0.946 - 0.974	0.960 - 0.968
	0.01	0.907 - 0.960	0.914 - 0.957	0.934 - 0.947
	0.001	0.886 - 0.949	0.896 - 0.945	0.916 - 0.934

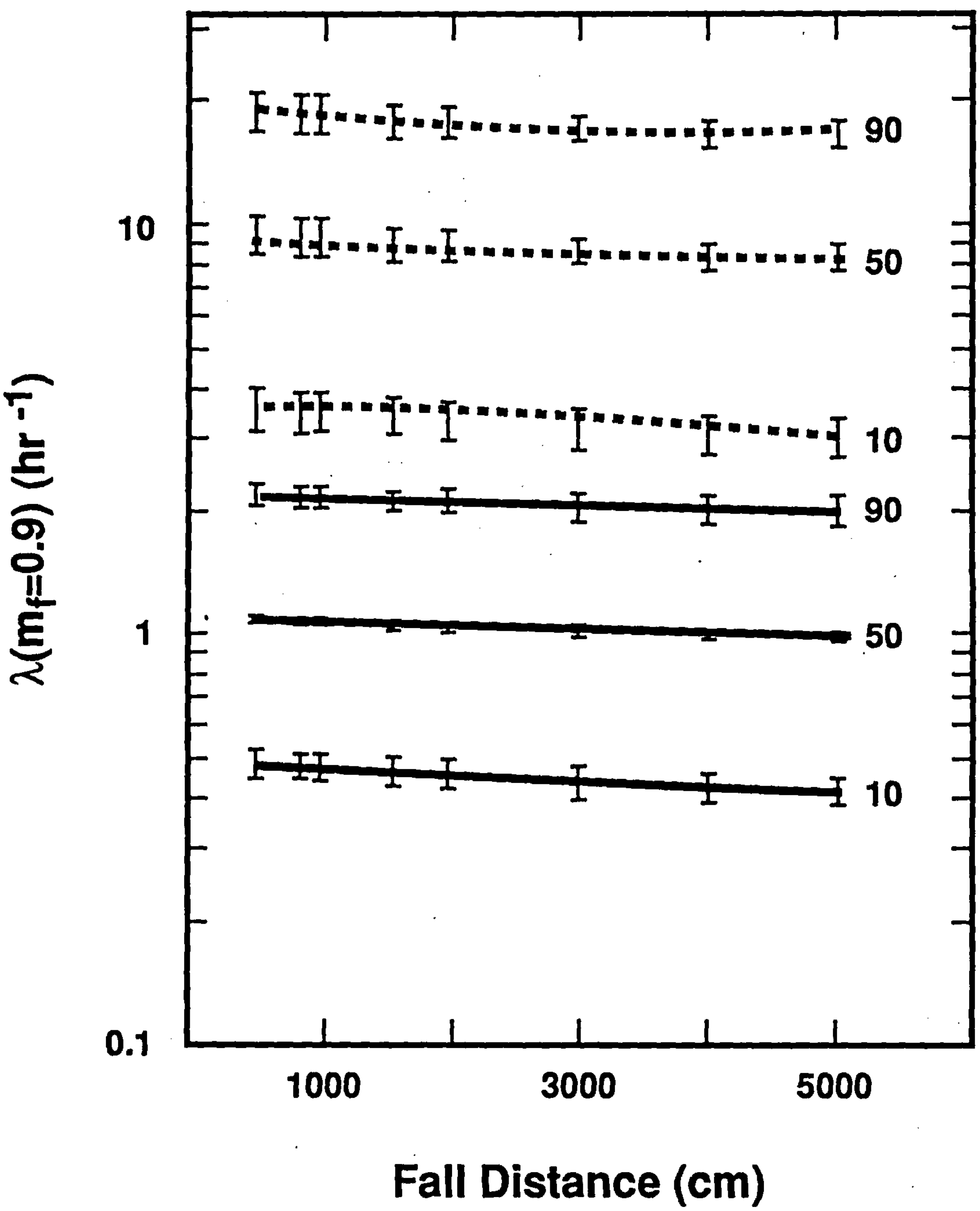

Figure 57 Comparison of $\lambda(m_f = 0.9)$ for aerosols subjected to scrubbing by a water pool (solid lines) to $\lambda(m_f = 0.9)$ for aerosol injected directly into the containment atmosphere (dashed lines). For both cases the water flux is 0.01 cm^3/cm^2-s. Symbols on curves for the 10 and 90 percentiles represent 90 percent confidence intervals. Symbols on the 50 percentile curve indicate 50 percent confidence intervals.

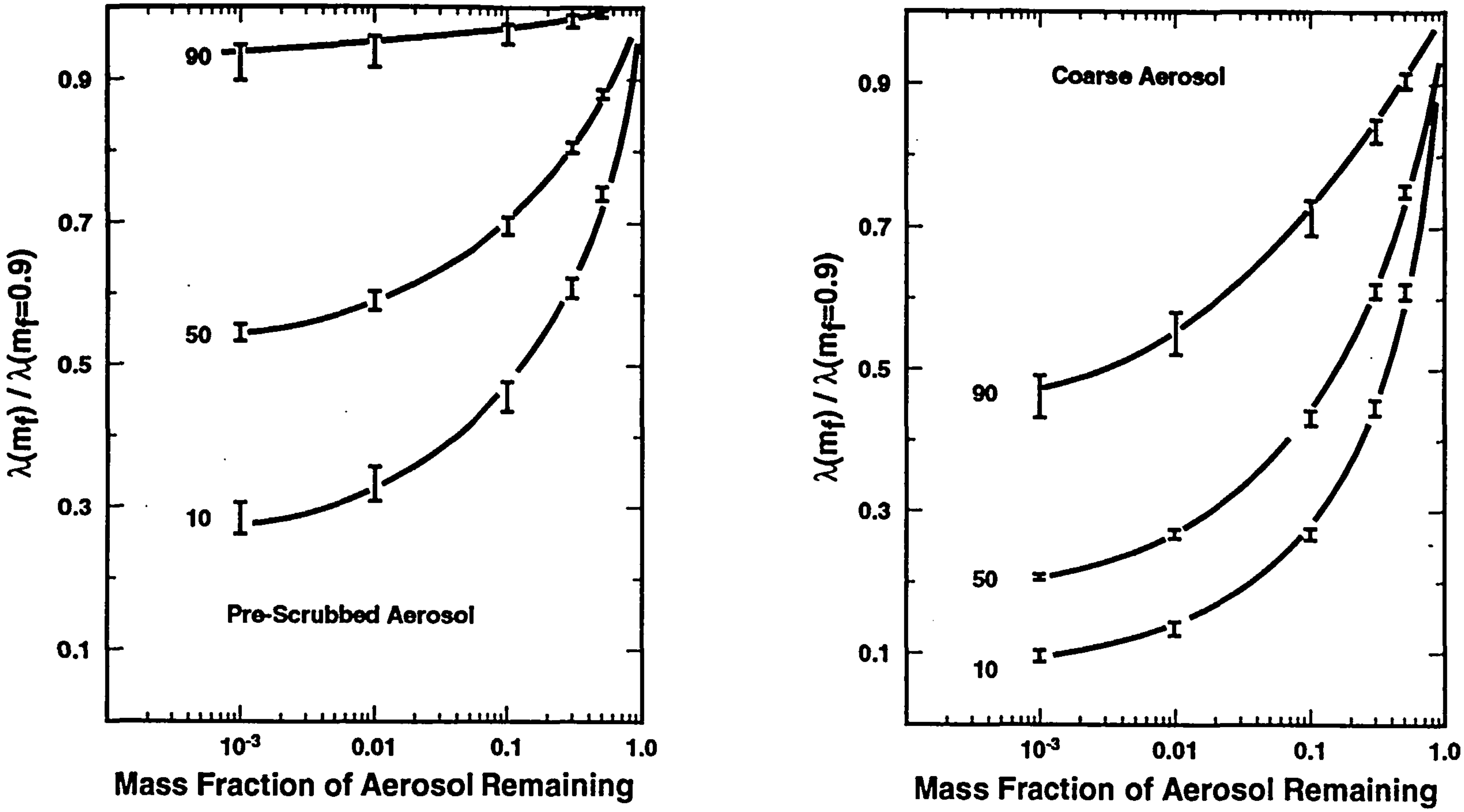

Figure 58 Comparison of $\lambda(m_f)/\lambda(m_f = 0.9)$ for aerosols subjected to scrubbing by a water pool (prescrubbed aerosol) to $\lambda(m_f)\lambda(m_f = 0.9)$ for aerosols injected directly into the containment atmosphere (coarse aerosol). For both cases the water flux is 0.01 cm^3/cm^2-s and the fall distance is 3000 cm. Curves are shown for 90, and 50, and 10 percentiles of the uncertainty distributions.

Results

The results of the calculations done here for the combined effects of a water pool and a containment spray show that decontamination factors associated with two mitigation systems cannot be simply multiplied to obtain an overall decontamination factor. Such a multiplication would overestimate the decontamination factor achieved by the combined attenuation systems. The overestimation comes about because aerosol removal is dependent on aerosol size.

A useful, approximate, method can be suggested to estimate the effectiveness of a spray operating on aerosols that had been previously exposed to the scrubbing actions of a water pool. If the water pool produces a decontamination factor DF, the spray effectiveness can be calculated using for the spray decontamination coefficient $\lambda(m_f = 1/DF)$ where $\lambda(m_f)$ is taken from the results of analyses for coarse aerosols presented above. The value of λ used in such combined analyses will decrease with increasing decontamination effectiveness. The value of λ will approach an asymptotic value corresponding to the minimum in the capture efficiency for the distribution of spray droplets.

V. Development of a Simplified Model

The results of the uncertainty analysis can be used to develop a simplified description of the decontamination coefficient for aerosol removal by sprays. The procedure to develop this model is to correlate results described in Chapter IV in terms of the known quantities, water flux, Q, and fall distance, H. Because the decontamination coefficient depends on the extent of decontamination, m_f must also be included in the correlation. The resulting description of $\lambda(Q, H, m_f)$ can be used in a simple differential equation to calculate decontamination:

$$\frac{dm_f}{dt} = -\lambda(Q, H, m_f)\, m_f$$

Based on the discussions in Chapter IV it is evident that separate correlations are needed for $\lambda(Q, H, m_f = 0.9)$ and $\lambda(m_f)/\lambda(m_f = 0.9)$. Further, it is useful to have correlations for different percentiles of the uncertainty distributions of $\lambda(Q, H, m_f)$.

Here, attentions are restricted to:

- the medians (50 percentile values) at 50 percent confidence

- the 90 percentile values at 90 percent confidence, and

- the 10 percentile values at 90 percent confidence.

Some readers might find it more useful to have a model cast in terms of the E/D ratios used in regulatory evaluations of spray performance (see Reference 63 and Chapter IV). The values of $\lambda(m_f = 0.9)$ have been converted to E/D ($m_f = 0.9$) values and the results are shown in Tables 29, 30 and 31 for spray fluxes of 0.01, 0.25, and 0.001 cm^3/cm^2-s, respectively. In comparing the values of E/D ($m_f = 0.9$) in these tables to the regulatory recommendation of 10 m^{-1}, bear in mind that the tabulated values do not account for unsprayed volume. The regulatory guidance probably accounts for some regions of the containment volume not being exposed to the spray. As discussed in Section D of Chapter IV, an unsprayed volume causes some reduction in the apparent value of λ or E/D.

The ratio of E/D (m_f) / E/D ($m_f = 0.9$) is identical to the ratio $\lambda(m_f)/\lambda(m_f = 0.9)$. These ratios are unaffected by the existence of an unsprayed volume and can be compared to the regulatory guidance of 0.1 for m_f less than 0.02.

The strategy for developing a simple representation for the many results obtained in the uncertainty study is to correlate values of $\lambda(m_f = 0.9)$ and E/D ($m_f = 0.9$) at specific percentiles in the uncertainty distribution in terms of the fall distance, H, and the water flux, Q. Then, the ratios $\lambda(m_f)/\lambda(m_f = 0.9)$ at specific percentiles in the distribution are correlated with m_f and Q. Results obtained in this correlation process are:

Table 29 Median values of E/D ($m_f = 0.9$) at 50 percent confidence level

Fall distance (cm)	E/D (meters^{-1}) at water fluxes of: 0.25 cm^3/cm^2-s	0.01 cm^3/cm^2-s	0.001 cm^3/cm^2-s
500	10.689 - 11.742	16.412 - 17.156	15.445 - 15.908
853	9.498 - 10.260	16.169 - 16.982	15.408 - 15.852
1000	8.988 - 10.084	16.130 - 16.971	15.389 - 15.834
1584	8.007 - 8.759	15.641 - 16.434	15.334 - 15.815
2000	7.172 - 8.166	15.391 - 16.213	15.297 - 15.815
3000	6.222 - 6.762	14.671 - 15.545	15.223 - 15.797
4000	5.471 - 6.249	14.256 - 15.089	15.148 - 15.630
5000	4.848 - 5.694	13.889 - 14.615	15.093 - 15.408

Table 30 10 percentile values of E/D ($m_f = 0.9$) at 90 percent confidence

	E/D ($meters^{-1}$) at water fluxes of:		
Fall Distance (cm)	0.25 cm^3/cm^2-s	0.01 cm^3/cm^2-s	0.001 cm^3/cm^2-s
500	4.040 - 4.586	5.811 - 7.389	6.574 - 7.852
853	3.418 - 3.915	5.720 - 7.158	6.537 - 7.852
1000	3.209 - 3.904	5.776 - 7.170	6.537 - 7.852
1584	2.605 - 3.235	5.544 - 6.854	6.519 - 7.852
2000	2.289 - 2.870	5.433 - 6.748	6.519 - 7.852
3000	1.868 - 2.247	5.152 - 6.458	6.463 - 7.852
4000	1.591 - 1.942	4.991 - 6.078	6.463 - 7.852
5000	1.402 - 1.727	4.850 - 6.102	6.500 - 7.834

Table 31 90 percentile values of E/D ($m_f = 0.9$) at 90 percent confidence

Fall distance (cm)	E/D (meters^{-1}) at water fluxes of: 0.25 cm^3/cm^2-s	0.01 cm^3/cm^2-s	0.001 cm^3/cm^2-s
500	23.580 - 27.176	31.180 - 38.399	33.112 - 43.779
853	21.946 - 25.842	32.275 - 37.858	33.112 - 43.631
1000	21.265 - 25.702	30.462 - 37.269	33.112 - 43.557
1584	20.181 - 24.918	29.845 - 36.242	33.056 - 43.316
2000	19.829 - 24.770	29.712 - 35.368	32.964 - 43.131
3000	18.726 - 23.234	28.938 - 33.406	32.742 - 42.668
4000	18.440 - 22.906	28.086 - 32.258	32.501 - 42.242
5000	18.276 - 22.660	27.941 - 32.036	32.353 - 41.797

- Median Values at 50 Percent Confidence

$$\ln \lambda(m_f = 0.9) = 6.83707 + (1.0074 \pm 0.0079) \ln Q$$
$$- (4.1731 \pm 0.5658) \times 10^{-3} Q^2H$$
$$- (1.2478 \pm 0.2311) Q$$
$$- (2.4045 \pm 0.5562) \times 10^{-5} H$$
$$+ (9.006 \pm 2.578) \times 10^{-8} QH^2$$

standard error = 0.0471

$$E/D(m_f = 0.9) = 21.4006 - (21.8270 \pm 2.2819) Q$$
$$- (9.6074 \pm 1.6614) \times 10^{-3} QH$$
$$+ (4.17724 \pm 1.14024) \times 10^{-6} Q^2H^2$$
$$+ (0.2542 \pm 0.00828) \ln Q$$
$$- (0.5466 \pm 0.1235 \ln H$$

standard error = 0.4387

- 90 Percentile Values at 90 Percent Confidence

$$\ln \lambda(m_f = 0.9) = 7.10927 - (8.0868 \pm 2.8048) \times 10^{-4} Q^2H$$
$$+ (0.92549 \pm 0.01060) \ln Q$$

standard error = 0.1185

$$E/D(m_f = 0.9) = 31.593 - (2.8237 \pm 0.2417) \ln Q$$
$$- (1.7102 \pm 0.7236) \ln H$$

standard error = 3.792

- 10 Percentile Values at 90 Percent Confidence

$$\ln \lambda(m_f = 0.9) = 5.5750 + (0.94362 \pm 0.01322) \ln Q$$
$$- (7.327 \pm 3.000) \times 10^{-7} QH^2$$
$$- (6.9821 \pm 1.0186) \times 10^{-3} Q^2H$$
$$+ (3.555 \pm 1.273) \times 10^{-6} Q^2H^2$$

standard error = 0.1066

Development

$$E/D(m_f = 0.9) = 4.36525 - (6.0860 \pm 1.5091) \times 10^{-3}\ QH$$
$$+ (2.7906) \pm 1.1523) \times 10^{-6}\ Q^2H^2$$
$$- (0.4080 \pm 0.0780) \ln Q$$

standard error = 0.6241

Values of the ratio $\lambda(m_f)/\lambda\ (m_f = 0.9)$ fit well the general expression:

$$\frac{\lambda(m_f)}{\lambda(m_f = 0.9)} = \left[a + b \log_{10} Q\right] \left[1 - \left(\frac{m_f}{0.9}\right)^c\right] + \left(\frac{m_f}{0.9}\right)^c$$

Where a, b, and c are parameters that depend on the percentile of the uncertainty distribution for the ratio $\lambda(m_f)/\lambda(m_f = 0.9)$ and the confidence level of interest. For the three cases of interest here:

- Median (50 percentile) at 50 Percent Confidence

$$\frac{\lambda(m_f)}{\lambda(m_f = 0.9)} = (0.1815 - 0.01153 \log_{10} Q) \left[1 - \left(\frac{m_f}{0.9}\right)^{0.5843}\right] + \left(\frac{m_f}{0.9}\right)^{0.5843}$$

- 10 Percentile at 30 Percent Confidence

$$\frac{\lambda(m_f)}{\lambda(m_f = 0.9)} = (0.1108 - 0.00201 \log_{10} Q) \left[1 - \left(\frac{m_f}{0.9}\right)^{0.8945}\right] + \left(\frac{m_f}{0.9}\right)^{0.8945}$$

- 90 Percentile at 90 Percent Confidence

$$\frac{\lambda(m_f)}{\lambda(m_f = 0.9)} = (0.3751 + 0.00648 \log_{10} Q) \left[1 - \left(\frac{m_f}{0.9}\right)^{0.2786}\right] + \left(\frac{m_f}{0.9}\right)^{0.2786}$$

For approximate work the weak dependence of $\lambda(m_f)/\lambda(m_f = 0.9)$ on Q may be neglected.

Predictions obtained with these correlation expressions are compared to results of the mechanistic analyses in Figures 59 to 67.

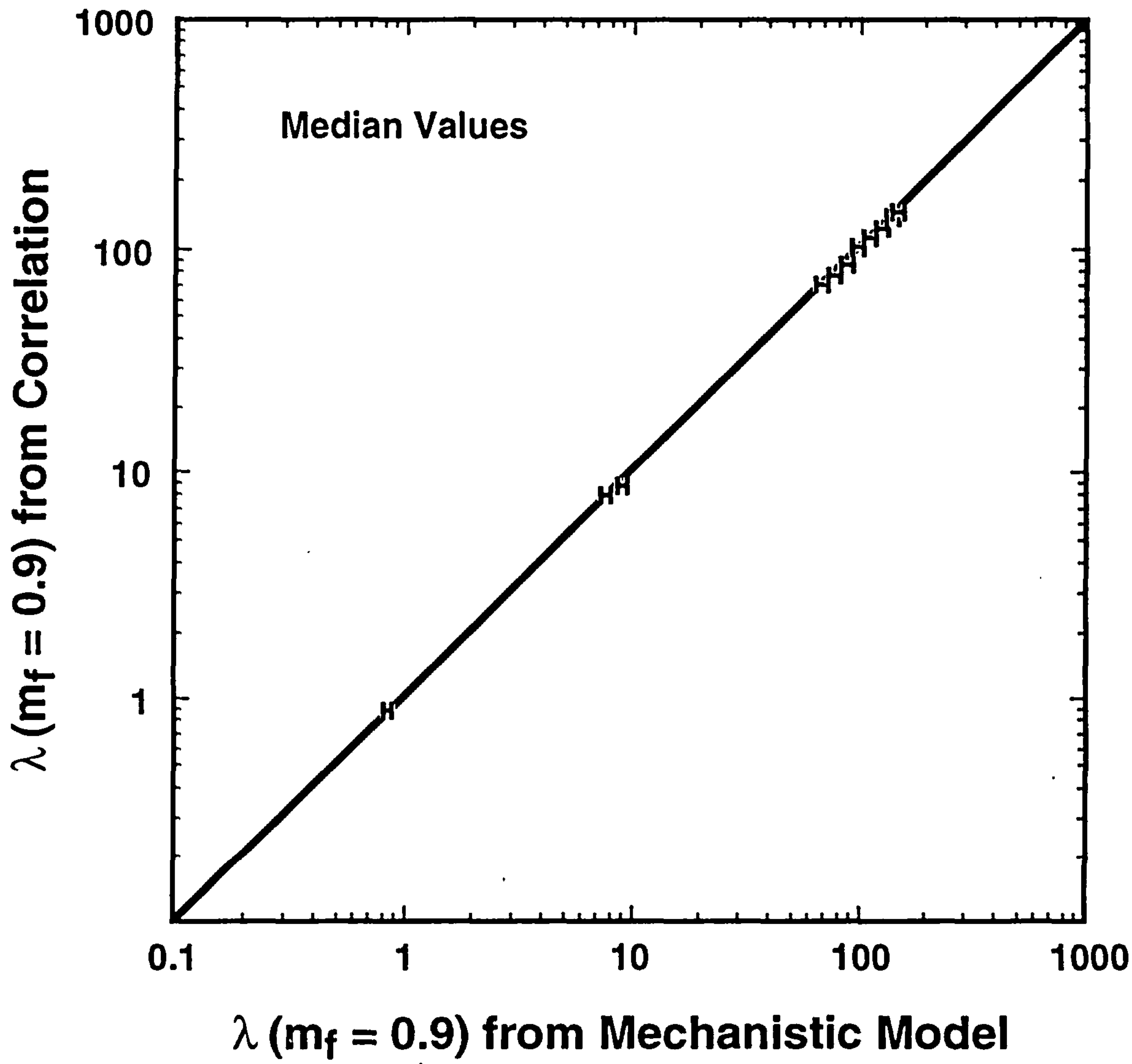

Figure 59 Comparison of median (50 percentile) values of $\lambda(m_f = 0.9)$ (in units of hr^{-1}) calculated with the correlation to values calculated with the mechanistic model. Bars indicate the 50 percent confidence intervals for medians in the distributions calculated with the mechanistic model.

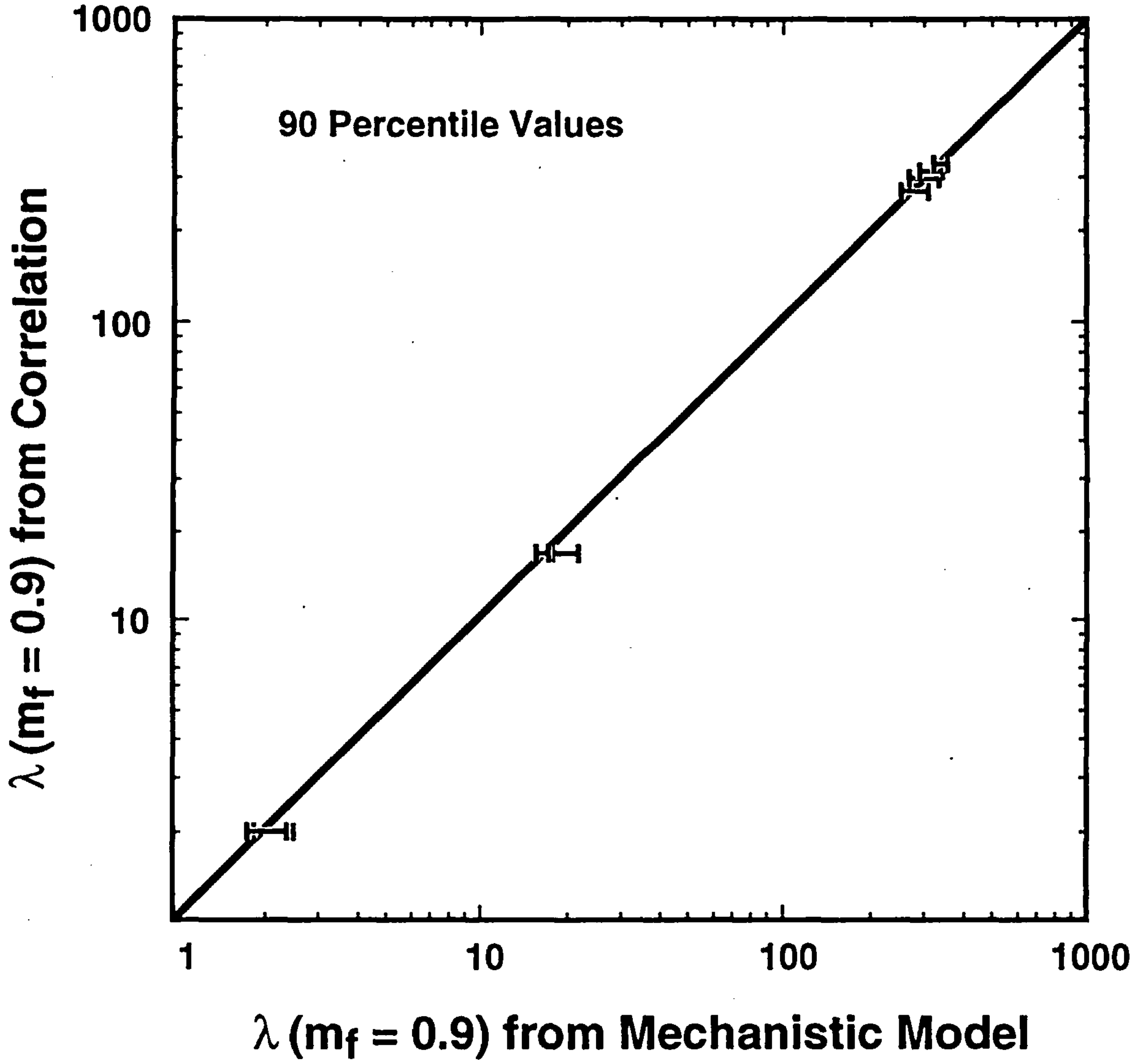

Figure 60 Comparison of 90 percentile values of $\lambda(m_f = 0.9)$ (in units of hr^{-1}) calculated with the correlation to values calculated with the mechanistic model. Bars indicate the 90 percent confidence intervals for the 90 percentile values in the distributions calculated with the mechanistic model.

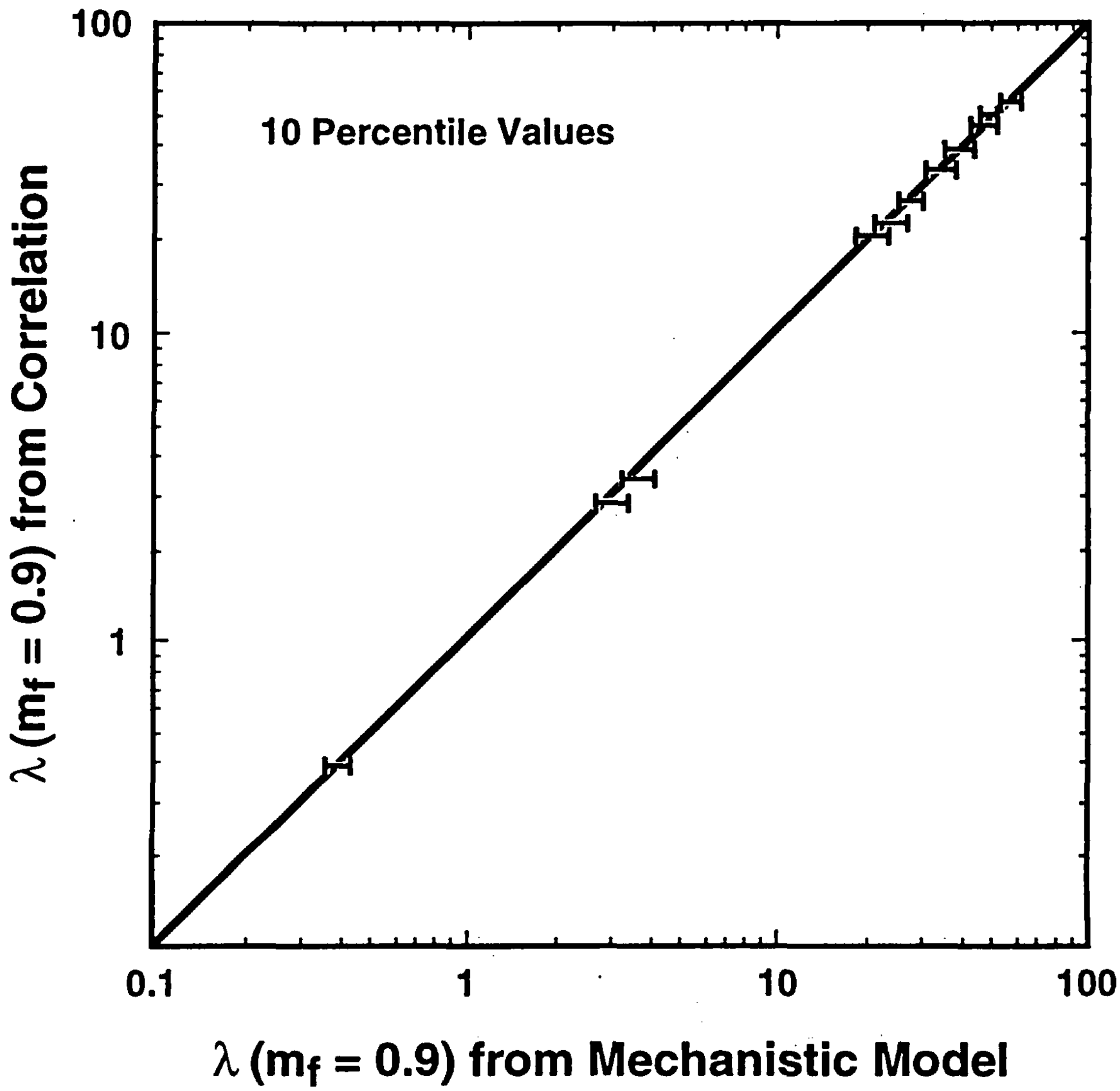

Figure 61 Comparison of 10 percentile values of $\lambda(m_f = 0.9)$ (in units of hr^{-1}) calculated with the correlation to values calculated with the mechanistic model. Bars indicate the 90 percent confidence intervals for the 10 percentile values in the distributions calculated with the mechanistic model.

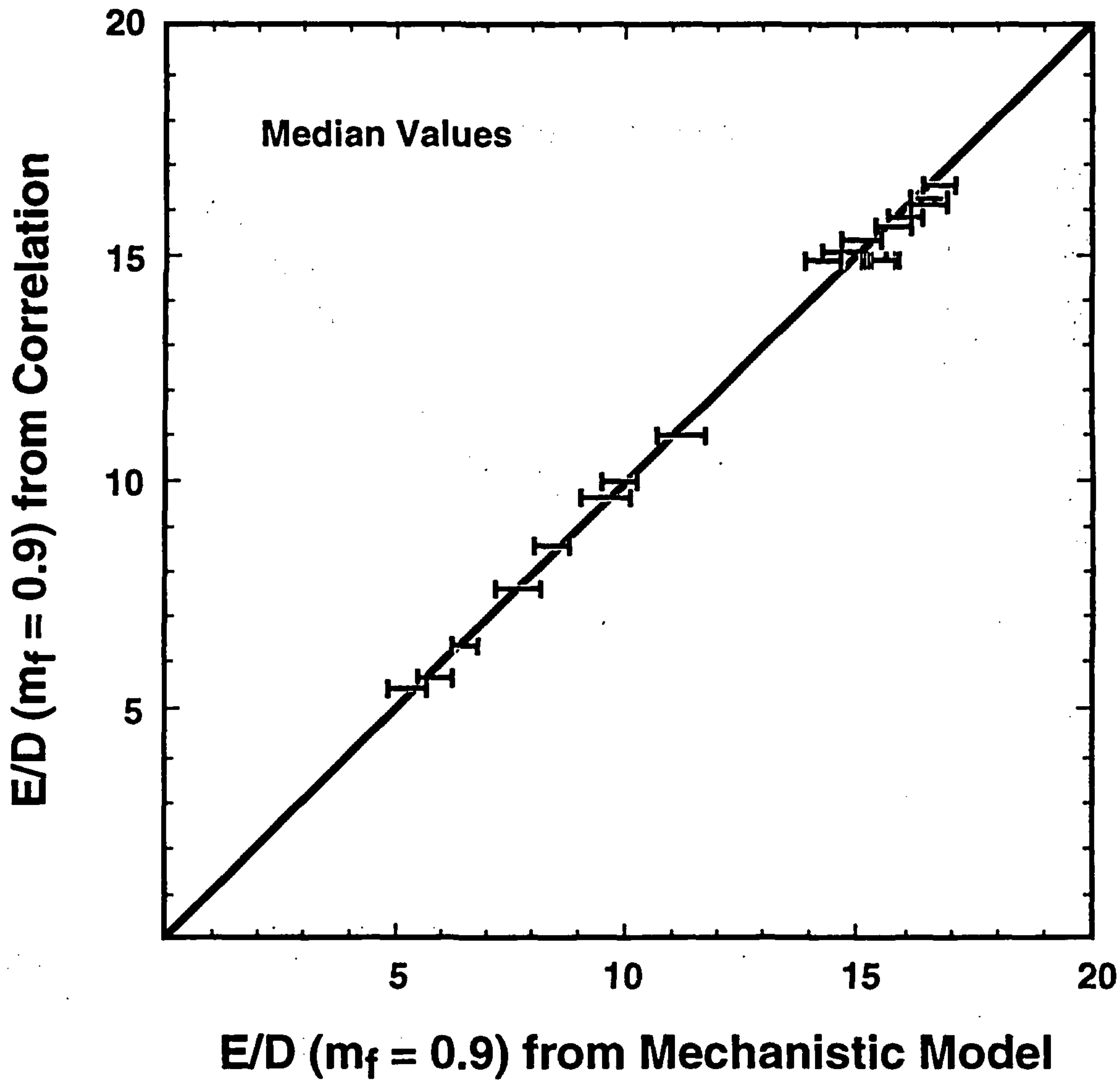

Figure 62 Comparison of median (50 percentile) values of E/D(m_f = 0.9) (in units of meters^{-1}) calculated with the correlation to values calculated with the mechanistic model. Bars indicate the 50 percent confidence intervals for median values in the distributions calculated with the mechanistic model.

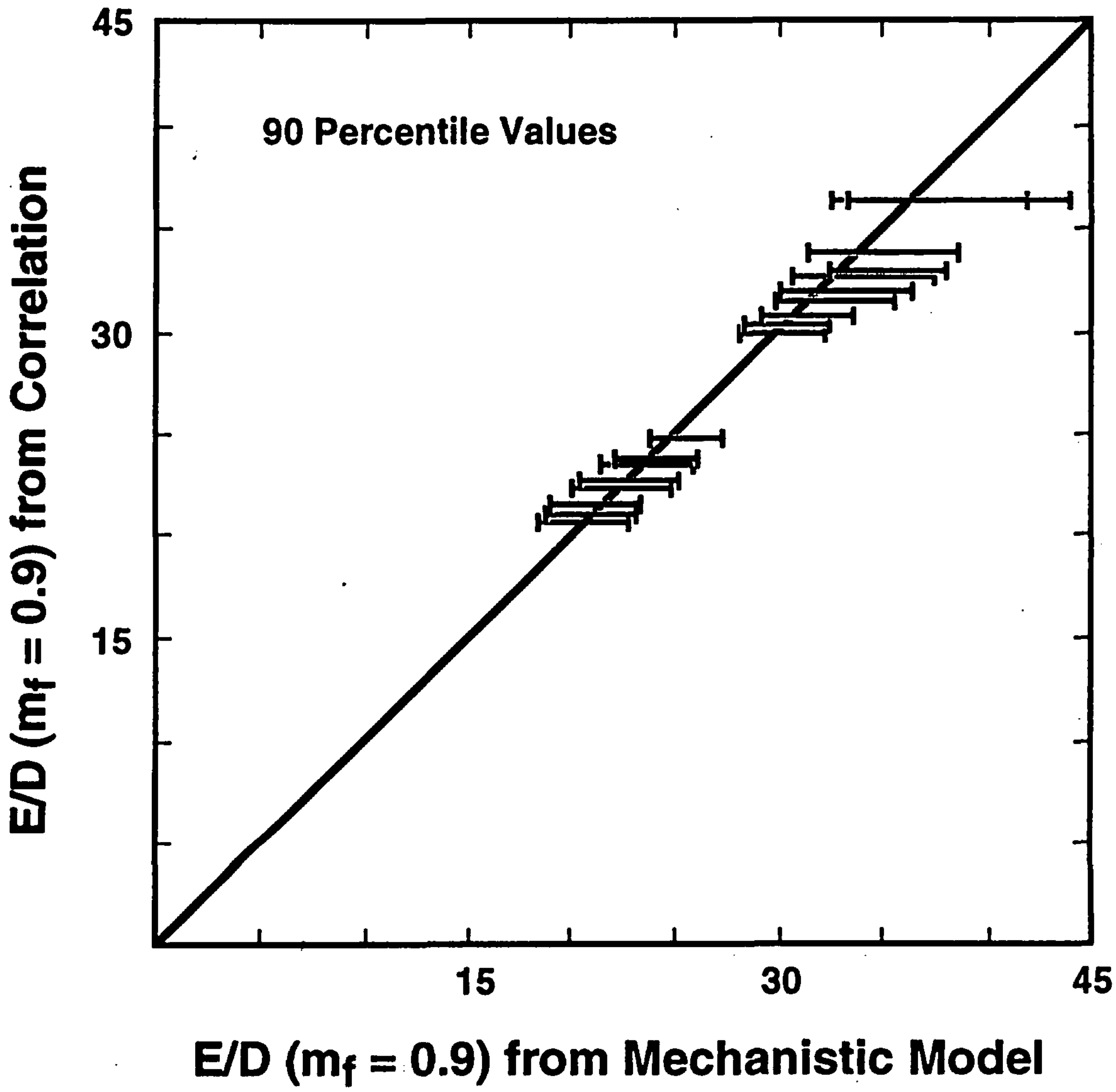

Figure 63 Comparison of 90 percentile values of E/D(m_f = 0.9) (in units of meters^{-1}) calculated with the correlation to values calculated with the mechanistic model. Bars indicate the 90 percent confidence intervals for the 90 percentile values in the distributions calculated with the mechanistic model.

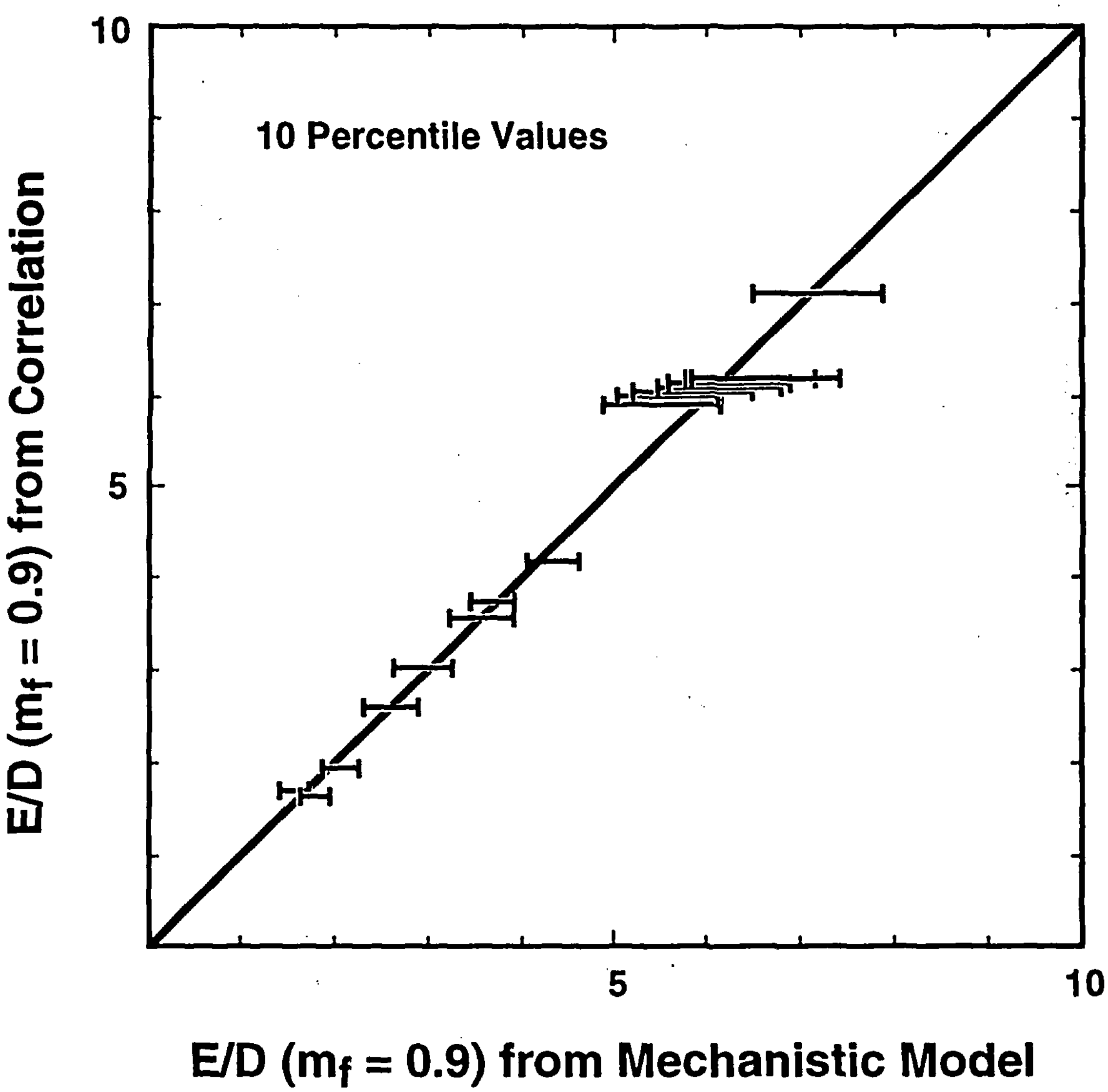

Figure 64 Comparison of the 10 percentile values of E/D(m_f = 0.9) (in units of $meters^{-1}$) calculated with the correlation to values calculated with the mechanistic model. Bars indicate the 90 percent confidence intervals for the 10 percentile values in the distributions calculated with the mechanistic model.

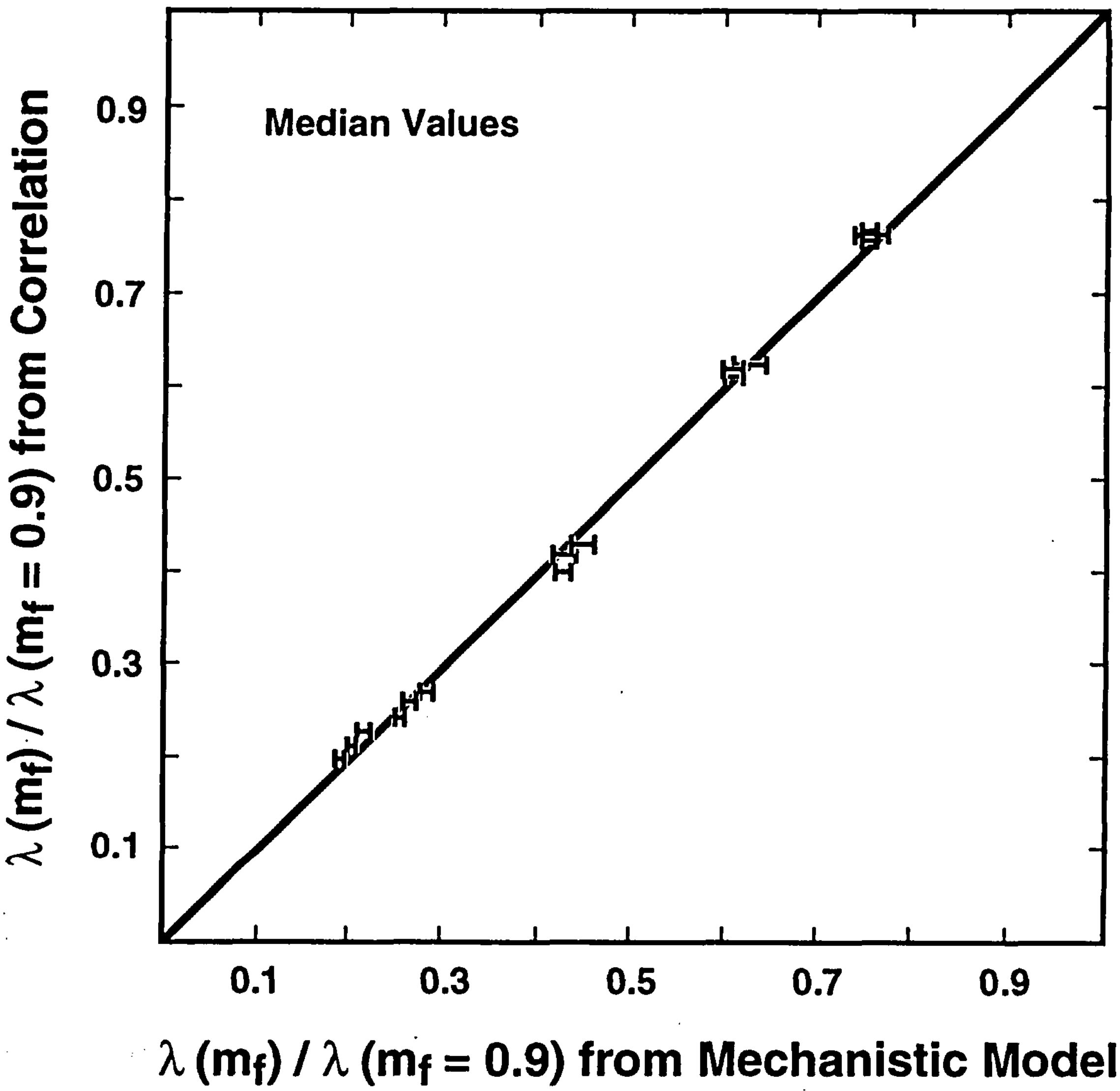

Figure 65 Comparison of the median (50 percentile) values of $\lambda(m_f)/\lambda(m_f = 0.9)$ calculated with the correlation to values calculated with the mechanistic model. Bars indicate the 50 percent confidence intervals for the median values in the distributions calculated with the mechanistic model.

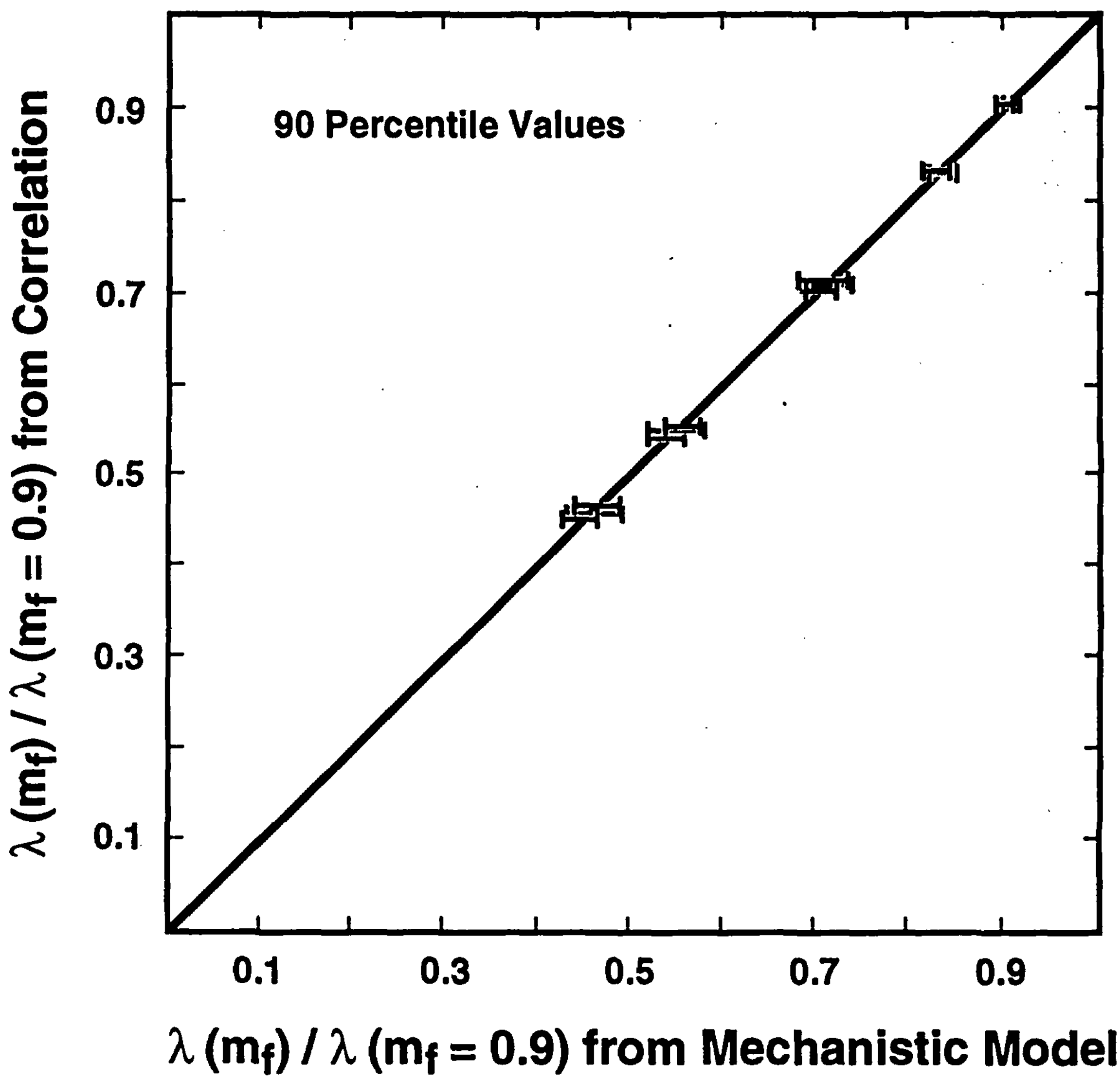

Figure 66 Comparison of the 90 percentile values of $\lambda(m_f)/\lambda(m_f = 0.9)$ calculated with the correlation to values calculated with the mechanistic model. Bars indicate the 90 percent confidence intervals for the 90 percentile values in the distributions calculated with the mechanistic model.

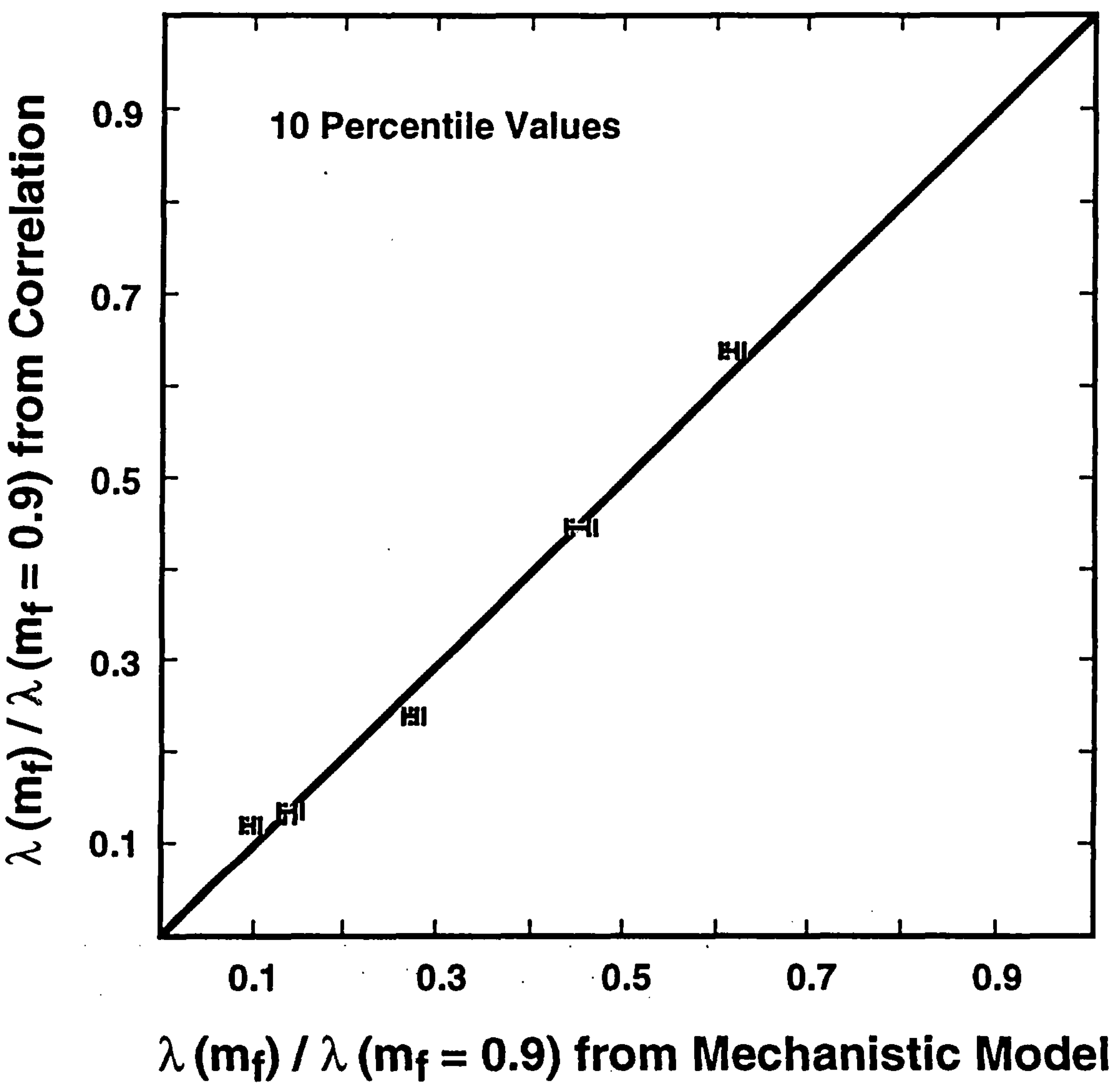

Figure 67 Comparison of the 10 percentile values of $\lambda(m_f)/\lambda(m_f = 0.9)$ calculated with the correlation to values calculated with the mechanistic model. Bars indicate the 90 percent confidence intervals for the 10 percentile values in the distributions calculated with the mechanistic model.

Development

The value of the decontamination coefficient for any set of conditions (values of Q, H, m_f) can be calculated from:

$$\lambda(Q,\ H,\ m_f) = \lambda(m_f = 0.9) \left[\frac{\lambda(m_f)}{\lambda(m_f = 0.9)} \right]$$

When unsprayed volumes are significant and there is rapid mixing of the sprayed and unsprayed volumes:

$$\lambda(Q,\ H,\ m_f,\ \alpha) = \lambda(Q,\ H,\ m_f)/(1 + \alpha)$$

where α is the ratio of unsprayed volume divided by the sprayed volume.

VI. Examples of the Use of the Simplified Model of Spray Removal of Aerosols

The simplified models of spray removal of aerosols derived in Chapter 5 provide a convenient way to calculate spray decontamination of a containment at known levels of conservatism. Two examples illustrating the use of the simplified models are presented below.

Example 1:

Consider a containment with spray headers located 3000 cm above the operating floor. Hypothesize that during a severe reactor accident this containment has an atmospheric loading of aerosols of 10 g/m^3 at the end of significant radionuclide release. Assume the sprays provide a water flux of 0.10 $cm^3 H_2O/cm^2$-s. The spray droplets pass through half the containment volume. What is the best estimate of the time required of spray operation to reduce the aerosol concentration to 0.1 g/m^3? What are reasonable upper and lower bounds on this time?

Analysis:

The example asks for a best estimate of the time required to achieve a DF of 100 with sprays for a situation in which there is no continuing release of material into the containment atmosphere. Assume that settling of the aerosols is negligible on the time scales of interest. Assume, further, that the median value of spray performance is, by definition, the best estimate. The differential equation for this problem is:

$$\frac{dM}{dt} = \frac{-\lambda M}{(1 + \alpha)}$$

where M is the mass of aerosol in the containment. The parameter α is just the ratio of the containment volume that is not contacted by spray droplets to the volume that is contacted by spray droplets:

$$\alpha = \frac{V(\text{unsprayed})}{V(\text{sprayed})}$$

In this case $\alpha = 1$.

Divide through the differential equation by the total mass of aerosol initially suspended in the containment atmosphere:

$$\frac{d\left[\frac{M(t)}{M(o)}\right]}{dt} = \frac{dm_f(t)}{dt} = \frac{-\lambda}{(1 + \alpha)}\frac{M(t)}{M(o)} = \frac{-\lambda}{(1 + \alpha)} m_f(t)$$

where

$m_f(t)$ = mass fraction of the initially-presented aerosol that remains suspended in the containment atmosphere

$M(t)$ = total mass of aerosol suspended in the containment atmosphere at time t

$M(o)$ = total mass of aerosol suspended in the containment atmosphere at time zero

Note that $m_f(t)$ is related to the decontamination factor, DF, by:

$$1/m_f(t) = DF$$

From the discussions in Chapter V, the decontamination coefficient, λ, is given by:

$$\lambda = \lambda(m_f = 0.9)\left[\frac{\lambda(m_f)}{\lambda(m_f = 0.9)}\right]$$

where median values of these quantities are:

$$\ln\left[\lambda(m_f = 0.9)\right] = 6.83707 + 1.0074 \ln Q - 4.1731 \times 10^{-3} Q^2H - 1.2478 Q - 2.4045 \times 10^{-5} H + 9.006 \times 10^{-8} QH^2$$

$$\frac{\lambda(m_f)}{\lambda(m_f = 0.9)} = (0.1815 - 0.01153 \log_{10}Q)\left[1 - \left[\frac{m_f}{0.9}\right]^{0.5843}\right] + \left[\frac{m_f}{0.9}\right]^{0.5843}$$

For the conditions specified here (H = 3000 cm and Q = 0.10):

$$\ln\left[\lambda(m_f = 0.9)\right] = 4.2764$$

or

$$\lambda(m_f = 0.9) = 71.980 \text{ hr}^{-1}$$

and

$$\frac{\lambda(m_f)}{\lambda(m_f = 0.9)} = 0.193 \left[1 - \left(\frac{m_f}{0.9} \right)^{0.5843} \right] + \left(\frac{m_f}{0.9} \right)^{0.5843}$$

$$= 0.193 + 0.8582 \; m_f^{0.5843}$$

The differential equation is then:

$$\frac{dm_f(t)}{dt} = - \frac{71.98}{2} \left[0.193 + 0.8582 \; m_f(t)^{0.5843} \right] m_f(t)$$

$$= - 6.946 \; m_f(t) - 30.887 \; m_f(t)^{1.5843}$$

This equation is easily solved numerically to give the time to achieve DF = $1/m_f$ (t) = 100 to be 0.31 hours. Times required to reach other levels of decontamination are shown in Table 32.

Assume that a reasonable upper bound for the time required to achieve DF = 100 is the 90 percentile value. A reasonable lower bound for the time is similarly assumed to be the 10 percentile value. Because of the reciprocal relationship between time and the spray decontamination coefficient, the 90 percentile and 10 percentile times to achieve a specified decontamination are found using the 10 percentile and 90 percentile values of the spray decontamination coefficient, respectively. Then, the appropriate differential equation for determining the reasonable upper bound time is:

$$\frac{dm_f(t)}{dt} = - \frac{\lambda(10 \text{ Percentile})}{(1 + \alpha)} \; m_f(t)$$

where λ(10 percentile) is found from:

$$\lambda = \lambda(m_f = 0.9) \left[\frac{\lambda(m_f)}{\lambda(m_f = 0.9)} \right]$$

$$\ln\left[\lambda(m_f = 0.9)\right] = 5.5750 + 0.94362 \ln Q - 7.327 \times 10^{-7} QH^2$$

$$- 6.9821 \times 10^{-3} \; Q^2H + 3.555 \times 10^{-6} \; Q^2H^2$$

Development

$$\frac{\lambda\,(m_f)}{\lambda(m_f\,=\,0.9)} = (0.1108\;-\;0.00201\;\log_{10}Q)\left[1\;-\;\left[\frac{m_f(t)}{0.9}\right]^{0.8945}\right] + \left[\frac{m_f(t)}{0.9}\right]^{0.8945}$$

For the conditions of the example:

$$\lambda(m_f\,=\,0.9)\;=\;17.345\;\mathrm{hr}^{-1}$$

$$\frac{\lambda(m_f)}{\lambda(m_f\,=\,0.9)} = 0.1128\;+\;0.9749\;m_f(t)^{0.8945}$$

Then, the differential equation for the reasonable upper bound (90 percentile) time is:

$$\frac{dm_f(t)}{dt} = -\,\frac{1.9565}{2}\,m_f(t)\;-\;\frac{16.9091}{2}\,m_f(t)^{1.8945}$$

Similarly, the reasonable lower bound (10 percentile) time is given using the 90 percentile values of the decontamination coefficient, and the appropriate equations are:

$$\ln\left[\lambda(m_f\,=\,0.9)\right] = 7.10927\;-\;8.0868\;\mathrm{x}\;10^{-4}\;Q^2H\;+\;0.92549\;\ln\,Q$$

$$\lambda(m_f\,=\,0.9)\;=\;141.7\;\mathrm{hr}^{-1}$$

$$\frac{\lambda(m_f)}{\lambda(m_f\,=\,0.9)} = (0.3751\;+\;0.00648\;\log_{10}Q)\left[1\;-\;\frac{m_f(t)^{0.2786}}{0.9}\right] + \left[\frac{m_f(t)}{0.9}\right]^{0.2786}$$

$$= 0.3686\;+\;0.6502\;m_f(t)^{0.2786}$$

$$\frac{dm_f(t)}{dt} = -\,\frac{52.231}{2}\,m_f(t)\;-\;\frac{92.132}{2}\,m_f(t)^{0.2786}$$

Results obtained with these equations are also summarized in Table 32.

Table 32 Results for example 1

DF	Time (hours) to reach DF		
	Median	90 Percentile	10 Percentile
10	0.10	0.61	0.05
100	0.31	2.27	0.14
1000	0.60	4.49	0.22
10000	0.91	6.83	0.31

Example 2:

For the second example, the containment is considered to have a total volume of 50,000 m^3. At time zero the containment is taken to contain no aerosol of safety significance. Also, at time zero an aerosol source of 1000 g/s is hypothesized to arise and to operate for one hour. If agglomeration, settling and deposition of the aerosols are neglected, this source will produce an aerosol concentration of 72 grams/m^3. What effect will sprays at an elevation of 3000 cm and a water flow rate of 0.1 cm^3/cm^2-s have on the aerosol concentration in containment? Again, sprays are considered to contact only half the containment volume.

Analysis

The appropriate differential equation for this example is:

$$\frac{dM(t)}{dt} = -\frac{\lambda M(t)}{(1+\alpha)} + \frac{1}{V}\frac{dS}{dt}$$

where

$M(t)$ = aerosol concentration in g/m^3

$\frac{dS}{dt}$ = aerosol source rate into the containment (g/hr)

V = containment volume (m^3)

This differential equation has a steady-state asymptote. At the steady-state the mass concentration of aerosol suspended in the containment is given by:

$$M(\infty) = \frac{dS/dt\ (1 + \alpha)}{\lambda\ V}$$

The only difficulty that arises is the selection of the value of λ. The correlations developed in Chapter V did not consider a continuing source. The correlations have λ dependent on the mass fraction of aerosol remaining in the containment atmosphere. But, this concept on mass fraction remaining becomes difficult to define in the face of a continuing source.

It can be recalled that the reason λ is dependent on the mass fraction of aerosol remaining in the atmosphere is that sprays not only trap aerosol particles, they also change the size distribution of the aerosols remaining in the atmosphere in such a way that what aerosols are left become progressively harder for sprays to remove. In the case of a continuing source, the size distribution is being renewed by the additional particulate being injected into the atmosphere. An approximate value for λ to use for a continuing source is then $\lambda(m_f = 0.9)$. The reason that $\lambda(m_f = 0.9)$ is such a surprisingly good approximate value is because, with a continuing source, most of the material suspended in the atmosphere at any one time is fresh material provided by the source. More accurate values of λ would have to consider the magnitude of the source and the magnitude of the water flux.

Using $\lambda(m_f = 0.9)$, the calculated steady-state mass concentrations in the containment atmosphere while the source is operating are:

- Median value:
  $M(t) = 2.0\ g/m^3$

- 90 percentile value:
  $M(t) = 8.3\ g/cm^3$

- 10 percentile value:
  $M(t) = 1.0\ g/m^3$

The median value corresponds to a decontamination factor of 36 when compared to the concentration of aerosol the source would produce in the absence of any aerosol deposition mechanisms. The 10 percentile and 90 percentile values of the decontamination factor similarly defined are 8.7 and 72, respectively.

The differential equation shown above can be solved numerically to show the fully dynamic behavior of aerosol concentration in the containment with both a source and the sprays operating. Results of such calculations are shown in Figure 68. In preparing this figure, correlations for λ that included the dependence on the mass fraction of aerosol remaining suspended in the atmosphere were used once the source stopped at one hour. Once the source is no longer providing fresh material to the containment atmosphere, the spray system rapidly decontaminates the atmosphere.

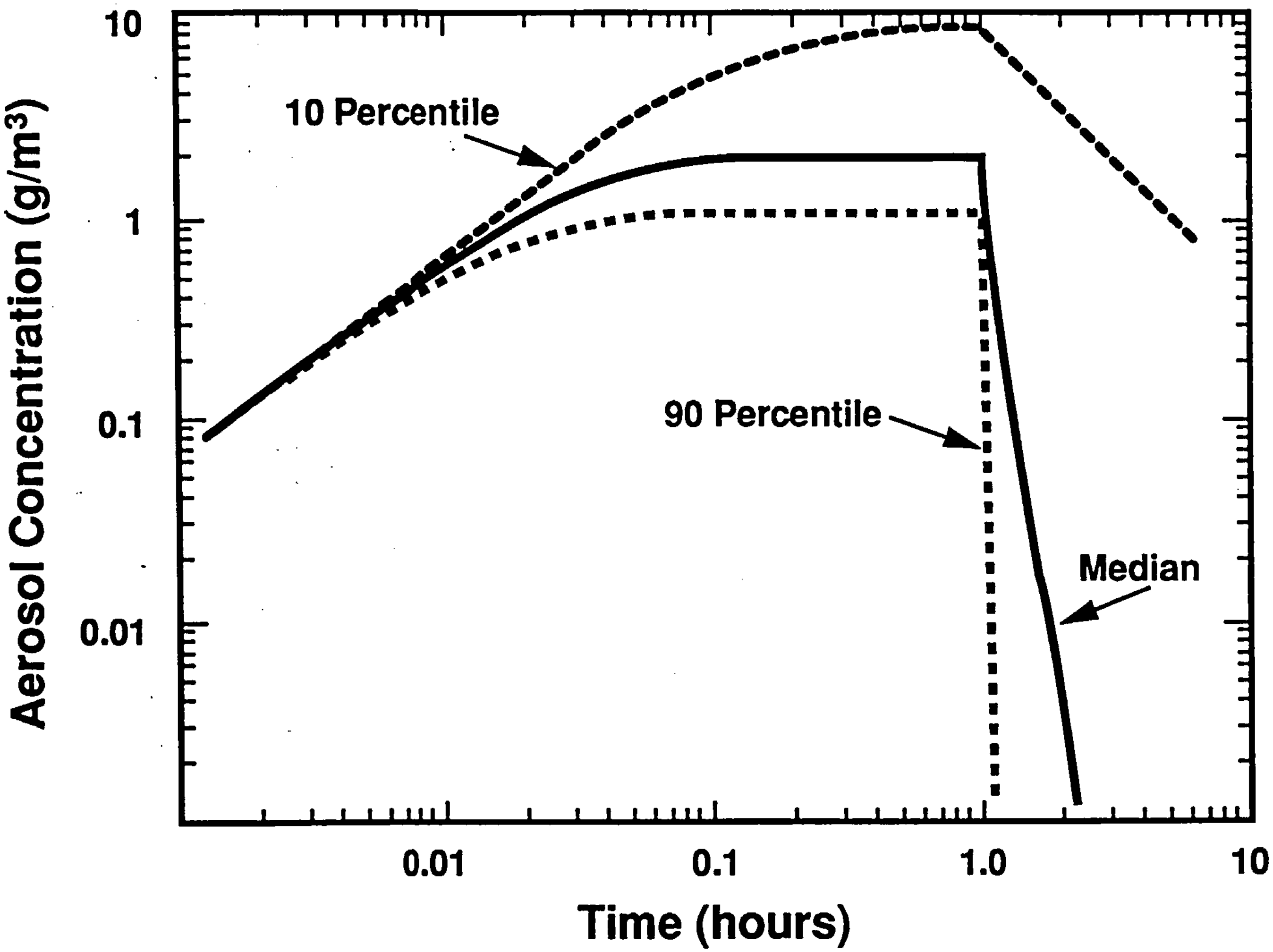

Figure 68 Dynamic analysis of aerosol concentration in the containment for example 2

VII. Conclusions

A description of the phenomena that affect the removal of aerosols by containment sprays has been presented. A mechanistic model of the aerosol removal process has been developed. An important feature of this model is that it recognizes both the distribution in size of spray droplets and the evolution of the droplet size distribution as the droplets fall through the atmosphere. The model has been used to conduct a quantitative uncertainty analysis for the spray decontamination coefficient, λ, used in the simple differential equation for prediction of aerosol mass removal from the containment atmosphere:

$$\frac{dm_f}{dt} = -\lambda m_f$$

where m_f is the mass fraction remaining in the containment atmosphere.

The decontamination coefficient has been shown to be a function of the water flux into the containment, the fall distance of droplets and the fraction of aerosol removed.

Uncertainty distributions for λ have been found for

- water flux = Q = 0.001, 0.01, and 0.25 cm^3/cm^2-s,
- fall distance = H = 500, 853, 1000, 1584, 2000, 3000, 4000, and 5000 cm, and
- mass fraction of aerosol remaining in the containment atmosphere = m_f = 0.9, 0.5, 0.3, 0.1, 0.01, and 0.001.

It has been shown that the decontamination coefficient λ, decreases with increasing decontamination. At a confidence level of 50 percent, the median value of the ratio $\lambda(m_f = 0.01)/\lambda(m_f = 0.9)$ is between 0.252 and 0.292 for the range of water fluxes considered here. The 90th percentile value of this ratio (at 90 percent confidence) is between 0.520 and 0.580. The 10th percentile value (again at 90 percent confidence) is between 0.128 and 0.146.

Simplified models of the spray process have been developed by correlating $\lambda(m_f = 0.9)$ and $\lambda(m_f)/\lambda(m_f = 0.9)$ with water flux, Q, fall distance, H, and the mass fraction of aerosol remaining in the containment, m_f. Median values of these quantities are given by:

$$\ln \lambda(m_f = 0.9) = 6.83707 + 1.0074 \ln Q - 4.1731 \times 10^{-3} Q^2H - 1.2478\,Q - 2.4045 \times 10^{-5} H + 9.006 \times 10^{-8} QH^2$$

$$\lambda(m_f)/\lambda(m_f = 0.9) = (0.1815 - 0.01153 \log_{10} Q)\left[1 - \left(\frac{m_f}{0.9}\right)^{0.5843}\right] + \left(\frac{m_f}{0.9}\right)^{0.5843}$$

The 90 percentile values are given by:

$$\ln \lambda(m_f = 0.9) = 7.10927 - 8.0868 \times 10^{-4} Q^2H + 0.92549 \ln Q$$

$$\lambda(m_f)/\lambda(m_f = 0.9) = (0.3751 + 0.00648 \log_{10} Q)\left[1 - \left(\frac{m_f}{0.9}\right)^{0.2786}\right] + \left(\frac{m_f}{0.9}\right)^{0.2786}$$

The 10 percentile values are given by:

$$\ln \lambda(m_f = 0.9) = 5.5750 + 0.94362 \ln Q - 7.327 \times 10^{-7} Q H^2 - 6.9821 \times 10^{-3} Q^2H + 3.555 \times 10^{-6} Q^2H^2$$

$$\lambda(m_f)/\lambda(m_f = 0.9) = (0.1108 - 0.00201 \log_{10} Q)\left[1 - \left(\frac{m_f}{0.9}\right)^{0.8945}\right] + \left(\frac{m_f}{0.9}\right)^{0.8945}$$

These simple expressions have been shown to effectively represent the predictions of the more detailed mechanistic analyses of spray removal of aerosol from a reactor containment atmosphere. Information necessary to prepare similar simple representations of the detailed analyses for different percentiles of the uncertainty distributions or different confidence levels is provided in this document.

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Appendix A

Uncertainty Distributions for $\lambda(Q, H, m_f)$

Uncertainty distributions for the decontamination coefficient $\lambda(Q, H, m_f)$ at confidence levels of 50, 90, and 95 percent are collected in this appendix. Distributions are presented for

Q = 0.001, 0.01, and 0.25 cm^3/cm^2-s

H = 500, 853, 1000, 1584, 2000, 3000, 4000 and 5000 cm

m_f = 0.9, 0.5, 0.3, 0.1, 0.01, and 0.001

where

Q = volummetric water flux into the containment

H = fall distance for water droplets

m_f = mass fraction of aerosol remaining in the containment.

Distribution are presented as ranges of values of $\lambda(Q, H, m_f)$ that define the percentiles of a cumulative probability distribution. Ranges for percentiles of 5 to 95 percent at 5 percent intervals are tabulated. Means and standard deviations for the distributions are also shown in the tables in this appendix. In the case of a water flux of 0.001 cm^3/cm^2-s, uncertainty distributions are tabulated only for fall distances of 500 and 5000 cm. Results for this low water flux are very insensitive to fall distance. Linear interpolation of the tabulated results yields distributions for other fall distances that are in quite good agreement with the actual calculated distributions.

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of 95%	90%	50%	
MEAN = 10.726	5	2.298 - 3.122	2.324 - 3.095	2.607 - 2.926	WATER FLUX =
	10	3.120 - 4.010	3.138 - 3.990	3.314 - 3.730	= 0.01 $cm^3/s\text{-}cm^2$
	15	3.795 - 4.874	3.950 - 4.770	4.105 - 4.411	
	20	4.410 - 5.615	4.487 - 5.553	4.875 - 5.322	
	25	5.235 - 6.510	5.361 - 6.421	5.577 - 5.928	
STD. DEV. =	30	5.819 - 6.958	5.897 - 6.890	6.409 - 6.736	FALL DISTANCE =
= 8.358	35	6.599 - 7.716	6.668 - 7.570	6.877 - 7.233	= 500 cm
	40	7.145 - 8.556	7.182 - 8.270	7.440 - 7.906	
	45	7.780 - 9.056	7.852 - 9.019	8.008 - 8.758	
	50	8.582 - 9.731	8.697 - 9.651	8.862 - 9.264	
SAMPLE SIZE =	55	9.114 - 10.594	9.182 - 10.493	9.495 - 10.055	AEROSOL MASS
= 400	60	9.835 - 11.097	9.883 - 11.054	10.404 - 10.766	FRACTION REMAINING =
	65	10.628 - 12.252	10.722 - 11.967	10.908 - 11.616	= 0.9
	70	11.327 - 12.991	11.565 - 12.933	11.926 - 12.626	
	75	12.467 - 14.554	12.550 - 14.264	12.913 - 13.279	
	80	13.121 - 15.970	13.463 - 15.517	14.358 - 14.988	
	85	15.022 - 17.511	15.278 - 17.296	15.949 - 16.625	
	90	16.744 - 20.863	16.837 - 20.735	17.670 - 18.212	
	95	20.851 - 27.940	21.063 - 27.010	22.113 - 25.449	

	Quantile (%)	Range for λ(hr^{-1}) at a confidence level of 95%	90%	50%	
MEAN = 7.828	5	1.934 - 2.458	2.019 - 2.439	2.145 - 2.279	WATER FLUX =
	10	2.451 - 3.122	2.514 - 3.068	2.672 - 2.942	= 0.01 cm^3/s-cm^2
	15	2.992 - 3.629	3.018 - 3.590	3.202 - 3.444	
	20	3.439 - 4.344	3.493 - 4.122	3.633 - 3.874	
	25	3.813 - 4.689	3.886 - 4.655	4.208 - 4.570	
STD. DEV. =	30	4.494 - 5.198	4.539 - 5.105	4.652 - 4.844	FALL DISTANCE =
= 5.692	35	4.759 - 5.796	4.807 - 5.623	5.003 - 5.349	= 500 cm
	40	5.242 - 6.252	5.305 - 6.195	5.514 - 5.958	
	45	5.828 - 6.704	5.889 - 6.674	6.140 - 6.351	
	50	6.259 - 7.448	6.302 - 7.280	6.464 - 7.064	
SAMPLE SIZE =	55	6.732 - 7.959	6.898 - 7.934	7.146 - 7.648	AEROSOL MASS
= 400	60	7.497 - 8.447	7.556 - 8.357	7.800 - 8.162	FRACTION REMAINING =
	65	7.985 - 8.889	8.078 - 8.732	8.323 - 8.549	= 0.5
	70	8.471 - 9.485	8.496 - 9.298	8.708 - 9.072	
	75	8.959 - 10.386	9.057 - 10.266	9.243 - 9.825	
	80	9.777 - 11.026	9.897 - 10.933	10.281 - 10.793	
	85	10.800 - 12.481	10.850 - 12.404	11.016 - 11.737	
	90	12.014 - 14.492	12.294 - 14.242	12.730 - 13.590	
	95	14.492 - 20.617	14.636 - 20.472	15.365 - 17.934	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of 95%	90%	50%	
MEAN = 6.387	5	1.682 - 2.124	1.714 - 2.112	1.770 - 1.979	WATER FLUX =
	10	2.123 - 2.626	2.128 - 2.584	2.216 - 2.503	= 0.01 $cm^3/s\text{-}cm^2$
	15	2.546 - 2.968	2.576 - 2.917	2.663 - 2.779	
	20	2.778 - 3.416	2.806 - 3.379	2.979 - 3.226	
	25	3.207 - 3.780	3.237 - 3.713	3.396 - 3.619	
STD. DEV. =	30	3.547 - 4.180	3.596 - 4.101	3.713 - 3.884	FALL DISTANCE =
= 4.550	35	3.824 - 4.510	3.876 - 4.493	4.079 - 4.335	= 500 cm
	40	4.276 - 5.122	4.310 - 5.060	4.463 - 4.742	
	45	4.590 - 5.517	4.616 - 5.444	4.960 - 5.369	
	50	5.184 - 5.973	5.252 - 5.936	5.412 - 5.799	
SAMPLE SIZE =	55	5.591 - 6.372	5.690 - 6.339	5.880 - 6.099	AEROSOL MASS
= 400	60	5.983 - 6.851	6.075 - 6.654	6.197 - 6.513	FRACTION REMAINING =
	65	6.420 - 7.234	6.476 - 7.165	6.580 - 6.992	= 0.3
	70	6.885 - 7.756	6.951 - 7.621	7.100 - 7.403	
	75	7.332 - 8.442	7.386 - 8.255	7.572 - 7.980	
	80	7.888 - 9.141	8.016 - 9.124	8.266 - 8.946	
	85	8.959 - 10.046	9.042 - 9.969	9.141 - 9.655	
	90	9.785 - 11.990	9.907 - 11.745	10.267 - 11.007	
	95	11.979 - 18.196	12.567 - 17.734	13.082 - 14.430	

	Quantile (%)	Range for λ(hr^{-1}) at a confidence level of 95%	90%	50%	
MEAN = 4.592	5	1.203 - 1.548	1.243 - 1.510	1.358 - 1.466	WATER FLUX =
	10	1.546 - 1.860	1.596 - 1.832	1.687 - 1.770	= 0.01 $cm^3/s\text{-}cm^2$
	15	1.785 - 2.168	1.813 - 2.144	1.905 - 2.016	
	20	2.016 - 2.398	2.028 - 2.373	2.169 - 2.281	
	25	2.223 - 2.642	2.282 - 2.558	2.378 - 2.492	
STD. DEV. =	30	2.474 - 2.830	2.487 - 2.803	2.555 - 2.743	FALL DISTANCE =
= 3.262	35	2.707 - 3.207	2.741 - 3.173	2.786 - 3.080	= 500 cm
	40	2.952 - 3.611	3.006 - 3.528	3.152 - 3.317	
	45	3.226 - 3.822	3.274 - 3.783	3.460 - 3.676	
	50	3.629 - 4.058	3.661 - 4.028	3.765 - 3.930	
SAMPLE SIZE =	55	3.844 - 4.441	3.889 - 4.353	3.982 - 4.154	AEROSOL MASS
= 400	60	4.068 - 4.769	4.136 - 4.659	4.319 - 4.494	FRACTION REMAINING =
	65	4.461 - 5.228	4.484 - 5.170	4.607 - 4.946	= 0.1
	70	4.860 - 5.564	4.938 - 5.486	5.091 - 5.385	
	75	5.318 - 6.215	5.377 - 6.127	5.485 - 5.837	
	80	5.733 - 6.848	5.852 - 6.727	6.170 - 6.489	
	85	6.499 - 7.464	6.557 - 7.449	6.843 - 7.232	
	90	7.330 - 9.214	7.410 - 8.923	7.524 - 8.003	
	95	9.134 - 13.779	9.432 - 13.409	10.425 - 11.803	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of 95%	90%	50%	
MEAN = 2.922	5	0.732 - 1.009	0.760 - 1.002	0.876 - 0.955	WATER FLUX =
	10	1.008 - 1.141	1.019 - 1.138	1.032 - 1.104	= 0.01 $cm^3/s\text{-}cm^2$
	15	1.130 - 1.300	1.134 - 1.281	1.204 - 1.242	
	20	1.241 - 1.476	1.249 - 1.448	1.301 - 1.405	
	25	1.393 - 1.621	1.409 - 1.610	1.456 - 1.556	
STD. DEV. =	30	1.512 - 1.797	1.540 - 1.776	1.607 - 1.684	FALL DISTANCE =
= 2.162	35	1.644 - 1.906	1.667 - 1.888	1.753 - 1.832	= 500 cm
	40	1.805 - 2.068	1.824 - 2.040	1.869 - 1.953	
	45	1.918 - 2.183	1.933 - 2.166	2.021 - 2.099	
	50	2.072 - 2.429	2.093 - 2.411	2.141 - 2.261	
SAMPLE SIZE =	55	2.193 - 2.691	2.212 - 2.658	2.378 - 2.532	AEROSOL MASS
= 400	60	2.434 - 3.001	2.461 - 2.933	2.587 - 2.813	FRACTION REMAINING =
	65	2.706 - 3.243	2.786 - 3.230	2.908 - 3.118	= 0.01
	70	3.026 - 3.580	3.077 - 3.527	3.204 - 3.324	
	75	3.290 - 3.970	3.322 - 3.916	3.500 - 3.810	
	80	3.787 - 4.432	3.814 - 4.388	3.929 - 4.230	
	85	4.231 - 5.056	4.252 - 4.930	4.429 - 4.579	
	90	4.609 - 6.428	4.708 - 6.311	5.242 - 5.675	
	95	6.419 - 9.424	6.588 - 9.272	7.474 - 8.518	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of 95%	90%	50%	
MEAN = 2.284	5	0.585 - 0.742	0.616 - 0.738	0.659 - 0.720	WATER FLUX =
	10	0.740 - 0.912	0.747 - 0.902	0.815 - 0.862	= 0.01 $cm^3/s\text{-}cm^2$
	15	0.869 - 1.009	0.882 - 1.000	0.924 - 0.970	
	20	0.970 - 1.164	0.979 - 1.141	1.010 - 1.075	
	25	0.107 - 1.255	1.077 - 1.253	1.156 - 1.225	
STD. DEV. =	30	1.193 - 1.332	1.215 - 1.324	1.253 - 1.293	FALL DISTANCE =
= 1.727	35	1.277 - 1.441	1.293 - 1.436	1.319 - 1.391	= 500 cm
	40	1.340 - 1.582	1.371 - 1.573	1.431 - 1.523	
	45	1.476 - 1.692	1.501 - 1.656	1.557 - 1.616	
	50	1.593 - 1.813	1.597 - 1.797	1.640 - 1.740	
SAMPLE SIZE =	55	1.694 - 2.098	1.717 - 2.068	1.760 - 1.877	AEROSOL MASS
= 400	60	1.821 - 2.304	1.845 - 2.252	2.042 - 2.142	FRACTION REMAINING =
	65	2.114 - 2.559	2.127 - 2.526	2.231 - 2.426	= 0.001
	70	2.349 - 2.725	2.381 - 2.720	2.516 - 2.642	
	75	2.583 - 3.121	2.638 - 3.075	2.716 - 2.927	
	80	2.873 - 3.480	2.934 - 3.431	3.085 - 3.291	
	85	3.296 - 4.136	3.333 - 3.970	3.475 - 3.715	
	90	3.802 - 5.383	3.894 - 4.952	4.286 - 4.623	
	95	5.359 - 7.455	5.404 - 7.227	5.679 - 6.791	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 10.511	5	2.212 - 3.061	2.275 - 2.995	2.538 - 2.802	WATER FLUX =
	10	3.051 - 3.945	3.089 - 3.865	3.222 - 3.530	= 0.01 $cm^3/s\text{-}cm^2$
	15	3.603 - 4.760	3.770 - 4.591	4.032 - 4.386	
	20	4.386 - 5.484	4.396 - 5.399	4.770 - 5.221	
	25	5.153 - 6.431	5.234 - 6.364	5.407 - 5.805	
STD. DEV. =	30	5.692 - 6.877	5.803 - 6.754	6.273 - 6.597	FALL DISTANCE =
= 8.130	35	6.510 - 7.556	6.575 - 7.372	6.734 - 7.112	= 853 cm
	40	6.936 - 8.363	7.090 - 8.000	7.325 - 7.765	
	45	7.579 - 8.854	7.670 - 8.828	7.969 - 8.579	
	50	8.371 - 9.624	8.466 - 9.458	8.731 - 9.170	
SAMPLE SIZE =	55	8.860 - 10.422	9.005 - 10.313	9.396 - 9.893	AEROSOL MASS
= 400	60	9.630 - 11.003	9.745 - 10.836	10.281 - 10.619	FRACTION REMAINING =
	65	10.475 - 11.976	10.519 - 11.876	10.771 - 11.463	= 0.9
	70	11.071 - 12.918	11.224 - 12.825	11.823 - 12.513	
	75	12.250 - 14.376	12.503 - 14.060	12.776 - 13.299	
	80	13.067 - 15.648	13.539 - 15.488	14.112 - 14.919	
	85	14.943 - 17.384	15.130 - 17.060	15.631 - 16.407	
	90	16.582 - 20.912	16.892 - 20.443	17.428 - 18.443	
	95	20.740 - 28.004	21.200 - 27.560	21.985 - 24.831	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 7.714	5	1.922 - 2.427	2.015 - 2.399	2.129 - 2.260	WATER FLUX =
	10	2.414 - 3.058	2.467 - 3.023	2.648 - 2.870	= 0.01 $cm^3/s\text{-}cm^2$
	15	2.936 - 3.577	2.973 - 3.518	3.133 - 3.356	
	20	3.355 - 4.226	3.446 - 4.098	3.586 - 3.864	
	25	3.787 - 4.647	3.872 - 4.591	4.133 - 4.479	
STD. DEV. =	30	4.443 - 5.143	4.463 - 5.008	4.579 - 4.789	FALL DISTANCE =
= 5.607	35	4.692 - 5.703	4.771 - 5.504	4.953 - 5.280	= 853 cm
	40	5.174 - 6.137	5.207 - 6.084	5.451 - 5.841	
	45	5.734 - 6.682	5.786 - 6.616	6.000 - 6.278	
	50	6.143 - 7.432	6.200 - 7.139	6.428 - 6.887	
SAMPLE SIZE =	55	6.684 - 7.934	6.777 - 7.854	7.050 - 7.537	AEROSOL MASS
= 400	60	7.441 - 8.348	7.510 - 8.241	7.726 - 8.017	FRACTION REMAINING =
	65	7.936 - 8.694	7.981 - 8.674	8.170 - 8.455	= 0.5
	70	8.429 - 9.298	8.449 - 9.229	8.620 - 8.874	
	75	8.777 - 10.260	8.871 - 10.081	9.216 - 9.694	
	80	9.616 - 10.918	9.702 - 10.856	10.142 - 10.529	
	85	10.535 - 12.226	10.627 - 12.094	10.914 - 11.631	
	90	11.960 - 14.150	12.052 - 14.136	12.513 - 13.450	
	95	14.148 - 20.575	14.597 - 20.344	15.164 - 17.496	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of 95%	90%	50%	
MEAN = 6.289	5	1.680 - 2.107	1.703 - 2.076	1.768 - 1.967	WATER FLUX =
	10	2.100 - 2.571	2.119 - 2.552	2.186 - 2.499	= 0.01 $cm^3/s\text{-}cm^2$
	15	2.526 - 3.008	2.544 - 2.898	2.619 - 2.771	
	20	2.769 - 3.395	2.805 - 3.340	3.026 - 3.174	
	25	3.142 - 3.712	3.181 - 3.700	3.363 - 3.549	
STD. DEV. =	30	3.514 - 4.072	3.543 - 4.040	3.697 - 3.841	FALL DISTANCE =
= 4.481	35	3.773 - 4.463	3.807 - 4.394	4.001 - 4.287	= 853 cm
	40	4.183 - 4.987	4.218 - 4.954	4.390 - 4.672	
	45	4.502 - 5.416	4.572 - 5.394	4.867 - 5.228	
	50	5.026 - 5.880	5.208 - 5.818	5.350 - 5.648	
SAMPLE SIZE =	55	5.434 - 6.272	5.598 - 6.192	5.787 - 6.025	AEROSOL MASS
= 400	60	5.893 - 6.662	5.963 - 6.518	6.138 - 6.411	FRACTION REMAINING =
	65	6.324 - 7.101	6.341 - 7.034	6.498 - 6.847	= 0.30
	70	6.719 - 7.484	6.835 - 7.446	6.972 - 7.281	
	75	7.187 - 8.342	7.263 - 8.215	7.424 - 7.745	
	80	7.674 - 9.121	7.766 - 9.077	8.243 - 8.805	
	85	8.815 - 9.975	8.919 - 9.886	9.118 - 9.414	
	90	9.586 - 11.942	9.688 - 11.655	10.106 - 10.823	
	95	11.847 - 17.780	12.488 - 17.676	12.957 - 14.226	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of 95%	90%	50%	
MEAN = 4.509	5	1.180 - 1.546	1.227 - 1.508	1.320 - 1.449	WATER FLUX =
	10	1.544 - 1.855	1.594 - 1.820	1.648 - 1.754	= 0.01 $cm^3/s\text{-}cm^2$
	15	1.758 - 2.114	1.785 - 2.098	1.877 - 1.994	
	20	1.994 - 2.377	2.014 - 2.342	2.115 - 2.218	
	25	2.198 - 2.578	2.231 - 2.532	2.347 - 2.464	
STD. DEV. =	30	2.420 - 2.803	2.457 - 2.752	2.510 - 2.656	FALL DISTANCE =
= 3.203	35	2.631 - 3.174	2.642 - 3.126	2.723 - 3.050	= 853 cm
	40	2.855 - 3.555	2.943 - 3.427	3.108 - 3.270	
	45	3.196 - 3.774	3.252 - 3.751	3.379 - 3.646	
	50	3.562 - 4.018	3.593 - 3.958	3.705 - 3.850	
SAMPLE SIZE =	55	3.786 - 4.331	3.827 - 4.267	3.936 - 4.110	AEROSOL MASS
= 400	60	4.033 - 4.682	4.063 - 4.614	4.227 - 4.480	FRACTION REMAINING =
	65	4.346 - 5.114	4.453 - 5.055	4.551 - 4.930	= 0.1
	70	4.762 - 5.461	4.868 - 5.391	5.020 - 5.224	
	75	5.178 - 6.074	5.223 - 6.013	5.376 - 5.656	
	80	5.604 - 6.671	5.674 - 6.568	6.041 - 6.377	
	85	6.380 - 7.360	6.421 - 7.304	6.666 - 7.118	
	90	7.215 - 8.971	7.266 - 8.352	7.411 - 7.902	
	95	8.940 - 13.736	9.074 - 13.381	10.100 - 11.517	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 2.865	5	0.702 - 0.981	0.727 - 0.979	0.861 - 0.920	WATER FLUX =
	10	0.980 - 1.134	0.982 - 1.117	1.020 - 1.087	= 0.01 $cm^3/s\text{-}cm^2$
	15	1.100 - 1.276	1.109 - 1.249	1.165 - 1.213	
	20	1.212 - 1.450	1.230 - 1.425	1.277 - 1.391	
	25	1.360 - 1.604	1.395 - 1.581	1.427 - 1.509	
STD. DEV. =	30	1.486 - 1.756	1.503 - 1.737	1.573 - 1.668	FALL DISTANCE =
= 2.130	35	1.623 - 1.872	1.640 - 1.855	1.725 - 1.806	= 853 cm
	40	1.770 - 2.009	1.797 - 1.994	1.836 - 1.915	
	45	1.882 - 2.164	1.904 - 2.136	1.980 - 2.056	
	50	2.010 - 2.381	2.019 - 2.349	2.112 - 2.210	
SAMPLE SIZE =	55	2.173 - 2.609	2.194 - 2.594	2.316 - 2.450	AEROSOL MASS
= 400	60	2.392 - 2.906	2.418 - 2.883	2.576 - 2.766	FRACTION REMAINING =
	65	2.639 - 3.197	2.708 - 3.181	2.862 - 3.029	= 0.01
	70	2.965 - 3.550	3.007 - 3.443	3.174 - 3.280	
	75	3.230 - 3.892	3.272 - 3.844	3.433 - 3.728	
	80	3.687 - 4.365	3.730 - 4.263	3.857 - 4.103	
	85	4.109 - 4.927	4.142 - 4.804	4.351 - 4.504	
	90	4.550 - 6.275	4.596 - 6.114	5.116 - 5.603	
	95	6.248 - 9.346	6.432 - 9.095	7.320 - 8.372	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 2.251	5	0.573 - 0.730	0.605 - 0.726	0.654 - 0.709	WATER FLUX =
	10	0.729 - 0.898	0.733 - 0.878	0.788 - 0.850	= 0.01 $cm^3/s\text{-}cm^2$
	15	0.863 - 0.990	0.870 - 0.985	0.913 - 0.959	
	20	0.957 - 1.147	0.968 - 1.118	0.991 - 1.067	
	25	1.049 - 1.248	1.068 - 1.236	1.137 - 1.200	
STD. DEV. =	30	1.187 - 1.311	1.198 - 1.296	1.233 - 1.266	FALL DISTANCE =
= 1.705	35	1.257 - 1.426	1.265 - 1.413	1.291 - 1.379	= 853 cm
	40	1.328 - 1.552	1.360 - 1.532	1.404 - 1.503	
	45	1.442 - 1.673	1.474 - 1.649	1.526 - 1.592	
	50	1.557 - 1.793	1.568 - 1.755	1.630 - 1.696	
SAMPLE SIZE =	55	1.677 - 2.051	1.687 - 2.031	1.746 - 1.853	AEROSOL MASS
= 400	60	1.802 - 2.288	1.830 - 2.225	2.013 - 2.119	FRACTION REMAINING =
	65	2.071 - 2.514	2.098 - 2.475	2.181 - 2.372	= 0.001
	70	2.341 - 2.715	2.356 - 2.698	2.457 - 2.608	
	75	2.555 - 3.108	2.577 - 3.026	2.688 - 2.841	
	80	2.798 - 3.429	2.855 - 3.408	3.046 - 3.250	
	85	3.252 - 4.049	3.263 - 3.949	3.427 - 3.661	
	90	3.746 - 5.346	3.880 - 4.864	4.268 - 4.524	
	95	5.334 - 7.439	5.383 - 7.141	5.653 - 6.731	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 10.455	5	2.248 - 3.083	2.305 - 3.025	2.589 - 2.878	WATER FLUX =
	10	3.059 - 3.967	3.119 - 3.872	3.249 - 3.543	= 0.01 $cm^3/s\text{-}cm^2$
	15	3.753 - 4.751	3.802 - 4.660	4.064 - 4.382	
	20	4.382 - 5.535	4.393 - 5.367	4.755 - 5.209	
	25	5.055 - 6.411	5.217 - 6.347	5.387 - 5.816	
STD. DEV. =	30	5.733 - 6.871	5.799 - 6.775	6.251 - 6.534	FALL DISTANCE =
= 8.086	35	6.492 - 7.497	6.504 - 7.369	6.739 - 7.131	= 1000 cm
	40	6.914 - 8.277	7.052 - 7.996	7.330 - 7.818	
	45	7.528 - 8.839	7.615 - 8.764	7.957 - 8.553	
	50	8.326 - 9.621	8.457 - 9.430	8.710 - 9.164	
SAMPLE SIZE =	55	8.840 - 10.402	8.979 - 10.305	9.378 - 9.880	AEROSOL MASS
= 400	60	9.628 - 11.019	9.738 - 10.824	10.200 - 10.579	FRACTION REMAINING =
	65	10.460 - 11.900	10.511 - 11.831	10.751 - 11.449	= 0.9
	70	11.075 - 12.874	11.204 - 12.732	11.762 - 12.447	
	75	12.234 - 14.141	12.439 - 13.900	12.716 - 13.094	
	80	13.004 - 15.486	13.204 - 15.412	13.942 - 14.739	
	85	14.759 - 17.162	14.966 - 16.712	15.483 - 16.191	
	90	16.360 - 20.363	16.449 - 20.125	17.333 - 17.965	
	95	20.335 - 27.421	20.956 - 26.632	21.306 - 24.326	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of 95%	90%	50%	
MEAN = 7.651	5	1.856 - 2.398	1.930 - 2.339	2.112 - 2.234	WATER FLUX =
	10	2.397 - 3.023	2.439 - 2.964	2.562 - 2.837	= 0.01 $cm^3/s\text{-}cm^2$
	15	2.870 - 3.520	2.944 - 3.499	3.082 - 3.326	
	20	3.324 - 4.115	3.380 - 4.071	3.523 - 3.811	
	25	3.735 - 4.626	3.815 - 4.568	4.082 - 4.434	
STD. DEV. =	30	4.381 - 5.080	4.422 - 4.931	4.566 - 4.752	FALL DISTANCE =
= 5.587	35	4.677 - 5.558	4.733 - 5.454	4.885 - 5.230	= 1000 cm
	40	5.121 - 6.055	5.178 - 6.021	5.379 - 5.784	
	45	5.670 - 6.665	5.728 - 6.453	5.904 - 6.218	
	50	6.082 - 7.377	6.143 - 7.084	6.379 - 6.802	
SAMPLE SIZE =	55	6.676 - 7.871	6.690 - 7.723	7.010 - 7.513	AEROSOL MASS
= 400	60	7.389 - 8.274	7.439 - 8.181	7.647 - 7.956	FRACTION REMAINING =
	65	7.921 - 8.599	7.733 - 8.548	8.107 - 8.437	= 0.5
	70	8.381 - 9.204	8.428 - 9.163	8.525 - 8.851	
	75	8.692 - 10.217	8.825 - 10.058	9.151 - 9.557	
	80	9.486 - 10.896	9.581 - 10.838	10.113 - 10.504	
	85	10.510 - 12.155	10.600 - 12.048	10.888 - 11.592	
	90	11.862 - 14.134	11.957 - 14.046	12.452 - 13.379	
	95	14.124 - 20.561	14.583 - 20.329	15.153 - 17.350	

	Quantile (%)	Range for $\lambda (hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 6.261	5	1.677 - 2.093	1.700 - 2.060	1.767 - 1.958	WATER FLUX =
	10	2.088 - 2.541	2.113 - 2.526	2.158 - 2.469	= 0.01 $cm^3/s\text{-}cm^2$
	15	2.507 - 2.928	2.514 - 2.861	2.581 - 2.736	
	20	2.730 - 3.391	2.785 - 3.328	2.934 - 3.166	
	25	3.122 - 3.697	3.173 - 3.668	3.357 - 3.542	
STD. DEV. =	30	3.486 - 4.058	3.521 - 4.003	3.657 - 3.815	FALL DISTANCE =
= 4.460	35	3.750 - 4.461	3.790 - 4.384	3.981 - 4.254	= 1000 cm
	40	4.134 - 5.016	4.206 - 4.947	4.346 - 4.612	
	45	4.474 - 5.436	4.546 - 5.387	4.865 - 5.235	
	50	5.091 - 5.878	5.174 - 5.819	5.338 - 5.656	
SAMPLE SIZE =	55	5.516 - 6.252	5.586 - 6.154	5.783 - 6.024	AEROSOL MASS
= 400	60	5.889 - 6.636	5.936 - 6.559	6.128 - 6.424	FRACTION REMAINING =
	65	6.301 - 7.092	6.358 - 7.046	6.492 - 6.810	= 0.3
	70	6.685 - 7.480	6.795 - 7.405	6.943 - 7.244	
	75	7.176 - 8.333	7.240 - 8.206	7.390 - 7.651	
	80	7.659 - 9.115	7.695 - 9.071	8.226 - 8.790	
	85	8.802 - 9.963	8.890 - 9.869	9.112 - 9.385	
	90	9.507 - 11.928	9.648 - 11.628	10.069 - 10.717	
	95	11.806 - 17.717	12.359 - 17.552	12.877 - 14.218	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 4.485	5	1.177 - 1.545	1.221 - 1.508	1.302 - 1.448	WATER FLUX =
	10	1.544 - 1.839	1.588 - 1.817	1.644 - 1.751	= 0.01 $cm^3/s\text{-}cm^2$
	15	1.757 - 2.103	1.784 - 2.064	1.866 - 1.980	
	20	1.978 - 2.360	2.014 - 2.339	2.106 - 2.216	
	25	2.196 - 2.562	2.221 - 2.499	2.344 - 2.461	
STD. DEV. =	30	2.402 - 2.794	2.453 - 2.750	2.498 - 2.633	FALL DISTANCE =
= 3.188	35	2.613 - 3.166	2.620 - 3.120	2.706 - 3.047	= 1000 cm
	40	2.841 - 3.487	2.938 - 3.382	3.097 - 3.260	
	45	3.193 - 3.748	3.240 - 3.718	3.370 - 3.607	
	50	3.522 - 3.982	3.562 - 3.951	3.665 - 3.823	
SAMPLE SIZE =	55	3.751 - 4.294	3.804 - 4.230	3.905 - 4.088	AEROSOL MASS
= 400	60	4.017 - 4.649	4.040 - 4.589	4.181 - 4.477	FRACTION REMAINING =
	65	4.338 - 5.043	4.450 - 5.013	4.532 - 4.911	= 0.1
	70	4.729 - 5.443	4.858 - 5.385	4.993 - 5.170	
	75	5.149 - 6.029	5.169 - 5.968	5.363 - 5.574	
	80	5.563 - 6.604	5.603 - 6.548	5.974 - 6.291	
	85	6.304 - 7.324	6.395 - 7.298	6.602 - 7.045	
	90	7.184 - 8.957	7.233 - 8.286	7.376 - 7.870	
	95	8.929 - 13.722	9.012 - 13.371	10.089 - 11.463	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 2.858	5	0.717 - 0.980	0.746 - 0.973	0.864 - 0.924	WATER FLUX =
	10	0.979 - 1.137	0.982 - 1.124	1.019 - 1.076	= 0.01 $cm^3/s\text{-}cm^2$
	15	1.100 - 1.277	1.106 - 1.258	1.166 - 1.212	
	20	1.211 - 1.446	1.226 - 1.426	1.278 - 1.394	
	25	1.378 - 1.607	1.394 - 1.585	1.437 - 1.504	
STD. DEV. =	30	1.490 - 1.744	1.501 - 1.732	1.582 - 1.658	FALL DISTANCE =
= 2.112	35	1.621 - 1.877	1.638 - 1.851	1.723 - 1.807	= 1000 cm
	40	1.771 - 2.005	1.793 - 1.976	1.838 - 1.924	
	45	1.895 - 2.163	1.911 - 2.151	1.964 - 2.076	
	50	2.010 - 2.388	2.016 - 2.360	2.120 - 2.233	
SAMPLE SIZE =	55	2.172 - 2.645	2.206 - 2.586	2.306 - 2.493	AEROSOL MASS
= 400	60	2.409 - 2.924	2.431 - 2.878	2.574 - 2.766	FRACTION REMAINING =
	65	2.684 - 3.217	2.725 - 3.171	2.860 - 3.033	= 0.01
	70	2.984 - 3.570	3.004 - 3.499	3.160 - 3.300	
	75	3.259 - 3.888	3.285 - 3.841	3.461 - 3.676	
	80	3.643 - 4.348	3.696 - 4.248	3.861 - 4.082	
	85	4.084 - 5.017	4.114 - 4.809	4.346 - 4.487	
	90	4.569 - 6.322	4.687 - 6.148	5.212 - 5.656	
	95	6.304 - 9.289	6.428 - 9.066	7.250 - 8.304	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 2.235	5	0.568 - 0.723	0.602 - 0.720	0.652 - 0.703	WATER FLUX =
	10	0.722 - 0.880	0.732 - 0.870	0.777 - 0.847	= 0.01 $cm^3/s\text{-}cm^2$
	15	0.851 - 0.985	0.865 - 0.983	0.908 - 0.952	
	20	0.952 - 1.142	0.960 - 1.103	0.985 - 1.065	
	25	1.046 - 1.238	1.067 - 1.229	1.127 - 1.196	
STD. DEV. =	30	1.181 - 1.314	1.193 - 1.292	1.228 - 1.263	FALL DISTANCE =
= 1.691	35	1.248 - 1.424	1.256 - 1.417	1.290 - 1.371	= 1000 cm
	40	1.330 - 1.540	1.358 - 1.529	1.396 - 1.489	
	45	1.438 - 1.658	1.461 - 1.652	1.520 - 1.592	
	50	1.552 - 1.792	1.567 - 1.752	1.631 - 1.702	
SAMPLE SIZE =	55	1.664 - 2.047	1.682 - 2.022	1.731 - 1.852	AEROSOL MASS
= 400	60	1.800 - 2.272	1.821 - 2.212	1.973 - 2.102	FRACTION REMAINING =
	65	2.057 - 2.503	2.082 - 2.445	2.174 - 2.366	= 0.001
	70	2.331 - 2.712	2.344 - 2.686	2.431 - 2.604	
	75	2.539 - 3.097	2.571 - 3.001	2.674 - 2.806	
	80	2.762 - 3.415	2.835 - 3.374	3.024 - 3.217	
	85	3.225 - 4.204	3.294 - 3.954	3.413 - 3.671	
	90	3.791 - 5.370	3.937 - 5.301	4.278 - 4.497	
	95	5.347 - 7.472	5.394 - 7.434	5.719 - 6.760	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 10.204	5	2.206 - 2.968	2.250 - 2.928	2.532 - 2.794	WATER FLUX =
	10	2.943 - 3.898	3.053 - 3.742	3.126 - 3.471	= 0.010 $cm^3/s\text{-}cm^2$
	15	3.633 - 4.537	3.695 - 4.505	3.976 - 4.327	
	20	4.319 - 5.384	4.377 - 5.202	4.545 - 4.941	
	25	4.897 - 6.128	4.981 - 6.044	5.224 - 5.685	
STD. DEV. =	30	5.578 - 6.717	5.668 - 6.680	5.989 - 6.413	FALL DISTANCE =
= 7.895	35	6.360 - 7.280	6.398 - 7.190	6.637 - 6.864	= 1584 cm
	40	6.783 - 7.976	6.816 - 7.930	7.128 - 7.619	
	45	7.289 - 8.647	7.355 - 8.550	7.856 - 8.289	
	50	7.981 - 9.399	8.228 - 9.350	8.446 - 8.874	
SAMPLE SIZE =	55	8.659 - 10.253	8.773 - 10.034	9.232 - 9.647	AEROSOL MASS
= 400	60	9.439 - 10.780	9.573 - 10.690	9.928 - 10.463	FRACTION REMAINING =
	65	10.262 - 11.840	10.362 - 11.690	10.672 - 11.032	= 0.9
	70	10.919 - 12.723	10.997 - 12.559	11.622 - 12.133	
	75	11.895 - 13.724	12.130 - 13.493	12.461 - 12.933	
	80	12.899 - 14.993	12.961 - 14.805	13.527 - 14.431	
	85	14.454 - 16.590	14.595 - 16.169	14.977 - 15.682	
	90	15.965 - 19.667	16.074 - 19.231	16.719 - 17.739	
	95	19.618 - 26.092	19.974 - 25.715	20.725 - 23.225	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 7.496	5	1.896 - 2.374	1.994 - 2.348	2.101 - 2.221	WATER FLUX =
	10	2.370 - 2.956	2.395 - 2.879	2.590 - 2.799	= 0.01 $cm^3/s\text{-}cm^2$
	15	2.829 - 3.507	2.844 - 3.463	3.021 - 3.259	
	20	3.257 - 4.059	3.322 - 4.020	3.509 - 3.736	
	25	3.724 - 4.551	3.752 - 4.481	4.045 - 4.356	
STD. DEV. =	30	4.248 - 4.902	4.326 - 4.855	4.481 - 4.664	FALL DISTANCE =
= 5.450	35	4.634 - 5.423	4.650 - 5.365	4.824 - 5.138	= 1584 cm
	40	4.967 - 5.932	5.102 - 5.856	5.291 - 5.593	
	45	5.439 - 6.453	5.524 - 6.411	5.750 - 6.167	
	50	5.965 - 7.156	6.068 - 7.021	6.342 - 6.651	
SAMPLE SIZE =	55	6.504 - 7.645	6.566 - 7.560	6.870 - 7.370	AEROSOL MASS
= 400	60	7.212 - 8.071	7.293 - 7.984	7.521 - 7.867	FRACTION REMAINING =
	65	7.667 - 8.517	7.817 - 8.428	7.962 - 8.226	= 0.5
	70	8.138 - 9.044	8.216 - 8.934	8.402 - 8.710	
	75	8.631 - 9.893	8.680 - 9.741	8.912 - 9.334	
	80	9.250 - 10.765	9.354 - 10.644	9.770 - 10.303	
	85	10.306 - 11.917	10.337 - 11.741	10.756 - 11.316	
	90	11.469 - 14.009	11.656 - 13.522	12.094 - 13.000	
	95	13.990 - 20.255	14.099 - 19.850	15.090 - 16.821	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 6.117	5	1.658 - 2.021	1.665 - 2.006	1.738 - 1.911	WATER FLUX =
	10	2.018 - 2.496	2.035 - 2.468	2.134 - 2.367	= 0.01 $cm^3/s\text{-}cm^2$
	15	2.406 - 2.882	2.424 - 2.828	2.525 - 2.679	
	20	2.677 - 3.312	2.765 - 3.281	2.886 - 3.129	
	25	3.100 - 3.626	3.141 - 3.590	3.287 - 3.474	
STD. DEV. =	30	3.428 - 3.944	3.456 - 3.871	3.573 - 3.742	FALL DISTANCE =
= 4.362	35	3.677 - 4.373	3.700 - 4.340	3.869 - 4.083	= 1584 cm
	40	3.988 - 4.889	4.038 - 4.829	4.257 - 4.471	
	45	4.376 - 5.353	4.450 - 5.280	4.777 - 5.091	
	50	4.930 - 5.785	5.014 - 5.722	5.222 - 5.495	
SAMPLE SIZE =	55	5.359 - 6.135	5.390 - 6.080	5.675 - 5.859	AEROSOL MASS
= 400	60	5.791 - 6.451	5.808 - 6.414	6.050 - 6.283	FRACTION REMAINING =
	65	6.184 - 6.940	6.233 - 6.810	6.391 - 6.579	= 0.3
	70	6.483 - 7.290	6.554 - 7.233	6.785 - 7.056	
	75	7.014 - 8.249	7.052 - 8.086	7.202 - 7.440	
	80	7.426 - 9.007	7.481 - 8.854	8.141 - 8.590	
	85	8.601 - 9.867	8.738 - 9.645	9.002 - 9.114	
	90	9.328 - 11.658	9.354 - 11.224	9.999 - 10.479	
	95	11.628 - 17.391	11.801 - 16.839	12.507 - 14.170	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 4.382	5	1.164 - 1.540	1.182 - 1.505	1.266 - 1.445	WATER FLUX =
	10	1.539 - 1.786	1.540 - 1.776	1.600 - 1.722	= 0.01 $cm^3/s\text{-}cm^2$
	15	1.748 - 2.024	1.753 - 2.012	1.840 - 1.912	
	20	1.911 - 2.300	1.956 - 2.289	2.025 - 2.198	
	25	2.171 - 2.472	2.201 - 2.459	2.295 - 2.387	
STD. DEV. =	30	2.372 - 2.758	2.384 - 2.699	2.457 - 2.547	FALL DISTANCE =
= 3.120	35	2.489 - 3.104	2.538 - 3.067	2.634 - 2.948	= 1584 cm
	40	2.798 - 3.354	2.901 - 3.328	3.034 - 3.196	
	45	3.122 - 3.641	3.156 - 3.620	3.294 - 3.496	
	50	3.361 - 3.918	3.416 - 3.848	3.594 - 3.744	
SAMPLE SIZE =	55	3.658 - 4.218	3.724 - 4.118	3.819 - 3.975	AEROSOL MASS
= 400	60	3.923 - 4.575	3.947 - 4.507	4.067 - 4.411	FRACTION REMAINING =
	65	4.275 - 4.909	4.327 - 4.869	4.486 - 4.729	= 0.1
	70	4.642 - 5.325	4.715 - 5.187	4.861 - 5.058	
	75	4.979 - 5.861	5.021 - 5.780	5.180 - 5.525	
	80	5.448 - 6.492	5.529 - 6.402	5.784 - 6.138	
	85	6.152 - 7.184	6.258 - 7.161	6.483 - 6.823	
	90	6.941 - 8.835	7.118 - 8.197	7.280 - 7.770	
	95	8.746 - 13.389	8.926 - 13.285	9.812 - 11.291	

	Quantile (%)	Range for λ(hr^{-1}) at a confidence level of 95%	90%	50%	
MEAN = 2.799	5	0.695 - 0.952	0.728 - 0.934	0.853 - 0.900	WATER FLUX =
	10	0.943 - 1.124	0.965 - 1.105	1.012 - 1.068	= 0.01 $cm^3/s\text{-}cm^2$
	15	1.087 - 1.264	1.099 - 1.245	1.134 - 1.198	
	20	1.197 - 1.403	1.204 - 1.392	1.266 - 1.346	
	25	1.337 - 1.574	1.354 - 1.551	1.396 - 1.480	
STD. DEV. =	30	1.452 - 1.699	1.471 - 1.675	1.550 - 1.618	FALL DISTANCE =
= 2.076	35	1.593 - 1.824	1.616 - 1.812	1.666 - 1.760	= 1584 cm
	40	1.722 - 1.914	1.740 - 1.905	1.804 - 1.862	
	45	1.829 - 2.139	1.846 - 2.107	1.894 - 2.001	
	50	1.937 - 2.322	1.990 - 2.273	2.083 - 2.182	
SAMPLE SIZE =	55	2.144 - 2.572	2.167 - 2.544	2.220 - 2.400	AEROSOL MASS
= 400	60	2.357 - 2.850	2.384 - 2.795	2.535 - 2.674	FRACTION REMAINING =
	65	2.595 - 3.150	2.622 - 3.114	2.762 - 2.962	= 0.01
	70	2.870 - 3.424	2.901 - 3.414	3.050 - 3.242	
	75	3.186 - 3.758	3.221 - 3.744	3.409 - 3.580	
	80	3.563 - 4.225	3.591 - 4.171	3.751 - 3.918	
	85	3.920 - 4.896	3.943 - 4.772	4.224 - 4.455	
	90	4.547 - 6.228	4.594 - 5.852	5.042 - 5.585	
	95	6.138 - 8.930	6.409 - 8.887	7.006 - 7.951	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 2.183	5	0.548 - 0.714	0.587 - 0.704	0.649 - 0.676	WATER FLUX =
	10	0.713 - 0.870	0.718 - 0.862	0.760 - 0.825	= 0.01 $cm^3/s\text{-}cm^2$
	15	0.840 - 0.974	0.850 - 0.966	0.880 - 0.931	
	20	0.930 - 1.104	0.950 - 1.074	0.974 - 1.034	
	25	1.024 - 1.193	1.038 - 1.188	1.086 - 1.169	
STD. DEV. =	30	1.148 - 1.291	1.167 - 1.284	1.187 - 1.237	FALL DISTANCE =
= 1.657	35	1.221 - 1.406	1.228 - 1.375	1.280 - 1.325	= 1584 cm
	40	1.300 - 1.506	1.316 - 1.490	1.369 - 1.419	
	45	1.409 - 1.618	1.412 - 1.602	1.470 - 1.553	
	50	1.511 - 1.752	1.541 - 1.734	1.582 - 1.642	
SAMPLE SIZE =	55	1.619 - 1.980	1.630 - 1.945	1.703 - 1.845	AEROSOL MASS
= 400	60	1.781 - 2.204	1.803 - 2.158	1.901 - 2.067	FRACTION REMAINING =
	65	2.004 - 2.388	2.042 - 2.366	2.124 - 2.302	= 0.001
	70	2.265 - 2.659	2.286 - 2.650	2.349 - 2.555	
	75	2.515 - 2.986	2.548 - 2.898	2.646 - 2.730	
	80	2.710 - 3.299	2.749 - 3.244	2.918 - 3.135	
	85	3.137 - 3.938	3.182 - 3.846	3.293 - 3.535	
	90	3.668 - 5.263	3.814 - 4.787	4.133 - 4.358	
	95	5.167 - 7.131	5.360 - 6.962	5.608 - 6.451	

	Quantile (%)	Range for λ(hr^{-1}) at a confidence level of			
		95%	90%	50%	
MEAN = 10.061	5	2.170 - 2.926	2.205 - 2.880	2.529 - 2.763	WATER FLUX =
	10	2.923 - 3.845	2.939 - 3.644	3.114 - 3.421	= 0.01 cm^3/s-cm^2
	15	3.532 - 4.490	3.590 - 4.395	3.956 - 4.316	
	20	4.311 - 5.345	4.356 - 5.223	4.495 - 4.887	
	25	4.823 - 5.979	4.895 - 5.925	5.235 - 5.657	
STD. DEV. =	30	5.566 - 6.643	5.633 - 6.596	5.908 - 6.367	FALL DISTANCE =
= 7.775	35	6.238 - 7.230	6.351 - 7.131	6.565 - 6.844	= 2000 cm
	40	6.678 - 7.938	6.776 - 7.891	7.063 - 7.415	
	45	7.250 - 8.481	7.344 - 8.423	7.816 - 8.111	
	50	7.951 - 9.334	8.019 - 9.127	8.311 - 8.755	
SAMPLE SIZE =	55	8.511 - 10.112	8.631 - 9.894	9.104 - 9.576	AEROSOL MASS
= 400	60	9.346 - 10.656	9.508 - 10.599	9.779 - 10.401	FRACTION REMAINING =
	65	10.201 - 11.650	10.286 - 11.498	10.552 - 10.920	= 0.9
	70	10.679 - 12.670	10.787 - 12.545	11.466 - 11.918	
	75	11.816 - 13.524	11.899 - 13.456	12.472 - 12.871	
	80	12.820 - 14.792	12.887 - 14.645	13.469 - 14.246	
	85	14.253 - 16.413	14.337 - 16.082	14.782 - 15.412	
	90	15.709 - 19.403	16.044 - 19.098	16.635 - 17.700	
	95	19.335 - 25.853	19.485 - 25.452	21.032 - 23.236	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 7.386	5	1.881 - 2.330	1.972 - 2.320	2.054 - 2.203	WATER FLUX =
	10	2.327 - 2.893	2.337 - 2.851	2.530 - 2.770	= 0.010 $cm^3/s\text{-}cm^2$
	15	2.782 - 3.486	2.804 - 3.424	2.970 - 3.222	
	20	3.215 - 3.995	3.297 - 3.926	3.490 - 3.696	
	25	3.676 - 4.491	3.710 - 4.469	3.946 - 4.260	
STD. DEV. =	30	4.149 - 4.823	4.239 - 4.767	4.447 - 4.636	FALL DISTANCE =
= 5.375	35	4.568 - 5.298	4.618 - 5.264	4.758 - 5.110	= 2000 cm
	40	4.879 - 5.867	4.966 - 5.744	5.247 - 5.452	
	45	5.338 - 6.361	5.399 - 6.310	5.679 - 6.118	
	50	5.924 - 6.997	6.056 - 6.970	6.264 - 6.593	
SAMPLE SIZE =	55	6.373 - 7.522	6.430 - 7.467	6.747 - 7.248	AEROSOL MASS
= 400	60	7.009 - 7.973	7.151 - 7.897	7.416 - 7.658	FRACTION REMAINING =
	65	7.539 - 8.447	7.635 - 8.371	7.867 - 8.142	= 0.5
	70	8.059 - 8.924	8.131 - 8.812	8.361 - 8.583	
	75	8.503 - 9.676	8.530 - 9.580	8.800 - 9.170	
	80	9.144 - 10.570	9.218 - 10.496	9.610 - 10.193	
	85	10.199 - 11.753	10.250 - 11.494	10.566 - 11.044	
	90	11.336 - 13.712	11.441 - 13.419	11.933 - 12.704	
	95	13.649 - 20.193	13.967 - 19.443	15.049 - 16.606	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 6.019	5	1.631 - 1.962	1.651 - 1.950	1.724 - 1.885	WATER FLUX =
	10	1.961 - 2.468	1.968 - 2.436	2.122 - 2.277	= 0.010 $cm^3/s\text{-}cm^2$
	15	2.339 - 2.812	2.365 - 2.792	2.492 - 2.631	
	20	2.621 - 3.291	2.743 - 3.269	2.813 - 3.106	
	25	3.085 - 3.558	3.110 - 3.516	3.277 - 3.414	
STD. DEV. =	30	3.358 - 3.857	3.397 - 3.824	3.516 - 3.712	FALL DISTANCE =
= 4.303	35	3.628 - 4.285	3.662 - 4.249	3.789 - 4.024	= 2000 cm
	40	3.893 - 4.814	3.963 - 4.726	4.235 - 4.437	
	45	4.319 - 5.265	4.360 - 5.181	4.657 - 4.985	
	50	4.831 - 5.641	4.922 - 5.577	5.138 - 5.364	
SAMPLE SIZE =	55	5.279 - 6.043	5.334 - 6.032	5.563 - 5.782	AEROSOL MASS
= 400	60	5.683 - 6.376	5.727 - 6.328	5.997 - 6.124	FRACTION REMAINING =
	65	6.066 - 6.759	6.077 - 6.686	6.264 - 6.455	= 0.3
	70	6.408 - 7.123	6.446 - 7.094	6.591 - 6.927	
	75	6.846 - 8.071	6.920 - 7.980	7.081 - 7.403	
	80	7.354 - 8.835	7.408 - 8.770	7.988 - 8.403	
	85	8.406 - 9.850	8.468 - 9.529	8.833 - 9.063	
	90	9.182 - 11.396	9.323 - 10.930	9.935 - 10.429	
	95	11.335 - 17.150	11.580 - 16.273	12.340 - 14.138	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 4.319	5	1.139 - 1.501	1.157 - 1.494	1.250 - 1.443	WATER FLUX =
	10	1.499 - 1.769	1.505 - 1.749	1.596 - 1.689	= 0.01 $cm^3/s\text{-}cm^2$
	15	1.722 - 2.008	1.746 - 1.993	1.808 - 1.889	
	20	1.888 - 2.281	1.913 - 2.250	2.008 - 2.175	
	25	2.143 - 2.431	2.179 - 2.392	2.260 - 2.360	
STD. DEV. =	30	2.334 - 2.741	2.354 - 2.674	2.390 - 2.501	FALL DISTANCE =
= 3.081	35	2.479 - 3.066	2.484 - 3.028	2.614 - 2.878	= 2000 cm
	40	2.786 - 3.303	2.828 - 3.245	2.980 - 3.168	
	45	3.093 - 3.611	3.117 - 3.589	3.232 - 3.398	
	50	3.318 - 3.832	3.342 - 3.799	3.527 - 3.691	
SAMPLE SIZE =	55	3.624 - 4.150	3.665 - 4.060	3.755 - 3.910	AEROSOL MASS
= 400	60	3.835 - 4.524	3.876 - 4.486	4.011 - 4.324	FRACTION REMAINING =
	65	4.196 - 4.838	4.264 - 4.768	4.474 - 4.611	= 0.1
	70	4.562 - 5.239	4.603 - 5.154	4.738 - 4.952	
	75	4.921 - 5.758	4.946 - 5.654	5.128 - 5.429	
	80	5.383 - 6.408	5.460 - 6.356	5.678 - 6.060	
	85	6.067 - 7.169	6.176 - 6.999	6.406 - 6.771	
	90	6.836 - 8.829	6.985 - 8.194	7.258 - 7.591	
	95	8.773 - 13.269	8.853 - 13.021	9.672 - 11.053	

	Quantile (%)	Range for λ(hr^{-1}) at a confidence level of 95%	90%	50%	
MEAN = 2.751	5	0.680 - 0.922	0.715 - 0.911	0.846 - 0.880	WATER FLUX =
	10	0.916 - 1.098	0.938 - 1.094	0.989 - 1.061	= 0.01 $cm^3/s\text{-}cm^2$
	15	1.072 - 1.257	1.084 - 1.228	1.113 - 1.180	
	20	1.178 - 1.390	1.200 - 1.380	1.259 - 1.322	
	25	1.316 - 1.540	1.325 - 1.520	1.381 - 1.471	
STD. DEV. =	30	1.437 - 1.672	1.463 - 1.648	1.514 - 1.602	FALL DISTANCE =
= 2.045	35	1.573 - 1.794	1.597 - 1.780	1.632 - 1.722	= 2000 cm
	40	1.695 - 1.899	1.718 - 1.881	1.775 - 1.818	
	45	1.800 - 2.101	1.814 - 2.086	1.854 - 1.989	
	50	1.905 - 2.268	1.928 - 2.241	2.069 - 2.149	
SAMPLE SIZE =	55	2.108 - 2.540	2.139 - 2.520	2.196 - 2.370	AEROSOL MASS
= 400	60	2.288 - 2.789	2.349 - 2.755	2.463 - 2.615	FRACTION REMAINING =
	65	2.558 - 3.104	2.579 - 3.038	2.697 - 2.890	= 0.01
	70	2.828 - 3.390	2.871 - 3.341	2.997 - 3.233	
	75	3.175 - 3.711	3.215 - 3.658	3.310 - 3.550	
	80	3.524 - 4.169	3.559 - 4.062	3.665 - 3.824	
	85	3.830 - 4.841	3.868 - 4.752	4.168 - 4.438	
	90	4.517 - 6.191	4.550 - 5.758	4.951 - 5.553	
	95	6.034 - 8.818	6.396 - 8.718	6.950 - 7.768	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 2.150	5	0.536 - 0.700	0.579 - 0.688	0.639 - 0.666	WATER FLUX =
	10	0.698 - 0.859	0.710 - 0.852	0.754 - 0.813	= 0.01 $cm^3/s\text{-}cm^2$
	15	0.828 - 0.956	0.841 - 0.950	0.869 - 0.928	
	20	0.927 - 1.077	0.935 - 1.065	0.956 - 1.022	
	25	1.007 - 1.178	1.024 - 1.165	1.065 - 1.143	
STD. DEV. =	30	1.127 - 1.281	1.136 - 1.267	1.164 - 1.228	FALL DISTANCE =
= 1.637	35	1.192 - 1.364	1.221 - 1.356	1.253 - 1.302	= 2000 cm
	40	1.285 - 1.501	1.294 - 1.455	1.332 - 1.408	
	45	1.364 - 1.593	1.393 - 1.575	1.440 - 1.517	
	50	1.504 - 1.749	1.508 - 1.708	1.552 - 1.632	
SAMPLE SIZE =	55	1.595 - 1.931	1.610 - 1.902	1.684 - 1.810	AEROSOL MASS
= 400	60	1.776 - 2.182	1.784 - 2.120	1.841 - 2.041	FRACTION REMAINING =
	65	1.950 - 2.367	2.028 - 2.326	2.103 - 2.247	= 0.001
	70	2.226 - 2.642	2.234 - 2.617	2.321 - 2.517	
	75	2.474 - 2.900	2.502 - 2.864	2.611 - 2.710	
	80	2.691 - 3.260	2.716 - 3.191	2.883 - 3.085	
	85	3.090 - 3.905	3.126 - 3.806	3.256 - 3.473	
	90	3.643 - 5.232	3.754 - 4.745	4.017 - 4.343	
	95	5.081 - 6.876	5.347 - 6.838	5.548 - 6.263	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 9.740	5	2.087 - 2.760	2.172 - 2.739	2.492 - 2.672	WATER FLUX =
	10	2.755 - 3.713	2.782 - 3.487	2.990 - 3.290	= 0.01 $cm^3/s\text{-}cm^2$
	15	3.359 - 4.307	3.400 - 4.286	3.837 - 4.152	
	20	4.150 - 5.174	4.202 - 5.042	4.310 - 4.609	
	25	4.554 - 5.761	4.650 - 5.711	5.080 - 5.452	
STD. DEV. =	30	5.377 - 6.403	5.434 - 6.330	5.687 - 6.182	FALL DISTANCE =
= 7.537	35	5.986 - 6.985	6.092 - 6.886	6.310 - 6.661	= 3000 cm
	40	6.467 - 7.698	6.605 - 7.661	6.807 - 7.182	
	45	7.021 - 8.200	7.141 - 8.040	7.519 - 7.796	
	50	7.746 - 8.952	7.775 - 8.760	7.922 - 8.394	
SAMPLE SIZE =	55	8.223 - 9.794	8.316 - 9.704	8.668 - 9.256	AEROSOL MASS
= 400	60	9.052 - 10.510	9.244 - 10.388	9.533 - 10.116	FRACTION REMAINING =
	65	9.816 - 11.363	9.930 - 10.995	10.354 - 10.676	= 0.9
	70	10.586 - 12.327	10.641 - 12.086	10.930 - 11.722	
	75	11.583 - 13.053	11.692 - 12.893	12.019 - 12.673	
	80	12.612 - 14.230	12.689 - 14.111	12.897 - 13.564	
	85	13.566 - 15.957	13.605 - 15.702	14.220 - 15.060	
	90	15.321 - 18.215	15.626 - 18.039	16.291 - 17.459	
	95	18.197 - 24.898	18.288 - 24.150	20.524 - 22.776	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 7.130	5	1.802 - 2.250	1.859 - 2.232	1.967 - 2.152	WATER FLUX =
	10	2.243 - 2.791	2.277 - 2.746	2.402 - 2.561	= 0.01 $cm^3/s\text{-}cm^2$
	15	2.647 - 3.340	2.688 - 3.283	2.866 - 3.061	
	20	3.039 - 3.818	3.199 - 3.735	3.342 - 3.653	
	25	3.636 - 4.346	3.659 - 4.251	3.769 - 4.008	
STD. DEV. =	30	3.945 - 4.633	4.005 - 4.607	4.231 - 4.492	FALL DISTANCE =
= 5.228	35	4.408 - 5.091	4.462 - 5.059	4.602 - 4.856	= 3000 cm
	40	4.710 - 5.734	4.818 - 5.537	5.004 - 5.229	
	45	5.129 - 6.203	5.160 - 6.093	5.340 - 5.914	
	50	5.740 - 6.688	5.824 - 6.611	6.032 - 6.294	
SAMPLE SIZE =	55	6.204 - 7.208	6.264 - 7.158	6.552 - 6.875	AEROSOL MASS
= 400	60	6.689 - 7.795	6.816 - 7.708	7.070 - 7.402	FRACTION REMAINING =
	65	7.242 - 8.190	7.330 - 8.124	7.597 - 7.883	= 0.5
	70	7.813 - 8.659	7.846 - 8.620	8.098 - 8.350	
	75	8.299 - 9.404	8.335 - 9.211	8.596 - 8.878	
	80	8.821 - 10.163	8.896 - 10.149	9.234 - 9.851	
	85	9.854 - 11.418	9.903 - 11.225	10.162 - 10.847	
	90	10.885 - 13.248	10.940 - 12.943	11.700 - 12.347	
	95	13.170 - 19.235	13.840 - 18.164	14.620 - 15.944	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of 95%	90%	50%	
MEAN = 5.837	5	1.585 - 1.899	1.609 - 1.874	1.703 - 1.797	WATER FLUX =
	10	1.891 - 2.357	1.938 - 2.304	2.088 - 2.160	= 0.01 $cm^3/s\text{-}cm^2$
	15	2.220 - 2.770	2.245 - 2.729	2.420 - 2.579	
	20	2.557 - 3.176	2.600 - 3.122	2.771 - 3.058	
	25	2.952 - 3.458	3.066 - 3.406	3.126 - 3.292	
STD. DEV. =	30	3.270 - 3.702	3.288 - 3.671	3.405 - 3.599	FALL DISTANCE =
= 4.187	35	3.490 - 4.103	3.566 - 4.030	4.640 - 3.879	= 3000 cm
	40	3.765 - 4.663	3.835 - 4.507	4.013 - 4.332	
	45	4.186 - 5.110	4.246 - 5.019	4.450 - 4.787	
	50	4.693 - 5.539	4.762 - 5.375	4.953 - 5.247	
SAMPLE SIZE =	55	5.132 - 5.838	5.192 - 5.811	5.311 - 5.653	AEROSOL MASS
= 400	60	5.545 - 6.211	5.591 - 6.153	5.772 - 5.970	FRACTION REMAINING =
	65	5.869 - 6.448	5.909 - 6.419	6.061 - 6.275	= 0.3
	70	6.219 - 7.057	6.239 - 7.014	6.408 - 6.617	
	75	6.530 - 7.750	6.607 - 7.669	6.998 - 7.344	
	80	7.307 - 8.573	7.351 - 8.442	7.679 - 8.105	
	85	8.117 - 9.414	8.179 - 9.325	8.561 - 9.001	
	90	9.070 - 10.773	9.208 - 10.664	9.495 - 10.258	
	95	10.759 - 15.976	11.429 - 15.125	11.821 - 13.760	

	Quantile (%)	Range for λ(hr^{-1}) at a confidence level of 95%	90%	50%	
MEAN = 4.182	5	1.065 - 1.446	1.124 - 1.439	1.196 - 1.379	WATER FLUX = = 0.01 cm^3/s-cm^2
	10	1.442 - 1.690	1.465 - 1.678	1.545 - 1.635	
	15	1.653 - 1.986	1.667 - 1.964	1.732 - 1.834	
	20	1.830 - 2.188	1.860 - 2.172	1.987 - 2.106	
	25	2.092 - 2.347	2.108 - 2.341	2.177 - 2.264	
STD. DEV. = = 3.001	30	2.220 - 2.672	2.251 - 2.620	2.336 - 2.453	FALL DISTANCE = = 3000 cm
	35	2.390 - 2.945	2.431 - 2.922	2.597 - 2.744	
	40	2.708 - 3.174	2.726 - 3.149	2.847 - 3.051	
	45	2.984 - 3.465	3.021 - 3.438	3.131 - 3.240	
	50	3.200 - 3.712	3.214 - 3.682	3.348 - 3.545	
SAMPLE SIZE = = 400	55	3.476 - 4.022	3.523 - 3.968	3.648 - 3.803	AEROSOL MASS FRACTION REMAINING = = 0.1
	60	3.722 - 4.423	3.782 - 4.351	3.935 - 4.183	
	65	4.029 - 4.623	4.117 - 4.559	4.320 - 4.454	
	70	4.437 - 5.060	4.449 - 4.992	4.526 - 4.828	
	75	4.702 - 5.525	4.819 - 5.491	4.967 - 5.276	
	80	5.215 - 6.168	5.286 - 6.138	5.503 - 5.858	
	85	5.862 - 7.015	5.907 - 6.831	6.166 - 6.661	
	90	6.688 - 8.258	6.760 - 7.983	7.159 - 7.492	
	95	8.182 - 12.530	8.449 - 12.466	9.564 - 10.408	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 2.664	5	0.651 - 0.884	0.688 - 0.880	0.797 - 0.850	WATER FLUX =
	10	0.884 - 1.057	0.898 - 1.050	0.966 - 1.012	= 0.01 $cm^3/s\text{-}cm^2$
	15	1.035 - 1.208	1.044 - 1.202	1.090 - 1.133	
	20	1.132 - 1.374	1.171 - 1.342	1.208 - 1.266	
	25	1.254 - 1.475	1.268 - 1.468	1.347 - 1.420	
STD. DEV. =	30	1.395 - 1.611	1.416 - 1.604	1.465 - 1.532	FALL DISTANCE =
= 1.994	35	1.489 - 1.710	1.526 - 1.701	1.596 - 1.655	= 3000 cm
	40	1.634 - 1.869	1.648 - 1.808	1.689 - 1.760	
	45	1.715 - 2.066	1.728 - 2.005	1.793 - 1.896	
	50	1.872 - 2.184	1.889 - 2.168	1.985 - 2.102	
SAMPLE SIZE =	55	2.070 - 2.485	2.077 - 2.407	2.158 - 2.311	AEROSOL MASS
= 400	60	2.191 - 2.673	2.236 - 2.642	2.369 - 2.546	FRACTION REMAINING =
	65	2.492 - 3.000	2.525 - 2.938	2.588 - 2.775	= 0.01
	70	2.701 - 3.260	2.755 - 3.236	2.880 - 3.142	
	75	3.095 - 3.534	3.140 - 3.519	3.223 - 3.393	
	80	3.377 - 3.920	3.399 - 3.902	3.524 - 3.717	
	85	3.721 - 4.600	3.763 - 4.534	3.918 - 4.390	
	90	4.486 - 6.148	4.499 - 5.625	4.813 - 5.331	
	95	5.966 - 8.378	6.340 - 8.246	6.839 - 7.656	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of 95%	90%	50%	
MEAN = 2.082	5	0.510 - 0.686	0.555 - 0.662	0.605 - 0.640	WATER FLUX = = 0.01 $cm^3/s\text{-}cm^2$
	10	0.676 - 0.824	0.703 - 0.812	0.725 - 0.785	
	15	0.803 - 0.931	0.809 - 0.922	0.848 - 0.888	
	20	0.888 - 1.048	0.898 - 1.040	0.931 - 0.980	
	25	0.976 - 1.142	0.989 - 1.136	1.044 - 1.068	
STD. DEV. = = 1.597	30	1.058 - 1.234	1.066 - 1.229	1.133 - 1.177	FALL DISTANCE = = 3000 cm
	35	1.162 - 1.311	1.171 - 1.292	1.222 - 1.264	
	40	1.239 - 1.415	1.247 - 1.410	1.283 - 1.360	
	45	1.322 - 1.542	1.349 - 1.534	1.390 - 1.468	
	50	1.422 - 1.691	1.430 - 1.672	1.494 - 1.599	
SAMPLE SIZE = = 400	55	1.546 - 1.859	1.587 - 1.827	1.649 - 1.760	AEROSOL MASS FRACTION REMAINING = = 0.001
	60	1.696 - 2.088	1.735 - 2.069	1.789 - 1.960	
	65	1.904 - 2.307	1.937 - 2.257	2.059 - 2.147	
	70	2.096 - 2.598	2.126 - 2.564	2.251 - 2.363	
	75	2.328 - 2.748	2.355 - 2.714	2.536 - 2.655	
	80	2.625 - 3.217	2.669 - 3.167	2.720 - 2.930	
	85	2.937 - 3.798	3.053 - 3.769	3.216 - 3.440	
	90	3.591 - 5.078	3.681 - 4.605	3.847 - 4.298	
	95	4.911 - 6.745	5.153 - 6.680	5.368 - 5.855	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 9.476	5	2.020 - 2.659	2.109 - 2.647	2.427 - 2.591	WATER FLUX =
	10	2.654 - 3.320	2.695 - 3.282	2.854 - 3.106	= 0.01 $cm^3/s\text{-}cm^2$
	15	3.135 - 4.165	3.228 - 4.111	3.518 - 3.955	
	20	3.952 - 4.994	4.030 - 4.870	4.166 - 4.468	
	25	4.365 - 5.662	4.489 - 5.530	4.945 - 5.207	
STD. DEV. =	30	5.177 - 6.272	5.204 - 6.131	5.496 - 5.836	FALL DISTANCE =
= 7.358	35	5.738 - 6.743	5.806 - 6.682	6.027 - 6.452	= 4000 cm
	40	6.325 - 7.348	6.379 - 7.297	6.642 - 7.068	
	45	6.776 - 7.824	6.936 - 7.745	7.199 - 7.512	
	50	7.350 - 8.667	7.426 - 8.535	7.698 - 8.148	
SAMPLE SIZE =	55	7.864 - 9.467	7.942 - 9.339	8.333 - 9.020	AEROSOL MASS
= 400	60	8.678 - 10.280	8.833 - 10.189	9.244 - 9.899	FRACTION REMAINING =
	65	9.508 - 10.923	9.650 - 10.872	10.168 - 10.498	= 0.9
	70	10.364 - 12.094	10.450 - 11.820	10.855 - 11.365	
	75	11.220 - 12.680	11.318 - 12.624	11.751 - 12.382	
	80	12.331 - 13.737	12.450 - 13.531	12.636 - 13.010	
	85	13.034 - 15.875	13.238 - 15.274	13.711 - 14.725	
	90	14.976 - 17.559	15.166 - 17.419	16.019 - 17.087	
	95	17.546 - 24.641	17.568 - 23.566	19.497 - 21.952	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of 95%	90%	50%	
MEAN = 6.958	5	1.783 - 2.206	1.829 - 2.192	1.918 - 2.124	WATER FLUX =
	10	2.206 - 2.774	2.227 - 2.720	2.315 - 2.509	= 0.01 $cm^3/s\text{-}cm^2$
	15	2.532 - 3.298	2.606 - 3.223	2.781 - 3.045	
	20	3.043 - 3.685	3.077 - 3.652	3.311 - 3.586	
	25	3.538 - 4.180	3.587 - 4.113	3.660 - 3.948	
STD. DEV. =	30	3.856 - 4.592	3.922 - 4.537	4.068 - 4.366	FALL DISTANCE =
= 5.108	35	4.265 - 4.945	4.336 - 4.826	4.528 - 4.679	= 4000 cm
	40	4.622 - 5.540	4.647 - 5.351	4.814 - 5.122	
	45	4.979 - 6.020	5.051 - 5.957	5.277 - 5.749	
	50	5.569 - 6.502	5.704 - 6.384	5.914 - 6.229	
SAMPLE SIZE =	55	6.038 - 6.940	6.128 - 6.865	6.353 - 6.617	AEROSOL MASS
= 400	60	6.508 - 7.530	6.577 - 7.441	6.804 - 7.258	FRACTION REMAINING =
	65	7.146 - 8.062	7.195 - 7.990	7.382 - 7.760	= 0.5
	70	7.676 - 8.464	7.738 - 8.435	7.959 - 8.262	
	75	8.226 - 9.171	8.255 - 9.064	8.420 - 8.799	
	80	8.702 - 10.091	8.825 - 9.992	9.072 - 9.433	
	85	9.438 - 11.159	9.620 - 11.117	10.089 - 10.495	
	90	10.663 - 13.139	10.879 - 12.889	11.206 - 12.000	
	95	13.064 - 18.066	13.417 - 17.117	14.538 - 15.475	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 5.674	5	1.526 - 1.854	1.574 - 1.814	1.672 - 1.732	WATER FLUX =
	10	1.851 - 2.232	1.900 - 2.182	1.967 - 2.123	= 0.01 $cm^3/s\text{-}cm^2$
	15	2.141 - 2.672	2.147 - 2.646	2.296 - 2.492	
	20	2.491 - 3.081	2.508 - 3.070	2.676 - 2.895	
	25	2.848 - 3.340	2.904 - 3.285	3.075 - 3.188	
STD. DEV. =	30	3.114 - 3.629	3.166 - 3.587	3.283 - 3.440	FALL DISTANCE =
= 4.106	35	3.389 - 3.935	3.426 - 3.878	3.555 - 3.737	= 4000 cm
	40	3.662 - 4.434	3.697 - 4.381	3.830 - 4.173	
	45	3.971 - 4.943	4.085 - 4.797	4.308 - 4.634	
	50	4.471 - 5.278	4.498 - 5.245	4.757 - 5.060	
SAMPLE SIZE =	55	4.948 - 5.709	4.980 - 5.603	5.180 - 5.481	AEROSOL MASS
= 400	60	5.351 - 5.973	5.382 - 5.958	5.525 - 5.798	FRACTION REMAINING =
	65	5.715 - 6.328	5.782 - 6.240	5.924 - 6.060	= 0.3
	70	6.004 - 6.991	6.047 - 6.921	6.227 - 6.447	
	75	6.372 - 7.366	6.438 - 7.317	6.910 - 7.194	
	80	7.157 - 8.515	7.210 - 8.214	7.323 - 7.778	
	85	7.787 - 9.132	8.020 - 9.011	8.487 - 8.921	
	90	8.955 - 10.685	8.980 - 10.431	9.284 - 9.854	
	95	10.675 - 15.031	10.908 - 14.381	11.653 - 13.363	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 4.071	5	1.049 - 1.438	1.084 - 1.430	1.145 - 1.321	WATER FLUX =
	10	1.436 - 1.635	1.459 - 1.628	1.502 - 1.580	= 0.01 $cm^3/s\text{-}cm^2$
	15	1.591 - 1.922	1.604 - 1.888	1.659 - 1.815	
	20	1.813 - 2.102	1.832 - 2.089	1.927 - 2.016	
	25	2.008 - 2.327	2.022 - 2.315	2.092 - 2.186	
STD. DEV. =	30	2.154 - 2.552	2.178 - 2.523	2.283 - 2.444	FALL DISTANCE =
= 2.939	35	2.370 - 2.828	2.415 - 2.784	2.511 - 2.687	= 4000 cm
	40	2.592 - 3.102	2.668 - 3.064	2.763 - 2.960	
	45	2.845 - 3.289	2.922 - 3.261	3.043 - 3.180	
	50	3.109 - 3.655	3.134 - 3.612	3.236 - 3.469	
SAMPLE SIZE =	55	3.299 - 3.931	3.324 - 3.885	3.546 - 3.735	AEROSOL MASS
= 400	60	3.681 - 4.211	3.699 - 4.180	3.816 - 4.035	FRACTION REMAINING =
	65	3.947 - 4.460	3.988 - 4.450	4.142 - 4.368	= 0.1
	70	4.261 - 4.928	4.319 - 4.886	4.440 - 4.712	
	75	4.563 - 5.411	4.665 - 5.329	4.857 - 5.095	
	80	5.080 - 6.004	5.119 - 5.887	5.353 - 5.590	
	85	5.593 - 6.801	5.688 - 6.713	5.996 - 6.428	
	90	6.614 - 7.973	6.644 - 7.834	7.101 - 7.440	
	95	7.960 - 11.831	8.058 - 11.637	9.185 - 10.158	

	Quantile (%)	Range for λ(hr^{-1}) at a confidence level of 95%	90%	50%	
MEAN = 2.591	5	0.627 - 0.853	0.663 - 0.848	0.761 - 0.804	WATER FLUX =
	10	0.852 - 1.048	0.877 - 1.014	0.945 - 0.994	= 0.01 $cm^3/s\text{-}cm^2$
	15	0.999 - 1.174	1.005 - 1.143	1.057 - 1.120	
	20	1.120 - 1.324	1.123 - 1.313	1.174 - 1.238	
	25	1.219 - 1.419	1.249 - 1.417	1.315 - 1.376	
STD. DEV. =	30	1.368 - 1.563	1.372 - 1.547	1.416 - 1.486	FALL DISTANCE =
= 1.955	35	1.450 - 1.637	1.462 - 1.620	1.542 - 1.603	= 4000 cm
	40	1.588 - 1.803	1.598 - 1.780	1.618 - 1.706	
	45	1.648 - 1.978	1.687 - 1.970	1.768 - 1.872	
	50	1.805 - 2.153	1.827 - 2.142	1.922 - 2.045	
SAMPLE SIZE =	55	1.984 - 2.394	2.032 - 2.349	2.088 - 2.219	AEROSOL MASS
= 400	60	2.158 - 2.559	2.193 - 2.545	2.318 - 2.478	FRACTION REMAINING =
	65	2.402 - 2.905	2.460 - 2.833	2.531 - 2.679	= 0.01
	70	2.601 - 3.193	2.642 - 3.162	2.801 - 3.052	
	75	2.998 - 3.452	3.039 - 3.370	3.143 - 3.253	
	80	3.231 - 3.817	3.283 - 3.747	3.379 - 3.680	
	85	3.686 - 4.516	3.698 - 4.465	3.809 - 4.347	
	90	4.384 - 5.940	4.420 - 5.650	4.713 - 5.193	
	95	5.836 - 8.009	6.188 - 7.797	6.668 - 7.527	

	Quantile (%)	Range for $\lambda (hr^{-1})$ at a confidence level of 95%	90%	50%	
MEAN = 2.026	5	0.491 - 0.670	0.525 - 0.658	0.577 - 0.623	WATER FLUX =
	10	0.670 - 0.805	0.672 - 0.778	0.699 - 0.748	= 0.01 $cm^3/s\text{-}cm^2$
	15	0.756 - 0.911	0.773 - 0.890	0.821 - 0.868	
	20	0.867 - 1.002	0.876 - 0.989	0.911 - 0.964	
	25	0.950 - 1.105	0.966 - 1.085	0.991 - 1.046	
STD. DEV. =	30	1.025 - 1.196	1.043 - 1.170	1.073 - 1.138	FALL DISTANCE =
= 1.566	35	1.126 - 1.278	1.136 - 1.274	1.164 - 1.233	= 4000 cm
	40	1.208 - 1.383	1.227 - 1.359	1.269 - 1.315	
	45	1.286 - 1.529	1.302 - 1.498	1.339 - 1.408	
	50	1.387 - 1.662	1.404 - 1.643	1.484 - 1.577	
SAMPLE SIZE =	55	1.533 - 1.819	1.540 - 1.797	1.614 - 1.715	AEROSOL MASS
= 400	60	1.668 - 2.019	1.684 - 2.006	1.757 - 1.942	FRACTION REMAINING =
	65	1.823 - 2.220	1.893 - 2.182	1.994 - 2.094	= 0.001
	70	2.049 - 2.503	2.074 - 2.490	2.160 - 2.327	
	75	2.301 - 2.659	2.319 - 2.657	2.487 - 2.598	
	80	2.586 - 3.078	2.602 - 3.062	2.657 - 2.800	
	85	2.804 - 3.602	2.893 - 3.578	3.078 - 3.365	
	90	3.436 - 4.804	3.515 - 4.586	3.722 - 4.252	
	95	4.735 - 6.708	4.846 - 6.644	5.307 - 5.662	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 7.215	5	1.948 - 2.589	2.040 - 2.578	2.236 - 2.496	WATER FLUX =
	10	2.586 - 3.446	2.619 - 3.295	2.894 - 3.090	= 0.01 $cm^3/s\text{-}cm^2$
	15	3.170 - 4.071	3.265 - 4.039	3.564 - 3.897	
	20	3.896 - 4.806	3.910 - 4.755	4.076 - 4.458	
	25	4.354 - 5.465	4.478 - 5.424	4.774 - 5.085	
STD. DEV. =	30	5.019 - 6.070	5.066 - 5.972	5.415 - 5.698	FALL DISTANCE =
= 9.247	35	5.516 - 6.641	5.646 - 6.582	5.899 - 6.312	= 5000 cm
	40	6.203 - 7.070	6.289 - 7.055	6.547 - 6.888	
	45	6.704 - 7.715	6.815 - 7.658	7.008 - 7.274	
	50	7.078 - 8.476	7.167 - 8.286	7.500 - 7.892	
SAMPLE SIZE =	55	7.721 - 9.422	7.828 - 9.204	8.192 - 8.859	AEROSOL MASS
= 400	60	8.509 - 10.192	8.634 - 10.130	9.127 - 9.638	FRACTION REMAINING =
	65	9.461 - 10.704	9.538 - 10.612	10.017 - 10.389	= 0.9
	70	10.273 - 11.708	10.332 - 11.628	10.563 - 11.210	
	75	10.828 - 12.503	11.151 - 12.404	11.617 - 12.043	
	80	12.018 - 13.509	12.051 - 13.292	12.417 - 12.725	
	85	12.733 - 15.520	12.766 - 15.200	13.476 - 14.373	
	90	14.904 - 17.385	15.088 - 17.299	15.740 - 16.511	
	95	17.366 - 24.322	17.477 - 23.405	18.850 - 21.430	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 6.793	5	1.733 - 2.149	1.778 - 2.136	1.886 - 2.066	WATER FLUX =
	10	2.142 - 2.654	2.171 - 2.615	2.211 - 2.409	= 0.01 $cm^3/s\text{-}cm^2$
	15	2.489 - 3.260	2.540 - 3.187	2.713 - 2.944	
	20	2.942 - 3.639	2.971 - 3.605	3.267 - 3.449	
	25	3.406 - 3.992	3.452 - 3.940	3.608 - 3.807	
STD. DEV. =	30	3.721 - 4.445	3.800 - 4.416	3.937 - 4.259	FALL DISTANCE =
= 5.017	35	4.103 - 4.778	4.210 - 4.696	4.400 - 4.587	= 5000 cm
	40	4.503 - 4.778	4.550 - 5.249	4.671 - 5.026	
	45	4.831 - 5.279	4.952 - 5.854	5.168 - 5.556	
	50	5.390 - 6.250	5.491 - 6.192	5.671 - 6.042	
SAMPLE SIZE =	55	5.914 - 6.841	5.977 - 6.755	6.148 - 6.447	AEROSOL MASS
= 400	60	6.288 - 7.375	6.380 - 7.310	6.602 - 6.950	FRACTION REMAINING =
	65	6.860 - 7.913	6.903 - 7.866	7.223 - 7.622	= 0.5
	70	7.432 - 8.420	7.513 - 8.366	7.823 - 8.124	
	75	7.991 - 8.969	8.081 - 8.954	8.326 - 8.622	
	80	8.586 - 9.908	8.641 - 9.693	8.963 - 9.193	
	85	9.217 - 10.798	9.349 - 10.714	9.881 - 10.446	
	90	10.545 - 12.824	10.600 - 12.647	10.967 - 11.678	
	95	12.792 - 17.104	12.888 - 16.628	14.287 - 15.135	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 5.545	5	1.470 - 1.813	1.512 - 1.780	1.618 - 1.705	WATER FLUX =
	10	1.811 - 2.213	1.824 - 2.150	1.910 - 2.074	= 0.01 $cm^3/s\text{-}cm^2$
	15	2.098 - 2.636	2.137 - 2.561	2.225 - 2.475	
	20	2.474 - 2.991	2.492 - 2.939	2.652 - 2.779	
	25	2.760 - 3.259	2.789 - 3.216	2.951 - 3.084	
STD. DEV. =	30	3.069 - 3.563	3.079 - 3.528	3.215 - 3.365	FALL DISTANCE =
= 4.027	35	3.309 - 3.876	3.349 - 3.813	3.500 - 3.655	= 5000 cm
	40	3.584 - 4.346	3.610 - 4.280	3.746 - 4.141	
	45	3.920 - 4.749	4.020 - 4.717	4.249 - 4.469	
	50	4.362 - 5.170	4.436 - 5.124	4.687 - 4.936	
SAMPLE SIZE =	55	4.796 - 5.555	4.868 - 5.489	5.088 - 5.286	AEROSOL MASS
= 400	60	5.212 - 5.827	5.240 - 5.762	5.465 - 5.687	FRACTION REMAINING =
	65	5.562 - 6.288	5.661 - 6.148	5.748 - 5.928	= 0.3
	70	5.894 - 6.835	5.926 - 6.742	6.110 - 6.398	
	75	6.339 - 7.262	6.374 - 7.208	6.717 - 6.980	
	80	6.963 - 8.296	6.990 - 8.048	7.217 - 7.668	
	85	7.681 - 8.934	7.822 - 8.908	8.266 - 8.618	
	90	8.836 - 10.464	8.868 - 10.371	9.058 - 9.752	
	95	10.454 - 14.467	10.487 - 13.912	11.597 - 13.301	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of 95%	90%	50%	
MEAN = 3.972	5	1.035 - 1.424	1.048 - 1.388	1.124 - 1.250	WATER FLUX =
	10	1.424 - 1.587	1.430 - 1.581	1.458 - 1.517	= 0.01 $cm^3/s\text{-}cm^2$
	15	1.540 - 1.854	1.577 - 1.842	1.615 - 1.774	
	20	1.774 - 2.029	1.814 - 2.002	1.855 - 1.960	
	25	1.943 - 2.296	1.962 - 2.251	2.009 - 2.136	
STD. DEV. =	30	2.092 - 2.484	2.122 - 2.441	2.247 - 2.370	FALL DISTANCE =
= 2.893	35	2.323 - 2.721	2.361 - 2.688	2.423 - 2.563	= 5000 cm
	40	2.521 - 3.037	2.548 - 2.963	2.677 - 2.801	
	45	2.744 - 3.208	2.777 - 3.154	2.940 - 3.082	
	50	3.043 - 3.559	3.063 - 3.529	3.131 - 3.292	
SAMPLE SIZE =	55	3.228 - 3.805	3.257 - 3.795	3.514 - 3.660	AEROSOL MASS
= 400	60	3.571 - 4.075	3.617 - 4.022	3.734 - 3.907	FRACTION REMAINING =
	65	3.834 - 4.435	3.886 - 4.401	3.977 - 4.225	= 0.1
	70	4.109 - 4.823	4.191 - 4.791	4.392 - 4.547	
	75	4.490 - 5.220	4.532 - 5.188	4.772 - 4.991	
	80	4.975 - 5.910	5.014 - 5.761	5.191 - 5.471	
	85	5.474 - 6.722	5.570 - 6.627	5.897 - 6.287	
	90	6.461 - 7.810	6.590 - 7.649	7.078 - 7.357	
	95	7.792 - 11.381	7.926 - 11.168	8.978 - 10.100	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 2.530	5	0.604 - 0.846	0.642 - 0.802	0.727 - 0.768	WATER FLUX =
	10	0.846 - 1.016	0.850 - 0.995	0.902 - 0.961	= 0.01 $cm^3/s\text{-}cm^2$
	15	0.983 - 1.125	0.993 - 1.121	1.042 - 1.080	
	20	1.080 - 1.298	1.088 - 1.269	1.126 - 1.211	
	25	1.195 - 1.383	1.215 - 1.368	1.285 - 1.328	
STD. DEV. =	30	1.311 - 1.506	1.327 - 1.486	1.366 - 1.448	FALL DISTANCE =
= 1.924	35	1.421 - 1.600	1.440 - 1.581	1.475 - 1.534	= 5000 cm
	40	1.523 - 1.766	1.528 - 1.741	1.553 - 1.683	
	45	1.609 - 1.931	1.644 - 1.881	1.733 - 1.814	
	50	1.772 - 2.108	1.795 - 2.092	1.872 - 2.007	
SAMPLE SIZE =	55	1.936 - 2.332	1.964 - 2.294	2.066 - 2.162	AEROSOL MASS
= 400	60	2.117 - 2.513	2.142 - 2.482	2.261 - 2.391	FRACTION REMAINING =
	65	2.341 - 2.838	2.371 - 2.783	2.461 - 2.582	= 0.01
	70	2.534 - 3.109	2.558 - 3.069	2.737 - 2.947	
	75	2.880 - 3.363	2.939 - 3.324	3.047 - 3.173	
	80	3.161 - 3.740	3.178 - 3.695	3.338 - 3.532	
	85	3.536 - 4.446	3.563 - 4.435	3.739 - 4.296	
	90	4.340 - 5.664	4.388 - 5.611	4.581 - 5.166	
	95	5.638 - 7.681	5.962 - 7.607	6.471 - 7.198	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 1.977	5	0.479 - 0.646	0.505 - 0.637	0.552 - 0.607	WATER FLUX =
	10	0.644 - 0.765	0.651 - 0.741	0.694 - 0.720	= 0.01 $cm^3/s\text{-}cm^2$
	15	0.738 - 0.888	0.740 - 0.876	0.802 - 0.850	
	20	0.850 - 0.965	0.855 - 0.960	0.888 - 0.938	
	25	0.931 - 1.054	0.938 - 1.047	0.962 - 1.016	
STD. DEV. =	30	0.997 - 1.163	1.011 - 1.136	1.046 - 1.098	FALL DISTANCE =
= 1.541	35	1.071 - 1.259	1.093 - 1.246	1.130 - 1.205	= 5000 cm
	40	1.183 - 1.333	1.202 - 1.314	1.230 - 1.270	
	45	1.262 - 1.474	1.267 - 1.457	1.302 - 1.387	
	50	1.335 - 1.612	1.348 - 1.600	1.428 - 1.536	
SAMPLE SIZE =	55	1.485 - 1.758	1.520 - 1.743	1.575 - 1.668	AEROSOL MASS
= 400	60	1.626 - 1.973	1.641 - 1.924	1.723 - 1.847	FRACTION REMAINING =
	65	1.792 - 2.151	1.823 - 2.105	1.911 - 2.028	= 0.001
	70	1.995 - 2.442	2.014 - 2.372	2.081 - 2.281	
	75	2.209 - 2.624	2.277 - 2.586	2.363 - 2.521	
	80	2.496 - 3.065	2.526 - 3.050	2.588 - 2.718	
	85	2.731 - 3.557	2.862 - 3.456	3.063 - 3.335	
	90	3.385 - 4.590	3.404 - 4.565	3.733 - 4.218	
	95	4.581 - 6.624	4.607 - 6.557	5.285 - 5.516	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of 95%	90%	50%	
MEAN = 179.373	5	42.275 - 54.420	42.841 - 54.320	44.552 - 51.580	WATER FLUX =
	10	54.326 - 62.650	54.533 - 61.904	56.655 - 59.630	= 0.25 $cm^3/s\text{-}cm^2$
	15	60.106 - 80.544	60.426 - 79.700	63.180 - 75.151	
	20	74.830 - 88.356	76.214 - 87.602	80.504 - 85.783	
	25	85.155 - 96.986	85.720 - 96.555	87.574 - 92.811	
STD. DEV. =	30	90.902 - 110.376	92.727 - 108.186	95.443 - 101.244	FALL DISTANCE =
= 121.228	35	97.854 - 125.942	99.912 - 122.281	107.115 - 114.005	= 500 cm
	40	111.136 - 135.726	111.912 - 133.949	116.361 - 129.597	
	45	125.814 - 150.031	126.751 - 148.549	132.704 - 141.580	
	50	135.278 - 166.429	136.196 - 165.840	144.302 - 158.520	
SAMPLE SIZE =	55	148.858 - 184.184	153.727 - 181.451	161.844 - 170.938	AEROSOL MASS
= 360	60	166.326 - 202.022	166.733 - 199.098	176.866 - 188.765	FRACTION REMAINING =
	65	184.023 - 214.980	186.118 - 213.849	195.213 - 206.437	= 0.9
	70	202.907 - 228.962	204.920 - 227.891	211.865 - 224.063	
	75	216.793 - 254.651	221.382 - 244.374	226.980 - 236.431	
	80	233.937 - 288.557	236.359 - 286.482	243.209 - 269.213	
	85	268.166 - 335.392	270.539 - 332.591	286.750 - 306.754	
	90	317.443 - 371.867	318.316 - 366.868	337.071 - 351.954	
	95	368.378 - 432.396	372.560 - 421.307	386.817 - 404.523	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 130.703	5	32.831 - 41.964	33.631 - 41.000	36.007 - 38.339	WATER FLUX =
	10	41.125 - 50.918	42.350 - 50.506	45.062 - 48.465	= 0.25 $cm^3/s\text{-}cm^2$
	15	48.646 - 57.109	49.376 - 56.569	51.111 - 54.283	
	20	53.785 - 67.815	54.411 - 66.067	56.939 - 62.190	
	25	60.456 - 75.886	61.891 - 74.316	66.062 - 71.458	
STD. DEV. =	30	69.986 - 83.194	70.785 - 81.162	73.470 - 79.521	FALL DISTANCE =
= 86.165	35	77.591 - 92.204	78.802 - 90.792	80.507 - 85.928	= 500 cm
	40	83.364 - 104.720	84.632 - 103.109	87.666 - 96.501	
	45	92.190 - 116.282	94.455 - 114.337	100.068 - 107.736	
	50	104.072 - 122.165	105.311 - 120.884	109.629 - 118.793	
SAMPLE SIZE =	55	115.861 - 130.754	116.562 - 129.150	120.502 - 123.320	AEROSOL MASS
= 360	60	121.599 - 144.965	122.580 - 143.602	127.317 - 137.904	FRACTION REMAINING =
	65	130.471 - 156.130	132.384 - 152.600	142.111 - 146.777	= 0.5
	70	145.201 - 168.198	146.080 - 164.669	150.093 - 158.149	
	75	156.682 - 179.889	156.952 - 178.154	162.452 - 172.345	
	80	170.658 - 200.165	172.125 - 198.296	178.070 - 191.294	
	85	189.754 - 231.724	192.274 - 221.914	199.393 - 211.822	
	90	213.620 - 261.032	218.596 - 258.747	233.888 - 252.187	
	95	259.433 - 324.108	261.049 - 322.959	272.787 - 302.453	

	Quantile (%)	Range for λ(hr^{-1}) at a confidence level of 95%	90%	50%	
MEAN = 106.332	5	25.414 - 35.517	25.918 - 34.609	29.597 - 32.497	WATER FLUX = = 0.25 $cm^3/s\text{-}cm^2$
	10	34.689 - 41.054	35.565 - 40.670	37.665 - 39.668	
	15	39.976 - 46.437	40.081 - 46.205	41.755 - 43.814	
	20	43.417 - 54.347	44.263 - 53.568	46.429 - 49.715	
	25	48.849 - 62.786	49.660 - 61.562	53.504 - 58.068	
STD. DEV. = = 69.432	30	57.335 - 69.889	57.967 - 69.484	61.015 - 65.536	FALL DISTANCE = = 500 cm
	35	63.505 - 76.328	64.958 - 75.314	67.830 - 72.060	
	40	69.948 - 85.143	70.682 - 84.650	74.485 - 80.154	
	45	76.203 - 90.411	77.412 - 90.044	82.563 - 87.352	
	50	84.813 - 100.684	85.722 - 99.404	89.046 - 93.558	
SAMPLE SIZE = = 360	55	90.093 - 108.721	90.486 - 107.047	97.194 - 103.749	AEROSOL MASS FRACTION REMAINING = = 0.3
	60	100.219 - 118.435	101.110 - 116.913	105.934 - 111.472	
	65	108.716 - 124.977	110.354 - 123.881	113.693 - 120.304	
	70	118.545 - 134.183	120.038 - 131.378	122.239 - 126.792	
	75	125.709 - 147.408	126.639 - 145.935	129.389 - 137.994	
	80	135.219 - 161.380	137.892 - 160.363	145.613 - 152.929	
	85	152.782 - 184.923	154.204 - 183.892	160.736 - 177.853	
	90	179.446 - 216.876	182.084 - 207.701	186.076 - 198.985	
	95	208.222 - 275.805	217.053 - 258.056	227.611 - 246.574	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 75.936	5	17.121 - 23.187	17.241 - 23.012	19.487 - 21.118	WATER FLUX =
	10	23.053 - 29.490	23.445 - 29.328	25.001 - 27.915	= 0.25 $cm^3/s\text{-}cm^2$
	15	28.257 - 33.165	28.376 - 32.827	29.825 - 31.719	
	20	31.644 - 39.051	32.033 - 38.676	33.100 - 36.195	
	25	35.351 - 44.312	35.891 - 43.992	38.628 - 41.075	
STD. DEV. =	30	39.668 - 49.758	40.885 - 48.960	43.340 - 46.880	FALL DISTANCE =
= 51.273	35	44.626 - 52.945	46.021 - 52.135	48.576 - 50.919	= 500 cm
	40	49.834 - 59.236	50.084 - 58.091	51.819 - 55.007	
	45	52.627 - 64.666	53.968 - 64.106	56.885 - 61.116	
	50	58.631 - 70.906	59.747 - 69.146	63.361 - 65.174	
SAMPLE SIZE =	55	64.363 - 76.744	64.888 - 75.368	67.083 - 72.548	AEROSOL MASS
= 360	60	70.089 - 84.541	71.723 - 83.306	74.478 - 78.471	FRACTION REMAINING =
	65	76.596 - 91.373	78.160 - 89.588	82.668 - 86.675	= 0.1
	70	84.937 - 96.711	85.686 - 95.683	89.119 - 93.488	
	75	92.038 - 103.152	92.316 - 101.492	95.348 - 98.624	
	80	97.478 - 114.777	98.511 - 112.557	101.409 - 108.345	
	85	107.796 - 136.532	108.594 - 133.713	112.738 - 120.299	
	90	121.091 - 162.157	130.062 - 156.260	138.260 - 145.994	
	95	156.537 - 203.318	162.200 - 194.298	166.840 - 181.878	

	Quantile (%)	Range for λ(hr^{-1}) at a confidence level of			
		95%	90%	50%	
MEAN = 47.779	5	10.299 - 13.328	10.385 - 12.452	10.912 - 11.594	WATER FLUX =
	10	12.495 - 17.485	13.461 - 17.325	15.100 - 16.514	= 0.25 $cm^3/s\text{-}cm^2$
	15	16.601 - 21.587	16.815 - 20.989	17.913 - 19.525	
	20	19.414 - 23.709	19.710 - 23.328	21.362 - 22.598	
	25	22.101 - 26.273	22.536 - 25.766	23.280 - 24.396	
STD. DEV. =	30	23.960 - 29.424	24.189 - 28.642	25.733 - 27.590	FALL DISTANCE =
= 35.133	35	26.784 - 32.678	27.146 - 32.515	28.359 - 31.105	= 500 cm
	40	29.652 - 35.054	30.634 - 34.813	31.988 - 33.121	
	45	32.592 - 39.156	32.860 - 38.419	33.832 - 36.708	
	50	34.941 - 43.034	35.223 - 42.333	37.780 - 40.456	
SAMPLE SIZE =	55	38.868 - 47.938	39.480 - 47.246	41.767 - 44.434	AEROSOL MASS
= 360	60	42.970 - 52.316	43.456 - 52.009	45.528 - 49.117	FRACTION REMAINING =
	65	47.894 - 56.473	48.680 - 55.641	51.134 - 53.726	= 0.01
	70	52.497 - 60.636	53.445 - 60.215	55.418 - 57.903	
	75	56.641 - 66.377	57.450 - 65.007	60.153 - 63.164	
	80	62.434 - 71.906	63.123 - 70.592	64.894 - 69.110	
	85	68.944 - 83.522	69.360 - 81.999	71.635 - 76.639	
	90	79.985 - 102.424	80.724 - 98.823	84.065 - 94.184	
	95	98.849 - 133.719	102.628 - 132.216	106.318 - 120.545	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of 95%	90%	50%	
MEAN = 39.459	5	7.479 - 10.051	7.768 - 9.315	8.064 - 8.463	WATER FLUX =
	10	9.348 - 13.313	10.162 - 13.121	11.382 - 12.578	= 0.25 $cm^3/s\text{-}cm^2$
	15	12.599 - 15.776	12.758 - 15.710	13.390 - 14.859	
	20	14.710 - 17.974	14.969 - 17.480	15.755 - 17.024	
	25	16.737 - 20.044	17.006 - 19.660	17.464 - 18.686	
STD. DEV. =	30	18,357 - 22.297	18.577 - 22.057	19.492 - 21.049	FALL DISTANCE =
= 44.391	35	20.181 - 24.869	20.567 - 24.729	21.603 - 23.526	= 500 cm
	40	22.484 - 27.517	23.109 - 26.954	24.672 - 25.511	
	45	24.837 - 30.068	25.090 - 29.840	26.066 - 28.924	
	50	27.455 - 32.748	28.243 - 32.450	29.481 - 30.926	
SAMPLE SIZE =	55	30.026 - 36.699	30.513 - 36.355	32.087 - 33.683	AEROSOL MASS
= 360	60	32.564 - 40.308	33.038 - 40.056	35.105 - 38.289	FRACTION REMAINING =
	65	36.685 - 43.672	37.292 - 43.092	39.569 - 41.168	= 0.001
	70	40.396 - 48.614	40.695 - 47.420	42.655 - 45.560	
	75	44.780 - 53.293	45.198 - 52.246	46.787 - 49.831	
	80	49.364 - 58.028	49.791 - 57.294	52.070 - 54.479	
	85	54.239 - 67.176	56.162 - 65.009	57.680 - 61.506	
	90	62.344 - 79.268	63.224 - 78.441	68.339 - 76.863	
	95	78.631 - 118.879	79.405 - 115.399	88.117 - 104.330	

	Quantile (%)	Range for λ(hr^{-1}) at a confidence level of			
		95%	90%	50%	
MEAN = 162.608	5	38.875 - 46.008	36.773 - 45.946	39.087 - 43.357	WATER FLUX =
	10	45.946 - 53.962	46.143 - 52.854	48.098 - 49.726	= 0.25 $cm^3/s\text{-}cm^2$
	15	50.518 - 68.012	51.146 - 66.783	56.979 - 64.080	
	20	63.734 - 73.124	64.786 - 72.570	67.751 - 69.694	
	25	69.086 - 81.865	69.635 - 81.776	72.486 - 76.183	
STD. DEV. =	30	75.430 - 91.688	76.154 - 90.239	80.929 - 85.074	FALL DISTANCE =
= 117.010	35	83.398 - 104.663	83.958 - 102.013	89.822 - 93.735	= 853 cm
	40	91.816 - 117.592	92.530 - 115.915	101.273 - 110.137	
	45	104.337 - 131.233	106.949 - 129.843	113.169 - 122.867	
	50	117.444 - 154.228	119.650 - 150.400	128.227 - 138.510	
SAMPLE SIZE =	55	130.354 - 167.888	134.399 - 166.535	147.470 - 159.673	AEROSOL MASS
= 360	60	152.948 - 180.662	156.127 - 179.668	163.638 - 171.108	FRACTION REMAINING =
	65	167.834 - 198.759	170.586 - 194.933	176.591 - 185.262	= 0.9
	70	180.974 - 215.694	182.995 - 214.343	190.975 - 207.005	
	75	199.470 - 233.203	204.814 - 227.291	213.360 - 217.866	
	80	217.088 - 257.837	217.858 - 254.234	227.183 - 243.682	
	85	240.439 - 313.511	248.189 - 300.690	256.092 - 274.625	
	90	287.947 - 353.723	296.267 - 348.861	320.069 - 337.157	
	95	349.695 - 403.029	355.516 - 398.835	379.474 - 394.194	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 118.646	5	28.042 - 35.528	29.638 - 34.724	31.058 - 32.895	WATER FLUX =
	10	34.774 - 41.461	35.891 - 41.298	37.428 - 40.227	= 0.25 $cm^3/s\text{-}cm^2$
	15	40.661 - 49.519	41.005 - 48.947	42.489 - 44.853	
	20	44.795 - 56.167	45.093 - 55.583	49.417 - 54.084	
	25	52.988 - 63.152	54.030 - 61.922	55.494 - 58.598	
STD. DEV. =	30	57.405 - 68.818	58.044 - 67.699	61.237 - 64.801	FALL DISTANCE =
= 82.576	35	63.883 - 77.203	64.254 - 76.503	66.008 - 72.205	= 853 cm
	40	68.980 - 89.288	69.785 - 86.969	75.329 - 82.354	
	45	77.073 - 98.361	78.602 - 97.199	84.292 - 93.860	
	50	87.752 - 112.222	90.956 - 109.120	95.617 - 102.228	
SAMPLE SIZE =	55	97.563 - 120.011	100.038 - 118.524	105.662 - 115.780	AEROSOL MASS
= 360	60	111.863 - 135.249	113.490 - 131.630	117.674 - 124.550	FRACTION REMAINING =
	65	119.717 - 142.921	123.218 - 141.700	128.990 - 138.698	= 0.5
	70	135.422 - 153.127	138.097 - 152.087	141.069 - 146.731	
	75	144.464 - 166.279	145.360 - 164.931	151.052 - 155.479	
	80	154.838 - 190.828	155.162 - 189.489	164.221 - 173.280	
	85	172.617 - 216.741	175.573 - 213.663	189.903 - 200.988	
	90	201.523 - 252.225	207.498 - 249.353	224.260 - 242.242	
	95	249.559 - 312.160	252.315 - 310.329	258.742 - 286.203	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of 95%	90%	50%	
MEAN = 96.439	5	22.557 - 29.804	22.699 - 29.256	24.931 - 26.741	WATER FLUX =
	10	29.310 - 33.939	29.871 - 33.451	31.218 - 32.652	= 0.25 $cm^3/s\text{-}cm^2$
	15	32.780 - 39.932	33.019 - 39.159	34.445 - 37.504	
	20	36.450 - 45.514	38.001 - 45.340	39.876 - 43.864	
	25	42.393 - 52.327	43.605 - 51.792	45.310 - 47.719	
STD. DEV. =	30	46.725 - 58.203	47.389 - 56.902	51.108 - 54.490	FALL DISTANCE =
= 66.126	35	53.168 - 64.205	53.693 - 62.834	56.067 - 60.193	= 853 cm
	40	58.441 - 71.046	59.416 - 69.969	62.143 - 67.498	
	45	63.836 - 81.073	66.506 - 80.169	69.280 - 73.740	
	50	70.654 - 90.981	71.531 - 88.291	77.661 - 82.729	
SAMPLE SIZE =	55	80.389 - 98.921	81.451 - 98.286	84.153 - 94.281	AEROSOL MASS
= 360	60	89.692 - 108.132	91.068 - 106.534	97.058 - 103.037	FRACTION REMAINING =
	65	98.889 - 116.125	100.702 - 115.467	105.164 - 111.361	= 0.3
	70	108.190 - 122.894	109.606 - 122.207	115.223 - 118.393	
	75	116.406 - 133.651	117.192 - 131.372	120.593 - 125.124	
	80	124.030 - 155.786	125.033 - 153.629	131.331 - 142.524	
	85	141.599 - 179.056	143.933 - 178.234	153.741 - 172.221	
	90	173.437 - 204.845	175.959 - 199.056	179.341 - 188.088	
	95	199.222 - 255.299	205.607 - 251.121	217.860 - 230.778	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 68.901	5	15.603 - 19.687	15.657 - 18.927	16.385 - 17.627	WATER FLUX =
	10	19.000 - 24.372	19.691 - 24.171	21.485 - 23.698	= 0.25 $cm^3/s\text{-}cm^2$
	15	23.860 - 27.504	24.080 - 26.940	24.619 - 25.878	
	20	25.835 - 32.785	26.058 - 32.064	27.361 - 30.669	
	25	29.718 - 37.190	30.567 - 36.746	31.991 - 35.260	
STD. DEV. =	30	33.698 - 41.479	34.692 - 40.865	36.574 - 38.562	FALL DISTANCE =
= 48.238	35	37.758 - 45.759	37.947 - 44.953	40.738 - 42.973	= 853 cm
	40	41.549 - 50.454	42.068 - 49.666	43.543 - 47.268	
	45	45.718 - 55.945	46.721 - 55.672	49.038 - 52.026	
	50	50.374 - 63.041	50.903 - 61.418	53.885 - 57.275	
SAMPLE SIZE =	55	55.758 - 70.260	56.120 - 69.645	59.982 - 65.092	AEROSOL MASS
= 360	60	62.585 - 76.263	63.352 - 75.724	68.353 - 71.765	FRACTION REMAINING =
	65	70.204 - 82.828	71.094 - 82.335	74.532 - 77.805	= 0.1
	70	76.580 - 90.006	77.448 - 88.533	80.194 - 84.520	
	75	83.295 - 97.676	84.019 - 96.009	87.781 - 92.507	
	80	91.423 - 110.062	92.391 - 106.810	95.757 - 100.697	
	85	99.835 - 132.209	101.247 - 127.826	108.561 - 115.075	
	90	115.907 - 153.494	121.338 - 148.608	134.257 - 141.650	
	95	150.339 - 189.701	154.047 - 182.635	161.986 - 176.218	

	Quantile (%)	Range for λ(hr^{-1}) at a confidence level of			
		95%	90%	50%	
MEAN = 43.564	5	8.664 - 10.981	8.672 - 10.562	9.079 - 9.483	WATER FLUX =
	10	10.568 - 14.889	11.026 - 14.579	12.753 - 13.734	= 0.25 $cm^3/s\text{-}cm^2$
	15	14.078 - 17.369	14.340 - 17.166	15.093 - 15.976	
	20	15.841 - 19.372	16.384 - 19.071	17.297 - 18.331	
	25	18.071 - 22.208	18.311 - 22.038	19.036 - 20.992	
STD. DEV. =	30	20.174 - 25.143	20.527 - 24.961	21.762 - 23.660	FALL DISTANCE =
= 33.080	35	22.316 - 28.057	23.174 - 27.238	24.749 - 25.657	= 853 cm
	40	25.202 - 31.266	25.356 - 30.810	26.524 - 28.679	
	45	28.017 - 34.402	28.151 - 33.943	30.056 - 32.462	
	50	31.222 - 38.980	31.769 - 38.747	33.343 - 36.243	
SAMPLE SIZE =	55	34.080 - 42.597	35.186 - 42.435	38.266 - 39.988	AEROSOL MASS
= 360	60	38.937 - 45.734	39.359 - 44.931	41.830 - 43.767	FRACTION REMAINING =
	65	42.575 - 50.503	43.058 - 50.251	44.390 - 47.251	= 0.01
	70	45.798 - 57.620	46.620 - 56.394	49.377 - 53.195	
	75	51.753 - 63.138	52.411 - 62.612	56.044 - 59.421	
	80	58.454 - 68.196	59.401 - 67.473	62.564 - 66.016	
	85	65.956 - 81.502	66.246 - 79.423	67.623 - 73.202	
	90	74.323 - 99.871	77.239 - 95.992	82.204 - 91.371	
	95	96.004 - 128.016	100.201 - 126.639	103.566 - 117.030	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 34.255	5	6.283 - 8.324	6.302 - 8.049	6.751 - 7.121	WATER FLUX =
	10	8.136 - 11.388	8.336 - 11.343	9.402 - 10.413	= 0.25 $cm^3/s\text{-}cm^2$
	15	10.594 - 12.851	10.800 - 12.741	11.494 - 12.172	
	20	12.104 - 14.798	12.398 - 14.610	12.826 - 13.936	
	25	13.540 - 16.918	13.820 - 16.845	14.610 - 16.018	
STD. DEV. =	30	15.429 - 18.882	15.681 - 18.513	16.582 - 17.747	FALL DISTANCE =
= 27.243	35	16.970 - 21.249	17.280 - 20.833	18.199 - 19.654	= 853 cm
	40	18.949 - 24.355	19.359 - 24.101	20.173 - 22.517	
	45	21.178 - 27.054	21.796 - 26.578	23.591 - 25.060	
	50	24.326 - 29.468	24.453 - 29.190	25.743 - 28.456	
SAMPLE SIZE =	55	26.754 - 32.125	27.974 - 31.758	28.930 - 30.877	AEROSOL MASS
= 360	60	29.335 - 36.034	29.768 - 35.696	31.565 - 33.658	FRACTION REMAINING =
	65	32.120 - 39.713	32.616 - 38.886	34.810 - 37.902	= 0.001
	70	36.210 - 44.525	37.407 - 43.670	38.177 - 40.719	
	75	39.938 - 50.347	40.425 - 49.500	42.520 - 47.370	
	80	45.756 - 55.423	47.308 - 54.672	49.441 - 52.397	
	85	52.209 - 63.014	52.516 - 61.482	55.395 - 58.442	
	90	59.677 - 76.909	60.560 - 75.928	65.580 - 72.550	
	95	76.030 - 105.144	76.927 - 103.465	82.141 - 94.062	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 157.848	5	32.600 - 43.203	34.424 - 42.923	37.284 - 40.243	WATER FLUX =
	10	43.011 - 53.839	43.322 - 52.706	44.969 - 46.836	= 0.25 $cm^3/s\text{-}cm^2$
	15	47.390 - 63.314	48.159 - 62.837	54.368 - 59.776	
	20	59.440 - 69.195	60.124 - 67.561	63.146 - 65.447	
	25	64.454 - 76.741	65.041 - 76.238	67.544 - 71.156	
STD. DEV. =	30	70.476 - 86.899	70.835 - 85.382	75.675 - 79.529	FALL DISTANCE =
= 116.345	35	77.385 - 97.246	78.402 - 94.812	84.463 - 91.377	= 1000 cm
	40	87.181 - 111.476	89.172 - 110.228	93.350 - 101.332	
	45	96.820 - 128.139	98.804 - 126.166	106.996 - 117.872	
	50	111.356 - 148.844	115.432 - 144.414	121.340 - 136.124	
SAMPLE SIZE =	55	127.335 - 162.658	129.392 - 160.288	140.643 - 153.609	AEROSOL MASS
= 360	60	147.740 - 176.220	151.276 - 173.226	155.718 - 166.369	FRACTION REMAINING =
	65	162.573 - 196.804	163.737 - 190.932	170.362 - 179.208	= 0.9
	70	177.116 - 211.720	178.145 - 207.004	186.452 - 202.733	
	75	197.762 - 224.554	201.614 - 218.990	205.732 - 214.886	
	80	213.977 - 254.190	214.763 - 250.328	218.387 - 234.925	
	85	233.687 - 305.581	237.562 - 294.999	251.228 - 272.144	
	90	277.592 - 351.812	287.074 - 346.965	312.847 - 334.422	
	95	347.649 - 396.822	353.672 - 394.313	377.465 - 392.147	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of 95%	90%	50%	
MEAN = 114.749	5	26.763 - 34.158	27.929 - 32.920	28.947 - 32.021	WATER FLUX =
	10	32.999 - 38.915	34.253 - 38.542	35.345 - 37.710	= 0.25 $cm^3/s\text{-}cm^2$
	15	38.037 - 47.239	38.295 - 45.879	39.676 - 42.219	
	20	42.122 - 52.714	42.678 - 52.051	46.729 - 50.417	
	25	50.008 - 59.345	50.277 - 58.782	52.016 - 55.350	
STD. DEV. =	30	54.415 - 64.048	54.846 - 63.652	58.319 - 60.600	FALL DISTANCE =
= 81.263	35	59.549 - 71.884	60.195 - 71.223	61.734 - 68.512	= 1000 cm
	40	64.348 - 84.074	65.631 - 83.333	69.907 - 77.849	
	45	71.812 - 95.246	75.081 - 91.112	81.883 - 87.269	
	50	84.033 - 108.380	86.010 - 107.654	89.496 - 99.013	
SAMPLE SIZE =	55	94.173 - 117.818	96.279 - 116.571	103.721 - 111.982	AEROSOL MASS
= 360	60	107.886 - 126.709	109.502 - 126.026	115.079 - 121.518	FRACTION REMAINING =
	65	117.816 - 140.540	119.595 - 138.879	124.875 - 131.499	= 0.5
	70	126.841 - 149.644	129.622 - 148.467	137.383 - 143.064	
	75	140.995 - 164.291	142.557 - 161.293	147.458 - 153.078	
	80	152.162 - 188.870	152.982 - 186.249	160.102 - 171.442	
	85	170.780 - 212.050	171.931 - 211.114	187.569 - 197.301	
	90	199.338 - 246.447	205.097 - 244.232	215.885 - 236.327	
	95	244.296 - 307.474	246.534 - 304.217	254.379 - 275.589	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 93.558	5	21.247 - 27.818	21.759 - 27.695	23.599 - 25.617	WATER FLUX =
	10	27.719 - 31.728	27.953 - 31.513	29.448 - 30.301	= 0.25 $cm^3/s\text{-}cm^2$
	15	30.500 - 38.115	30.663 - 37.191	32.171 - 35.223	
	20	34.915 - 43.983	35.636 - 43.532	37.731 - 41.296	
	25	39.640 - 49.566	41.208 - 48.388	43.387 - 45.557	
STD. DEV. =	30	44.343 - 54.120	45.233 - 53.073	47.904 - 51.229	FALL DISTANCE =
= 65.393	35	49.819 - 61.418	50.860 - 59.433	52.203 - 56.787	= 1000 cm
	40	54.399 - 68.142	55.411 - 65.782	58.127 - 62.694	
	45	61.391 - 75.980	61.625 - 75.116	64.125 - 70.821	
	50	68.034 - 86.165	68.489 - 85.202	74.114 - 81.176	
SAMPLE SIZE =	55	75.736 - 96.607	78.662 - 94.793	82.476 - 89.953	AEROSOL MASS
= 360	60	85.872 - 105.771	89.147 - 104.798	92.275 - 98.831	FRACTION REMAINING =
	65	96.366 - 114.393	97.600 - 113.073	103.594 - 107.566	= 0.3
	70	106.178 - 120.452	106.949 - 118.749	110.727 - 115.552	
	75	115.054 - 131.252	115.305 - 129.770	118.253 - 122.898	
	80	121.694 - 154.106	122.742 - 152.267	129.270 - 141.368	
	85	140.472 - 177.140	142.588 - 175.451	152.460 - 168.890	
	90	171.436 - 202.846	173.763 - 196.900	177.477 - 186.293	
	95	197.052 - 252.397	203.517 - 249.096	214.421 - 227.587	

	Quantile (%)	Range for $\lambda (hr^{-1})$ at a confidence level of 95%	90%	50%	
MEAN = 66.821	5	14.465 - 18.257	14.576 - 17.641	15.732 - 16.772	WATER FLUX =
	10	17.699 - 22.860	18.439 - 22.685	20.093 - 22.251	= 0.25 $cm^3/s\text{-}cm^2$
	15	22.294 - 26.087	22.380 - 25.535	23.137 - 24.317	
	20	24.232 - 30.690	24.397 - 30.520	25.865 - 29.256	
	25	28.201 - 34.855	29.254 - 34.283	30.467 - 32.859	
STD. DEV. =	30	31.801 - 38.984	32.794 - 38.545	34.032 - 37.583	FALL DISTANCE =
= 47.535	35	35.103 - 43.330	36.435 - 42.601	37.866 - 40.225	= 1000 cm
	40	39.105 - 48.452	39.528 - 47.267	41.348 - 45.452	
	45	43.301 - 52.056	43.811 - 51.680	46.541 - 49.724	
	50	48.399 - 61.921	48.711 - 59.885	50.931 - 55.178	
SAMPLE SIZE =	55	51.869 - 68.315	52.691 - 66.317	57.727 - 63.483	AEROSOL MASS
= 360	60	60.851 - 74.327	62.688 - 73.464	64.952 - 70.422	FRACTION REMAINING =
	65	68.066 - 81.264	68.843 - 78.611	71.859 - 75.284	= 0.1
	70	74.588 - 88.652	74.970 - 87.013	77.602 - 82.780	
	75	81.946 - 95.387	82.386 - 93.885	86.190 - 91.195	
	80	90.309 - 107.559	91.152 - 105.367	93.446 - 99.693	
	85	98.765 - 130.900	100.408 - 126.745	106.009 - 113.803	
	90	114.570 - 151.895	120.046 - 146.943	133.025 - 139.536	
	95	148.550 - 187.145	152.386 - 179.834	160.630 - 171.087	

	Quantile (%)	Range for λ(hr^{-1}) at a confidence level of			
		95%	90%	50%	
MEAN = 42.222	5	8.055 - 10.341	8.065 - 10.076	8.454 - 9.267	WATER FLUX =
	10	10.114 - 14.062	10.412 - 13.886	11.897 - 13.212	= 0.25 $cm^3/s\text{-}cm^2$
	15	13.362 - 16.290	13.446 - 16.120	14.165 - 14.830	
	20	14.795 - 18.008	15.282 - 17.694	16.256 - 17.112	
	25	16.825 - 20.874	17.062 - 20.487	17.669 - 19.517	
STD. DEV. =	30	18.752 - 23.530	19.369 - 23.286	20.319 - 22.317	FALL DISTANCE =
= 32.539	35	20.969 - 26.040	21.984 - 25.714	23.068 - 24.179	= 1000 cm
	40	23.605 - 30.362	23.980 - 29.646	25.176 - 26.831	
	45	26.021 - 33.093	26.277 - 32.810	28.595 - 30.935	
	50	30.166 - 38.429	30.452 - 36.961	31.844 - 34.513	
SAMPLE SIZE =	55	33.003 - 40.785	33.341 - 40.047	36.307 - 39.247	AEROSOL MASS
= 360	60	37.943 - 44.070	38.656 - 43.567	39.477 - 41.374	FRACTION REMAINING =
	65	40.722 - 49.968	41.134 - 49.216	42.356 - 46.356	= 0.01
	70	44.190 - 56.264	45.463 - 54.823	47.723 - 52.026	
	75	50.584 - 61.784	51.683 - 61.372	54.037 - 58.963	
	80	57.907 - 67.256	58.945 - 66.800	61.256 - 65.370	
	85	65.226 - 79.641	65.517 - 78.280	66.988 - 72.353	
	90	73.479 - 96.218	76.400 - 95.113	81.094 - 90.470	
	95	95.138 - 126.438	96.599 - 122.327	103.034 - 115.831	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 33.223	5	5.858 - 7.733	5.869 - 7.481	6.282 - 6.840	WATER FLUX =
	10	7.542 - 10.732	7.894 - 10.632	8.738 - 9.878	= 0.25 $cm^3/s\text{-}cm^2$
	15	9.906 - 12.345	10.316 - 11.990	10.755 - 11.426	
	20	11.346 - 13.908	11.623 - 13.672	12.324 - 12.981	
	25	12.678 - 16.001	12.860 - 15.729	13.668 - 14.813	
STD. DEV. =	30	14.390 - 18.007	14.711 - 17.892	15.533 - 16.737	FALL DISTANCE =
= 26.711	35	16.073 - 20.084	16.544 - 19.659	17.297 - 18.661	= 1000 cm
	40	18.026 - 23.614	18.265 - 23.242	19.240 - 21.082	
	45	20.051 - 26.081	20.206 - 25.240	22.437 - 24.169	
	50	23.604 - 28.887	23.732 - 28.718	24.370 - 27.429	
SAMPLE SIZE =	55	25.601 - 31.207	26.516 - 30.701	28.257 - 29.379	AEROSOL MASS
= 360	60	28.855 - 35.093	29.163 - 34.628	30.174 - 31.889	FRACTION REMAINING =
	65	31.146 - 38.804	31.261 - 38.112	33.607 - 35.778	= 0.001
	70	35.161 - 44.062	35.493 - 42.966	37.616 - 39.960	
	75	39.325 - 49.036	39.767 - 48.310	42.187 - 46.108	
	80	45.097 - 54.811	45.926 - 53.655	48.174 - 51.687	
	85	51.631 - 62.010	51.828 - 60.815	54.233 - 57.782	
	90	58.030 - 76.351	59.776 - 75.256	64.754 - 71.780	
	95	75.389 - 103.845	76.413 - 98.508	77.798 - 91.953	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 144.382	5	26.338 - 35.099	27.728 - 34.515	30.824 - 32.880	WATER FLUX =
	10	34.590 - 46.083	35.167 - 43.669	36.088 - 38.272	= 0.25 $cm^3/s\text{-}cm^2$
	15	39.052 - 51.446	41.149 - 51.132	46.310 - 50.331	
	20	49.984 - 56.476	50.381 - 55.407	51.349 - 53.384	
	25	52.476 - 62.652	53.377 - 61.986	55.309 - 59.543	
STD. DEV. =	30	57.632 - 71.533	59.023 - 69.910	61.628 - 67.440	FALL DISTANCE =
= 114.627	35	63.179 - 82.384	65.796 - 79.761	69.342 - 76.326	= 1584 cm
	40	71.755 - 92.883	74.774 - 92.040	77.734 - 86.303	
	45	82.231 - 115.372	84.197 - 112.043	88.412 - 100.874	
	50	92.655 - 128.004	93.911 - 126.419	108.094 - 118.246	
SAMPLE SIZE =	55	114.330 - 148.424	116.532 - 142.756	124.351 - 133.958	AEROSOL MASS
= 360	60	127.619 - 162.792	129.680 - 160.579	138.657 - 154.516	FRACTION REMAINING =
	65	147.949 - 176.079	150.343 - 174.243	158.163 - 167.211	= 0.9
	70	163.426 - 197.100	164.936 - 192.622	173.186 - 182.194	
	75	178.271 - 209.992	180.368 - 208.995	190.080 - 202.830	
	80	201.439 - 240.670	202.672 - 238.968	208.861 - 215.937	
	85	215.760 - 287.877	221.195 - 284.604	239.450 - 261.364	
	90	263.399 - 340.811	272.434 - 336.391	297.600 - 317.514	
	95	336.459 - 389.639	340.846 - 388.093	365.532 - 385.259	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 105.152	5	22.658 - 27.930	22.740 - 27.562	23.880 - 25.329	WATER FLUX =
	10	27.634 - 31.803	27.952 - 31.652	28.788 - 30.795	= 0.25 $cm^3/s\text{-}cm^2$
	15	30.912 - 38.174	31.260 - 37.692	32.008 - 35.546	
	20	35.455 - 44.184	35.751 - 43.624	37.905 - 41.772	
	25	41.130 - 48.769	41.494 - 48.215	43.582 - 46.455	
STD. DEV. =	30	45.082 - 53.025	45.892 - 52.426	47.917 - 49.683	FALL DISTANCE =
= 80.061	35	48.896 - 59.788	49.474 - 58.685	51.185 - 54.799	= 1584 cm
	40	53.320 - 69.684	54.506 - 68.362	57.037 - 64.946	
	45	59.721 - 81.490	63.069 - 80.195	67.023 - 72.561	
	50	69.349 - 95.779	70.630 - 94.864	78.832 - 86.987	
SAMPLE SIZE =	55	81.363 - 106.594	84.716 - 105.903	91.634 - 99.796	AEROSOL MASS
= 360	60	95.703 - 116.020	96.153 - 114.889	102.903 - 110.708	FRACTION REMAINING =
	65	106.505 - 132.841	107.712 - 128.368	113.108 - 122.096	= 0.5
	70	116.689 - 143.586	118.880 - 142.290	124.640 - 137.065	
	75	134.531 - 157.251	136.227 - 153.490	141.046 - 146.354	
	80	145.544 - 180.690	146.241 - 177.344	153.468 - 165.560	
	85	164.914 - 205.718	167.023 - 199.966	178.660 - 186.527	
	90	191.684 - 238.362	194.375 - 237.302	206.465 - 224.575	
	95	237.452 - 297.041	238.407 - 296.049	246.475 - 265.623	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 85.522	5	18.015 - 22.854	18.110 - 22.785	19.034 - 21.699	WATER FLUX =
	10	22.799 - 25.963	22.889 - 25.700	23.917 - 24.619	= 0.25 $cm^3/s\text{-}cm^2$
	15	24.760 - 30.682	25.111 - 29.962	26.581 - 28.313	
	20	28.178 - 36.889	28.397 - 36.023	30.569 - 33.490	
	25	32.192 - 41.031	33.126 - 40.680	35.913 - 38.260	
STD. DEV. =	30	37.520 - 44.605	38.035 - 44.168	40.308 - 42.067	FALL DISTANCE =
= 63.832	35	41.163 - 49.110	41.718 - 48.167	43.427 - 46.109	= 1584 cm
	40	44.643 - 57.868	45.090 - 56.210	47.034 - 50.031	
	45	48.887 - 67.891	49.716 - 67.013	54.204 - 59.987	
	50	57.622 - 77.126	58.591 - 74.638	63.324 - 70.572	
SAMPLE SIZE =	55	67.557 - 85.694	68.711 - 83.853	72.770 - 79.531	AEROSOL MASS
= 360	60	76.917 - 95.720	78.155 - 94.906	81.795 - 89.090	FRACTION REMAINING =
	65	85.356 - 107.965	87.637 - 105.994	94.563 - 102.107	= 0.3
	70	96.172 - 116.212	98.103 - 114.255	104.112 - 111.364	
	75	110.131 - 126.688	110.932 - 125.351	113.697 - 119.161	
	80	117.893 - 148.550	119.114 - 145.629	124.935 - 136.910	
	85	136.030 - 171.183	137.998 - 168.869	148.494 - 164.236	
	90	165.945 - 192.267	167.435 - 188.991	171.519 - 179.870	
	95	190.125 - 239.514	193.092 - 230.645	205.902 - 215.008	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 60.960	5	11.549 - 16.011	11.860 - 15.854	12.961 - 14.243	WATER FLUX =
	10	15.882 - 18.178	16.026 - 18.175	16.762 - 17.805	= 0.25 $cm^3/s\text{-}cm^2$
	15	17.961 - 21.511	18.090 - 21.047	18.238 - 19.266	
	20	19.243 - 25.428	19.553 - 24.559	21.325 - 23.444	
	25	23.151 - 28.412	23.357 - 27.831	24.552 - 26.176	
STD. DEV. =	30	25.945 - 32.143	26.162 - 31.419	27.543 - 30.011	FALL DISTANCE =
= 45.999	35	29.099 - 36.822	29.735 - 36.138	31.087 - 34.255	= 1584 cm
	40	32.198 - 40.157	32.728 - 39.732	34.973 - 37.549	
	45	36.814 - 46.842	37.099 - 45.550	39.159 - 41.606	
	50	40.046 - 53.357	40.239 - 52.963	43.873 - 49.038	
SAMPLE SIZE =	55	45.703 - 59.679	47.729 - 58.474	51.466 - 55.663	AEROSOL MASS
= 360	60	53.215 - 68.179	53.574 - 66.198	57.566 - 62.369	FRACTION REMAINING =
	65	59.563 - 75.005	60.234 - 74.520	63.752 - 71.852	= 0.1
	70	68.486 - 84.265	69.470 - 81.636	73.346 - 79.350	
	75	75.801 - 92.284	78.048 - 90.131	81.303 - 87.505	
	80	85.939 - 103.663	87.419 - 102.795	90.066 - 96.621	
	85	95.947 - 124.786	97.079 - 122.851	103.274 - 109.739	
	90	110.272 - 143.848	115.276 - 139.034	127.701 - 134.490	
	95	140.151 - 174.098	114.251 - 173.554	152.370 - 161.149	

	Quantile (%)	Range for λ(hr^{-1}) at a confidence level of			
		95%	90%	50%	
MEAN = 38.720	5	6.460 - 8.371	6.494 - 8.213	6.621 - 7.898	WATER FLUX =
	10	8.231 - 11.293	8.383 - 10.961	9.416 - 10.444	= 0.25 $cm^3/s\text{-}cm^2$
	15	10.471 - 13.028	10.702 - 12.908	11.311 - 12.305	
	20	12.275 - 14.643	12.400 - 14.150	12.987 - 13.679	
	25	13.582 - 17.349	13.657 - 16.504	14.072 - 15.905	
STD. DEV. =	30	15.306 - 19.981	15.620 - 19.460	16.325 - 17.780	FALL DISTANCE =
= 31.384	35	17.477 - 22.597	17.683 - 21.621	18.678 - 20.627	= 1584 cm
	40	19.992 - 25.887	20.279 - 24.803	21.058 - 23.550	
	45	22.569 - 29.852	23.090 - 29.497	23.999 - 27.141	
	50	25.517 - 32.166	26.284 - 31.846	28.567 - 30.560	
SAMPLE SIZE =	55	29.638 - 36.451	29.966 - 35.587	31.471 - 32.785	AEROSOL MASS
= 360	60	31.977 - 41.173	32.531 - 40.622	34.367 - 38.012	FRACTION REMAINING =
	65	36.192 - 47.438	37.338 - 46.238	40.125 - 43.447	= 0.010
	70	41.470 - 53.734	42.448 - 51.796	45.056 - 48.865	
	75	47.900 - 59.733	48.232 - 59.391	51.302 - 56.154	
	80	54.766 - 65.154	56.123 - 64.180	59.333 - 63.165	
	85	63.060 - 76.981	63.308 - 75.553	64.696 - 69.901	
	90	71.271 - 93.407	73.762 - 92.430	78.543 - 87.699	
	95	92.590 - 121.577	93.460 - 117.629	99.163 - 107.005	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 30.353	5	4.850 - 6.737	4.948 - 6.289	5.139 - 5.876	WATER FLUX =
	10	6.315 - 8.574	6.758 - 8.490	6.974 - 7.892	= 0.25 $cm^3/s\text{-}cm^2$
	15	7.994 - 9.798	8.233 - 9.692	8.691 - 9.231	
	20	9.221 - 11.332	9.421 - 11.248	9.794 - 10.679	
	25	10.489 - 13.005	10.597 - 12.698	11.233 - 12.103	
STD. DEV. =	30	11.488 - 14.992	11.793 - 14.710	12.534 - 13.598	FALL DISTANCE =
= 25.448	35	13.224 - 17.192	13.338 - 16.802	14.565 - 15.708	= 1584 cm
	40	15.102 - 19.902	15.458 - 19.111	16.418 - 18.129	
	45	17.179 - 23.133	17.556 - 22.929	18.585 - 21.195	
	50	19.748 - 25.703	20.141 - 24.647	22.411 - 23.651	
SAMPLE SIZE =	55	23.029 - 28.107	23.247 - 27.834	23.931 - 27.006	AEROSOL MASS
= 360	60	25.289 - 31.244	25.828 - 30.708	27.683 - 29.043	FRACTION REMAINING =
	65	28.083 - 36.480	28.272 - 36.173	30.083 - 33.915	= 0.001
	70	31.425 - 40.442	32.913 - 39.280	35.788 - 38.186	
	75	37.011 - 47.052	38.041 - 46.681	39.000 - 43.500	
	80	42.327 - 52.538	43.409 - 51.386	46.611 - 49.732	
	85	49.648 - 59.246	49.826 - 58.698	51.852 - 54.107	
	90	55.647 - 73.089	57.034 - 72.418	59.486 - 68.294	
	95	72.670 - 99.845	73.161 - 94.726	75.261 - 87.888	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 138.403	5	24.444 - 30.789	25.197 - 30.432	27.879 - 29.532	WATER FLUX =
	10	30.510 - 39.726	30.898 - 38.743	32.030 - 34.451	= 0.25 $cm^3/s\text{-}cm^2$
	15	35.626 - 45.576	37.238 - 45.115	40.706 - 44.586	
	20	44.248 - 51.878	44.642 - 51.068	45.404 - 47.775	
	25	47.429 - 56.188	47.763 - 55.754	51.058 - 53.661	
STD. DEV. =	30	52.861 - 65.890	53.285 - 64.169	55.384 - 60.019	FALL DISTANCE =
= 114.599	35	57.347 - 74.661	58.084 - 71.894	62.491 - 67.787	= 2000 cm
	40	66.053 - 87.184	66.587 - 85.854	69.234 - 78.235	
	45	74.477 - 104.954	75.537 - 102.255	82.011 - 91.812	
	50	86.396 - 119.933	89.913 - 117.300	96.826 - 110.243	
SAMPLE SIZE =	55	102.734 - 139.448	109.499 - 137.038	113.708 - 127.068	AEROSOL MASS
= 360	60	119.686 - 154.978	121.636 - 154.204	132.959 - 145.714	FRACTION REMAINING =
	65	139.442 - 169.911	140.931 - 166.790	151.551 - 158.556	= 0.9
	70	155.200 - 192.563	156.161 - 188.653	164.045 - 175.324	
	75	171.349 - 206.852	173.607 - 205.574	187.173 - 200.277	
	80	198.220 - 242.277	199.984 - 234.193	205.436 - 212.178	
	85	210.744 - 284.483	214.539 - 274.050	235.574 - 256.687	
	90	258.763 - 337.465	267.688 - 334.389	296.412 - 312.170	
	95	335.039 - 385.759	337.590 - 383.297	359.275 - 380.496	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 100.481	5	20.348 - 24.669	20.554 - 24.165	21.252 - 22.675	WATER FLUX =
	10	24.310 - 28.079	24.718 - 27.847	25.585 - 27.249	= 0.25 $cm^3/s\text{-}cm^2$
	15	27.393 - 34.217	27.550 - 33.900	28.521 - 31.995	
	20	31.885 - 40.269	32.112 - 39.318	34.098 - 37.269	
	25	36.524 - 43.488	37.181 - 43.084	39.190 - 41.751	
STD. DEV. =	30	40.704 - 47.920	41.221 - 47.245	42.754 - 45.277	FALL DISTANCE =
= 79.472	35	43.930 - 56.304	44.504 - 54.430	46.504 - 49.215	= 2000 cm
	40	48.081 - 61.926	48.715 - 61.407	51.343 - 57.862	
	45	56.130 - 78.423	56.734 - 75.454	59.705 - 67.338	
	50	61.790 - 88.673	62.933 - 86.165	70.160 - 79.865	
SAMPLE SIZE =	55	77.902 - 101.702	78.898 - 97.781	84.432 - 92.463	AEROSOL MASS
= 360	60	88.099 - 113.198	90.136 - 111.186	94.528 - 105.790	FRACTION REMAINING =
	65	101.674 - 128.822	103.010 - 125.460	109.670 - 118.338	= 0.5
	70	113.502 - 140.933	114.541 - 139.502	123.037 - 134.802	
	75	131.442 - 153.733	133.382 - 151.175	138.950 - 144.456	
	80	143.013 - 175.551	144.276 - 172.254	150.923 - 161.973	
	85	161.644 - 199.430	162.549 - 195.044	174.781 - 184.096	
	90	189.058 - 234.317	189.821 - 231.738	202.890 - 219.964	
	95	232.332 - 292.814	234.391 - 290.224	240.539 - 261.221	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 81.733	5	15.924 - 19.965	16.145 - 19.833	17.492 - 19.376	WATER FLUX =
	10	19.837 - 23.564	19.975 - 23.439	21.119 - 22.267	= 0.25 $cm^3/s\text{-}cm^2$
	15	22.370 - 26.955	22.728 - 26.765	23.942 - 25.040	
	20	24.935 - 33.134	25.098 - 32.327	26.888 - 29.721	
	25	28.469 - 36.580	29.204 - 36.338	32.312 - 35.003	
STD. DEV. =	30	33.727 - 40.224	34.586 - 39.415	35.974 - 37.829	FALL DISTANCE =
= 63.308	35	36.927 - 44.124	37.101 - 43.696	39.192 - 41.430	= 2000 cm
	40	40.484 - 52.180	40.872 - 50.208	43.190 - 45.243	
	45	44.055 - 62.639	44.467 - 59.756	48.727 - 55.559	
	50	52.032 - 71.232	52.764 - 70.736	58.499 - 65.342	
SAMPLE SIZE =	55	62.503 - 80.295	64.385 - 78.012	67.255 - 75.152	AEROSOL MASS
= 360	60	71.138 - 94.536	71.992 - 93.156	76.727 - 84.300	FRACTION REMAINING =
	65	79.704 - 106.130	81.470 - 104.677	88.849 - 101.069	= 0.3
	70	94.863 - 113.242	96.819 - 112.335	102.705 - 109.529	
	75	108.247 - 123.268	108.963 - 120.974	111.825 - 116.893	
	80	115.134 - 145.642	116.737 - 142.362	120.783 - 134.926	
	85	133.954 - 167.696	135.569 - 166.260	143.507 - 161.106	
	90	164.046 - 186.569	164.554 - 185.425	168.389 - 176.400	
	95	186.021 - 235.147	186.665 - 226.068	198.217 - 210.870	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of 95%	90%	50%	
MEAN = 58.349	5	10.510 - 14.228	10.610 - 14.088	11.341 - 12.608	WATER FLUX =
	10	14.115 - 16.220	14.256 - 16.199	15.271 - 15.936	= 0.25 $cm^3/s\text{-}cm^2$
	15	16.036 - 18.917	16.091 - 18.728	16.342 - 17.260	
	20	17.254 - 22.825	17.351 - 22.307	18.855 - 20.800	
	25	20.278 - 25.513	20.670 - 25.194	22.242 - 23.459	
STD. DEV. =	30	23.196 - 28.885	23.382 - 28.649	24.482 - 27.054	FALL DISTANCE =
= 45.447	35	25.728 - 32.563	26.414 - 32.216	28.445 - 30.400	= 2000 cm
	40	29.109 - 36.976	29.831 - 35.787	31.812 - 34.331	
	45	32.484 - 44.808	33.140 - 44.043	34.899 - 38.106	
	50	36.810 - 48.731	37.290 - 48.267	41.186 - 45.819	
SAMPLE SIZE =	55	44.436 - 57.298	45.128 - 56.126	47.251 - 51.812	AEROSOL MASS
= 360	60	48.662 - 66.783	49.872 - 64.749	53.236 - 59.928	FRACTION REMAINING =
	65	57.221 - 74.235	57.997 - 73.628	62.699 - 70.290	= 0.1
	70	67.190 - 83.512	68.407 - 80.927	71.587 - 77.821	
	75	74.698 - 90.455	76.506 - 88.919	80.624 - 86.005	
	80	84.664 - 101.637	85.893 - 101.181	88.747 - 94.547	
	85	93.308 - 121.907	95.239 - 119.688	101.536 - 107.566	
	90	108.197 - 139.155	112.953 - 136.156	122.796 - 131.790	
	95	136.640 - 170.955	139.315 - 169.063	146.854 - 157.433	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 37.092	5	5.751 - 7.634	5.769 - 7.417	6.093 - 7.241	WATER FLUX =
	10	7.420 - 10.151	7.663 - 9.965	8.692 - 9.324	= 0.25 $cm^3/s\text{-}cm^2$
	15	9.363 - 11.634	9.590 - 11.453	10.360 - 10.870	
	20	10.805 - 13.162	10.933 - 12.976	11.574 - 12.311	
	25	12.130 - 15.343	12.310 - 15.193	12.960 - 13.959	
STD. DEV. =	30	13.748 - 17.719	13.919 - 17.329	15.102 - 16.232	FALL DISTANCE =
= 38.781	35	15.518 - 20.540	16.057 - 20.283	16.701 - 18.621	= 2000 cm
	40	17.814 - 23.574	18.195 - 23.465	19.740 - 21.566	
	45	20.498 - 27.223	20.693 - 27.039	23.335 - 24.748	
	50	23.506 - 29.803	23.802 - 29.499	25.847 - 28.431	
SAMPLE SIZE =	55	27.209 - 35.304	27.334 - 34.693	29.216 - 31.549	AEROSOL MASS
= 360	60	29.740 - 40.219	30.638 - 39.733	32.540 - 37.230	FRACTION REMAINING =
	65	35.213 - 45.476	35.960 - 45.503	38.690 - 42.216	= 0.01
	70	40.433 - 51.835	41.712 - 50.539	43.760 - 47.745	
	75	46.327 - 58.663	47.322 - 58.310	50.300 - 55.124	
	80	53.670 - 64.211	55.053 - 63.010	58.110 - 61.929	
	85	61.823 - 75.509	61.962 - 74.202	63.506 - 68.860	
	90	69.134 - 90.752	70.545 - 89.629	77.125 - 83.051	
	95	89.710 - 119.026	90.856 - 115.154	97.997 - 105.418	

	Quantile (%)	Range for λ(hr^{-1}) at a confidence level of 95%	90%	50%	
MEAN = 28.911	5	4.364 - 5.821	4.440 - 5.687	4.707 - 5.328	WATER FLUX = = 0.25 $cm^3/s\text{-}cm^2$
	10	5.688 - 7.601	5.914 - 7.548	6.251 - 6.976	
	15	7.080 - 8.644	7.244 - 8.472	7.662 - 8.225	
	20	8.219 - 9.972	8.334 - 9.841	8.560 - 9.658	
	25	9.340 - 11.665	9.628 - 11.543	9.832 - 10.600	
STD. DEV. = = 24.850	30	10.152 - 13.477	10.466 - 13.142	11.472 - 12.328	FALL DISTANCE = = 2000 cm
	35	11.796 - 16.057	12.058 - 15.330	13.009 - 14.197	
	40	13.509 - 18.114	13.914 - 17.828	14.937 - 16.427	
	45	16.022 - 21.074	16.223 - 20.602	17.240 - 19.438	
	50	18.074 - 23.472	18.586 - 23.202	20.030 - 21.962	
SAMPLE SIZE = = 360	55	20.783 - 27.567	21.339 - 27.323	22.978 - 24.794	AEROSOL MASS FRACTION REMAINING = = 0.001
	60	23.406 - 30.228	23.939 - 29.555	26.309 - 27.858	
	65	27.542 - 35.387	27.693 - 34.808	29.083 - 32.837	
	70	30.383 - 39.026	32.034 - 38.433	34.312 - 36.776	
	75	35.408 - 46.003	36.243 - 45.070	38.233 - 42.406	
	80	41.672 - 50.498	42.291 - 50.220	44.845 - 48.147	
	85	47.469 - 57.820	48.596 - 56.677	50.292 - 52.897	
	90	53.350 - 70.940	54.451 - 70.048	58.241 - 65.364	
	95	70.195 - 97.750	71.024 - 92.745	73.788 - 86.074	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of 95%	90%	50%	
MEAN = 127.946	5	20.269 - 25.222	20.434 - 25.018	22.507 - 23.518	WATER FLUX =
	10	25.022 - 31.567	25.222 - 30.337	25.916 - 27.639	= 0.25 $cm^3/s\text{-}cm^2$
	15	28.515 - 36.253	29.768 - 35.782	32.964 - 35.182	
	20	35.075 - 42.786	35.340 - 41.442	36.142 - 39.007	
	25	38.058 - 47.376	38.748 - 46.374	41.339 - 44.457	
STD. DEV. =	30	43.540 - 53.330	44.274 - 52.233	46.109 - 50.893	FALL DISTANCE =
= 113.145	35	48.028 - 61.314	49.869 - 60.050	51.702 - 55.166	= 3000 cm
	40	53.812 - 75.033	54.467 - 72.610	58.453 - 65.236	
	45	60.887 - 88.602	62.978 - 85.859	69.440 - 79.403	
	50	74.487 - 108.078	75.466 - 105.661	83.989 - 91.291	
SAMPLE SIZE =	55	86.393 - 124.552	89.002 - 120.634	98.691 - 111.947	AEROSOL MASS
= 360	60	107.992 - 147.445	110.002 - 143.102	117.789 - 129.400	FRACTION REMAINING =
	65	123.688 - 163.819	126.502 - 158.211	138.248 - 152.262	= 0.9
	70	148.689 - 186.046	150.731 - 182.390	156.086 - 168.946	
	75	164.682 - 200.625	167.326 - 198.810	178.999 - 194.495	
	80	191.794 - 227.748	194.207 - 221.810	198.566 - 206.242	
	85	206.195 - 265.244	208.234 - 261.649	227.208 - 248.127	
	90	251.526 - 320.789	252.802 - 313.652	265.430 - 299.166	
	95	315.454 - 379.618	321.183 - 378.013	339.548 - 374.872	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 93.042	5	16.317 - 19.925	16.549 - 19.761	17.284 - 19.142	WATER FLUX =
	10	19.780 - 22.223	19.983 - 21.942	20.589 - 21.629	= 0.25 $cm^3/s\text{-}cm^2$
	15	21.790 - 28.334	21.851 - 27.385	22.708 - 25.081	
	20	25.052 - 32.368	25.331 - 32.102	27.917 - 30.562	
	25	29.958 - 35.505	30.547 - 35.093	32.077 - 33.809	
STD. DEV. =	30	32.935 - 38.921	33.274 - 38.397	34.909 - 36.422	FALL DISTANCE =
= 78.683	35	35.840 - 46.295	36.009 - 45.656	37.581 - 41.955	= 3000 cm
	40	39.115 - 53.841	40.060 - 51.957	43.975 - 48.140	
	45	46.251 - 64.528	47.020 - 63.003	49.457 - 57.316	
	50	53.239 - 75.914	55.595 - 74.112	60.442 - 68.414	
SAMPLE SIZE =	55	63.646 - 92.262	66.048 - 90.421	71.655 - 78.987	AEROSOL MASS
= 360	60	75.696 - 109.874	76.472 - 108.161	88.074 - 100.351	FRACTION REMAINING =
	65	91.904 - 123.917	97.752 - 121.612	104.983 - 114.963	= 0.5
	70	110.246 - 136.320	112.283 - 135.312	120.225 - 130.164	
	75	124.966 - 148.539	127.233 - 145.480	134.862 - 139.627	
	80	138.014 - 169.034	139.480 - 167.576	144.687 - 156.527	
	85	155.902 - 191.954	157.156 - 187.062	168.327 - 179.418	
	90	180.844 - 225.762	182.912 - 223.418	194.647 - 210.685	
	95	223.937 - 280.110	225.864 - 260.022	232.343 - 250.353	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of 95%	90%	50%	
MEAN = 75.662	5	12.662 - 15.970	13.211 - 15.832	14.327 - 15.499	WATER FLUX =
	10	15.838 - 18.987	16.038 - 18.707	16.576 - 18.070	= 0.25 $cm^3/s\text{-}cm^2$
	15	18.475 - 21.732	18.527 - 21.275	19.455 - 20.316	
	20	20.118 - 26.326	20.491 - 25.916	21.690 - 24.822	
	25	23.983 - 29.459	24.770 - 28.711	25.852 - 27.829	
STD. DEV. =	30	27.510 - 32.177	27.787 - 31.845	28.590 - 30.389	FALL DISTANCE =
= 62.616	35	29.678 - 37.249	30.192 - 35.840	31.703 - 33.634	= 3000 cm
	40	32.232 - 43.943	32.931 - 43.450	35.116 - 39.166	
	45	37.162 - 52.596	37.837 - 51.470	41.791 - 46.029	
	50	43.881 - 62.906	44.806 - 59.950	48.749 - 55.514	
SAMPLE SIZE =	55	51.707 - 75.165	53.217 - 74.459	57.401 - 65.529	AEROSOL MASS
= 360	60	61.003 - 91.841	63.843 - 87.939	69.448 - 78.536	FRACTION REMAINING =
	65	75.113 - 102.150	76.219 - 100.970	87.031 - 95.301	= 0.3
	70	92.322 - 110.987	93.263 - 109.320	100.466 - 105.284	
	75	103.305 - 118.767	104.909 - 117.738	108.177 - 112.793	
	80	111.823 - 138.651	112.658 - 134.945	117.289 - 128.343	
	85	124.472 - 161.563	131.128 - 159.624	138.423 - 149.748	
	90	155.721 - 179.821	157.956 - 175.482	162.124 - 169.173	
	95	176.285 - 219.081	179.909 - 214.195	191.848 - 203.475	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 54.005	5	8.740 - 11.330	8.861 - 11.200	8.977 - 9.960	WATER FLUX =
	10	11.219 - 13.025	11.376 - 13.019	12.306 - 12.599	= 0.25 $cm^3/s\text{-}cm^2$
	15	12.677 - 15.827	12.905 - 15.459	13.098 - 14.734	
	20	14.323 - 17.823	14.883 - 17.425	15.734 - 16.701	
	25	16.395 - 20.781	16.698 - 19.782	17.366 - 18.674	
STD. DEV. =	30	18.185 - 23.593	18.464 - 23.224	19.638 - 21.950	FALL DISTANCE =
= 44.748	35	21.014 - 26.491	21.503 - 26.351	22.896 - 25.100	= 3000 cm
	40	23.628 - 30.625	24.400 - 30.025	25.655 - 27.792	
	45	26.477 - 37.741	26.609 - 36.550	29.152 - 35.208	
	50	30.466 - 43.556	31.547 - 43.076	36.021 - 38.510	
SAMPLE SIZE =	55	37.511 - 51.675	37.829 - 50.265	41.151 - 46.302	AEROSOL MASS
= 360	60	43.389 - 64.281	44.431 - 61.619	49.956 - 56.138	FRACTION REMAINING =
	65	51.609 - 72.585	54.595 - 71.003	60.928 - 67.971	= 0.1
	70	64.685 - 80.755	66.562 - 78.536	69.795 - 74.971	
	75	72.909 - 87.684	73.646 - 86.817	77.802 - 83.298	
	80	82.261 - 99.123	83.140 - 97.797	86.665 - 90.178	
	85	90.000 - 118.415	92.047 - 113.183	98.103 - 103.663	
	90	104.247 - 132.710	105.802 - 130.606	118.470 - 126.531	
	95	130.853 - 166.218	133.108 - 164.719	140.626 - 154.134	

	Quantile (%)	Range for λ(hr⁻¹) at a confidence level of 95%	90%	50%	
MEAN = 34.326	5	4.625 - 6.246	4.696 - 6.166	5.040 - 5.829	WATER FLUX =
	10	6.178 - 8.276	6.333 - 8.045	6.960 - 7.577	= 0.25 $cm^3/s\text{-}cm^2$
	15	7.616 - 9.246	7.900 - 9.129	8.373 - 8.758	
	20	8.750 - 10.492	8.771 - 10.280	9.193 - 9.861	
	25	9.743 - 12.618	9.845 - 12.061	10.275 - 11.416	
STD. DEV. =	30	10.986 - 14.447	11.228 - 13.932	11.776 - 13.125	FALL DISTANCE =
= 30.054	35	12.727 - 16.475	12.914 - 16.159	13.562 - 15.259	= 3000 cm
	40	14.513 - 20.026	14.733 - 19.790	16.058 - 18.570	
	45	16.436 - 23.019	17.897 - 22.861	19.295 - 20.973	
	50	19.898 - 28.279	20.493 - 27.082	22.498 - 23.609	
SAMPLE SIZE =	55	22.924 - 33.076	23.312 - 31.990	25.549 - 29.099	AEROSOL MASS
= 360	60	28.198 - 38.545	28.620 - 38.138	30.979 - 34.142	FRACTION REMAINING =
	65	32.883 - 43.983	33.614 - 42.579	36.402 - 39.891	= 0.01
	70	38.628 - 49.756	39.080 - 49.232	42.114 - 46.076	
	75	44.457 - 56.832	45.617 - 56.254	48.454 - 52.390	
	80	51.464 - 62.291	52.274 - 61.204	55.969 - 59.558	
	85	59.319 - 71.641	59.634 - 69.932	61.462 - 65.921	
	90	66.527 - 88.076	67.533 - 87.285	72.606 - 81.688	
	95	87.424 - 111.321	88.276 - 110.512	95.021 - 100.560	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of 95%	90%	50%	
MEAN = 26.827	5	3.488 - 4.855	3.513 - 4.830	3.847 - 4.374	WATER FLUX =
	10	4.831 - 6.065	4.868 - 5.990	4.994 - 5.614	= 0.25 $cm^3/s\text{-}cm^2$
	15	5.675 - 6.837	5.831 - 6.776	6.144 - 6.648	
	20	6.622 - 7.988	6.697 - 7.905	6.787 - 7.595	
	25	7.464 - 9.442	7.590 - 9.274	7.902 - 8.432	
STD. DEV. =	30	8.125 - 11.201	8.369 - 10.758	9.180 - 10.228	FALL DISTANCE =
= 24.287	35	9.627 - 12.776	9.851 - 12.458	10.554 - 11.881	= 3000 cm
	40	11.247 - 15.814	11.437 - 15.432	12.140 - 13.881	
	45	12.751 - 17.590	12.977 - 17.180	14.870 - 16.206	
	50	15.673 - 22.155	15.936 - 21.247	16.882 - 18.893	
SAMPLE SIZE =	55	17.485 - 26.200	17.897 - 25.598	19.972 - 22.708	AEROSOL MASS
= 360	60	22.004 - 28.590	22.256 - 28.157	24.861 - 26.844	FRACTION REMAINING =
	65	26.074 - 34.013	26.590 - 33.611	27.361 - 29.887	= 0.001
	70	28.663 - 37.514	29.124 - 37.101	33.010 - 35.298	
	75	34.210 - 44.502	34.462 - 42.903	36.763 - 40.446	
	80	39.985 - 49.242	40.410 - 48.681	42.871 - 46.394	
	85	45.901 - 55.683	46.789 - 53.416	49.150 - 51.431	
	90	51.576 - 69.427	52.521 - 68.300	56.263 - 64.698	
	95	68.626 - 89.916	69.579 - 87.932	73.075 - 82.446	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 121.583	5	17.110 - 21.362	18.467 - 21.310	18.965 - 20.058	WATER FLUX =
	10	21.326 - 26.431	21.484 - 26.221	22.012 - 23.844	= 0.25 $cm^3/s\text{-}cm^2$
	15	24.317 - 30.580	24.936 - 30.119	27.406 - 29:281	
	20	29.110 - 36.233	29.396 - 35.825	30.302 - 32.527	
	25	31.647 - 40.175	32.459 - 39.317	35.730 - 38.134	
STD. DEV. =	30	37.139 - 46.390	37.701 - 45.978	39.105 - 42.987	FALL DISTANCE =
= 112.669	35	41.067 - 54.474	42.413 - 52.936	45.075 - 50.098	= 4000 cm
	40	46.467 - 63.760	48.255 - 62.401	52.479 - 58.036	
	45	54.456 - 78.114	54.650 - 75.539	61.388 - 69.596	
	50	63.533 - 93.959	66.476 - 91.227	73.854 - 84.354	
SAMPLE SIZE =	55	77.166 - 118.278	80.536 - 112.428	89.081 - 99.369	AEROSOL MASS
= 360	60	92.047 - 142.269	96.927 - 138.797	107.289 - 126.110	FRACTION REMAINING =
	65	116.725 - 156.302	121.716 - 154.732	134.828 - 148.200	= 0.90
	70	143.660 - 180.503	146.749 - 177.559	151.774 - 165.533	
	75	161.123 - 196.436	164.383 - 195.699	169.703 - 190.874	
	80	185.750 - 218.415	190.552 - 218.320	195.689 - 204.253	
	85	204.098 - 257.822	204.528 - 251.936	218.409 - 237.296	
	90	244.619 - 316.002	248.930 - 309.229	258.594 - 293.299	
	95	312.595 - 376.437	316.208 - 373.027	335.504 - 369.839	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of 95%	90%	50%	
MEAN = 88.344	5	13.796 - 17.018	14.126 - 16.824	14.765 - 16.028	WATER FLUX =
	10	16.828 - 19.150	17.068 - 18.748	17.709 - 18.180	= 0.25 $cm^3/s\text{-}cm^2$
	15	18.333 - 23.823	18.499 - 23.178	19.497 - 21.029	
	20	20.830 - 27.233	21.413 - 27.105	23.672 - 25.552	
	25	25.187 - 30.596	25.511 - 30.139	27.086 - 28.834	
STD. DEV. =	30	28.066 - 32.843	28.756 - 32.432	29.786 - 31.016	FALL DISTANCE =
= 78.240	35	30.627 - 40.111	30.892 - 39.421	32.202 - 36.192	= 4000 cm
	40	33.213 - 48.036	34.749 - 47.032	38.352 - 41.918	
	45	40.087 - 57.096	40.871 - 55.347	44.447 - 51.528	
	50	47.914 - 68.062	48.304 - 64.796	53.575 - 59.184	
SAMPLE SIZE =	55	56.509 - 89.731	58.097 - 88.050	61.775 - 75.123	AEROSOL MASS
= 360	60	65.787 - 107.340	72.288 - 103.724	82.961 - 98.385	FRACTION REMAINING =
	65	89.446 - 120.641	93.553 - 118.302	101.493 - 110.677	= 0.5
	70	107.608 - 133.334	108.430 - 132.095	116.680 - 125.499	
	75	122.291 - 144.573	123.770 - 141.384	131.594 - 136.325	
	80	134.884 - 165.392	136.300 - 162.862	141.319 - 152.384	
	85	151.784 - 188.331	153.100 - 183.196	164.068 - 175.468	
	90	178.407 - 218.444	180.940 - 216.779	190.577 - 206.531	
	95	217.017 - 272.680	218.653 - 253.195	226.735 - 244.030	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 71.869	5	11.049 - 13.577	11.445 - 13.297	12.300 - 12.950	WATER FLUX =
	10	13.301 - 16.313	13.606 - 15.787	14.312 - 15.184	= 0.25 $cm^3/s\text{-}cm^2$
	15	15.482 - 18.328	15.676 - 17.966	16.558 - 17.103	
	20	17.077 - 22.893	17.288 - 22.176	18.138 - 21.232	
	25	20.677 - 25.000	21.144 - 24.662	22.157 - 23.644	
STD. DEV. =	30	23.126 - 27.240	23.477 - 26.893	24.517 - 25.785	FALL DISTANCE =
= 62.243	35	25.098 - 32.584	25.548 - 31.338	26.548 - 28.410	= 4000 cm
	40	27.331 - 38.928	27.711 - 37.985	29.861 - 34.251	
	45	32.439 - 45.570	33.466 - 44.668	36.939 - 43.130	
	50	38.751 - 55.809	39.699 - 54.898	43.660 - 48.285	
SAMPLE SIZE =	55	45.189 - 73.242	45.926 - 72.165	51.557 - 63.693	AEROSOL MASS
= 360	60	55.161 - 89.911	58.288 - 87.078	68.335 - 75.843	FRACTION REMAINING =
	65	73.214 - 100.148	74.069 - 99.579	84.018 - 92.887	= 0.3
	70	90.389 - 108.304	91.412 - 106.357	98.605 - 102.235	
	75	100.702 - 115.788	102.175 - 115.139	106.047 - 110.284	
	80	109.973 - 133.678	110.220 - 131.538	114.937 - 121.232	
	85	120.899 - 157.298	126.082 - 155.886	131.637 - 147.948	
	90	151.636 - 175.340	154.402 - 171.409	158.233 - 165.073	
	95	171.599 - 213.051	175.558 - 210.258	186.163 - 196.605	

	Quantile (%)	Range for $\lambda (hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 51.263	5	7.395 - 9.728	7.512 - 9.463	7.830 - 8.587	WATER FLUX =
	10	9.484 - 11.028	9.753 - 10.985	10.210 - 10.761	= 0.25 $cm^3/s\text{-}cm^2$
	15	10.827 - 13.539	10.893 - 13.245	11.143 - 12.555	
	20	12.376 - 15.170	12.584 - 14.936	13.400 - 14.097	
	25	13.898 - 17.434	14.093 - 16.828	14.895 - 16.157	
STD. DEV. =	30	15.613 - 20.179	15.872 - 19.438	16.544 - 18.531	FALL DISTANCE =
= 44.386	35	17.825 - 22.773	18.169 - 22.230	19.178 - 21.056	= 4000 cm
	40	20.327 - 28.686	20.956 - 26.404	21.882 - 23.683	
	45	22.647 - 32.763	23.204 - 31.922	25.180 - 30.019	
	50	28.369 - 41.417	29.301 - 39.688	31.066 - 36.164	
SAMPLE SIZE =	55	32.199 - 49.935	34.215 - 48.801	37.685 - 43.108	AEROSOL MASS
= 360	60	40.653 - 62.709	42.139 - 60.409	46.339 - 54.935	FRACTION REMAINING =
	65	49.679 - 71.516	52.326 - 69.789	58.793 - 66.110	= 0.1
	70	62.893 - 78.767	65.661 - 76.380	68.217 - 72.862	
	75	71.911 - 85.730	72.250 - 84.707	75.686 - 81.286	
	80	80.500 - 96.517	81.259 - 95.092	84.214 - 88.152	
	85	87.900 - 115.839	89.659 - 105.488	95.718 - 100.197	
	90	100.866 - 129.603	101.459 - 127.837	116.581 - 123.334	
	95	128.367 - 160.745	129.915 - 154.115	136.910 - 150.322	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 32.570	5	3.963 - 5.625	4.071 - 5.368	4.474 - 4.944	WATER FLUX =
	10	5.397 - 6.877	5.628 - 6.798	5.885 - 6.449	= 0.25 $cm^3/s\text{-}cm^2$
	15	6.535 - 7.853	6.662 - 7.767	7.097 - 7.421	
	20	7.377 - 8.941	7.427 - 8.796	7.829 - 8.411	
	25	8.274 - 10.650	8.410 - 10.263	8.781 - 9.618	
STD. DEV. =	30	9.330 - 12.384	9.501 - 12.156	10.146 - 11.060	FALL DISTANCE =
= 29.665	35	10.746 - 14.915	10.899 - 13.901	11.918 - 13.146	= 4000 cm
	40	12.443 - 17.280	12.725 - 16.813	13.442 - 15.945	
	45	14.894 - 20.787	15.253 - 19.883	16.161 - 18.934	
	50	17.230 - 26.707	17.325 - 24.867	19.421 - 22.569	
SAMPLE SIZE =	55	20.542 - 31.053	21.287 - 30.344	23.501 - 27.955	AEROSOL MASS
= 360	60	26.483 - 37.689	27.677 - 36.119	29.016 - 32.976	FRACTION REMAINING =
	65	30.956 - 42.788	32.075 - 41.341	35.272 - 39.014	= 0.01
	70	37.873 - 48.662	38.234 - 47.517	40.758 - 44.858	
	75	43.581 - 55.436	44.429 - 54.729	47.105 - 51.390	
	80	50.152 - 59.784	51.281 - 58.987	54.720 - 56.561	
	85	56.176 - 69.757	57.860 - 67.969	59.679 - 63.909	
	90	65.146 - 85.745	66.120 - 85.082	71.017 - 79.712	
	95	85.590 - 107.627	85.797 - 104.675	91.038 - 99.629	

	Quantile (%)	Range for λ(hr^{-1}) at a confidence level of 95%	90%	50%	
MEAN = 25.485	5	2.962 - 4.130	3.018 - 4.111	3.282 - 3.703	WATER FLUX =
	10	4.114 - 5.114	4.152 - 5.050	4.452 - 4.793	= 0.25 $cm^3/s\text{-}cm^3$
	15	4.818 - 6.104	4.882 - 5.843	5.312 - 5.599	
	20	5.597 - 6.752	5.672 - 6.671	6.030 - 6.352	
	25	6.323 - 7.991	6.348 - 7.807	6.663 - 7.188	
STD. DEV. =	30	6.914 - 9.544	6.997 - 9.395	7.737 - 8.646	FALL DISTANCE =
= 23.997	35	8.080 - 11.131	8.498 - 10.728	9.121 - 10.023	= 4000 cm
	40	9.571 - 13.539	9.682 - 13.205	10.429 - 12.180	
	45	10.990 - 16.119	11.609 - 15.786	12.674 - 14.248	
	50	13.502 - 20.758	13.944 - 19.811	14.826 - 16.922	
SAMPLE SIZE =	55	15.802 - 24.900	16.386 - 23.636	18.470 - 22.020	AEROSOL MASS
= 360	60	20.667 - 28.106	21.317 - 27.170	22.943 - 25.985	FRACTION REMAINING =
	65	24.800 - 33.062	25.439 - 32.693	26.815 - 28.960	= 0.001
	70	28.328 - 36.488	28.659 - 36.119	32.193 - 33.870	
	75	33.343 - 42.049	33.768 - 41.824	35.771 - 39.710	
	80	37.984 - 47.926	39.654 - 46.548	41.796 - 44.711	
	85	44.645 - 54.265	45.175 - 52.297	47.173 - 50.138	
	90	50.761 - 67.258	51.447 - 66.678	55.233 - 63.352	
	95	67.106 - 87.555	67.297 - 85.633	70.870 - 80.704	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of 95%	90%	50%	
MEAN = 117.276	5	15.827 - 18.894	16.171 - 18.695	16.584 - 17.596	WATER FLUX =
	10	18.695 - 23.706	18.934 - 23.316	19.500 - 20.926	= 0.25 $cm^3/s\text{-}cm^2$
	15	21.270 - 26.644	21.942 - 26.255	23.840 - 25.403	
	20	25.329 - 31.694	25.562 - 31.041	26.411 - 28.012	
	25	27.381 - 35.635	27.942 - 34.445	30.920 - 33.126	
STD. DEV. =	30	32.416 - 40.724	33.051 - 40.308	34.297 - 37.753	FALL DISTANCE =
= 112.495	35	36.229 - 50.739	36.717 - 48.316	39.715 - 45.003	= 5000 cm
	40	41.065 - 58.636	43.086 - 55.159	46.718 - 53.096	
	45	50.445 - 73.263	51.379 - 66.686	54.137 - 62.323	
	50	57.498 - 85.878	59.796 - 83.549	65.440 - 76.867	
SAMPLE SIZE =	55	70.859 - 111.450	75.478 - 110.107	80.719 - 90.732	AEROSOL MASS
= 360	60	85.297 - 140.614	89.074 - 136.918	104.312 - 124.289	FRACTION REMAINING =
	65	111.052 - 153.373	118.476 - 151.297	131.001 - 145.253	= 0.9
	70	141.708 - 177.634	143.808 - 174.684	150.075 - 162.316	
	75	155.044 - 194.749	161.110 - 193.796	171.123 - 187.663	
	80	182.978 - 215.985	187.404 - 213.862	192.905 - 202.119	
	85	201.781 - 252.796	202.710 - 248.316	214.297 - 234.484	
	90	240.261 - 312.396	246.726 - 305.904	253.568 - 288.417	
	95	310.479 - 373.957	312.440 - 370.694	332.524 - 365.953	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 85.048	5	12.004 - 14.877	12.421 - 14.867	12.827 - 14.535	WATER FLUX =
	10	14.870 - 16.687	14.957 - 16.499	15.388 - 15.957	= 0.25 $cm^3/s\text{-}cm^2$
	15	16.046 - 20.788	16.219 - 20.372	17.173 - 18.541	
	20	18.242 - 23.732	19.429 - 23.460	20.712 - 22.204	
	25	22.011 - 26.739	22.137 - 26.278	23.438 - 25.136	
STD. DEV. =	30	24.637 - 29.987	24.906 - 28.381	26.217 - 27.192	FALL DISTANCE =
= 77.924	35	26.873 - 35.810	26.970 - 34.873	28.311 - 31.634	= 5000 cm
	40	30.347 - 44.288	31.331 - 42.635	33.636 - 37.497	
	45	35.806 - 51.748	36.151 - 50.599	40.608 - 46.735	
	50	43.134 - 64.358	45.241 - 58.793	47.699 - 53.529	
SAMPLE SIZE =	55	51.456 - 87.873	52.364 - 86.221	56.277 - 72.335	AEROSOL MASS
= 360	60	63.169 - 105.737	67.742 - 101.931	82.087 - 94.938	FRACTION REMAINING =
	65	87.850 - 118.466	88.817 - 115.798	99.421 - 108.027	= 0.5
	70	105.899 - 131.543	107.088 - 130.459	114.446 - 123.236	
	75	120.238 - 140.954	120.683 - 139.522	128.990 - 133.755	
	80	131.956 - 162.562	133.660 - 160.143	139.250 - 149.273	
	85	148.795 - 183.438	150.205 - 179.680	161.972 - 172.105	
	90	174.598 - 213.963	177.006 - 212.539	186.432 - 203.207	
	95	212.878 - 267.069	214.180 - 249.686	223.813 - 239.079	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 69.150	5	9.640 - 11.767	10.032 - 11.678	10.830 - 11.400	WATER FLUX =
	10	11.680 - 14.151	11.835 - 13.796	12.664 - 13.225	= 0.25 $cm^3/s\text{-}cm^2$
	15	13.378 - 16.118	13.667 - 15.605	14.496 - 15.053	
	20	14.963 - 19.762	15.079 - 19.361	16.009 - 18.505	
	25	18.369 - 21.998	18.499 - 21.668	19.346 - 20.717	
STD. DEV. =	30	20.129 - 23.851	20.579 - 23.555	21.583 - 22.802	FALL DISTANCE =
= 61.996	35	22.201 - 28.507	22.482 - 27.790	23.454 - 25.314	= 5000 cm
	40	23.959 - 34.981	24.553 - 33.902	26.426 - 31.074	
	45	28.203 - 42.082	29.393 - 41.165	32.823 - 38.190	
	50	34.397 - 54.440	37.329 - 50.247	39.577 - 43.410	
SAMPLE SIZE =	55	41.858 - 71.636	42.558 - 69.443	45.367 - 62.353	AEROSOL MASS
= 360	60	53.775 - 87.913	55.455 - 85.550	64.842 - 74.312	FRACTION REMAINING =
	65	71.595 - 99.352	72.623 - 98.131	82.285 - 91.961	= 0.3
	70	88.450 - 106.087	90.329 - 105.044	97.443 - 100.238	
	75	99.647 - 113.395	100.190 - 111.662	104.592 - 108.981	
	80	108.431 - 132.318	108.965 - 129.782	111.474 - 118.335	
	85	117.825 - 154.205	119.835 - 153.388	130.067 - 147.310	
	90	148.595 - 170.289	151.242 - 168.371	154.331 - 162.141	
	95	168.518 - 209.498	170.469 - 207.313	182.325 - 192.519	

	Quantile (%)	Range for $\lambda (hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 49.175	5	6.460 - 8.518	6.548 - 8.380	6.945 - 7.491	WATER FLUX =
	10	8.397 - 9.688	8.521 - 9.652	8.928 - 9.447	= 0.25 $cm^3/s\text{-}cm^2$
	15	9.478 - 11.790	9.588 - 11.632	9.798 - 10.964	
	20	10.794 - 13.238	11.012 - 13.111	11.766 - 12.418	
	25	12.155 - 15.602	12.341 - 15.440	13.080 - 14.115	
STD. DEV. =	30	13.628 - 17.757	13.912 - 16.846	15.171 - 16.432	FALL DISTANCE =
= 43.776	35	16.055 - 19.829	16.251 - 19.310	16.697 - 18.337	= 5000 cm
	40	17.846 - 25.384	18.094 - 23.355	18.877 - 21.337	
	45	19.561 - 29.949	20.540 - 28.468	22.913 - 26.783	
	50	25.284 - 39.247	25.713 - 37.178	28.085 - 33.663	
SAMPLE SIZE =	55	29.649 - 49.143	30.733 - 47.856	35.938 - 41.924	AEROSOL MASS
= 360	60	37.767 - 62.010	40.512 - 59.862	45.439 - 52.580	FRACTION REMAINING =
	65	48.943 - 70.193	50.866 - 68.207	57.474 - 65.019	= 0.1
	70	62.140 - 77.301	63.702 - 75.226	66.704 - 71.675	
	75	70.722 - 84.293	71.387 - 82.495	74.251 - 80.072	
	80	79.017 - 94.631	79.992 - 92.908	82.390 - 86.580	
	85	86.174 - 113.901	86.845 - 104.041	93.389 - 97.168	
	90	98.799 - 125.670	99.381 - 124.472	115.184 - 120.898	
	95	124.565 - 152.793	125.685 - 151.789	133.312 - 145.146	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of 95%	90%	50%	
MEAN = 31.378	5	3.522 - 4.893	3.596 - 4.806	3.998 - 4.341	WATER FLUX =
	10	4.824 - 5.975	4.903 - 5.924	5.222 - 5.690	= 0.25 $cm^3/s\text{-}cm^2$
	15	5.751 - 6.881	5.818 - 6.759	6.163 - 6.475	
	20	6.466 - 7.883	6.516 - 7.733	6.859 - 7.358	
	25	7.216 - 9.388	7.350 - 9.071	7.722 - 8.370	
STD. DEV. =	30	8.242 - 10.853	8.299 - 10.546	9.018 - 9.676	FALL DISTANCE =
= 29.445	35	9.459 - 12.988	9.501 - 12.788	10.408 - 11.525	= 5000 cm
	40	10.898 - 15.202	11.178 - 14.901	12.232 - 13.881	
	45	12.987 - 19.558	13.332 - 18.562	14.321 - 16.490	
	50	15.152 - 24.624	15.815 - 23.731	17.208 - 21.212	
SAMPLE SIZE =	55	19.244 - 30.510	20.067 - 29.891	22.584 - 27.345	AEROSOL MASS
= 360	60	24.328 - 36.924	25.819 - 35.701	28.793 - 31.856	FRACTION REMAINING =
	65	30.382 - 42.154	31.100 - 40.390	34.273 - 38.152	= 0.01
	70	37.077 - 47.625	37.767 - 46.323	39.711 - 44.352	
	75	43.206 - 54.146	43.864 - 53.666	45.854 - 49.470	
	80	48.863 - 59.788	49.367 - 58.377	53.367 - 56.017	
	85	55.702 - 68.306	56.618 - 67.434	59.162 - 63.560	
	90	64.595 - 84.715	66.520 - 83.500	68.896 - 78.653	
	95	84.038 - 105.470	84.766 - 101.319	89.334 - 97.037	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 24.523	5	2.591 - 3.600	2.642 - 3.572	3.007 - 3.291	WATER FLUX =
	10	3.576 - 4.477	3.623 - 4.409	3.951 - 4.148	= 0.25 $cm^3/s\text{-}cm^2$
	15	4.193 - 5.270	4.272 - 5.232	4.604 - 4.923	
	20	4.901 - 5.954	4.977 - 5.902	5.258 - 5.529	
	25	5.478 - 6.928	5.520 - 6.793	5.898 - 6.364	
STD. DEV. =	30	6.152 - 8.278	6.226 - 8.154	6.742 - 7.534	FALL DISTANCE =
= 23.718	35	7.277 - 9.774	7.510 - 9.458	8.016 - 8.930	= 5000 cm
	40	8.303 - 12.138	8.574 - 11.763	9.278 - 10.774	
	45	9.723 - 15.496	10.487 - 14.311	11.491 - 12.485	
	50	11.955 - 19.874	12.316 - 18.634	13.505 - 16.358	
SAMPLE SIZE =	55	14.527 - 24.486	15.602 - 22.759	16.883 - 20.841	AEROSOL MASS
= 360	60	19.565 - 26.751	20.249 - 26.577	22.263 - 25.295	FRACTION REMAINING =
	65	24.467 - 32.355	24.984 - 32.116	26.262 - 28.576	= 0.001
	70	26.896 - 35.964	28.058 - 35.449	31.179 - 33.411	
	75	32.459 - 41.368	33.384 - 40.869	35.089 - 38.780	
	80	36.582 - 47.575	38.495 - 46.098	40.861 - 44.129	
	85	43.753 - 53.642	44.342 - 52.128	47.246 - 50.005	
	90	50.176 - 66.036	51.393 - 64.798	54.311 - 61.002	
	95	64.972 - 84.053	66.073 - 80.984	70.008 - 75.425	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 1.088	5	0.252 - 0.353	0.253 - 0.349	0.278 - 0.317	WATER FLUX =
	10	0.352 - 0.430	0.355 - 0.424	0.378 - 0.410	= 0.001 $cm^3/s\text{-}cm^2$
	15	0.418 - 0.490	0.422 - 0.483	0.435 - 0.466	
	20	0.466 - 0.547	0.467 - 0.542	0.490 - 0.518	
	25	0.512 - 0.619	0.520 - 0.605	0.545 - 0.587	
STD. DEV. =	30	0.582 - 0.677	0.585 - 0.658	0.605 - 0.633	FALL DISTANCE =
= 0.953	35	0.624 - 0.736	0.632 - 0.730	0.652 - 0.709	= 500 cm
	40	0.687 - 0.798	0.699 - 0.790	0.725 - 0.742	
	45	0.739 - 0.856	0.739 - 0.838	0.775 - 0.821	
	50	0.801 - 0.925	0.804 - 0.920	0.834 - 0.859	
SAMPLE SIZE =	55	0.857 - 1.003	0.857 - 0.994	0.903 - 0.955	AEROSOL MASS
= 400	60	0.926 - 1.081	0.938 - 1.071	0.983 - 1.050	FRACTION REMAINING =
	65	1.005 - 1.169	1.030 - 1.159	1.065 - 1.120	= 0.9
	70	1.101 - 1.287	1.117 - 1.272	1.157 - 1.243	
	75	1.204 - 1.409	1.237 - 1.390	1.269 - 1.351	
	80	1.331 - 1.628	1.357 - 1.608	1.394 - 1.476	
	85	1.478 - 1.832	1.538 - 1.807	1.628 - 1.711	
	90	1.762 - 2.388	1.788 - 2.364	1.891 - 2.227	
	95	2.378 - 2.705	2.391 - 2.705	2.474 - 2.663	

	Quantile (%)	Range for λ(hr^{-1}) at a confidence level of			
		95%	90%	50%	
MEAN = 0.792	5	0.167 - 0.293	0.172 - 0.290	0.202 - 0.263	WATER FLUX =
	10	0.292 - 0.327	0.296 - 0.327	0.305 - 0.318	= 0.001 $cm^3/s\text{-}cm^2$
	15	0.320 - 0.377	0.325 - 0.365	0.334 - 0.346	
	20	0.346 - 0.420	0.353 - 0.416	0.377 - 0.392	
	25	0.387 - 0.457	0.395 - 0.452	0.417 - 0.440	
STD. DEV. =	30	0.436 - 0.502	0.439 - 0.494	0.451 - 0.471	FALL DISTANCE =
= 0.616	35	0.470 - 0.534	0.470 - 0.523	0.488 - 0.508	= 500 cm
	40	0.504 - 0.615	0.505 - 0.597	0.518 - 0.558	
	45	0.539 - 0.682	0.556 - 0.657	0.586 - 0.628	
	50	0.621 - 0.722	0.621 - 0.713	0.644 - 0.694	
SAMPLE SIZE =	55	0.682 - 0.757	0.687 - 0.756	0.710 - 0.743	AEROSOL MASS
= 400	60	0.724 - 0.836	0.733 - 0.827	0.746 - 0.778	FRACTION REMAINING =
	65	0.765 - 0.910	0.768 - 0.904	0.826 - 0.844	= 0.5
	70	0.838 - 0.987	0.844 - 0.970	0.898 - 0.943	
	75	0.925 - 1.041	0.943 - 1.022	0.968 - 1.006	
	80	1.002 - 1.117	1.008 - 1.087	1.023 - 1.047	
	85	1.047 - 1.260	1.073 - 1.241	1.112 - 1.164	
	90	1.204 - 1.615	1.227 - 1.552	1.262 - 1.477	
	95	1.595 - 2.151	1.625 - 2.018	1.680 - 1.892	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of 95%	90%	50%	
MEAN = 0.647	5	0.143 - 0.232	0.147 - 0.232	0.180 - 0.219	WATER FLUX =
	10	0.232 - 0.201	0.240 - 0.279	0.252 - 0.272	= 0.001 $cm^3/s\text{-}cm^2$
	15	0.276 - 0.305	0.276 - 0.303	0.283 - 0.295	
	20	0.295 - 0.339	0.296 - 0.335	0.305 - 0.325	
	25	0.318 - 0.373	0.325 - 0.373	0.336 - 0.355	
STD. DEV. =	30	0.352 - 0.402	0.355 - 0.399	0.372 - 0.391	FALL DISTANCE =
= 0.456	35	0.381 - 0.447	0.389 - 0.443	0.399 - 0.412	= 500 cm
	40	0.404 - 0.501	0.408 - 0.496	0.438 - 0.461	
	45	0.448 - 0.552	0.459 - 0.551	0.489 - 0.518	
	50	0.510 - 0.609	0.512 - 0.591	0.539 - 0.559	
SAMPLE SIZE =	55	0.552 - 0.659	0.558 - 0.647	0.574 - 0.627	AEROSOL MASS
= 400	60	0.616 - 0.694	0.624 - 0.689	0.639 - 0.668	FRACTION REMAINING =
	65	0.666 - 0.747	0.667 - 0.737	0.679 - 0.704	= 0.3
	70	0.696 - 0.784	0.698 - 0.775	0.736 - 0.766	
	75	0.749 - 0.857	0.763 - 0.848	0.774 - 0.802	
	80	0.799 - 0.929	0.804 - 0.919	0.852 - 0.898	
	85	0.898 - 1.023	0.901 - 1.000	0.928 - 0.962	
	90	0.987 - 1.232	0.997 - 1.196	1.063 - 1.073	
	95	1.222 - 1.796	1.264 - 1.618	1.410 - 1.523	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 0.463	5	0.101 - 0.160	0.102 - 0.156	0.128 - 0.145	WATER FLUX =
	10	0.159 - 0.197	0.162 - 0.195	0.180 - 0.187	= 0.001 $cm^3/s\text{-}cm^2$
	15	0.191 - 0.224	0.194 - 0.221	0.200 - 0.212	
	20	0.212 - 0.249	0.217 - 0.247	0.224 - 0.234	
	25	0.232 - 0.264	0.236 - 0.262	0.247 - 0.253	
STD. DEV. =	30	0.250 - 0.291	0.253 - 0.284	0.261 - 0.276	FALL DISTANCE =
= 0.326	35	0.273 - 0.315	0.275 - 0.314	0.278 - 0.301	= 500 cm
	40	0.293 - 0.359	0.295 - 0.353	0.314 - 0.324	
	45	0.316 - 0.393	0.322 - 0.392	0.344 - 0.368	
	50	0.359 - 0.432	0.359 - 0.429	0.379 - 0.412	
SAMPLE SIZE =	55	0.400 - 0.461	0.406 - 0.456	0.428 - 0.444	AEROSOL MASS
= 400	60	0.434 - 0.498	0.435 - 0.496	0.454 - 0.468	FRACTION REMAINING =
	65	0.461 - 0.538	0.465 - 0.523	0.490 - 0.512	= 0.10
	70	0.503 - 0.583	0.512 - 0.571	0.520 - 0.544	
	75	0.542 - 0.612	0.542 - 0.605	0.569 - 0.590	
	80	0.590 - 0.649	0.591 - 0.644	0.605 - 0.631	
	85	0.632 - 0.747	0.637 - 0.736	0.649 - 0.702	
	90	0.709 - 0.908	0.719 - 0.904	0.779 - 0.823	
	95	0.907 - 1.387	0.910 - 1.315	0.994 - 1.105	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of 95%	90%	50%	
MEAN = 0.295	5	0.060 - 0.096	0.061 - 0.091	0.072 - 0.087	WATER FLUX =
	10	0.096 - 0.118	0.097 - 0.116	0.106 - 0.111	= 0.001 $cm^3/s\text{-}cm^2$
	15	0.112 - 0.134	0.114 - 0.132	0.119 - 0.128	
	20	0.127 - 0.156	0.130 - 0.150	0.134 - 0.141	
	25	0.141 - 0.172	0.142 - 0.170	0.154 - 0.164	
STD. DEV. =	30	0.163 - 0.184	0.164 - 0.183	0.170 - 0.177	FALL DISTANCE =
= 0.210	35	0.174 - 0.200	0.177 - 0.196	0.181 - 0.185	= 500 cm
	40	0.184 - 0.219	0.184 - 0.216	0.195 - 0.207	
	45	0.201 - 0.239	0.203 - 0.237	0.210 - 0.230	
	50	0.223 - 0.263	0.228 - 0.256	0.235 - 0.252	
SAMPLE SIZE =	55	0.241 - 0.284	0.248 - 0.280	0.255 - 0.271	AEROSOL MASS
= 400	60	0.264 - 0.308	0.267 - 0.307	0.279 - 0.291	FRACTION REMAINING =
	65	0.285 - 0.329	0.288 - 0.326	0.301 - 0.313	= 0.01
	70	0.311 - 0.360	0.313 - 0.356	0.325 - 0.336	
	75	0.331 - 0.397	0.335 - 0.393	0.356 - 0.383	
	80	0.377 - 0.456	0.384 - 0.438	0.393 - 0.405	
	85	0.405 - 0.512	0.415 - 0.508	0.455 - 0.483	
	90	0.501 - 0.609	0.508 - 0.596	0.522 - 0.580	
	95	0.607 - 0.895	0.633 - 0.833	0.658 - 0.710	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of 95%	90%	50%	
MEAN = 0.231	5	0.044 - 0.070	0.046 - 0.069	0.056 - 0.065	WATER FLUX =
	10	0.070 - 0.088	0.072 - 0.087	0.078 - 0.083	= 0.001 $cm^3/s\text{-}cm^2$
	15	0.086 - 0.104	0.086 - 0.103	0.090 - 0.099	
	20	0.099 - 0.118	0.100 - 0.115	0.104 - 0.111	
	25	0.108 - 0.134	0.111 - 0.132	0.116 - 0.123	
STD. DEV. =	30	0.121 - 0.148	0.122 - 0.146	0.132 - 0.142	FALL DISTANCE =
= 0.171	35	0.137 - 0.153	0.141 - 0.153	0.145 - 0.151	= 500 cm
	40	0.149 - 0.172	0.151 - 0.164	0.152 - 0.159	
	45	0.153 - 0.185	0.155 - 0.184	0.163 - 0.177	
	50	0.174 - 0.200	0.175 - 0.199	0.181 - 0.193	
SAMPLE SIZE =	55	0.185 - 0.211	0.190 - 0.210	0.197 - 0.202	AEROSOL MASS
= 400	60	0.201 - 0.238	0.201 - 0.234	0.206 - 0.220	FRACTION REMAINING =
	65	0.213 - 0.254	0.215 - 0.252	0.233 - 0.245	= 0.001
	70	0.241 - 0.280	0.244 - 0.276	0.250 - 0.269	
	75	0.264 - 0.312	0.269 - 0.310	0.275 - 0.302	
	80	0.287 - 0.362	0.303 - 0.336	0.310 - 0.319	
	85	0.319 - 0.417	0.321 - 0.415	0.359 - 0.404	
	90	0.408 - 0.489	0.411 - 0.489	0.425 - 0.448	
	95	0.489 - 0.702	0.490 - 0.668	0.524 - 0.571	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of 95%	90%	50%	
MEAN = 1.058	5	0.248 - 0.348	0.252 - 0.342	0.267 - 0.317	WATER FLUX =
	10	0.348 - 0.424	0.351 - 0.423	0.364 - 0.400	= 0.001 $cm^3/s\text{-}cm^2$
	15	0.401 - 0.486	0.417 - 0.471	0.429 - 0.452	
	20	0.451 - 0.544	0.455 - 0.535	0.487 - 0.511	
	25	0.505 - 0.602	0.515 - 0.593	0.539 - 0.561	
STD. DEV. =	30	0.553 - 0.657	0.559 - 0.649	0.589 - 0.623	FALL DISTANCE =
= 0.912	35	0.607 - 0.706	0.619 - 0.695	0.649 - 0.690	= 5000 cm
	40	0.665 - 0.774	0.676 - 0.765	0.693 - 0.733	
	45	0.711 - 0.830	0.727 - 0.817	0.758 - 0.807	
	50	0.777 - 0.900	0.796 - 0.882	0.815 - 0.832	
SAMPLE SIZE =	55	0.830 - 0.992	0.830 - 0.980	0.881 - 0.927	AEROSOL MASS
= 400	60	0.903 - 1.057	0.910 - 1.045	0.949 - 0.997	FRACTION REMAINING =
	65	0.993 - 1.165	0.996 - 1.135	1.029 - 1.087	= 0.9
	70	1.079 - 1.263	1.085 - 1.251	1.124 - 1.193	
	75	1.166 - 1.372	1.189 - 1.363	1.251 - 1.318	
	80	1.308 - 1.601	1.319 - 1.579	1.365 - 1.470	
	85	1.470 - 1.819	1.494 - 1.784	1.600 - 1.674	
	90	1.707 - 2.270	1.747 - 2.257	1.852 - 2.217	
	95	2.265 - 2.616	2.308 - 2.615	2.454 - 2.533	

	Quantile (%)	Range for λ(hr^{-1}) at a confidence level of			
		95%	90%	50%	
MEAN = 0.773	5	0.168 - 0.282	0.176 - 0.282	0.201 - 0.260	WATER FLUX =
	10	0.282 - 0.324	0.286 - 0.321	0.298 - 0.312	= 0.001 $cm^3/s\text{-}cm^2$
	15	0.319 - 0.369	0.321 - 0.365	0.331 - 0.345	
	20	0.345 - 0.409	0.347 - 0.405	0.369 - 0.389	
	25	0.385 - 0.453	0.390 - 0.449	0.407 - 0.432	
STD. DEV. =	30	0.428 - 0.476	0.431 - 0.475	0.449 - 0.468	FALL DISTANCE =
= 0.590	35	0.461 - 0.522	0.467 - 0.516	0.475 - 0.484	= 5000 cm
	40	0.477 - 0.598	0.482 - 0.591	0.508 - 0.544	
	45	0.535 - 0.654	0.543 - 0.640	0.578 - 0.625	
	50	0.599 - 0.709	0.600 - 0.701	0.636 - 0.669	
SAMPLE SIZE =	55	0.655 - 0.742	0.664 - 0.739	0.697 - 0.723	AEROSOL MASS
= 400	60	0.710 - 0.820	0.722 - 0.798	0.732 - 0.765	FRACTION REMAINING =
	65	0.744 - 0.886	0.758 - 0.876	0.787 - 0.834	= 0.5
	70	0.826 - 0.965	0.833 - 0.952	0.871 - 0.918	
	75	0.912 - 1.014	0.918 - 1.011	0.952 - 0.996	
	80	0.995 - 1.079	0.997 - 1.072	1.012 - 1.041	
	85	1.041 - 1.255	1.042 - 1.223	1.078 - 1.151	
	90	1.184 - 1.562	1.203 - 1.496	1.259 - 1.431	
	95	1.554 - 2.029	1.615 - 1.957	1.658 - 1.798	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 0.629	5	0.143 - 0.224	0.147 - 0.224	0.177 - 0.213	WATER FLUX =
	10	0.224 - 0.273	0.228 - 0.273	0.246 - 0.267	= 0.001 $cm^3/s\text{-}cm^2$
	15	0.271 - 0.297	0.271 - 0.296	0.275 - 0.289	
	20	0.288 - 0.337	0.293 - 0.332	0.297 - 0.315	
	25	0.310 - 0.370	0.316 - 0.364	0.335 - 0.351	
STD. DEV. =	30	0.344 - 0.391	0.348 - 0.386	0.360 - 0.373	FALL DISTANCE =
= 0.456	35	0.373 - 0.434	0.373 - 0.427	0.385 - 0.404	= 5000 cm
	40	0.394 - 0.496	0.399 - 0.483	0.423 - 0.454	
	45	0.434 - 0.528	0.442 - 0.525	0.477 - 0.505	
	50	0.498 - 0.589	0.498 - 0.572	0.519 - 0.545	
SAMPLE SIZE =	55	0.529 - 0.636	0.533 - 0.635	0.568 - 0.620	AEROSOL MASS
= 400	60	0.599 - 0.677	0.615 - 0.671	0.634 - 0.646	FRACTION REMAINING =
	65	0.640 - 0.721	0.646 - 0.718	0.666 - 0.689	= 0.3
	70	0.683 - 0.767	0.684 - 0.761	0.716 - 0.744	
	75	0.735 - 0.838	0.743 - 0.837	0.760 - 0.790	
	80	0.775 - 0.901	0.791 - 0.897	0.837 - 0.863	
	85	0.866 - 0.999	0.886 - 0.974	0.900 - 0.949	
	90	0.957 - 1.199	0.966 - 1.190	1.024 - 1.059	
	95	1.196 - 1.683	1.214 - 1.572	1.392 - 1.478	

	Quantile (%)	Range for λ(hr^{-1}) at a confidence level of			
		95%	90%	50%	
MEAN = 0.450	5	0.100 - 0.154	0.101 - 0.148	0.126 - 0.139	WATER FLUX =
	10	0.153 - 0.191	0.159 - 0.189	0.171 - 0.180	= 0.001 $cm^3/s\text{-}cm^2$
	15	0.183 - 0.218	0.186 - 0.215	0.195 - 0.202	
	20	0.202 - 0.243	0.206 - 0.239	0.218 - 0.230	
	25	0.228 - 0.259	0.230 - 0.259	0.239 - 0.249	
STD. DEV. =	30	0.248 - 0.283	0.249 - 0.275	0.259 - 0.263	FALL DISTANCE =
= 0.313	35	0.260 - 0.309	0.262 - 0.305	0.273 - 0.293	= 5000 cm
	40	0.289 - 0.346	0.291 - 0.340	0.304 - 0.321	
	45	0.313 - 0.386	0.319 - 0.369	0.334 - 0.358	
	50	0.347 - 0.423	0.352 - 0.422	0.365 - 0.406	
SAMPLE SIZE =	55	0.389 - 0.455	0.399 - 0.451	0.411 - 0.427	AEROSOL MASS
= 400	60	0.425 - 0.492	0.426 - 0.482	0.439 - 0.465	FRACTION REMAINING =
	65	0.459 - 0.521	0.464 - 0.517	0.475 - 0.495	= 0.1
	70	0.493 - 0.574	0.495 - 0.549	0.516 - 0.528	
	75	0.525 - 0.604	0.526 - 0.590	0.548 - 0.586	
	80	0.586 - 0.643	0.586 - 0.636	0.592 - 0.615	
	85	0.615 - 0.718	0.620 - 0.713	0.642 - 0.685	
	90	0.701 - 0.871	0.705 - 0.871	0.749 - 0.795	
	95	0.871 - 1.344	0.906 - 1.253	0.945 - 1.073	

	Quantile (%)	Range for λ(hr^{-1}) at a confidence level of			
		95%	90%	50%	
MEAN = 0.287	5	0.058 - 0.090	0.061 - 0.089	0.070 - 0.083	WATER FLUX =
	10	0.090 - 0.112	0.093 - 0.111	0.101 - 0.107	= 0.001 $cm^3/s\text{-}cm^2$
	15	0.108 - 0.131	0.109 - 0.130	0.116 - 0.125	
	20	0.125 - 0.149	0.127 - 0.147	0.131 - 0.141	
	25	0.138 - 0.169	0.141 - 0.168	0.147 - 0.162	
STD. DEV. =	30	0.157 - 0.178	0.162 - 0.176	0.167 - 0.171	FALL DISTANCE =
= 0.206	35	0.170 - 0.195	0.170 - 0.194	0.174 - 0.182	= 5000 cm
	40	0.179 - 0.209	0.181 - 0.206	0.190 - 0.201	
	45	0.197 - 0.236	0.198 - 0.234	0.205 - 0.225	
	50	0.217 - 0.254	0.222 - 0.254	0.231 - 0.241	
SAMPLE SIZE =	55	0.237 - 0.282	0.239 - 0.273	0.248 - 0.263	AEROSOL MASS
= 400	60	0.255 - 0.298	0.261 - 0.293	0.271 - 0.286	FRACTION REMAINING =
	65	0.283 - 0.321	0.285 - 0.318	0.289 - 0.310	= 0.01
	70	0.301 - 0.348	0.304 - 0.340	0.317 - 0.330	
	75	0.322 - 0.387	0.327 - 0.381	0.340 - 0.375	
	80	0.370 - 0.449	0.375 - 0.422	0.382 - 0.404	
	85	0.404 - 0.497	0.405 - 0.491	0.447 - 0.475	
	90	0.478 - 0.594	0.482 - 0.594	0.510 - 0.548	
	95	0.594 - 0.869	0.595 - 0.808	0.637 - 0.688	

	Quantile (%)	Range for $\lambda(hr^{-1})$ at a confidence level of			
		95%	90%	50%	
MEAN = 0.224	5	0.044 - 0.068	0.046 - 0.066	0.053 - 0.063	WATER FLUX =
	10	0.068 - 0.086	0.069 - 0.084	0.075 - 0.080	= 0.001 $cm^3/s\text{-}cm^2$
	15	0.081 - 0.103	0.082 - 0.100	0.088 - 0.094	
	20	0.094 - 0.113	0.096 - 0.112	0.103 - 0.107	
	25	0.106 - 0.131	0.107 - 0.130	0.113 - 0.120	
STD. DEV. =	30	0.117 - 0.142	0.119 - 0.141	0.130 - 0.134	FALL DISTANCE =
= 0.166	35	0.134 - 0.150	0.134 - 0.150	0.140 - 0.145	= 5000 cm
	40	0.143 - 0.165	0.143 - 0.163	0.148 - 0.154	
	45	0.151 - 0.183	0.152 - 0.178	0.162 - 0.172	
	50	0.165 - 0.198	0.171 - 0.194	0.177 - 0.190	
SAMPLE SIZE =	55	0.184 - 0.206	0.185 - 0.203	0.192 - 0.200	AEROSOL MASS
= 400	60	0.198 - 0.230	0.199 - 0.228	0.202 - 0.212	FRACTION REMAINING =
	65	0.208 - 0.247	0.210 - 0.243	0.221 - 0.238	= 0.001
	70	0.236 - 0.271	0.237 - 0.271	0.242 - 0.266	
	75	0.260 - 0.304	0.265 - 0.304	0.271 - 0.288	
	80	0.282 - 0.343	0.291 - 0.328	0.304 - 0.312	
	85	0.312 - 0.405	0.318 - 0.404	0.342 - 0.385	
	90	0.400 - 0.487	0.404 - 0.478	0.409 - 0.437	
	95	0.486 - 0.677	0.488 - 0.647	0.500 - 0.588	

Appendix B

Uncertainty Distributions for $\lambda(m_f)/\lambda(m_f = 0.9)$

Cumulative probability distributions for $\lambda(m_f)/\lambda(m_f = 0.9)$ are shown in the tables of this appendix. The distributions of $\lambda(m_f)/\lambda(m_f = 0.9)$ are, of course, identical to distributions of $E/D(m_f)/E/D(m_f = 0.9)$. The distributions are essentially independent of the fall distance of the spray droplets. Consequently, distributions have only been tabulated for H = 3000 cm and Q = 0.001, 0.01, and 0.25 cm^3/cm^2-s.

	Quantile (%)	Range for $\lambda(m_f)/\lambda(m_f = 0.9)$ at a confidence level of 95%	90%	50%	
MEAN = 0.750	5	0.583 - 0.598	0.585 - 0.595	0.587 - 0.590	WATER FLUX =
	10	0.596 - 0.620	0.598 - 0.619	0.605 - 0.615	= 0.25 $cm^3/s\text{-}cm^2$
	15	0.616 - 0.635	0.617 - 0.634	0.622 - 0.628	
	20	0.628 - 0.649	0.629 - 0.648	0.635 - 0.645	
	25	0.643 - 0.666	0.644 - 0.661	0.648 - 0.655	
STD. DEV. =	30	0.651 - 0.689	0.653 - 0.684	0.660 - 0.675	FALL DISTANCE =
= 0.107	35	0.667 - 0.710	0.672 - 0.704	0.682 - 0.694	= 3000 cm
	40	0.690 - 0.732	0.691 - 0.724	0.701 - 0.714	
	45	0.709 - 0.751	0.721 - 0.750	0.721 - 0.739	
	50	0.730 - 0.767	0.733 - 0.763	0.749 - 0.756	
SAMPLE SIZE =	55	0.751 - 0.788	0.753 - 0.785	0.762 - 0.774	AEROSOL MASS
= 360	60	0.766 - 0.807	0.771 - 0.803	0.784 - 0.797	FRACTION REMAINING =
	65	0.788 - 0.825	0.791 - 0.823	0.802 - 0.811	= 0.5
	70	0.807 - 0.840	0.808 - 0.839	0.818 - 0.832	
	75	0.827 - 0.858	0.829 - 0.857	0.836 - 0.852	
	80	0.844 - 0.884	0.851 - 0.882	0.857 - 0.872	
	85	0.872 - 0.893	0.875 - 0.892	0.882 - 0.888	
	90	0.888 - 0.907	0.891 - 0.906	0.894 - 0.900	
	95	0.907 - 0.926	0.908 - 0.925	0.913 - 0.922	

	Quantile (%)	Range for $\lambda(m_f)/\lambda(m_f = 0.9)$ at a confidence level of			
		95%	90%	50%	
MEAN = 0.622	5	0.417 - 0.432	0.418 - 0.432	0.420 - 0.425	WATER FLUX =
	10	0.432 - 0.460	0.432 - 0.460	0.439 - 0.452	= 0.25 $cm^3/s\text{-}cm^2$
	15	0.453 - 0.473	0.454 - 0.472	0.462 - 0.466	
	20	0.465 - 0.487	0.466 - 0.486	0.473 - 0.484	
	25	0.480 - 0.503	0.483 - 0.501	0.486 - 0.496	
STD. DEV. =	30	0.490 - 0.534	0.494 - 0.530	0.501 - 0.522	FALL DISTANCE =
= 0.142	35	0.509 - 0.559	0.515 - 0.558	0.528 - 0.541	= 3000 cm
	40	0.534 - 0.585	0.538 - 0.579	0.546 - 0.567	
	45	0.559 - 0.613	0.563 - 0.609	0.576 - 0.597	
	50	0.582 - 0.635	0.590 - 0.631	0.601 - 0.618	
SAMPLE SIZE =	55	0.613 - 0.663	0.614 - 0.660	0.625 - 0.643	AEROSOL MASS
= 360	60	0.635 - 0.686	0.638 - 0.683	0.655 - 0.674	FRACTION REMAINING =
	65	0.662 - 0.713	0.666 - 0.709	0.680 - 0.696	= 0.3
	70	0.687 - 0.737	0.690 - 0.734	0.706 - 0.721	
	75	0.715 - 0.766	0.720 - 0.762	0.727 - 0.752	
	80	0.746 - 0.803	0.752 - 0.798	0.762 - 0.788	
	85	0.787 - 0.820	0.790 - 0.819	0.801 - 0.810	
	90	0.814 - 0.843	0.815 - 0.842	0.821 - 0.831	
	95	0.842 - 0.872	0.843 - 0.869	0.853 - 0.867	

	Quantile (%)	Range for $\lambda(m_f)/\lambda(m_f = 0.9)$ at a confidence level of			
		95%	90%	50%	
MEAN = 0.458	5	0.238 - 0.257	0.239 - 0.256	0.244 - 0.251	WATER FLUX =
	10	0.256 - 0.277	0.257 - 0.275	0.260 - 0.269	= 0.25 $cm^3/s\text{-}cm^2$
	15	0.271 - 0.293	0.274 - 0.290	0.279 - 0.287	
	20	0.286 - 0.309	0.287 - 0.308	0.291 - 0.300	
	25	0.298 - 0.326	0.300 - 0.322	0.308 - 0.316	
STD. DEV. =	30	0.314 - 0.352	0.315 - 0.346	0.319 - 0.336	FALL DISTANCE =
= 0.164	35	0.328 - 0.373	0.333 - 0.370	0.345 - 0.357	= 3000 cm
	40	0.353 - 0.400	0.356 - 0.395	0.365 - 0.382	
	45	0.372 - 0.430	0.379 - 0.427	0.391 - 0.410	
	50	0.398 - 0.460	0.405 - 0.453	0.423 - 0.438	
SAMPLE SIZE =	55	0.430 - 0.489	0.433 - 0.485	0.445 - 0.465	AEROSOL MASS
= 360	60	0.456 - 0.516	0.463 - 0.512	0.479 - 0.499	FRACTION REMAINING =
	65	0.488 - 0.547	0.493 - 0.541	0.509 - 0.528	= 0.1
	70	0.516 - 0.579	0.521 - 0.575	0.540 - 0.560	
	75	0.549 - 0.625	0.554 - 0.618	0.567 - 0.604	
	80	0.592 - 0.669	0.603 - 0.662	0.615 - 0.650	
	85	0.647 - 0.699	0.653 - 0.697	0.666 - 0.682	
	90	0.684 - 0.733	0.685 - 0.732	0.700 - 0.716	
	95	0.732 - 0.773	0.733 - 0.770	0.745 - 0.765	

	Quantile (%)	Range for $\lambda(m_f)/\lambda(m_f = 0.9)$ at a confidence level of			
		95%	90%	50%	
MEAN = 0.302	5	0.112 - 0.128	0.114 - 0.128	0.117 - 0.125	WATER FLUX =
	10	0.128 - 0.141	0.128 - 0.140	0.132 - 0.137	= 0.25 $cm^3/s\text{-}cm^2$
	15	0.138 - 0.152	0.139 - 0.151	0.142 - 0.148	
	20	0.148 - 0.170	0.150 - 0.170	0.151 - 0.161	
	25	0.158 - 0.186	0.161 - 0.182	0.169 - 0.175	
STD. DEV. =	30	0.173 - 0.200	0.175 - 0.197	0.180 - 0.189	FALL DISTANCE =
= 0.155	35	0.187 - 0.218	0.188 - 0.217	0.196 - 0.207	= 3000 cm
	40	0.200 - 0.236	0.204 - 0.235	0.215 - 0.224	
	45	0.218 - 0.258	0.221 - 0.256	0.230 - 0.245	
	50	0.236 - 0.286	0.240 - 0.285	0.252 - 0.263	
SAMPLE SIZE =	55	0.258 - 0.313	0.258 - 0.308	0.277 - 0.292	AEROSOL MASS
= 360	60	0.285 - 0.337	0.288 - 0.330	0.304 - 0.320	FRACTION REMAINING =
	65	0.312 - 0.364	0.316 - 0.363	0.328 - 0.354	= 0.01
	70	0.338 - 0.399	0.347 - 0.396	0.361 - 0.378	
	75	0.367 - 0.453	0.370 - 0.445	0.389 - 0.423	
	80	0.419 - 0.502	0.422 - 0.496	0.443 - 0.479	
	85	0.479 - 0.536	0.482 - 0.532	0.497 - 0.516	
	90	0.517 - 0.581	0.530 - 0.577	0.540 - 0.559	
	95	0.577 - 0.630	0.582 - 0.626	0.595 - 0.618	

	Quantile (%)	Range for $\lambda(m_f)/\lambda(m_f = 0.9)$ at a confidence level of			
		95%	90%	50%	
MEAN = 0.240	5	0.079 - 0.091	0.079 - 0.091	0.082 - 0.088	WATER FLUX =
	10	0.091 - 0.102	0.091 - 0.101	0.096 - 0.099	= 0.25 $cm^3/s\text{-}cm^2$
	15	0.099 - 0.110	0.100 - 0.109	0.102 - 0.108	
	20	0.108 - 0.125	0.108 - 0.124	0.110 - 0.118	
	25	0.115 - 0.138	0.118 - 0.136	0.124 - 0.130	
STD. DEV. =	30	0.128 - 0.149	0.130 - 0.147	0.135 - 0.141	FALL DISTANCE =
= 0.137	35	0.138 - 0.166	0.139 - 0.165	0.146 - 0.154	= 3000 cm
	40	0.149 - 0.183	0.150 - 0.180	0.160 - 0.173	
	45	0.166 - 0.194	0.170 - 0.193	0.175 - 0.186	
	50	0.181 - 0.218	0.185 - 0.216	0.191 - 0.199	
SAMPLE SIZE =	55	0.193 - 0.242	0.196 - 0.238	0.209 - 0.225	AEROSOL MASS
= 360	60	0.217 - 0.262	0.220 - 0.255	0.236 - 0.248	FRACTION REMAINING =
	65	0.242 - 0.288	0.243 - 0.286	0.253 - 0.275	= 0.001
	70	0.263 - 0.316	0.273 - 0.314	0.284 - 0.296	
	75	0.290 - 0.366	0.292 - 0.362	0.309 - 0.341	
	80	0.335 - 0.413	0.340 - 0.407	0.361 - 0.394	
	85	0.393 - 0.452	0.400 - 0.446	0.411 - 0.426	
	90	0.427 - 0.493	0.439 - 0.488	0.452 - 0.472	
	95	0.488 - 0.541	0.494 - 0.537	0.507 - 0.528	

	Quantile (%)	Range for $\lambda(m_f)/\lambda(m_f = 0.9)$ at a confidence level of			
		95%	90%	50%	
MEAN = 0.752	5	0.586 - 0.598	0.587 - 0.597	0.590 - 0.592	WATER FLUX =
	10	0.598 - 0.621	0.599 - 0.620	0.604 - 0.612	= 0.01 $cm^3/s\text{-}cm^2$
	15	0.615 - 0.638	0.617 - 0.636	0.622 - 0.629	
	20	0.629 - 0.652	0.631 - 0.650	0.638 - 0.646	
	25	0.644 - 0.676	0.647 - 0.672	0.651 - 0.661	
STD. DEV. =	30	0.659 - 0.695	0.660 - 0.693	0.670 - 0.681	FALL DISTANCE =
= 0.113	35	0.677 - 0.711	0.679 - 0.707	0.692 - 0.699	= 3000 cm
	40	0.695 - 0.725	0.697 - 0.723	0.706 - 0.716	
	45	0.712 - 0.748	0.713 - 0.746	0.722 - 0.736	
	50	0.725 - 0.768	0.729 - 0.765	0.742 - 0.759	
SAMPLE SIZE =	55	0.751 - 0.792	0.752 - 0.786	0.764 - 0.773	AEROSOL MASS
= 400	60	0.769 - 0.809	0.771 - 0.806	0.782 - 0.800	FRACTION REMAINING =
	65	0.796 - 0.828	0.799 - 0.826	0.804 - 0.816	= 0.5
	70	0.812 - 0.846	0.815 - 0.842	0.824 - 0.835	
	75	0.832 - 0.865	0.835 - 0.863	0.841 - 0.857	
	80	0.856 - 0.885	0.858 - 0.884	0.864 - 0.876	
	85	0.876 - 0.899	0.878 - 0.896	0.885 - 0.892	
	90	0.895 - 0.915	0.896 - 0.914	0.900 - 0.908	
	95	0.915 - 0.928	0.916 - 0.928	0.920 - 0.925	

	Quantile (%)	Range for $\lambda(m_f)/\lambda(m_f = 0.9)$ at a confidence level of			
		95%	90%	50%	
MEAN = 0.626	5	0.418 - 0.433	0.418 - 0.433	0.422 - 0.429	WATER FLUX =
	10	0.433 - 0.457	0.435 - 0.456	0.439 - 0.446	= 0.01 $cm^3/s\text{-}cm^2$
	15	0.454 - 0.475	0.455 - 0.474	0.459 - 0.470	
	20	0.470 - 0.496	0.472 - 0.494	0.475 - 0.486	
	25	0.483 - 0.519	0.486 - 0.517	0.495 - 0.507	
STD. DEV. =	30	0.503 - 0.542	0.506 - 0.541	0.516 - 0.526	FALL DISTANCE =
= 0.142	35	0.523 - 0.565	0.525 - 0.561	0.540 - 0.550	= 3000 cm
	40	0.544 - 0.582	0.547 - 0.578	0.559 - 0.572	
	45	0.565 - 0.610	0.566 - 0.604	0.574 - 0.592	
	50	0.582 - 0.634	0.587 - 0.630	0.601 - 0.621	
SAMPLE SIZE =	55	0.610 - 0.668	0.618 - 0.659	0.627 - 0.640	AEROSOL MASS
= 400	60	0.634 - 0.689	0.637 - 0.686	0.651 - 0.677	FRACTION REMAINING =
	65	0.671 - 0.715	0.674 - 0.711	0.685 - 0.698	= 0.3
	70	0.692 - 0.742	0.696 - 0.736	0.710 - 0.726	
	75	0.724 - 0.771	0.725 - 0.767	0.736 - 0.760	
	80	0.758 - 0.804	0.760 - 0.801	0.768 - 0.787	
	85	0.787 - 0.824	0.790 - 0.820	0.804 - 0.813	
	90	0.817 - 0.850	0.819 - 0.849	0.825 - 0.839	
	95	0.850 - 0.873	0.852 - 0.872	0.859 - 0.867	

	Quantile (%)	Range for $\lambda(m_f)/\lambda(m_f = 0.9)$ at a confidence level of 95%	90%	50%	
MEAN = 0.463	5	0.238 - 0.259	0.239 - 0.256	0.243 - 0.246	WATER FLUX =
	10	0.258 - 0.279	0.259 - 0.275	0.261 - 0.271	= 0.01 $cm^3/s\text{-}cm^2$
	15	0.274 - 0.296	0.274 - 0.295	0.283 - 0.290	
	20	0.290 - 0.319	0.292 - 0.316	0.297 - 0.304	
	25	0.302 - 0.339	0.305 - 0.336	0.316 - 0.327	
STD. DEV. =	30	0.325 - 0.363	0.327 - 0.360	0.336 - 0.351	FALL DISTANCE =
= 0.163	35	0.348 - 0.381	0.349 - 0.376	0.356 - 0.368	= 3000 cm
	40	0.364 - 0.406	0.367 - 0.403	0.375 - 0.388	
	45	0.384 - 0.431	0.386 - 0.424	0.395 - 0.414	
	50	0.406 - 0.452	0.408 - 0.450	0.421 - 0.442	
SAMPLE SIZE =	55	0.434 - 0.493	0.439 - 0.488	0.447 - 0.463	AEROSOL MASS
= 400	60	0.453 - 0.520	0.457 - 0.517	0.476 - 0.505	FRACTION REMAINING =
	65	0.498 - 0.548	0.500 - 0.544	0.511 - 0.528	= 0.1
	70	0.525 - 0.583	0.527 - 0.578	0.543 - 0.563	
	75	0.560 - 0.624	0.563 - 0.621	0.576 - 0.608	
	80	0.606 - 0.671	0.608 - 0.666	0.621 - 0.643	
	85	0.643 - 0.697	0.647 - 0.692	0.671 - 0.682	
	90	0.687 - 0.739	0.689 - 0.737	0.701 - 0.720	
	95	0.738 - 0.773	0.740 - 0.772	0.749 - 0.763	

	Quantile (%)	Range for $\lambda(m_f)/\lambda(m_f = 0.9)$ at a confidence level of 95%	90%	50%	
MEAN = 0.308	5	0.114 - 0.125	0.114 - 0.123	0.116 - 0.118	WATER FLUX =
	10	0.124 - 0.144	0.125 - 0.143	0.131 - 0.138	= 0.01 $cm^3/s\text{-}cm^2$
	15	0.139 - 0.160	0.142 - 0.158	0.147 - 0.151	
	20	0.151 - 0.179	0.153 - 0.178	0.160 - 0.170	
	25	0.168 - 0.195	0.171 - 0.193	0.178 - 0.186	
STD. DEV. =	30	0.181 - 0.216	0.185 - 0.214	0.193 - 0.204	FALL DISTANCE =
= 0.154	35	0.200 - 0.232	0.202 - 0.229	0.214 - 0.221	= 3000 cm
	40	0.218 - 0.246	0.218 - 0.243	0.223 - 0.237	
	45	0.233 - 0.269	0.235 - 0.265	0.241 - 0.249	
	50	0.246 - 0.285	0.248 - 0.282	0.261 - 0.273	
SAMPLE SIZE =	55	0.270 - 0.320	0.271 - 0.317	0.279 - 0.302	AEROSOL MASS
= 400	60	0.286 - 0.345	0.294 - 0.342	0.314 - 0.328	FRACTION REMAINING =
	65	0.321 - 0.370	0.323 - 0.366	0.338 - 0.354	= 0.01
	70	0.347 - 0.413	0.352 - 0.404	0.363 - 0.383	
	75	0.377 - 0.452	0.382 - 0.448	0.402 - 0.427	
	80	0.427 - 0.500	0.427 - 0.497	0.449 - 0.470	
	85	0.470 - 0.530	0.477 - 0.526	0.500 - 0.516	
	90	0.520 - 0.581	0.521 - 0.580	0.540 - 0.559	
	95	0.581 - 0.629	0.585 - 0.627	0.596 - 0.613	

	Quantile (%)	Range for $\lambda(m_f)/\lambda(m_f = 0.9)$ at a confidence level of			
		95%	90%	50%	
MEAN = 0.246	5	0.079 - 0.087	0.080 - 0.086	0.081 - 0.084	WATER FLUX = = 0.01 $cm^3/s\text{-}cm^2$
	10	0.087 - 0.104	0.088 - 0.103	0.093 - 0.100	
	15	0.101 - 0.118	0.102 - 0.117	0.105 - 0.110	
	20	0.109 - 0.131	0.113 - 0.130	0.119 - 0.127	
	25	0.123 - 0.147	0.127 - 0.145	0.131 - 0.140	
STD. DEV. = = 0.136	30	0.137 - 0.163	0.139 - 0.160	0.145 - 0.154	FALL DISTANCE = = 3000 cm
	35	0.150 - 0.178	0.152 - 0.177	0.159 - 0.168	
	40	0.164 - 0.190	0.167 - 0.185	0.176 - 0.182	
	45	0.179 - 0.204	0.179 - 0.203	0.184 - 0.198	
	50	0.191 - 0.223	0.194 - 0.218	0.202 - 0.210	
SAMPLE SIZE = = 400	55	0.204 - 0.249	0.208 - 0.247	0.216 - 0.236	AEROSOL MASS FRACTION REMAINING = = 0.001
	60	0.226 - 0.272	0.232 - 0.267	0.246 - 0.258	
	65	0.251 - 0.295	0.254 - 0.294	0.266 - 0.278	
	70	0.275 - 0.333	0.277 - 0.323	0.293 - 0.304	
	75	0.301 - 0.364	0.304 - 0.361	0.320 - 0.346	
	80	0.342 - 0.412	0.348 - 0.408	0.361 - 0.384	
	85	0.384 - 0.438	0.391 - 0.437	0.412 - 0.428	
	90	0.430 - 0.491	0.432 - 0.490	0.451 - 0.471	
	95	0.490 - 0.541	0.494 - 0.540	0.507 - 0.525	

	Quantile (%)	Range for $\lambda(m_f)/\lambda(m_f = 0.9)$ at a confidence level of			
		95%	90%	50%	
MEAN = 0.757	5	0.587 - 0.601	0.589 - 0.599	0.592 - 0.598	WATER FLUX =
	10	0.600 - 0.625	0.603 - 0.623	0.611 - 0.615	= 0.001 $cm^3/s\text{-}cm^2$
	15	0.617 - 0.636	0.620 - 0.634	0.625 - 0.629	
	20	0.629 - 0.652	0.630 - 0.648	0.636 - 0.642	
	25	0.642 - 0.677	0.643 - 0.675	0.648 - 0.664	
STD. DEV. =	30	0.660 - 0.690	0.662 - 0.689	0.674 - 0.683	FALL DISTANCE =
= 0.108	35	0.679 - 0.711	0.682 - 0.710	0.687 - 0.696	= 3000 cm
	40	0.692 - 0.728	0.693 - 0.723	0.710 - 0.718	
	45	0.712 - 0.764	0.717 - 0.758	0.722 - 0.740	
	50	0.729 - 0.787	0.733 - 0.784	0.750 - 0.775	
SAMPLE SIZE =	55	0.764 - 0.805	0.772 - 0.800	0.781 - 0.793	AEROSOL MASS
= 400	60	0.787 - 0.812	0.790 - 0.808	0.798 - 0.807	FRACTION REMAINING =
	65	0.806 - 0.830	0.807 - 0.830	0.808 - 0.821	= 0.5
	70	0.818 - 0.858	0.821 - 0.855	0.828 - 0.845	
	75	0.834 - 0.868	0.844 - 0.867	0.853 - 0.864	
	80	0.864 - 0.883	0.864 - 0.882	0.867 - 0.874	
	85	0.874 - 0.898	0.876 - 0.897	0.883 - 0.893	
	90	0.895 - 0.908	0.896 - 0.908	0.900 - 0.903	
	95	0.908 - 0.928	0.909 - 0.928	0.916 - 0.924	

	Quantile (%)	Range for $\lambda(m_f)/\lambda(m_f = 0.9)$ at a confidence level of			
		95%	90%	50%	
MEAN = 0.631	5	0.423 - 0.437	0.424 - 0.435	0.430 - 0.431	WATER FLUX =
	10	0.437 - 0.459	0.438 - 0.459	0.447 - 0.452	= 0.001 $cm^3/s\text{-}cm^2$
	15	0.455 - 0.475	0.458 - 0.473	0.464 - 0.468	
	20	0.468 - 0.492	0.470 - 0.491	0.475 - 0.483	
	25	0.483 - 0.519	0.484 - 0.517	0.492 - 0.506	
STD. DEV. =	30	0.501 - 0.540	0.506 - 0.540	0.517 - 0.532	FALL DISTANCE =
= 0.142	35	0.527 - 0.565	0.530 - 0.559	0.540 - 0.548	= 3000 cm
	40	0.541 - 0.583	0.544 - 0.580	0.559 - 0.571	
	45	0.568 - 0.626	0.571 - 0.624	0.576 - 0.599	
	50	0.584 - 0.660	0.594 - 0.658	0.612 - 0.645	
SAMPLE SIZE =	55	0.629 - 0.683	0.639 - 0.682	0.654 - 0.670	AEROSOL MASS
= 400	60	0.663 - 0.697	0.667 - 0.691	0.674 - 0.687	FRACTION REMAINING =
	65	0.684 - 0.720	0.686 - 0.719	0.689 - 0.707	= 0.30
	70	0.704 - 0.761	0.707 - 0.756	0.718 - 0.740	
	75	0.726 - 0.775	0.740 - 0.773	0.755 - 0.768	
	80	0.768 - 0.797	0.768 - 0.796	0.773 - 0.784	
	85	0.784 - 0.821	0.787 - 0.820	0.797 - 0.813	
	90	0.817 - 0.840	0.820 - 0.839	0.825 - 0.830	
	95	0.840 - 0.872	0.840 - 0.872	0.851 - 0.865	

	Quantile (%)	Range for $\lambda(m_f)/\lambda(m_f = 0.9)$ at a confidence level of 95%	90%	50%	
MEAN = 0.467	5	0.246 - 0.259	0.247 - 0.257	0.247 - 0.251	WATER FLUX =
	10	0.258 - 0.281	0.261 - 0.280	0.270 - 0.273	= 0.001 $cm^3/s\text{-}cm^2$
	15	0.275 - 0.297	0.280 - 0.295	0.283 - 0.290	
	20	0.290 - 0.318	0.291 - 0.314	0.297 - 0.306	
	25	0.304 - 0.333	0.306 - 0.330	0.316 - 0.325	
STD. DEV. =	30	0.321 - 0.367	0.325 - 0.362	0.330 - 0.349	FALL DISTANCE =
= 0.162	35	0.342 - 0.381	0.348 - 0.378	0.359 - 0.373	= 3000 cm
	40	0.368 - 0.411	0.371 - 0.405	0.375 - 0.383	
	45	0.382 - 0.443	0.383 - 0.440	0.396 - 0.420	
	50	0.412 - 0.486	0.415 - 0.481	0.436 - 0.465	
SAMPLE SIZE =	55	0.453 - 0.508	0.460 - 0.507	0.475 - 0.497	AEROSOL MASS
= 400	60	0.487 - 0.527	0.491 - 0.523	0.505 - 0.516	FRACTION REMAINING =
	65	0.508 - 0.559	0.512 - 0.552	0.521 - 0.537	= 0.1
	70	0.532 - 0.608	0.536 - 0.604	0.549 - 0.579	
	75	0.562 - 0.628	0.578 - 0.627	0.601 - 0.618	
	80	0.617 - 0.661	0.619 - 0.658	0.627 - 0.639	
	85	0.639 - 0.691	0.645 - 0.691	0.661 - 0.682	
	90	0.687 - 0.720	0.690 - 0.720	0.699 - 0.708	
	95	0.720 - 0.771	0.721 - 0.771	0.738 - 0.760	

	Quantile (%)	Range for $\lambda(m_f)/\lambda(m_f = 0.9)$ at a confidence level of 95%	90%	50%	
MEAN = 0.311	5	0.116 - 0.131	0.117 - 0.127	0.120 - 0.124	WATER FLUX = = 0.001 $cm^3/s\text{-}cm^2$
	10	0.130 - 0.147	0.132 - 0.146	0.138 - 0.141	
	15	0.141 - 0.160	0.144 - 0.158	0.148 - 0.154	
	20	0.154 - 0.174	0.155 - 0.172	0.160 - 0.168	
	25	0.168 - 0.198	0.169 - 0.194	0.173 - 0.183	
STD. DEV. = = 0.151	30	0.180 - 0.213	0.183 - 0.208	0.193 - 0.203	FALL DISTANCE = = 3000 cm
	35	0.202 - 0.231	0.203 - 0.222	0.207 - 0.216	
	40	0.214 - 0.248	0.214 - 0.248	0.220 - 0.237	
	45	0.234 - 0.284	0.236 - 0.280	0.247 - 0.260	
	50	0.248 - 0.315	0.255 - 0.313	0.276 - 0.292	
SAMPLE SIZE = = 400	55	0.284 - 0.333	0.286 - 0.324	0.303 - 0.322	AEROSOL MASS FRACTION REMAINING = = 0.01
	60	0.317 - 0.354	0.317 - 0.351	0.323 - 0.336	
	65	0.334 - 0.372	0.335 - 0.372	0.348 - 0.361	
	70	0.356 - 0.423	0.359 - 0.423	0.369 - 0.398	
	75	0.386 - 0.454	0.396 - 0.454	0.420 - 0.439	
	80	0.437 - 0.483	0.440 - 0.483	0.454 - 0.464	
	85	0.464 - 0.520	0.475 - 0.520	0.488 - 0.510	
	90	0.519 - 0.556	0.520 - 0.556	0.532 - 0.541	
	95	0.560 - 0.625	0.567 - 0.625	0.578 - 0.611	

	Quantile (%)	Range for $\lambda(m_f)/\lambda(m_f = 0.9)$ at a confidence level of			
		95%	90%	50%	
MEAN = 0.247	5	0.081 - 0.095	0.082 - 0.091	0.084 - 0.088	WATER FLUX =
	10	0.095 - 0.107	0.095 - 0.106	0.098 - 0.102	= 0.001 $cm^3/s\text{-}cm^2$
	15	0.104 - 0.119	0.104 - 0.117	0.108 - 0.112	
	20	0.112 - 0.130	0.114 - 0.125	0.119 - 0.122	
	25	0.121 - 0.148	0.122 - 0.146	0.127 - 0.138	
STD. DEV. =	30	0.134 - 0.159	0.138 - 0.157	0.146 - 0.153	FALL DISTANCE =
= 0.133	35	0.151 - 0.176	0.153 - 0.174	0.156 - 0.160	= 3000 cm
	40	0.160 - 0.199	0.160 - 0.196	0.172 - 0.184	
	45	0.182 - 0.218	0.184 - 0.217	0.190 - 0.203	
	50	0.200 - 0.246	0.201 - 0.244	0.213 - 0.225	
SAMPLE SIZE =	55	0.220 - 0.257	0.221 - 0.251	0.239 - 0.247	AEROSOL MASS
= 400	60	0.247 - 0.282	0.247 - 0.278	0.249 - 0.265	FRACTION REMAINING =
	65	0.259 - 0.307	0.260 - 0.298	0.275 - 0.290	= 0.001
	70	0.283 - 0.344	0.286 - 0.338	0.295 - 0.315	
	75	0.308 - 0.366	0.315 - 0.366	0.338 - 0.353	
	80	0.350 - 0.399	0.355 - 0.398	0.366 - 0.383	
	85	0.383 - 0.435	0.387 - 0.430	0.399 - 0.421	
	90	0.428 - 0.475	0.429 - 0.466	0.442 - 0.451	
	95	0.471 - 0.537	0.477 - 0.537	0.487 - 0.522	

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11. ABSTRACT *(200 words or less)*

Spray systems in nuclear reactor containments are described. The scrubbing of aerosols from containment atmospheres by spray droplets is discussed. Uncertainties are identified in the prediction of spray performance when the sprays are used as a means for decontaminating containment atmospheres. A mechanistic model based on current knowledge of the physical phenomena involved in spray performance is developed. With this model, a quantitative uncertainty analysis of spray performance is conducted using a Monte Carlo method to sample 20 uncertain quantities related to phenomena of spray droplet behavior as well as the initial and boundary conditions expected to be associated with severe reactor accidents. Results of the uncertainty analysis are used to construct simplified expressions for spray decontamination coefficients. Two variables that affect aerosol capture by water droplets are not treated as uncertain; they are (1) \`Q´, spray water flux into the containment, and (2) \`H´, the total fall distance of spray droplets. The choice of values of these variables is left to the user since they are plant and accident specific. Also, they can usually be ascertained with some degree of certainty. The spray decontamination coefficients are found to be sufficiently dependent on the extent of decontamination that the fraction of the initial aerosol remaining in the atmosphere, m_f, is explicitly treated in the simplified expressions.

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