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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

In the matter of:

CAROLINA POWER & LIGHT COMPANY
and NORTH CAROLINA EASTERN
MUNICIPAL POWER AGENCY

Docket No. 50-400 OL
50-401 OL

(Shearon Harris Nuclear Power Plant,
Units 1 & 2)

Location: Raleigh, North Carolina Pages: 1595 - 1860A

Date: Monday, June 18, 1984

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of:	:	
CAROLINA POWER & LIGHT COMPANY and NORTH CAROLINA EASTERN MUNICIPAL POWER AGENCY	:	Docket Nos. 50-400 OL 50-401 OL
Shearon Harris Nuclear Power Plant, Units 1 and 2	:	

Old Post Office Building
Courtroom 205
300 Fayetteville Street
Raleigh, North Carolina

Monday, June 18, 1984

The hearing in the above-entitled matter convened, pursuant to recess, at 9:35 a.m.

BEFORE:

JAMES L. KELLEY, ESQUIRE, Chairman
Atomic Safety and Licensing Board
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

DR. JAMES H. CARPENTER, Member
Atomic Safety and Licensing Board
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

DR. GLENN O. BRIGHT, Member
Atomic Safety and Licensing Board
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

DR. HARRY FOREMAN
Technical Interrogator

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On Behalf of the Intervenor CHANGE:

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I N D E X

EXHIBITS

* * *

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P R O C E E D I N G S

JUDGE KELLEY: We are back on the record. Good morning.

Starting today and over the course of the next day or two, we are going to be hearing Joint Contentions II(e) and II(c), II(e) today and II(c) immediately following that.

Let me make just a couple of comments about the composition of our Board. Judge Carpenter was ill early last week, and it wasn't at all clear that he would be with us for this hearing. So as you will recall, last Thursday Dr. Foreman, who was to have been a technical interrogator but not a Board member, became a Board member last Thursday and hear the case along with Judge Bright and myself on Contention 3(f)(1).

This morning we are happy to have Dr. Carpenter back with us, and he is resuming his place on the Board, and the Board for the contentions to be heard now, Joint Contentions II(c) and II(e) will be composed of myself and Judge Bright and Judge Carpenter, with Judge Foreman participating in the capacity of technical interrogator, the capacity to which he was originally appointed under 10 CFR 2.722(a)(1).

One more point, Judge Foreman, then, would act as a panel member and voting judge with respect to 3(f)(1)

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that we heard last week, and Judge Carpenter will not be participating on that particular contention. But as of now, anyway, Judge Carpenter and Bright and myself will be hearing the rest of the case. It's the kind of thing that could crop up again. Judge Bright might get sick or I might get sick, and you may see someone else sitting up here if that sort of thing happens. But we hope it won't.

We discussed just briefly off the record with the parties and their counsel, and that's what we propose to do. And I don't think we need party approval, but we didn't hear any party assent or objection to the course we are taking in the respects that I just described.

Okay, are there any preliminaries that we ought to address before we swear in this morning's first panel?

MS. MOORE: Yes, Your Honor. The Staff has one preliminary matter. We had spoken with counsel for Applicants and Mr. Eddleman, and we would like to request an extension of time to respond to a motion for summary dispostion on Eddleman Contention 45. The response is due tomorrow.

Applicants had no objection, and Mr. Eddleman had no objection, provided that he be given until the 15th of July to respond. We would like an extension until the 2nd of July.

JUDGE KELLEY: Mr. Eddleman's request for the 15th

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is satisfactory with you?

MS. MOORE: It is to us, yes.

JUDGE KELLEY: And the Applicants?

MR. EDDLEMAN: The problem is, I am going to be out of town on June 30th and Jully 11th, and I am not going to be in a place where I can carry along enough stuff to work on this.

JUDGE KELLEY: Any objection?

MR. BAXTER: No, sir.

JUDGE KELLEY: Granted.

Staff, July 2nd, you said?

MS. MOORE: Yes, sir.

JUDGE KELLEY: And, Mr. Eddleman, July 15th?

MR. EDDLEMAN: May I inquire of the Staff, on the reconsideration motions for Joint IV, when do you anticipate getting that out?

MS. MOORE: The Staff has no date. The motion is presently undergoing agency management review, and that is the only response I can give, unfortunately.

JUDGE KELLEY: This refers to thermoluminescent dosimeters?

MS. MOORE: Yes, sir.

JUDGE KELLEY: And in the normal course of events, for our hearing on management scheduled to begin the 5th of September, correct?

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MS. MOORE: That's correct.

JUDGE KELLEY: And then there is a break between the two safety hearings. So we don't have a fixed date for the second hearing; is that correct?

MR. BAXTER: We do. It is October 10th.

JUDGE KELLEY: That assumes, then, a certain period of time. Okay.

What I would say to the Staff is, if they want a reconsideration from the Board on thermoluminsescent dosimeters, the sooner the better.

MR. BAXTER: All of the testimony for both phases of that hearing are due on August 9.

JUDGE KELLEY: Glad you mentioned that. That means that our decisions on summary disposition are due even before that.

What are there, five or six such motions at this point?

MR. BAXTER: I didn't count, but that sounds about right.

MR. EDDLEMAN: There are, I think, six that have been filed. And lets' see, I think I've already filed responses to three or four of them.

JUDGE KELLEY: Okay. Well, we have our work cut out in the month of July. Thank you.

Anything else before we swear in the first panel?

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(No response.)

JUDGE KELLEY: Okay.

MS. BAUSER: Mr. Chairman, Applicants call to the witness stand Dr. Steven A. Schaffer and John J. Mauro, and we ask that they be sworn.

Whereupon,

STEVEN A. SCHAFFER

JOHN J. MAURO

Were called as witness on behalf of the Applicant and, having been first duly sworn, were examined and testified as follows:

DIRECT EXAMINATION

BY MS. BAUSER:

Q Gentlemen, please state your name, position and place of employment.

A (Witness Mauro) My name is John Mauro. I am Director of Radiological Assessment of Health Physics, Ebasco Services, New York City.

A (Witness Schaffer) My name is Steven A. Schaffer. I am Senior Radiological Assessment Engineer, Ebasco Services, New York City.

Q Dr. Mauro and Dr. Schaffer, I draw your attention to the document, May 31, 1984, entitled "Applicants' Testimony of John J. Mauro and Steven A. Schaffer on Joint Contention II(e) (Fly Ash)," consisting of 16 pages,

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three attachments, and a list of references.

Dr. Mauro, does this document represent testimony prepared by you and Dr. Schaffer or under your supervision in this proceeding?

A (Witness Mauro) Yes, it does.

Q Do you have any changes or corrections to make to this testimony, Doctor?

A Yes. We have several typos that we would like to correct.

JUDGE KELLEY: If they are obvious, we don't care, but go ahead.

WITNESS SCHAFFER: Starting on page 6 of the testimony, the middle of the page where we reference the tables from Reg Guide 1.109, it says "Table C-1 to C-4." It should be Table E-7 through E-10.

Further down on the page, four lines up from the bottom, it says "first described in ICRP-2," "described" is misspelled. On page 14 --

line

BY MS. BAUSER:

Q Dr. Schaffer, is that just taking an S out of the word "described"? You are not changing the word?

A (Witness Schaffer) No, I'm not.

On page 14, the fourth line down, there is a dose given, 0.74 millirems. That is a typo. It should be 0.074 millirems.

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On page 15, four lines above the conclusions, there is a rate of 0.21 micrometers per second. Change "micrometers" to "centimeters."

And in Attachment 1-A, Dr. Mauro's resume, the first line, it gives the date of his BS. Change 1963 to 1967.

Q Dr. Schaffer, with those changes, is the testimony true and correct, to the best of your knowledge?

A Yes.

Q Dr. Mauro, with those changes, is that correct?

A (Witness Mauro) Yes.

MS. BAUSER: Mr. Chairman, I move that the testimony identified as Applicants' Testimony of John J. Mauro and Steven A. Schaffer on Joint Contention II(e) (Fly Ash) be admitted into evidence and physically incorporated into the transcript as if read.

MR. EDDLEMAN: No objection. But just for clarity, does that include this attachment where they make the calculations, Attachment 2?

MS. BAUSER: Yes.

MR. EDDLEMAN: No objection.

JUDGE KELLEY: The testimony is admitted.

(The prepared testimony and professional qualifications of John J. Mauro and Steven A. Schaffer was admitted into evidence. The testimony follows.)

May 31, 1984

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
CAROLINA POWER & LIGHT COMPANY	)	Docket Nos. 50-400 OL
and NORTH CAROLINA EASTERN	)	50-401 OL
MUNICIPAL POWER AGENCY	)	
	)	
(Shearon Harris Nuclear Power	)	
Plant, Units 1 and 2)	)	

APPLICANTS' TESTIMONY OF JOHN J. MAURO AND STEVEN A. SCHAFFER ON JOINT CONTENTION II(e) (FLY ASH)

Table of Contents

I. Introduction

My name is John J. Mauro. I am the Director of the Radiological Assessment and Health Physics Department of Envirosphere Company, a division of Ebasco Services, Inc. Ebasco is the architect-engineer for the Shearon Harris Nuclear Power Plant. As indicated in Attachment 1A to this testimony, I have a doctorate in biology and radiological health and am a certified health physicist. I have worked for the last twelve years in the field of radiological assessment, and have written a number of publications in this field.

My name is Steven A. Schaffer. I am Senior Radiological Assessment Engineer at Envirosphere Company. As indicated in Attachment 1B, I have a doctorate in biology and environmental health science. I have worked for the last ten years in the field of environmental assessment. I also have published in my field.

We have assisted Carolina Power & Light Company (CP&L) in the preparation of the radiological assessments contained in the Harris Plant Environmental Report (ER). We also have reviewed the Draft and Final Environmnental Statements (DES and FES) prepared by the NRC Staff which assess the environmental impact of operation of the Harris Plant.

The purpose of this testimony is to respond to part of Joint Contention II(e), which states:

> The long term somatic and genetic health effects of radiation releases from the facility during normal operations, even where such releases are within existing guidelines, have been seriously underestimated for the following reasons ... e) the radionuclide concentration models used by Applicants and the NRC are inadequate because they underestimate or exclude the following means of concentrating radionuclides in the environment .... radionuclides absorbed in or attached to fly ash from coal plants which are in the air around the SHNPP site.

A review of the pleadings on Contention II(e) reveals that the contention may be interpreted as follows. The radionuclides in the routine gaseous effluent from the Harris Plant may become associated with fine airborne particles originating from the combustion of fossil fuels. It is contended that once bound to the particles, the radionuclides will behave differently than that assumed in the calculation performed by Applicants and the NRC Staff and, as a consequence, result in doses which are greater than those presented in the ER and the FES for the Harris Plant.

More particularly, Contention II(e) is concerned with two distinct issues. The first issue is whether doses calculated via the inhalation route are underestimated because radionuclide adsorption onto respirable fly ash in the ambient atmosphere was not taken into account. It is contended that this particle adsorption would cause more of the radionuclides in the gaseous effluent to penetrate deeper into the lungs and be retained for longer periods of time. The second issue is

whether the doses from the radioactive gaseous emissions, calculated by Applicants and the NRC Staff for the crop-food-chain pathway, are underestimated because the calculations did not account for radionuclides bound to particles depositing more readily onto the ground, pasture and crops. It should be noted that these two concerns are not mutually exclusive. Increased radionuclide deposition on the ground due to particle adsorption decreases the quantity of radionuclides available to be inhaled. However, for simplicity and conservativism, we will neglect the inverse relationship between particle deposition rate and inhalation dose and deal with the two issues separately.

With regard to the first issue, Joint Intervenors are challenging the inhalation dose conversion factors tabulated in Regulatory Guide 1.109. With regard to the second issue, Joint Intervenors are challenging the deposition velocities assumed in Regulatory Guide 1.111. This testimony demonstrates that neither of the concerns identified in Joint Contention II(e) invalidates the dose calculations performed by Applicants and the NRC Staff.

II. Inhalation Dosimetry

In this portion of our testimony, we review the inhalation dose calculation methodology used by Applicants and the NRC Staff. First, we consider the significance of the phenomenon

of radionuclides attaching to fly ash. Detailed consideration is then given to the bases for the inhalation dose conversion factors because this is where the exposure model treats particle adsorption and subsequent lung deposition and retention. From this review, it will be seen that the assumptions used to develop the inhalation dose conversion factors account for the concerns raised by the Joint Intervenors. Next, we describe the nature of ambient atmospheric particles, especially coal combustion fly ash, and show that the calculational models properly account for the presence of these particles. Finally, we present two calculations of inhaled dose, first assuming radionuclide binding to very small particles and then assuming low solubility. They demonstrate that, notwithstanding these assumptions, the calculated doses from inhalation remain unchanged.

A. Significance of Joint Contention II(e) for Inhaled Radionuclides

It is important to understand that the phenomenon of concern in Joint Contention II(e), namely, radionuclides attaching to fly ash in the atmosphere and then lodging in the lung, is only applicable to radionuclides that can take particulate form. This is because radionuclides that cannot take particulate form will not stay in the lung, but will be immediately exhaled or absorbed into the body fluids. Tritium is not

in particulate form; it is inhaled as water vapor and, hence, that fraction not exhaled is immediately absorbed. Tritium makes up over 98 percent of the whole body dose from inhalation. See Table 1. Thus, the concern identified in Joint Contention II(e) only applies to the remaining two percent of the inhalation dose.

Notwithstanding the fact that the fly ash phenomenon of concern in Joint Contention II(e) can have little impact since it only affects a small fraction of the dose received by the public, this testimony considers whether the inhalation dose model used by Applicants and the NRC Staff adequately accounts for this phenomenon.

B. Inhalation Dose Model

The calculational method used by both Applicants and the NRC Staff is in accord with Regulatory Guide 1.109. The calculation requires four pieces of information:

1) the source term, expressed as curies per year (Ci/yr);

2) the atmospheric dispersion factor at the location of the maximally exposed individual, expressed in units of curies per cubic meter (ci/m^3) at a point offsite, per curies released from the plant per second (Ci/sec);

Inhalation Dose for the Harris Plant, Based on Regulatory Guide 1.109*/

NUCLIDE	T.BODY	GI-TRACT	BONE	LIVER	KIDNEY	THYROID	LUNG	SKIN
H 3	7.44E-02 98.98%	7.44E-02 99.34%	0. 0.00%	7.44E-02 98.60%	7.44E-02 99.08%	7.44E-02 54.00%	7.44E-02 92.45%	7.44E-02 100.00%
I 131	8.81E-05 0.12%	2.70E-05 0.04%	1.08E-04 8.95%	1.54E-04 0.20%	2.64E-04 0.35%	5.13E-02 37.23%	0. 0.00%	0. 0.00%
I 133	2.54E-05 0.03%	4.98E-05 0.07%	4.85E-05 4.00%	8.30E-05 0.11%	1.45E-04 0.19%	1.21E-02 8.77%	0. 0.00%	0. 0.00%
MN 54	2.66E-06 0.00%	3.24E-05 0.04%	0. 0.00%	1.66E-05 0.02%	4.13E-06 0.00%	0. 0.00%	5.87E-04 0.73%	0. 0.00%
FE 59	1.45E-06 0.00%	2.57E-05 0.03%	1.61E-06 0.13%	3.80E-06 0.00%	0. 0.00%	0. 0.00%	1.39E-04 0.17%	0. 0.00%
CO 58	2.84E-06 0.00%	1.46E-04 0.19%	0. 0.00%	2.17E-06 0.00%	0. 0.00%	0. 0.00%	1.27E-03 1.58%	0. 0.00%
CO 60	9.63E-06 0.01%	1.85E-04 0.25%	0. 0.00%	7.49E-06 0.00%	0. 0.00%	0. 0.00%	3.88E-03 4.83%	0. 0.00%
SR 89	2.69E-07 0.00%	1.08E-05 0.01%	9.37E-06 0.77%	0. 0.00%	0. 0.00%	0. 0.00%	4.31E-05 0.05%	0. 0.00%
SR 90	3.39E-05 0.05%	4.01E-06 0.00%	5.52E-04 45.54%	0. 0.00%	0. 0.00%	0. 0.00%	5.34E-05 0.07%	0. 0.00%
CS134	3.05E-04 0.41%	4.36E-06 0.00%	1.56E-04 12.90%	3.56E-04 0.47%	1.20E-04 0.16%	0. 0.00%	4.09E-05 0.05%	0. 0.00%
CS137	3.00E-04 0.40%	5.90E-06 0.00%	3.36E-04 27.71%	4.36E-04 0.58%	1.56E-04 0.21%	0. 0.00%	5.28E-05 0.07%	0. 0.00%
TOTAL	7.51E-02	7.49E-02	1.21E-03	7.54E-02	7.51E-02	1.38E-01	8.04E-02	7.44E-02

Age Group = Adult Location = 1.7 mi. NNE

* This Table relies on Revision 1 to Reg. Guide 1.109 (1977), whereas the ER relies on Revision 0 to Reg. Guide 1.109 (1976).

3) the inhalation rate of the maximally exposed individual expressed as cubic meters per second (m^3/sec); and

4) the inhalation dose conversion factor, expressed as millirem per picocurie (mrem/pCi) inhaled.

The product of these four terms, with appropriate unit conversion, yields the inhalation dose, as presented in the ER and the FES.

A discussion of the bases for the fourth factor, the inhalation dose conversion factor, is important because it is this factor which accounts for radionuclide lung deposition and clearance, which is the subject of Joint Contention II(e). The inhalation dose conversion factors used by Applicants and the NRC Staff are listed by radionuclide, organ and age group, in Tables E-7 through E-10 of Regulatory Guide 1.109. These values are expressed as the 50-year integrated dose commitment to the specified organ per unit of radionuclide activity inhaled (i.e., mrem/pCi).

In order to derive the dose conversion factor values, a two-compartment lung model was developed which simulates the behavior of radionuclides following inhalation. The model was first described in ICRP-2 (1959). Upon inhalation of any material, the material is either immediately exhaled or it is deposited in two areas of the respiratory region (the upper and lower respiratory passages). Once deposited in the two

compartments of the respiratory system, the material is cleared at varying rates depending on the chemistry of the particle and the site of deposition. Once cleared from the lung, the material is translocated to other locations in the body and is eventually eliminated via radioactive decay and excretion. The dose conversion factors listed in Regulatory Guide 1.109 for inhalation reflect the time-integrated dose to each organ as the radionuclides are transported through the body following inhalation.

Deposition and retention of radionuclides in the lungs depend on many factors such as size, shape and density of the radioactive material, the chemical form and whether or not the person is a mouth-breather. At the time the lung model was developed, there was limited emperical data to determine the actual effects of particle size, shape and chemistry on lung deposition patterns. The model therefore makes assumptions about the deposition and clearance pattern of the inhaled radionuclides. Specifically, the model assumes that 75 percent of the inhaled material is deposited and 25 percent is immediately exhaled. Of the 75 percent deposited, 50 percent is deposited in the upper respiratory tract and 25 percent in the deep lung. The model also assumes that half of the insoluble particles deposited in the deep lung are removed in 24 hours, and half are retained with a half life of 120 days (ICRP-2). Soluble particles are assumed to pass through the lung.

More recently, several studies using human subjects have measured particle deposition in the lung as a function of particle aerodynamic diameter. The term aerodynamic diameter refers to the diameter of a unit density sphere having the same terminal settling velocity as the particle under consideration. Terminal settling velocity is the equilibrium velocity of a particle that is falling under the influence of gravity and fluid resistance and is dependent upon particle size, shape and density.

A comparison of the experimental data and the assumptions in the lung model for percent deposition and distribution shows the model used to derive the dose conversion factors to be somewhat conservative. The percent particle deposition in the total respiratory system (upper and lower lung compartments) ranges from less than 10 to 100 percent of the total particles inhaled, depending upon particle size. (EPA 1982). However, the size of respirable fly ash particles in ambient atmospheres has a median aerodynamic diameter of about 2.0 micrometer (μm) (see next section). As indicated in the review by the EPA (EPA 1982), the deposition fraction for most particles in the size range of fly ash is about 30 percent but can approach 60 percent for sizes near the 2.0μm diameter. These fractions can be compared to the 75 percent fraction assumed in the model. Thus, the model assumes a greater quantity of particles of the size of fly ash is deposited in the total lung than has actually been observed to occur.

With respect to particle deposition in the deep lung, where long term retention can occur, the emperical data indicate that 10 to 30 percent of the inhaled particles in the size range of 0.1 to 2.0μm is deposited (Figure 1). This fraction is estimated to be less for nose-breathing (Figure 1). Comparing the measured deposition fraction (10 to 30 percent) to the fraction assumed in the model (25 percent), it can be seen that the model is reasonable, if not somewhat conservative, in its assumption of radionuclide deposition fraction in the deep lung. Therefore, the inhalation doses calculated by Applicants and the NRC have not been underestimated due to inappropriate lung deposition patterns.

Joint Contention II(e) focuses on the retention of particles in the lung. Particle retention in, as well as subsequent translocation from the lung is also dependent upon the solubility of inhaled material. The less soluble a radioactive particle, the greater dose it will deliver to the lung. Thus, soluble radionuclides are rapidly transported into the body which tends to reduce the lung dose, whereas insoluble radionuclides remain in the lung for a much longer time producing a greater dose to the lung and a much smaller dose to the rest of the body.

The inhalation dose conversion factors in Regulatory Guide 1.109 take into account lung retention based upon a solubility classification. Radioelements are classified as soluble or unsoluble as follows:

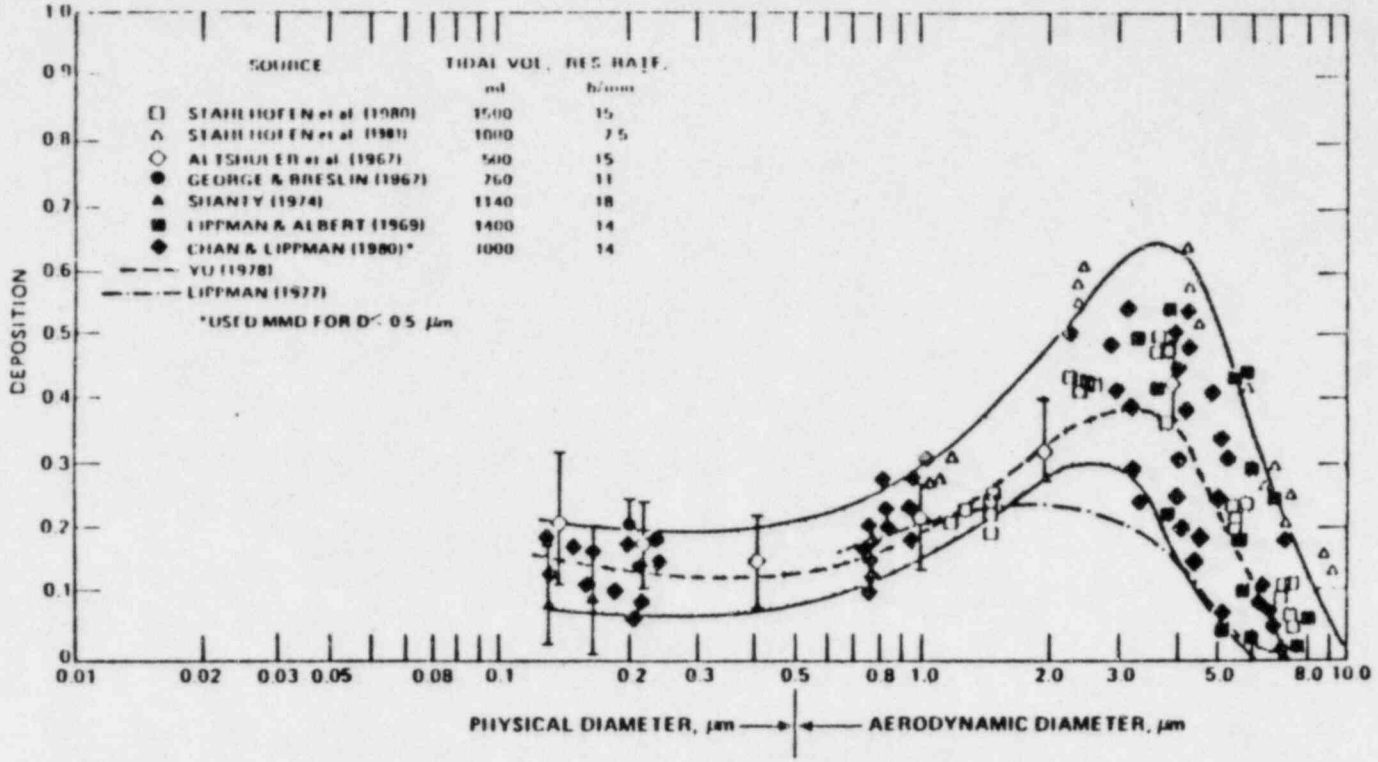

Figure 1 - Deposition of monodisperse aerosols in the pulmonary region for mouth breathing in humans as a function of aerodynamic diameter, except below 0.5 μm, where deposition is plotted vs. physical diameter. The eye-fit band envelops deposition data cited by the different investigators. The dashed line is the theoretical deposition model of Yu (1978) and the broken line is an estimate of pulmonary deposition for nose breathing derived by Lippmann (1977) - (from EPA 1982).

Radioelement	Solubility
H-3, C-14, Na-22, Na-24, I-129, I-131, I-132, I-133, I-135, Cs-134, Cs-137	Soluble
Mn-54, Fe-55, Fe-59, Co-58, Co-60, Ni-63, Sr-89, Sr-90, Zr-95, Nb-95, Ru-103, Ru-106, Te-132 Cr-51, Cu-64, Zn-65, Mo-99, Ba-140, La-140, Ce-141, Ce-144	Insoluble

This classification is based upon the recommendations of the ICRP Task Group on lung dynamics (ICRP, 1966). Thus, the model accounts for the retention characteristics of radionuclides.

There is one group of radionuclides that has not yet been addressed in this discussion about inhalation dosimetry. These are the noble gases, xenon, krypton and argon. Because of their inert nature they do not bind significantly to particles or adsorb onto surfaces. This fact is confirmed by the calculation described in Attachment 2 to this testimony. However, even if one assumes significant particle binding by noble gases, this is inconsequential to the resulting dose because the source terms of these radioactive gases would also significantly decrease due to holdup and removal of gases in the HVAC charcoal filtration system.

C. Particulate Material in the Ambient Environment

In addition to the model's consideration of particle deposition and retention behavior in the lungs, data about ambient particle size, especially coal fly ash, confirms that the model

effectively accounts for coal fly ash lung deposition and retention.

Data collected during the 1970s, which describe the distribution of atmospheric particulate matter in the United States, indicate the existence of three separate particle size modes having independent behavior in ambient air (EPA, 1982). The first mode, the nuclei mode, is below 0.1 μm and generally consists of primary particles emitted as a result of fuel combustion (oil, gasoline, natural gas and coal). These particles are formed by condensation from the gaseous phase and only exist for short times due to rapid coagulation and aggregation. The second size mode falls between 0.1μm and about 2.0μm. These particles typically remain airborne for several days, and this mode is called the accumulation mode. These particles are largely formed by coagulation of particles from the smaller mode and by aggregation of additional particles. Because of their relatively long life, these particles are the ones most easily transported from point source emissions. The third and final mode includes particles above about 2.0μm, generally produced through mechanical action and easily removed by washout and sedimentation. These particles exist in the atmosphere for only a few hours.

The most prevalent particle mode present in the atmosphere around the Shearon Harris site from an industrial source would be the accumulation mode. This is because the plant is located

in a forested region with no major industrial combustion source within five miles of the plant (FSAR Section 2.2.1). In this rural, non-industrial area, larger particles (> 2.0μm) emitted from faraway sources would not be present because they would have rapidly settled out; however, smaller particles (< 0.1μm) transported from faraway industrial sources would have aggregated and thus grown in size by the time they reach the site.

Not only can the particle size from industrial combustion sources transported to the Harris Plant vicinity generally be deduced based on area conditions, but it is possible to make certain assumptions about coal fly ash particle size in particular. The results of a survey for coal plants equipped with electrostatic precipitators show a typical size distribution for fly ash with a median aerodynamic diameter of approximately 2.0μm (Figure 1). Thus, fly ash in the atmosphere will be in the size range that is implied in the model. This is because the inhalation dose model used by Applicants and the NRC Staff assumes particle deposition fractions for the lung representative of particles in the size range of about 0.1 to 2.0μm.

In summary, considering the sizes of ambient atmospheric particles generally, and fly ash in particular, it can be concluded that the inhalation dosimetry model accurately accounts for lung deposition of inhaled ambient particles including fly ash at the site.

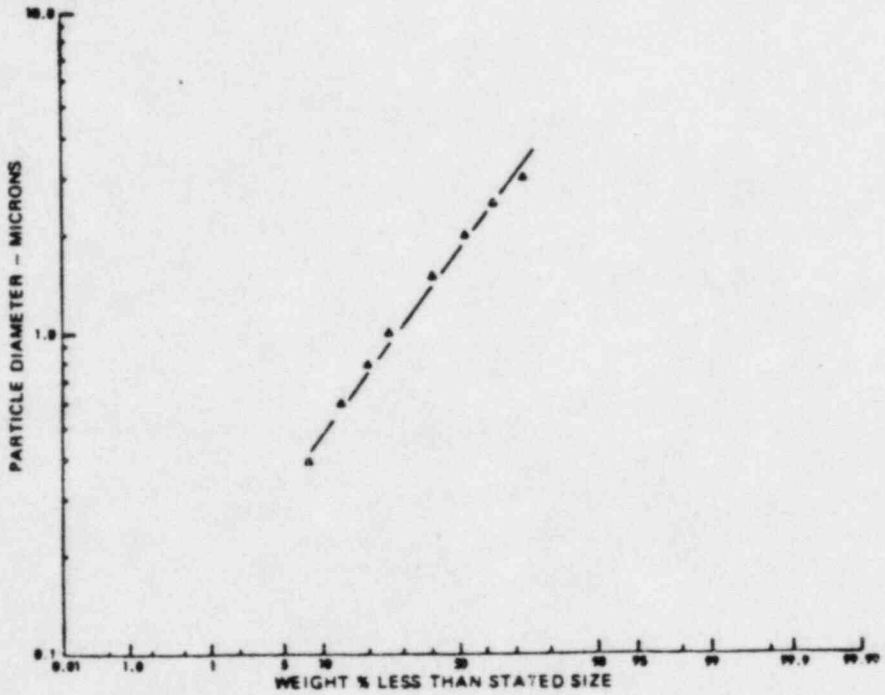

Figure 2 - Emissions from Electric Utility Power Plants Controlled by Electrostatic Precipitators (From Natusch, 1978)

D. Inhalation Dose Comparison

Notwithstanding the above analyses, the doses calculated for the Harris Plant vicinity would not change even if one assumes greater lung particle deposition, or longer lung retention of radionuclides (due to decreased solubility) than are assumed in the calculation performed in accordance with Reg. Guide 1.109.

Table 1 lists the breakdown of doses by organ and radionuclide. These are maximum adult doses which are expected to occur from the annual releases at Shearon Harris and were calculated using standard Reg. Guide 1.109 methodology. Based on these doses, the whole body dose is about 0.075 mrem and the critical organ dose (thyroid) is about 0.14 mrem.

Table 2 lists a similar dose breakdown; however, the doses listed in this table were calculated assuming 60 percent radionuclide deposition in the deep lung. This is the maximum fraction observed from human studies (EPA 1982) as opposed to the 25 percent deposition assumed in the model. Doses were adjusted using ICRP-30 (ICRP, 1979) correction equations for different deposition fractions. Assuming a 60 percent deposition fraction, the whole-body dose remains about 0.075 mrem, and the dose to the critical organ (thyroid) is about 0.16 mrem.

In order to assess the significance of alternative assumptions regarding solubility, another calculation was performed.

Inhalation Dose Assuming All Radionuclides 0.1um AMAD

Nuclide	Critical Organ (m rem)							
	Total Body	GI Tract	Bone	Liver	Kidney	Thyroid	Lung	Skin
H-3	7.44(-2)	7.44(-2)	0	7.44(-2)	7.44(-2)	7.44(-2)	7.44(-2)	7.44(-2)
I-131	1.23(-4)	3.78(-5)	1.51(-4)	2.15(-4)	3.69(-4)	7.17(-2)	0	0
I-133	3.14(-5)	6.15(-5)	5.99(-5)	1.03(-4)	1.79(-4)	1.49(-2)	0	0
Mn-54	6.23(-6)	7.65(-5)	0	3.92(-5)	9.75(-6)	0	1.39(-3)	0
Fe-59	3.39(-6)	6.01(-5)	3.77(-6)	8.89(-6)	0	0	3.25(-4)	0
Co-58	6.82(-6)	3.50(-4)	0	5.21(-6)	0	0	3.05(-3)	0
Co-60	2.31(-5)	4.44(-4)	0	1.80(-5)	0	0	9.31(-3)	0
Sr-89	6.46(-7)	2.59(-5)	2.25(-5)	0	0	0	1.03(-4)	0
Sr-90	5.59(-5)	6.61(-6)	8.64(-4)	0	0	0	8.81(-5)	0
Cs-134	4.39(-4)	6.28(-6)	2.25(-4)	5.13(-4)	1.78(-4)	0	5.89(-5)	0
Cs-137	4.32(-4)	8.50(-6)	4.84(-4)	6.28(-4)	2.25(-4)	0	7.60(-5)	0
TOTAL	7.55(-2)	7.55(-2)	1.81(-3)	7.59(-2)	7.54(-2)	1.61(-1)	8.88(-2)	7.44(-2)

Table 3, which presents the results of that calculation, illustrates the dose breakdown assuming all radionuclides (except tritium) are insoluble. This calculation results in a whole body dose of about ~~0.74~~ 0.074 mrem, and the critical organ dose (lung) is about 0.084 mrem.

When comparing the results listed in Tables 1 through 3, it can be seen that some organ doses increase, others decrease and others remain unchanged. However, the overall conclusion is that particle size and solubility have no significant effect on the final dose outcome.

In summary, the phenomenon of radionuclides attaching to fly ash impacts only a small fraction of the inhaled dose and, with respect to that fraction, the inhalation dose model used by Applicants and the NRC Staff effectively accounts for the attachment of radionuclides to fly ash particles in the atmosphere around the Harris Plant.

III. Doses From Particle Deposition onto Food Crops

In order to assess whether the phenomenon of radionuclides attaching to fly ash impacts the calculation made by Applicants and the NRC Staff of the food pathway dose for the Harris Plant, it is necessary to examine the assumptions used in Regulatory Guide 1.111 as to particle deposition velocities. This is because, in general, the greater the deposition rate, the higher the dose from the food ingestion pathways. Analysis of

Inhalation Dose Assuming All Radionuclides Insoluble

Critical Organ (m rem)

Nuclide	Total Body	GI Tract	Bone	Liver	Kidney	Thyroid	Lung	Skin
H-3	7.44(-2)	7.44(-2)	0	7.44(-2)	7.44(-2)	7.44(-2)	7.44(-2)	7.44(-2)
I-131	7.15(-6)	1.59(-3)	1.84(-5)	4.50(-5)	1.12(-5)	0	1.59(-3)	0
I-133	1.36(-6)	1.73(-3)	3.50(-6)	8.54(-6)	2.12(-6)	0	3.02(-4)	0
Mn-54	2.64(-6)	3.24(-5)	0	1.66(-5)	4.13(-6)	0	5.87(-4)	0
Fe-59	1.45(-6)	2.57(-5)	1.61(-6)	3.80(-6)	0	0	1.39(-4)	0
Co-58	2.84(-6)	1.46(-4)	0	2.17(-6)	0	0	1.27(-3)	0
Co-60	9.63(-6)	1.85(-4)	0	7.49(-6)	0	0	3.88(-3)	0
Sr-89	2.69(-7)	1.08(-5)	9.37(-6)	0	0	0	4.31(-5)	0
Sr-90	3.39(-5)	4.01(-6)	5.52(-4)	0	0	0	5.34(-5)	0
Cs-134	3.43(-6)	4.36(-5)	8.84(-6)	2.16(-5)	5.37(-6)	0	7.63(-4)	0
Cs-137	5.41(-6)	7.50(-5)	1.39(-5)	3.39(-5)	8.44(-6)	0	1.20(-3)	0
TOTAL	7.44(-2)	7.81(-2)	6.11(-5)	7.44(-2)	7.44(-2)	7.44(-2)	8.42(-2)	7.44(-2)

deposition velocities establishes that the food pathway dose calculation conservatively accounts for the attachment of radionuclides to fly ash particles and the effect this phenomenon may have on the rate at which radionuclides deposit on the ground.

The particle deposition velocities on which the Regulatory Guide 1.111 calculation is based were taken from Markee (1967). These velocities range from 0.12 cm/sec to 1.81 cm/sec. At issue here is the validity of these rates, assuming radionuclides are attached to fly ash particles.

EPA has published data (EPA 1982) on deposition velocities which are based on field and laboratory measurements. For particles 0.1, 1.0 and 10μm in diameter, the corresponding deposition velocity is 0.015, 0.21 and 4.0 centimeters per second. The median size of fly ash is about 2μm. See Figure 2. Therefore, an appropriate deposition velocity for fly ash is slightly above 0.21 cm/sec. This is well within the range assumed in Regulatory Guide 1.111. Thus, the assumed deposition velocities are appropriate, if not conservative for fly ash particles.

IV. Conclusion

In summary, the inhalation dose conversion factors used by Applicants and the NRC Staff appropriately account for radionuclide adsorption onto respirable fly ash in the ambient

atmosphere. In addition, the calculation of doses from the crop-food-chain pathway appropriately accounts for the binding of radionuclides to particles deposited onto the ground, pasture and crops.

ATTACHMENT 1A

Resume

JOHN J MAURO

Education:

BS - Long Island University 1963
MS - New York University 1970
PhD - New York University Medical Center - Institute of Environmental Medicine 1973

Awards:

- Alvin Gruder Memorial Award for Excellence in Biological Sciences
- Member of the Optimates Society for Academic Achievement
- Founder's Day Award for Doctoral Dissertation

Societies:

- Health Physics Society
- American National Standards Committee on Emergency Planning

Certifications:

Certified by the American Board of Health Physics

Consultancies:

- Radiological Health Bureau of the California Office of Emergency Services
- Battelle Memorial Institute
- Louisiana Power and Light Company
- Shaw Pittman, Potts and Trowbridge
- EG&G Idaho
- Union Carbide Corporation - Nuclear Division

Current Position:

Director of the Radiological Assessment and Health Physics Department of Envirosphere Company in New York City.

Summary of Professional Experience:

While a graduate student at the Institute of Environmental Medicine of New York University, I was also a full-time Research Assistant from 1970 to 1973. In this position I assisted Principal Investigators on numerous research projects on the ecology and radioecology of the lower Hudson River Estuary. These activities included the collection of aquatic organisms from the estuary to determine species abundance and diversity, the life history of white perch and the concentration of radionuclides in aquatic organisms, water and sediment. These activities also included experimentation into the ability of microorganisms collected from the Hudson River sediment to organify inorganic mercury.

In addition to my responsibilities as Research Assistant, I was a full-time graduate student, studying environmental health, health physics and radioecology. My doctoral research was on the radioecological behavior of Cs-137 in the lower Hudson River Estuary. Research for my thesis covered a three-year period which included extensive field studies and laboratory experimentation to identify and mathematically model the uptake and elimination of Cs-137 by aquatic organisms.

After receiving my doctoral degree in 1973, I joined Ebasco Services as a Radiological Assessment Engineer. Ebasco Services is a major architect-engineer-constructor for power generating facilities. My initial responsibilities at Ebasco were to evaluate the radionuclide release rates from proposed and operating nuclear power facilities under normal plant operation and following postulated accidents, and to determine the radiation exposures and health risks to workers and members of the nearby general population. In this capacity I developed several models for performing radiological impact assessment, and have prepared the radiological impact assessment sections of license applications.

Since joining Ebasco I have held positions of increasing responsibility, and am currently Director of the Radiological Assessment and Health Physics Department in Envirosphere Company, the Nuclear Licensing and Environmental Health Division of Ebasco Services. In this position, I report directly to the Vice President of Nuclear Operations and, I am responsible for all radiological health and emergency planning services provided by Envirosphere Company. I manage a technical staff of 10 senior level consultants with advanced degrees in nuclear and biological sciences, with a combined 150 years of professional experience in technological risk management.

My responsibilities as Director of the department are divided into radiological health consulting (40%), project management (30%), marketing and business development (20%), and department administration (10%). A brief description of each of these areas of responsibilities follows.

Though my management responsibilities have increased considerably since joining Ebasco, I continue to personally provide consulting services to our clients. These services include the analysis of radiological source terms, environmental transport, radio-ecology, internal and external dosimetry, health risk assessment, radiological surveillance, emergency planning, regulatory analysis and the preparation and defense of expert testimony on these subjects. Recently I have also become involved in the evaluation of toxic chemical hazards at industrial sites and low-level radioactive waste management. These services have been provided for a large number of clients representing the nuclear power industry and federal and state agencies and their subcontractors.

I have also managed several consulting contracts in the areas of radiological and chemical toxicology, health physics, and emergency planning. A detailed description of these projects will be provided upon request. Most of these projects have been of a multidisciplined nature and included participation of specialists in the areas of toxicology, nuclear engineering, mathematical modelling, meteorology, hydrology and computer sciences. On these projects I had overall responsibility for budget, schedule and technical quality of deliverables.

As director of the Radiological Assessment and Health Physics Department, I am also responsible for developing and meeting an annual budget. The budget includes staff and non-staff salaries and out-of-pocket expenses for client billable work, department overhead and business development. My effectiveness as Director is judged by my ability to achieve or exceed the budget for billable work and to effectively control non-billable expenses. Non-billable expenses include business development, training and publications, presentations, participation on standards committees and other professional practices. I have responsibility for hiring new staff and for staff performance review, promotions and merit increases. In this capacity I am assisted by 2 department managers who report directly to me.

Publications and Presentations:

Mauro, J J and M E Wrenn 1972. A Review of Radiocesium in Aquatic Biota. Presented at the Health Physics Society Annual Meeting, Las Vegas, Nevada, June 12-16, 1972.

Mauro, J J and M E Wrenn 1973. Reasons for the Absence of a Trophic Level Effect for Radiocesium in the Hudson River Estuary. Presented at the IRPA meeting held in Washington, D C in October. Published in the proceedings of that meeting.

Mauro, J J and J Porrovecchio 1976. Numerical Criteria for In-plant As Low as is Reasonably Achievable. In "Operational Health Physics". Proceedings of the 9th Mid-Year Topical Symposium of the Health Physics Society.

Mauro, J J, D Michlewicz and A Letizia 1977. Evaluation of Environmental Dosimetry Models for Applicability to Possible Radioactive Waste Repository Discharges, Y/OWI/SUB-77/45705.

Mauro, J J 1978. Comparison of Gaseous Effluent Standards for Nuclear and Fossile Fuel Power Production Facilities. Proceedings of the December 1979 Annual Meeting of the American Nuclear Society.

J Thomas, J J Mauro, J Ryniker and R Fellman 1979. Airborne Uranium, Its Concentration and Toxicity in Uranium Enrichment Facilities, K/PO/SUB -79/31057/1, February.

Lind K E, Mauro, J J, J D Levine, L Yemin, H J Howe, Jr and C W Pierce 1979. Safety Related Research Required to Support Future Fusion Research Reactors. Presented at the Annual Meeting of the American Nuclear Society-San Francisco, November, 1979.

O'Donnell E P, and Mauro J J 1979. A Cost-Benefit Comparison of Nuclear and Nonnuclear Health and Safety Protective Measures and Regulations. Nuclear Safety, Vol 20 No. 5, September-October, 1979.

Mauro, J J 1980. A Real Time Computer Program for Offsite Radiological Impact Assessment. Presented at the 1980 Annual Meeting of the American Nuclear Society. TANSAO 34 1-899.

Bhatia R, Mauro, J J and G Martin 1980. Effects of Containment Purge on the Consequences of a Loss of Coolant Accident. Presented at the 1980 Annual Meeting of the American Nuclear Society. TANSAO 34 1-899.

Marschke S, and Mauro, J J 1980. Radiocesium Transport Into Reservoir Bottom Sediments - A Licensing Approach. Presented at the 1980 Annual Meeting of the ANS. TANSAO 34 1-899.

Mauro, J J and D Michlewicz 1981. Deployment Concepts for Real Time Environmental Dosimetry Systems. Presented at the 1981 Annual Meeting of the Health Physics Society.

Mauro, J J and E P O'Donnell 1982. The Role of the Architect/Engineer in the Emergency Planning Process. Presented at the Annual Meeting of the American Nuclear Society. June 6-10, 1982.

Mauro, J J and W R Rish 1982. Dealing with Uncertainties in Examining Safety Goals for Nuclear Power Plants. In NUREG-CP-0027. Proceedings of the International Meeting on Thermal Reactor Safety.

Mauro, J J, S Schaffer, J Ryniker, and J Roetzer. Survey of Chemical and Radiological Indices Evaluating Toxicity. National Low-Level Radioactive Waste Management Program. DOE/LLW-17T. March, 1983.

Vold E, J J Mauro and D Michlewicz 1984. Dose Projection for Nuclear Emergency Response on a Microcomputer. Published in "Computer Applications in Health Physics." Proceedings of the Health Physics Midyear Topical Meeting, Pasco, Washington. February 5-9, 1984.

Mauro, J J, S Schaffer, W Rish and J Parry. Application of Probabilistic Techniques to Dose and Risk Assessment Performed by EPA in Support of 40 CFR 191. Submitted for Publication.

ATTACHMENT 1B

STEVEN A. SCHAFFER
Senior Radiological Assessment Engineer

SUMMARY OF EXPERIENCE (Since 1973)

Total Experience - Ten years experience in the design and implementation of research and assessment projects addressing the problems of environmental contamination and human health affairs.

Education - PhD, Biology/Environmental Health Science, New York University, June 1982

MS, Biology, 1978, New York University

BS, Biology, 1973, State University of New York, Oneonta

REPRESENTATIVE ENVIROSPHERE PROJECT EXPERIENCE (Since 1981)

High Level Waste

Provide technical and regulatory support to the DOE concerning the proposed EPA standard on high-level waste (40 CFR 191). This support included:

1. Co-authoring a report submitted by the DOE to the EPA Science Advisory Board. This work quantified the uncertainty in the EPA health risk estimates used as the basis of the proposed regulation.

2. Critically evaluated the REPRISK methodology used by the EPA for determining the risk from high-level waste.

3. Acted as a technical liaison between DOE and EPA especially in the area of environmental transport.

Provided technical and regulatory support to the DOE concerning high-level waste disposal in salt. Responsibilities included formulating a safety plan for a salt repository and developing technical interpretations of current high level waste regulations.

Low-Level Waste

Aided in the preparation of a toxicity index for the radiological and toxicological hazard in low-level waste for the DOE.

General Radiological Assessment

Evaluated the radiological impact of nuclear power plant operation for Ebasco client utilities. Prepared postulated source terms and subsequent doses to surrounding areas for Safety Analysis and Environmental Reports.

Aided in the preparation of testimony on the synergistic action of radiation and chemical carcinogens.

Assisted in the preparation and implementation of an environmental radiological monitoring program for a nuclear power plant.

Prepared testimony on the radiological effects of coal fired electric generating facilities.

Developed uncertainty distributions for environmental pathway model parameters that were utilized in an uncertainty analysis of the environmental risks of high-level waste.

PRIOR EXPERIENCE (8 Years)

Research Scientist

New York University Medical Center, Institute of Environmental Medicine, Laboratory for Environmental Studies, Tuxedo, New York 10987.

Member of a research group for 3 years, examining the transport and ultimate fate of nuclear reactor produced radionuclides discharged into the Hudson River estuary. Responsible for the Beta/Gamma emitting nuclide portion of this project.

Conducting Ph.D thesis research on the effects of alpha radiation and polychlorinated biphenyls (PCBs) on the biochemical energy production of algae.

Assisted in laboratory and field research which analyzed the aerobic and anaerobic degradation of PCBs.

Assisted in a field and laboratory research program which studied the biological and physical transport of PCBs and heavy metals in the Hudson River.

Carried out and subsequently published the results of laboratory experiments dealing with the effects of high LET radiation on the survival and energy metabolism of algae.

Supervised and conducted, for 5 years, field sampling programs for nuclear power plant entrainment studies on the Hudson River. Solely responsible for a research project designed to assess the effects of different sampling gear on icthyoplankton.

Assisted in an ichthyoplankton population survey of the Hudson River.

Conducted and reported on thermal tolerance and chlorination bioassays with fish and numerous invertebrate plankton as part of a nuclear power plant entrainment study.

Masters research involving the quantitative and qualitative chemical analysis of Hudson River water.

Publications

O'Connor, J.M. and S.A. Schaffer, 1977. The Effects of Sampling Gear on the Survival of Striped Bass Icthyoplankton, Chesapeake Science 18:312-315.

Schaffer, S.A. and C.C. Lee. Organic Carbon and Protein Concentrations of Hudson River Water in the Vicinity of Indian Point. (abstract) American Society of Limnology and Oceanography Annual Meeting, 1978.

Steinhausler, F., S.A. Schaeffer, N. Cohen, C.C. Lee, J.M. O'Connor, M.E. Wrenn. Effects of High LET Radiation on Intracellular ATP Content of Prokaryotic and Eukaryotic Algae. Abstracts of the 26th Annual Meetings of Radiation Research Society, Toronto, Canada, May 1978. Radiation Research 74:591-92.

Steinhausler, F., S.A. Schaffer, C.C. Lee, J. O'Connor, and M.E. Wrenn, 1980, Effects of Low-Level Alpha Radiation on Intracelular Energy Metabolism. Radiation Research 81:393-401.

Rish, W.R., J.J. Mauro, S.A. Schaffer. 1983. Uncertainties in EPA Modeling Used to Develop Draft Standard 40 CFR 191. Proceedings of the American Nuclear Society, Winter 1983.

Schaffer, S.A. (accepted for publication). The bioenergetic response of chlorella vulgaris to alpha radiation. Environmental and Experimental Botany.

Professional Societies

Society of Environmental Toxicology and Chemistry (SETAC).

Attachment 2

Adsorption of Noble Gases onto Airborne Fly Ash

The fraction of the annual release of radioactive noble gas from the Shearon Harris site absorbed onto airborne fly ash particles can be estimated by the following relationship:

$$\text{Fraction Absorbed} = \frac{\text{Conc.}_{fa}}{\text{Conc.}_{t}}$$

$$\text{Where Conc.}_{fa} = \frac{\text{weight of fly ash (g)}}{m^3} \cdot K_d \frac{g}{g}$$

$$\text{Conc.}_{t} = \frac{\text{stable gas (g)}}{m^3} + \frac{\text{radioactive gas (g)}}{m^3}$$

Using these equations, we have calculated the fraction absorbed onto fly ash for Kr-85, Xe-133 and Ar-41. These radionuclides were chosen because they represent the three elemental types released and are the worst case combination of half-life and release quantity.

Table A-1 lists the various parameters used in our calculation and Table A-2 lists our results. In summary, an insignificant fraction of radioactive noble gases released from Shearon Harris would become associated with airborne fly ash particles. It should be noted that the actual fraction would probably be lower than the quantity calculated, because the calculation assumes a fly ash concentration representative of the maximum total respirable airborne particle load for

northeastern cities, which is a higher concentration than exists in the vicinity of the Harris Plant (Pedco 1982, EPA 1982). Moreover, our calculation is additionally conservative because it assumes that all particles have surface adsorption characteristics of activated charcoal, which is manufactured for the specific purpose of efficiently adsorbing radionuclides.

Table A-1

List of Parameters

Parameter	Value	Notes
Fly ash concentration (g/m^3)	$1x10^{-4}$	1
Adsorption coefficient (g/g)		
Krypton	$1.5x10^{-10}$	
Xenon	$2.3x10^{-9}$	2
Argon	$1.07x10^{-11}$	
Concentration of stable gas in atmosphere (g/m^3)		
Krypton	$3.8x10^{-3}$	
Xenon	$2.9x10^{-4}$	3
Argon	1.6	
Radioactive gas concentration in atmosphere (g/m^3)		4
Krypton-85	$1.7x10^{-6}$	
Xenon-133	$4.4x10^{-6}$	
Argon-41	$1.9x10^{-12}$	

Notes:

1. The concentration of all respirable particles in large industrial N.E. cities can be as high as $1x10^{-4}$ g/m^3 (Pedco 1982). The calculation assumes the fly ash concentration around Shearon Harris site to be equal to this concentration.

2. Adsorption coefficients for fly ash was assumed to be the same as activated charcoal (NUREG-0678) divided by a reduction factor of 332 to account for the difference in specific surface area.

3. Taken from CRC Handbook of Chemistry and Physics 64th ed.

4. Concentration of radioactive noble gases was calculated by multiplying the annual site releases by the annual average atmospheric dispersion factor for the critical residence (3.2×10^{-6} sec/m^3).

Table A-2

Fraction of Annual Release of Radioactive Noble Gases Absorbed to Airborne Fly Ash Particles

Radionuclide	Fraction Absorbed
Kr-85	1.2×10^{-5}
Xe-133	2.4×10^{-3}
Ar-41	2.0×10^{-9}

References

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Markee, E.H. Jr. 1967. A parametric study of gaseous plume depletion by ground surface adsorption, in Proceedings of USAEC Meteorological Information Meeting, C.A. Mawson [ed.], AECL-2784: 602-613.

Natusch, D.F.S. 1978. Potentially carcinogenic species emitted to the atmosphere by fossil-fueled power plants. Environmental Health Perspective Vol. 22: 79-90.

NUREG-0678. The effects of temperature, moisture, concentration, pressure and mass transfer on the adsorption of krypton and xenon on activated carbon.

Pedco, 1982. Compilation of ambient particulate matter size and composition data. Pedco Environmental Inc.

Regulatory Guide 1.109. 1977. Calculation of annual doses to man from routine releases of reactor effluents for the purpose of evaluating compliance with 10 CFR part 50, Appendix I. Rev. 1., U.S. Nuclear Regulatory Commission.

Regulatory Guide 1.111. 1977. Methods for estimating atmospheric transport and dispersion of gaseous effluents in routine releases from light-water-cooled reactors. Rev. 1., U.S. Nuclear Regulatory Commission.

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BY MS. BAUSER:

Q Dr. Mauro, would you please explain which part of this testimony on Contention II(e) is yours and which is Dr. Schaffer's?

A (Witness Mauro) Well, it's difficult to make a distinction between portions of the testimony that I prepared and that Dr. Schaffer prepared. It was more of a collaborative effort where drafts were prepared and worked on jointly. So it is difficult for me to point out specific sections that I can say that I prepared, as opposed to Dr. Schaffer.

Q Dr. Schaffer, could you briefly summarize the substance of the testimony on fly ash?

A (Witness Schaffer) As we understood the contention, it seemed like Intervenors were concerned about radionuclides emitted in the gaseous emissions from the Harris plant being adsorbed onto particles in the atmosphere and thereby causing a greater deposition and retention in the lung or a greater deposition onto the ground. And they seemed to be concerned about the fact that this was not taken into consideration in our dosimetry models, and we therefore underestimated the doses.

As explained in our testimony, we actually show that this phenomenon of adsorption onto atmospheric particles is only concerned with a small fraction of the

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total dose. However, adsorption onto particles has been taken into consideration in modeling the remainder of the dose in the assumptions in the models. So therefore the doses seem to be correct, and we have accounted for the deposition of the particles, rather deposition of radionuclides onto particles in fly ash

MS. BAUSER: I have no more questions.

JUDGE KELLEY: Does that summarize it for both gentlemen?

MS. BAUSER: Yes.

JUDGE KELLEY: Okay.

Just a question and then a comment.

Mr. Eddleman, is the questioning going to be coming primarily or exclusively from you? How are you going to work this?

MR. EDDLEMAN: I believe so.

JUDGE KELLEY: Okay.

Gentlemen, as to the format you find yourselves in this morning -- perhaps you've done this before -- but we very often use panel formats. And Mr. Eddleman is the questioner, and he will address the question to whomever he wishes between the two of you. But usually he will get going on something or hear anybody that is more especially to one than the other, there may be a string of questions to one and not the other, but you indicated already that this

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was a collaborative effort, and the person to whom the question is directed should go ahead and respond if he can, and if not, send it to his colleague. Very often you might want to give an answer, and then if the other person wants to add something, feel free to do so.

But one of the main points of this is to put together in one place the knowledge of two or more expert witnesses, so you do need to speak up and add whatever is on your mind.

CROSS-EXAMINATION

BY MR. EDDLEMAN:

Q Gentlemen, since both of you are Ph.D.s, I will probably address you as Doctors, and please do feel free at any time to amplify or explain the answer, either of you. Just jump right in if you have something to say.

Let me ask Dr. Mauro first about his resume on page 2 of Attachment 1-A.

Do you have that, Doctor?

A (Witness Mauro) Yes.

Q It says in the first line, "After receiving my doctoral degree in 1973, I joined Ebasco Services as a Radiological Assessment Engineer."

Now is it true that Ebasco is the only full-time employer that you have had since that time?

A Since graduating?

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Q Since receiving your doctorate.

A That's correct.

Q Dr. Schaffer, I believe in your Attachment 1-B, when it says "envirosphere project experience," is that referring to the Envirosphere Company?

MS. BAUSER: Excuse me. Could you identify where --

MR. EDDLEMAN: Attachment 1-B, Dr. Schaffer's resume, the second underlined line on the page , about a third of the way down. It says "representative envirosphere project experience (since 1971)."

BY MR. EDDLEMAN:

Q And I am asking you, does that refer to the Envirosphere Company or to the area of work you are doing?

A (Witness Schaffer) Envirosphere Company.

Q Okay. And how does Envirosphere relate to Ebasco?

A Envirosphere is a wholly-owned subsidiary of Ebasco. We are actually the environmental consultants to Ebasco.

Q So Ebasco's environmental consultants are a wholly-owned subsidiary of Ebasco?

A That's correct.

End 1

2pb1

Q Let me ask you if you know what Ebasco's relationship to the Shearon Harris nuclear power plant is?

A Are you asking you?

Q I'm asking both of you.

A (Witness Mauro) Ebasco is the architect engineer for theHarris plant.

Q In other words, they are the ones who do the design and engineering of the plant?

A That's correct.

Q And if I take it right, your services are basically assisting them in carrying out the studies that they need to do to get the plant license; is that correct?

A Correct.

Q Let me now turn back toward the beginning of your testimony. Let's look on page 2, right below where you have repeated Contention II(e). Now it says, the contention may be interpreted as follows, and I believe you also stated an interpretation that Dr. Schaffer just stated, an interpretation in summarizing the testimony.

Dr. Schaffer, I believe you used the word absorbed, with a "b", did you not?

A (Witness Schaffer) No, I used it with a "d."

Q Adsorbed, okay, so I misunderstood you. Could you tell us what the difference between absorption with a "b" and adsorption with a "d" is?

2pb2

A Absorption with a "b" is sort of like the way a sponge operates where you have capillary action working into surfaces of particles. And adsorption is actually sticking onto a surface.

Q Okay. So absorption implies some kind of an uptake inside of a surface. And adsorption is sticking to the outside of a surface. Is that a reasonable interpretation?

A Yes.

Q Does not the contention state, if I can refer you to the third from the last line of the contention as you reprint it up there on the top of page 2, nuclides absorb with a "b" in, or are attached to fly ash, doesn't it say that?

A Yes, it does.

Q And you say -- you were using the word adsorbed in your summary of what you dealt with. Did you make any study of absorption with a "b" as in boy of any of these radionuclides into coal-fired fly ash? Did either of you?

A (Witness Mauro) I would say to the extent that we felt it was relevant to the analysis.

Q Okay. Can you direct me to where in your testimony the study of absorption with a "b" or your opinion as to the relevance of the analysis is stated?

A It's not directly described. It is the particles themselves that we deal with as they are formed and emitted

2pb3

we are treating as particulate matter upon emission. And whether or not they are adsorbed or absorbed on the particles they are associated with is not really relevant to the analysis.

So the particles that are being released we are treating as particles. The extent to which the emitted particles as adsorbed on the surface or inside a part really does not have very much influence, or any influence on the way in which we model and perform our calculations.

Q Assuming that one of these particulates with either absorbed or adsorbed radioactive material on it, from whatever source related to the power plant were inside the lung of a person, would the substances being adsorbed or absorbed have any material effect on the radiation dose to the lung?

A The way in which we modeled it, you have to bear in mind, it is empirically related. So we actually observed how these particles behaved, the extent to which they are dissolved or remain as a particle is based on empirical data.

So the actual location, for example, of a radionuclide in a particle doesn't have too much influence because we are dealing with empirical relationships. Ones that we are observing and not the actual, let's say, fine structure of the behavior of the atom on the particle or

2pb4

in the particle and how it is transported.

Q Okay. So what you're saying is, it would not make very much difference to the dose?

A It would not make -- the way in which we calculate it is an empirical relationship.

Q And it's an empirical relationship having to do with the particle that has the radionuclide on it or in it behaves.

A The radionuclide behaves.

Q Okay. So again, I just want to get clear on this, what you are saying is, whether that nuclide were adsorbed or absorbed on or in this particle, it doesn't make much difference to your computation of how that radionuclide is going to behave?

A That's correct.

Q Okay. Now you stated, I believe just a minute ago, that you assumed that these things that attach to the coal particulates come out the plant in particle form. Did you make any analysis of substances which might come out of the plant in gaseous form?

A Yes.

Q And that is taken up later on in your testimony, isn't it?

A It's in the testimony, yes.

Q Let me just ask you one short thing about that

2pb5

now. I'm probably going to come back to it.

Isn't it true that some things that are emitted from the plant as a gas then decay into forms which are not gaseous?

A Are you referring -- is that just a general statement?

Q Well, let's first start off in general.

A Yes, I believe that's true.

Q Okay. And would that be true of many of the zenon isotopes, for example that they could or would decay into forms which are not gaseous?

A No, not for this plant.

Q The zenon does not decay into non-gaseous nuclides?

A If you give me a moment, let me think.

(Pause.)

A I believe it is the reverse. The iodines decay into zenon. I would have to check the table of isotopes.

Q Okay. But you would refer to a table of isotopes to answer that question?

A Yes, I would.

Q Okay. And if it were a standard generally accepted table of isotopes you would accept the statement of that table?

A Yes. For example, we use the table of the isotopes by Lederer & Hollander.

2pb6

Q This may be something I will have to ask counsel. Would you be willing to stipulate that that is the same table of isotopes that was presented on discovery to Joint Intervenors?

MS. BAUSER: No, I'd have to see it.

MR. EDDLEMAN: You don't have it here?

MS. BAUSER: No.

BY MR. EDDLEMAN:

Q Do you have it, Doctor?

A (Witness Mauro) I do not have it with you.

Q But it is that standard table of isotopes to which you would refer?

A That is correct.

Q Let me then ask you likewise for say a krypton isotope or for tritium or any isotope that the Harris plant emits, would you refer to the same table of isotopes to see what it would decay into?

A Yes, some of the radionuclides I am familiar with their decay scheme, and that would not be necessary. But for others, yes I would check the Lederer & Hollander to give me the information I need.

Q Okay. And is it fair to say that you did not do any analysis of these decay schemes in analyzing this contention?

A No, that would not be correct to say that. We

2pb7

have analyzed decay schemes.

Q Where in your testimony do you make that analysis?

A It's not contained in this testimony.

Q So what you're saying is, you made some analysis, but you don't have the analysis in the testimony.

A That's correct.

Q But in preparing for this testimony you did some analysis which you did not put in the testimony?

A This and other pieces of information related to this hearing.

Q Well, Doctor, is there anything in your testimony that would indicate to someone reading it that you had made such an analysis?

A No, sir.

MR. EDDLEMAN: May I have a moment?

(Pause.)

JUDGE KELLEY: Let me ask the Applicant, do you think you could find out whether that table is the same table you turned over in discovery?

MS. BAUSER: We're going to see if we have it here.

JUDGE KELLEY: Fine.

BY MR. EDDLEMAN:

Q Doctors, let me shift back to this question of the empirical analysis that you did on how the coal particles

2pb8

and radionuclides behave. Now did I understand you to say that -- or did I understand correctly that you said that you used empirical data about how both the nuclides and the coal particles behave?

A (Witness Mauro) We used empirical data regarding the radionuclide behavior.

Q What data did you use regarding the coal particulate behavior?

A A lot of information regarding the behavior of coal particu'ates came from Natusch and Fisher, and the Natusch article.

Q Is that the Natusch & Fisher, is that the same document that's been introduced in this case as Eddleman Exhibit 1, do you know?

A I believe so, yes.

Q You used that article, and what was the other, Doctor?

A Natusch. In fact, the original -- one of the sources of the original information that we drew heavily upon is a publication by Natusch which is referenced in our list of references.

Q And if we could just turn to that list, maybe you could point that out to me. Is it the 1978 Natusch reference in the middle of the page?

A That's correct.

2pb9

A (Witness Schaffer) I'd also like to add that the EPA reference in 1982 was relied on heavily.

Q EPA 1982, this is the air quality criteria document, volumes 2 and 3. Could you tell me, if you know, where in those volumes one would look for the information that you used on the behavior of coal particulates?

end 2.

mgc 3-1

MS. BAUSER: Excuse me. Could Mr. Eddleman be more specific? Used in their entire testimony, or used with respect to a particular point?

They have references. They cited two volumes of work.

MR. EDDLEMAN: I believe that they testified that, just in general in their analyses, they used certain sources of data regarding coal particulates behavior, and that's what I want to know. When they start talking about how these particles behave, where does that information come from? And I believe the statement is that Eddleman Exhibit 1 and this Natusch 1978 reference and also heavy reliance was made on the EPA 1982 reference.

Dr. Schaffer emphasized his reliance on the EPA 1982 document, and those are two pretty big, thick documents.

BY MR. EDDLEMAN:

Q I was just wondering if you could point to me where in those documents you drew the information about particulate behavior that you say you relied on?

A (Witness Schaffer) In the EPA reference, it would be in Section 2.4.5, starting on page 2-69 where they talk about the characterization of atmospheric aerosols.

Q Okay.

A (Witness Mauro) And I want to add to that also.

mgc 3-2

There is a figure that we drew upon that we used in our testimony. It's on page 11-28, and it is Figure 11.9 -- 11-9 -- in the EPA publication. That is some additional information.

Q Now Figure 11-9 on page 11-28; is that correct?

A That's correct.

Q Let me ask you, would you take a look at that figure if you have it with you? This figure is reproduced in your testimony, isn't it?

A That's correct.

Q And let me see if I can locate it. It is, in fact, Figure 1 of your testimony, following page 9, is it not?

A (Witness Schaffer) It is Figure 1.

Q All right. Let me ask you to do a little manipulation of that figure. Reference is made in the second sentence of the description of that figure to the eye-fit -- E Y E (spelling)-fit -- band. Now is that explanation of the figure, the same explanation that's attached in the EPA document?

A Correct.

Q Okay. What is an eye-fit band, Doctors?

A It's basically looking at the scatter in the data and the range and fitting a lower bound and an upper bound by eye on that range.

Q So it's a judgmental fit, is it not?

mgc 3-3

A Yes.

Q Just by the apparent shape of the data. And if we look at that eye-fit band, is that the upper and lower dark lines that -- dark curves, I should say, that move across that figure?

A It is the upper and lower solid lines.

Q Okay. Can you tell me how many of these observations are at or above the upper of those solid lines, just by counting them?

A Yes.

Q How many are there, Doctor?

A You'll have to give me a minute.

(Pause.)

I got myself confused. Do you want to know up above the upper solid line or the lower solid line?

Q On or above the upper solid line.

A Okay.

(Pause.)

I counted nineteen.

Q That's what I got.

Now you could make the same count for the lower solid line, could you not? Count the number --

A I'm not sure. You can, yes, do that.

Q Okay. Count the number of observations at or below the lower solid line. Could you do that for me,

mgc 3-4

Doctor?

(Pause.)

A I count eleven.

Q Okay. Now you also said that you would look at these error bands. Now just for clarity purposes, the error bands are the vertical lines which have kind of little T marks at their ends, starting from some observation or other, are they not?

A That's correct.

Q And what range of error do these represent?

A Approximately -- for the larger ones, plus or minus 10 percent; for the smaller ones, something less than that. I cannot really tell from the figure.

Q Okay. Are those typically one standard deviation in the observations?

A I don't know.

Q And you did not examine what the standard deviations were in your use of this figure, then, I take it? What the standard deviations -- how many standard deviations these error bars represent, you did not examine that in your analysis, did you, Doctor?

A I did not examine the specific standard deviations that these represent. However, I did examine the bars on this graph as it relates to my testimony.

Q All right, Doctor. Those bars that you are

mgc 3-5

referring to are still those error bars, right?

A Yes.

Q Now let's do a count of those and see how many of the error bars extend to or beyond the upper solid line, if we might.

A Three.

Q I count four, Doctor. Did you start from the lefthand side?

A Yes, you are right.

Q Okay. How many extend to or below the lower line, the lower solid line?

A Five.

Q Now the fifth of those -- well, one of those that you counted in that five is the second in from the left, is it not?

A Yes.

Q And can you find me the upper end of that error bar, Doctor?

A You cannot tell it from the figure.

Q Does the vertical line not extend all the way up to the upper solid line?

A I believe it does not. I think it's probably where that other data point is above it. I think the one that extends to the upper solid line is from the upper data point.

mgc 3-6

Q Okay. But in either case, there is another bar extending to the upper solid line, which is not very obvious, because it is T'ed in in that line, isn't it?

A Yes.

Q And if you counted that, you would then have five extending to or above the upper end, also, wouldn't you?

A There would be five.

Q Okay. Now I believe you have used a 30 to 60 percent deposition range for the approximately two micrometer particles, have you not, in your testimony, Doctors?

A (Witness Mauro) That is correct.

Q Okay. On this chart, can you tell me about what percentage deposition the peak of the upper solid line is?

A (Witness Schaffer) It is approximately 60 percent.

Q Is it closer to 60 or 70, Doctor?

A (Witness Mauro) I would say it is a little above 60, probably between 60 and 70. 65 would probably be accurate.

Q Dr. Schaffer, would you concur that 65 is a reasonable estimate for where the top of that line is?

A Yes.

Q Okay. The first line of the description of this figure says that it's deposition of monodisperse aerosols.

Can you tell us what a monodisperse aerosol is, Doctors?

mgc 3-7
ck

A (Witness Schaffer) A monodisperse aerosol is a particle, a single particle of a given size.

Q Would that include particles that have agglomerated to make that size?

A No. From these studies, it's the particle size that the experiments used; whether or not they tested agglomeration before inhalation is unknown.

Q All right. Is what you're saying that as far as you know, these studies used particles which were of these sizes, but you don't know if any look at agglomeration was made in these studies?

A These studies look at a particle size in breathing air and subsequent deposition in the lungs. So whether agglomeration has occurred is unknown. But the empirical data show the deposition. Therefore, if agglomeration occurred, it would show it there.

Q But didn't you just tell me that a monodisperse aerosol was a particle, a single particle of a given size?

A Yes, I did. But I think you misunderstood my previous explanation.

Q Well, now, are you saying that a monodisperse aerosol includes particles which are formed by agglomeration?

A I am saying that the experimenter used a monodisperse aerosol of one particle size. However, when

mgc 3-8

the experimental subject inhaled those particles, there may have been agglomeration. And when the experimenter measured the deposition, what he measured may have included agglomeration. However, there is no way to tell.

Q All right. So if I understand that correctly, suppose, for example, that I might have been one of these subjects hypothetically, if I breathe in a number of half-micron particles, it is possible that some of those might have agglomerated up to, say, two micron size, and then when the researcher looked into my lung to find what was in there, they would find a 2-micron size particle and not necessarily examine whether that came from a whole bunch of half-micron particles or was one particle that started out at two microns.

A No. It was assumed that it would be one particle that went in at a half-micron.

JUDGE FOREMAN: Could I interrupt for a minute for an interpretation? How was the deposition measured?

line660

How did you determine what the particle size was?

WITNESS SCHAFFER: Deposition on these lung studies, they tagged the particle with a radioactive label.

JUDGE FOREMAN: And then you did an external count?

WITNESS SCHAFFER: Then they can count, and they can look at clearance.

JUDGE FOREMAN: An external count? I'm just

mgc 3-9 drop

curious as to which isotopes they used.

WITNESS SCHAFFER: Technetium-99 metastaple is one of the isotopes they usually use, and I know a gold -- I'm not sure which of the isotopes of the gold, but a short-lived gold isotope.

JUDGE FOREMAN: Thank you. I just needed that explanation. I'm sorry to interrupt you, Mr. Eddleman.

MR. EDDLEMAN: Well, I think that's a very helpful clarification, Judge.

BY MR. EDDLEMAN:

Q By your answer to the Judge's question, what you are saying is, they didn't actually examine what size these particles might have become inside the lung at all. They simply tagged the particles with a radioisotope and knew what size the person was inhaling and then surveyed their chest to see how much of the radioactivity was still inside them after they had been breathing this for awhile; is that right?

A (Witness Schaffer) That's correct.

Q How was this radioisotope tagging of these particles done, Doctor?

A I don't know.

Q Okay. But for the study to be valid, the radioisotope must remain attached to the particle, must it not?

mgc 3-10

A Yes.

A (Witness Mauro) Until, of course, it is deposited.

Q Right. Okay. So in other words, if the isotope and the particle are breathed in together, then what this study measures is those particles where the particle and the isotope both stayed in the lung long enough for a measurement to be taken of the radioactivity emitted by the radioisotope.

S2BU

A Yes.

Q You both agree?

A (Witness Schaffer) Yes.

A (Witness Mauro) Yes.

Q This figure refers to seven studies of this type, inhalation studies, does it not, if you look into the upper left corner?

A (Witness Schaffer) Yes.

End 3

Q Okay.

4pbl

Q Now the data from all those studies are reproduced on this one graph, if I understand, is that right?

A That's correct.

Q And each little triangle or circle, or whatever here, diamond, each represents one data point, does it not?

A I cannot say for sure. It might. Obviously the ones with error bands on them are a combination of more than one data point where they can actually calculate an error.

Q Right. Okay, and most of the ones with error bands are at five microns and less, are they not, in size, particle size?

A Most of the data points there are below .5 microns. Did you say five microns?

Q I said five.

A Yes, below five microns have error bands. The error bands are below five microns.

Q Right, okay. If we were to distinguish on this graph the fine particulate fraction from the inhalable particle fraction, the dividing line would be about two and a half microns, wouldn't it?

A I'm not sure what you mean by inhalable. Could you detail it a little more?

Q Well, as I understand it, and of course I can't testify but I'm just going to ask you if you think this

4pb2

is correct. As I understand it, inhalable particulates are those below about 10 or sometimes 15 microns in aerodynamic diameter, which are larger than two and a half microns in aerodynamic diameter. And the fraction that is below two and a half microns in aerodynamic diameter is classified as fine particulates.

Have you ever heard of any such distinction, Doctor?

A Yes.

A (Witness Mauro) Your distinction between -- you lost me when you were describing. You started off and I was in agreement with you. That is, inhalable particulates less than 15 microns approximately. But then you went on and you made some qualifications, and that's when I lost your line of description.

Q All right. Well, let's go through it step by step, Doctors. We agree that inhalable particulates are generally less than 15 microns in aerodynamic diameter, don't we?

A Yes.

A (Witness Schaffer) Yes.

Q Do we also agree that fine particulates are a fraction less than about two and a half microns in aerodynamic diameters?

A Yes.

4pb3

A (Witness Mauro) Yes.

Q Now, if I wanted to distinguish on this chart which ones are the fine particulates, I would start off at about two and a half microns and look to the left. That is to the smaller sizes, wouldn't I?

A (Witness Schaffer) That's correct.

Q And if we attempt to locate two and a half on this logarithmic scale, we know it is somewhere between two and three, it's more than halfway from the two to the three, isn't it, because of the logarithmic nature of the scale?

A That's correct.

Q Now let me ask you to look up vertically over that section between two and three, and you might want to do what I'm doing, which is kind of use another piece of paper for a straight edge. There are three little triangles at or above the solid black line toward the top of this figure, that are somewhere between two and three microns aerodynamic diameter, are they not, Doctors?

A Yes.

Q Okay. And those three are three out of the five or 10 highest points on this graph, are they not?

A Yes, they are.

Q Now, the eyeball curve, if we move over toward the larger diameters, somewhere toward four. Well, let's see, somewhere between three and four it reaches its maximum,

4pb4

this eyeball curve, does it not? This eyefit curve.

A Yes.

Q Okay. And at about four there is the highest single data point, which is just above the curve at that point, is there not?

A The triangular data point?

Q Yes.

A Yes, I agree with you.

Q And then the curve, again referring to the eyefit upper solid line curve, that curve drops down rather sharply toward the larger sizes from that point, does it not?

A Yes, it does.

Q Now if I looked at the three open triangles of which that highest one is the highest -- in other words the highest on the graph is the highest of the three, you see another open triangle below that, and then another one down below, a black diamond, all in the same general area vertically about four micron size, Doctors?

A Yes.

Q It's true, isn't it, that this eyefit curve comes up well above the two lower ones there and almost up to the top one, is it not?

A There is a reason for those open triangles being so high.

Q Yes, sir. What is that reason?

4pb5

A The reason is many things affect particle deposition. Things such as breathing through the nose, taking a very deep breath and breathing fast. And the normal breathing of a human being is nose breathing with a normal breath of about 500 mils and a normal breathing rate of about 15 breaths per minute. And if you look at the data for that triangular study over to the left, you will find that is a very slow deep breathing through the mouth.

Therefore, it is not representative of normal breathing. It is representative of taking a deep slow breath through the mouth. So obviously you would have deposition of around, between 60 and 70 percent.

Q Well now Doctor, first the data that you're referring to is in the upper-left corner of that chart, is it not?

A Yes. The tidal t-i-d-a-l volume --

Q You have a tidal volume and a respiration rate shown, do you not?

A Yes.

Q The volume there is 1,000. You say that is a deep breath, but in fact, many of these studies use that volume or a larger volume, do they not?

A It is a deep breath compared to the average of 500 mils.

Q Let me ask you this, does the average amount that

4pb6

a person breathes vary with their size?

A These are all adults, so it would of course vary with size.

Q Okay. In other words, a larger person takes a larger average breath than a smaller person does, all other things being equal?

A Yes.

Q Now you say this rate is seven and a half breaths per minute. That is shown in the right-most column of this little box of data up here in the corner, isn't it?

A Yes.

Q Okay. Where in this does it show that the persons are breathing through their mouths?

A In the explanation of the figure. Deposition amount dispersed aerosols in the pulmonary region for mouth breathing in humans.

Q Okay. Now Doctor, is there any condition where a person might normally be breathing fairly deeply and slowly through their mouth? For example, when they are asleep.

(Pause.)

A I really don't know. It would seem, just from my intuition that when I observe people breathing it isn't very deep.

Q You have observed sleeping people breathing?

4pb7

A Yes.

Q Okay. Do you know if people have a greater tendency to breathe through their mouths when asleep than awake, all other things being equal?

A No, I don't.

Q All right. Now let me return to this curve just a minute now that you have made that explanation of those little triangles. The curve at about the four micron size, the eyefit, upper solid curve passes above the lower two of those three highest triangles, does it not?

A I lost the place. Where are you?

Q We are at about the four micron size, and there is, if you will, a chain of three little open triangles there starting from that very highest triangle on the graph, coming downwards. Do you see that?

A Yes.

Q That is about four micron size on the graph, isn't it?

A Yes, it is about that.

Q The eyefit solid line on the upper side of this graph comes above two of those three open triangles, and almost touches the highest one, does it not?

A Yes.

MS. BAUSER: I think the graphs are in the record and it speaks for itself. And I'm losing -- if you have a

4pb8

specific point --

MR. EDDLEMAN: I'm trying to get the basis of the question about the shape of this curve. He said it's a judgmental matter and I'm going to compare it with those three triangles over toward the two micron or two and a half micron size and ask him his opinion of where that curve ought to go.

MS. BAUSER: Well, I think the graphs speaks for itself. I don't have an objection to the question, asking hypothetically if the graph could go somewhere else.

JUDGE KELLEY: Well, it would seem to me that when you are dealing with something as complex as this, the fact

850

that you state the obvious from time to time to give it context in the record, certainly doesn't hurt anything. I will overrule the objection.

BY MR. EDDLEMAN:

Q Doctor, if I could now refer you to the little chain of three open triangles again, at or above the solid black eyefit curve on the upper side of this graph you see another -- if I can call it -- vertical chain of three open triangles between two and three microns aerodynamic diameter.

A Yes, I see those.

Q All right. Now the curve here passes below all

end 4.

three of those, does it not?

5pbl

A For all intents and purposes, yes.

Q Now this curve is fitted by eye to the data, isn't it?

A Yes.

Q Would it be reasonable, or let's say as reasonable as this curve is in your opinion to make that curve come up a little more sharply between the two and three micron diameters and capture as much of those three open triangles as is captured of the three open triangles at four microns under the curve?

A I wouldn't do that considering the large amount of data points that are below the closed line. You have to give weight to that large amount. In other words it is trying to -- the eyefit is trying to incorporate those large number of data points also. It has to do with both. We call them outliers, but the ones that reflect high deposition as opposed to ones that reflect lower deposition, you have to find somewhere in between those.

I think that's a reasonable representation of the eyefit.

Q Okay. You would agree with me, wouldn't you, that on an eyefit curve like this, there could be a little difference between the eyefit curve and somebody else's eyefit curve, couldn't there? Could be some minor differences.

5pb2

A There would be some minor differences.

Q In particular, can you see an obvious basis for the shape of the way that curve turns over between about two and five microns? The upper solid curve. We have established that it drops from four microns to 10 microns rather sharply. It just follows the bulk of those data points down, doesn't it?

A I don't know the question. Could you rephrase it?

Q All right. If we just start with that highest single data point, the upper-most triangle, about four microns and it is just barely -- the triangle itself just barely touches that upper eyefit curve, doesn't it?

A It does barely touch it.

Q Okay. And in fact the data point is probably just a little bit above and outside the curve then.

A Yes.

Q Now from that point, if we follow this graph and the curve down toward 10 microns to the right on this figure, that curve drops rather sharply, does it not?

A The curve drops very sharply, yes.

Q And in fact, the curve has a goodly number of data points at or above it in this range, does it not, between four and 10 microns?

A Between that uppermost point and the bottom of the curve going down to the right there seems to be about

5pb3

nine or ten data points at or above.

Q In other words, half of the points at or above the curve are on this side of it, aren't they?

A I don't know what you mean by this side of it.

Q To the right side of the peak of that curve, Doctor. I believe you already counted 19 points touching the upper --

A About half of the data points on or above that upper curve is to the right of the curve.

Q Okay. Between four and 10 microns.

A Between four and 10 microns.

Q So then logically, between four microns and the lowest data that is on here, about another half of the points at or above the curve are found for that upper curve.

A What do you mean by lower? Are you going now to the left, in the left direction?

Q Lower size, yes leftward of four microns.

A About half I will agree.

Q All right. Now the three points that I was referring to you earlier between two and three microns, those three little open triangles that are at or above the curve in that size range, Doctor. Do you see those?

bu 2

A Yes.

Q That highest one is nearly 10 percent above the curve, isn't it?

A It is less than 10 percent.

5pb4

Q But is fairly close with these percent ranges, isn't it? It is more than 5 percent above, isn't it?

I realize this is a small figure and it's hard to estimate percentage right.

A I would say somewhere between 5 and 10 percent, but definitely less than 10 percent.

Q Okay. I will accept that. That's the read I read it, too.

Now as to the shape of the curve as it heels over near its maximum, we have established that maximum is up there between three and four microns, it curves down sharply above four microns. It curves down rather less sharply below four microns, does it not?

A Yes.

Q Okay. And it is in that section below four microns where it is curving down less sharply that these three triangles at or above the curve appear, isn't it?

A Oh, that high up on the size range. It's very difficult to tell the slope of the curve, but in general it is maybe a little bit less of a slope than to the right of four microns.

Q Well, I would agree with your counsel that the graph can speak for itself. But I just want to make clear that the section that I'm referring to is between two and three microns on that upper solid curve. And wouldn't you

5pb5

agree that if we came over to four microns and looked between four and five that that slope down between four and five is considerably steeper than the slope down between three and two microns?

A I understood you to be talking about the area just directly below those three open triangular data points. When you expand it from the two to three microns, I will agree that the slope is slightly less between two and three as compared to between four and five.

Q You say slightly less. Let's just try to sketch this thing out. The 60 percent line, I believe we agreed comes within about 5 percent of the top of this curve. I'm just taking a straight edge and laying it across this thing to get my line up. It looks to me that with the open triangles between two and three microns, the highest of those has a bottom sitting just at 60 percent. Does that appear reasonable in your view, Doctors?

A Yes.

A (Witness Mauro) Yes.

Q Okay. And we already established that the top of the curve is probably somewhere around 65, the highest point of that solid curve.

A Yes.

A (Witness Schaffer) Yes.

Q Now you also cross the 60 percent a little bit

5pb6

below the very highest triangle over in the four micron range as the curve is dropping down on that side, do you not?

A (Witness Mauro) Yes.

Q Now in this very top of the curve above 60 percent it's kind of hard to see which side slopes more sharply from the top, isn't it?

MS. BAUSER: Objection. The witness has already answered this question. Two or three times he said that the left slope is slightly less precipitious than the right. And I think we're pursuing the same point repeatedly.

MR. EDDLEMAN: No, I'm between about three and four and a half microns here. I haven't asked that question. They may have answered it, but that's what I'm trying to get at, whether we really understand the same thing.

JUDGE KELLEY: You maintain you are at a different point?

MR. EDDLEMAN: Yes.

JUDGE KELLEY: Go ahead.

BY MR. EDDLEMAN:

Q If you just look at the part of the curve that's above 60 percent here, Doctors, it is kind of hard to tell which side slopes down more sharply: the larger sizes or lower sizes, isn't it?

A (Witness Schaffer) It is hard to tell.

5pb7

Q Okay. Now suppose we reverse our straight edge and put it so it covers the area above 60 percent, so we are looking at everything under 60 percent on this chart. Can you arrange that?

A We're looking at everything under 60 percent?

Q Yes. Now, looking at it that way, Doctors, the slope down between four and five microns you have already said is pretty sharp, isn't it? Pretty steep.

A (Witness Mauro) Yes, sir.

Q Now if you look between three and two microns on the other side, the leftward side, that's only about half as much drop per unit distance --

A I would say the slope is less steep.

Q It's hard to quantify how much less. The graph would have to speak for itself on that.

A That's correct.

Q You accept what it says?

A Yes.

Q Okay. The dashed line in this chart or this figure rather, it says in the third sentence of the description, "The theoretical deposition model of yield in 1978." Is that theoretical model for mouth breathing or nose breathing?

A (Witness Schaffer) It's a theoretical model for mouth breathing.

Q And the broken line, which I take it is the one

5pb8

with the long dashes and then a little dot and then another dash is an estimate of pulmonary deposition by nose breathing derived by Lipman.

A I agree with you.

Q In the sizes above about a micron and a half, the mouth breathing dashed line is a good bit above the nose breathing estimate, is it not?

A Yes.

Q However, if we try to follow that nose breathing broken line down below about a micron and a half as far down as it goes, which I think is down to about six or 7/10ths micron if I am reading this correctly, it is in the same range, if not above the nose breathing curve, is it not?

A It is in the same range if not above it.

Q Okay. And while the mouth breathing curve goes all the way down as far as the data points do, down to somewhere between 0.1 and 0.2 microns -- I mean the mouth breathing curve goes down that far, doesn't it? Between 0.1 and 0.2 microns.

A Yes.

Q Okay --

JUDGE KELLEY: Mr. Eddleman, let me ask you this. We are approaching a time where a break would be appropriate.

MR. EDDLEMAN: I have one or two questions left.

JUDGE KELLEY: Can you finish the chart?

5pb9

MR. EDDLEMAN: Sure.

JUDGE KELLEY: All right, go ahead.

BY MR. EDDLEMAN:

Q The nose breathing curve cuts off between about 0.6 and 0.7 microns, doesn't it?

A (Witness Schaffer) Yes.

Q Okay.

MR. EDDLEMAN: This is a good point for a break.

JUDGE KELLEY: Judge Carpenter has a question he wants to get.

JUDGE CARPENTER: I am looking at this Figure 1 that you have been talking about. I see physical diameter in micrometers as part of the scale, and aerodynamic diameter for part of the scale. Can you tell me if there is a ready conversion factor between the two ways of expressing some property of a particle?

WITNESS MAURO: The relationship between the two?

JUDGE CARPENTER: Yes.

WITNESS MAURO: Aerodynamic diameter, you normalize the particle to one density sphere. So the relationship really is an equation that relates the two and it accounts for the difference in density and differences in the tortuousness or the sponginess of the surface.

The best way to think about it is to picture a particle in the air --

5pb10

JUDGE CARPENTER: Let me interrupt you. Is there any difference between what is plotted here in the right-hand half of this and the Stokes diameter?

WITNESS MAURO: It is not the Stokes.

JUDGE CARPENTER: Fine. Go ahead.

WITNESS MAURO: It's the physical diameter, the actual measured diameter of the particle on the left side. While the right side is the aerodynamic diameter, which is where you normalize the particle to a sphere of unit density.

JUDGE CARPENTER: Thank you.

MR. EDDLEMAN: I can ask a follow up on that after the break or now.

JUDGE KELLEY: Go ahead.

BY MR. EDDLEMAN:

Q The aerodynamic diameter, Dr. Mauro, you said has to do with the sponginess of the surface. Is that another way of saying, the irregular shape of the surface?

A (Witness Mauro) Yes, it accounts for that.

Q Okay. Now, do particles with physical diameters of less than half a micron have perfectly spherical shapes in these studies? Do either of you know?

A (Witness Schaffer) I don't know the exact particle makeup.

Q Well, let me ask you this. If you know, physically do you know of any studies that examine the physical

9pb11

difference in behavior between spheres of half micron size or less and coal particulates or other airborne particulates of half micron size or less?

A (Witness Mauro) Yes. I have read some material on the physical shape of coal particulates. That is at these fine particulate size. And my recollection, they are predominantly spherical.

Q Do you think you could find a reference for that for us over the break?

A I believe I could point you to it. It's in Natusch and Fisher. They have a nice description of characteristics of particles of fly ash. And they have a table in there which describes the shapes of particles. And if I recall correctly, the finer particles are generally spherical. The densities are also given, which are on the order of a density of one to two, in that area.

So you would expect that the physical diameter in the case of the particles we're talking about are comparable to the aerodynamic diameter because their density is comparable. And they are spherical, primarily. So I would say the distinction here between aerodynamic diameter and physical diameter is not all that important, since in the context we are dealing with here. Namely, with regard to ash particles. They are almost the same.

Q And that holds true when the particles are

5pb12

very small and approximately spherical.

A That's correct.

MR. EDDLEMAN: I would rather take the break now and come back to it afterwards.

JUDGE KELLEY: Ten minutes.

JUDGE FOREMAN: In your inhalation dose calculation there is a model used at 75 percent deposition. I am curious as to whether at the perturbations that may come about from changing the slopes, say, the upper bound slope on your Figure _ would make your model any less conservative. Could there be significant changes in the shape of that curve that would make 75 percent be less conservative than you have calculated?

In other words, could any of the changes bring it up to 75 percent?

WITNESS SCHAFFER: On Figure 1, as I said before, the extreme upper end studies, those open triangles are mouth breathing, deeply and slowly. So that's about as bad as you can get. And normal breathing is through the nose, small volume and at a faster rate.

And the studies bear out that the deposition is always less for those cases. So although there might be a wide scatter in the data, the extreme case is between 60 and 70 percent.

JUDGE FOREMAN: That's what I wanted to hear you

5pbl3

say. That's what I wanted to hear anyway. Thank you.

JUDGE KELLEY: Ten minutes.

end 5.

(Recess.)

mgc 6-1

JUDGE KELLEY: We are on the record.

MS. BAUSER: Judge, can I ask as a preliminary matter, we have reproduced Eddleman Exhibit 1 and have included in it the pages that were missing in the original exhibit that was put in the record, I think on Thursday. And I have given the reporter and parties a copy, and I will give the Board a copy of this.

JUDGE KELLEY: Is that the Natusch paper?

MS. BAUSER: Yes. We would ask that these replace the earlier exhibit, so that there be no confusion.

JUDGE KELLEY: Would you read the title?

MS. BAUSER: The exhibit is entitled "Size Dependence of Physical and Chemical Properties of Fly Ash," by G.L. Fisher and D.F.S. Natusch.

JUDGE KELLEY: Fine, thank you.

MR. EDDLEMAN: Judge, the only problem I have with that, and it's one that I cannot correct right now, is that if you look in the following page 9 here, there are some photo figures that the Xerox machine did not pick up very well, if at all. There is one page here following page 11 where you can't hardly see anything. And then the figures that I was referring to in cross-examining some of the witnesses are less well reproduced here than they were in the copy that the witnesses have.

I will try to get you a better reproduction of

c 6-2

those figures for the record. But I think --

JUDGE KELLEY: This copy represents progress over the preceding copy.

MR. EDDLEMAN: And I am going to try to make still further progress.

MS. BAUSER: Mr. Chairman, I would also like to point out that the handwriting on the copy which was the original Eddleman exhibit -- I don't know whose handwriting it is; it's not any of our witnesses' handwriting.

MR. EDDLEMAN: Some of the handwriting is mine. Some of it is some of these non-witness folks, but I don't think you can identify them from their handwriting, and I don't think it makes a lot of difference.

MS. BAUSER: We just want to clarify that it is not part of the original paper, and we have not made changes to the original exhibit.

JUDGE KELLEY: We will take a copy as if clean. So we can resume at this point with Mr. Eddleman's cross-examination.

BY MR. EDDLEMAN:

Q Gentlemen, before the break, we were discussing this business of the shape of some of these small particles, and you referred to the same exhibit that we have been talking about here, the Fisher and Natusch. That's right, isn't it?

mgc 6-3

A (Witness Mauro) Yes, that's correct.

Q Now there was also a question raised before the break that I think I want to take up out of the Judge's questions. Judge Foreman had just asked you about whether something could change the shape of these curves in order to make your figures less conservative or your calculations less conservative.

Do you know what concentrations of particles were used in the studies reported in this Figure 1 of your testimony?

A (Witness Schaffer) Offhand, no.

Q Do you know if you have any references that tell you what concentrations these particles were breathed at to get these deposition rates?

A I'm sure those references cited there on the figure would have that.

Q Okay. Now those references are Yu in 1978, Lippmann in 1977, and finally EPA 1982, which is the source of the figure.

A That's correct.

Q So that is where you would look for information about the concentration of particles that were used in these inhalation studies?

A That's where I would look, yes.

Q Okay. And you would accept what it said?

mgc 6-4

A That's correct.

Q Okay. Dr. Schaffer, just for completeness, do you have any reservations about those answers? If you were looking at them, would you do the same thing?

A (Witness Schaffer) I'd go to the studies.

Q And you would accept what they said?

A Yes. These are experts.

Q Now if we can look at the improved copy of Eddleman Exhib it 1, the Fisher and Natusch, can you point out to me where in this the very fine, tiny particle shape data is that you were talking about before the break?

A (Witness Mauro) If you will give me a few minutes. I'll have to find it.

Q I'm sorry. I thought I had asked you to try to look that up over the break. Go right ahead.

(Pause.)

Let me ask you if possibly Table 1 on page 7 might be relevant?

A Yes, I have that. But there was also some text that described it that I felt was relevant, and I am trying to find that.

Q Okay.

A I recall reading, there was some text material that also talked about these sizes and shapes. However, Table 1, for the sake of this discussion, I think it

mgc 6-5

demonstrates fairly well that the smaller particles -- namely on the order of 2.2 microns in that table -- are predominantly solid spheres.

Q 87 percent approximately, isn't it?

A That's correct.

Q Let me ask you if the text that appears right above that table on that page, basically it describes how these fractions were collected and analyzed. In other words, it basically describes what data was analyzed to produce the results that are given in Table 1, doesn't it?

A Yes, it does.

Q So that is one part of the text that is relevant to describing this table, isn't it?

A Yes.

Q Okay. The particle classes, I is the non-opaque solid sphere that is about 87 percent of these 2.2-micron mean diameter particles, isn't it?

A That's correct.

Q And the other largest component of that 2.2-micron fraction is the Class G, non-opaque cenosphere at about 8 percent, isn't it?

A That's correct.

Q Those shapes, in fact, are illustrated, are they not, in some of the illustrations that are hard to read -- let's see -- if you will turn to -- I think it is page 14 --

mgc 6-6

A (Witness Schaffer) We still have an old copy that was provided, so that page is missing.

Q Okay (handing document to witness). That modified exhibit --

(Pause.)

MR. EDDLEMAN: My problem is that these figures are the things that did not reproduce that I was talking about, that show what these non-opaque spheres and cenospheres look like.

JUDGE KELLEY: Are you read to go with Table 1?

MR. EDDLEMAN: Well, I want to refer them to a thing that actually shows what those particles look like. But since it is not shown here, --

JUDGE KELLEY: Is there a page missing, or it didn't copy?

MR. EDDLEMAN: It didn't copy, Judge.

JUDGE KELLEY: Could we just look at what you are referring to? What page is it?

MR. EDDLEMAN: Well, I have yet another copy of it. I am going to look in here and see if I can find the figures.

Yes, this copy reproduces these figures.

JUDGE KELLEY: What page is it?

MR. EDDLEMAN: It's page 4 and 5, and it reproduces them, I think, better than this substitute.

MS. BAUSER: Four and five are part of the original

mgc 6-7

copy.

MR. EDDLEMAN: That's right. Okay. So what I have here, four and five are part of the original.

JUDGE KELLEY: Does the original that you have have good copies of four and five, or is it just incomplete as to other pages?

MR. EDDLEMAN: That's correct, Judge.

JUDGE KELLEY: And now you would like to use your original because of its better copy, right?

MR. EDDLEMAN: Yes.

JUDGE KELLEY: Ms. Bauser, do you have a copy of that?

MS. BAUSER: I don't have the original, but I have no objection to him showing that to the witness.

JUDGE KELLEY: All right, thank you.

(Mr. Eddleman tenders the document to the witness.)

BY MR. EDDLEMAN:

Q I am going to show you, gentlemen, if I may, this copy of page 4, and you have pages 4 and 5 of the modified exhibit. You have pages 4 and 5 of the modified exhibit in front of you, do you not?

A (Witness Schaffer) Yes.

Q Now what I want to show you, these are page 4 and 5 of the original Eddleman Exhibit 1, and I will ask you first if they don't appear to be the same things that are shown

mgc 6-8

by the same pages that are pages 4 and 5 of modified Exhibit 1?

A (Witness Mauro) Yes. They appear to be a little clearer copy of the copy that we have, yes.

Q The same text and everything?

A Yes.

Q All right. Now we were talking about Classes G and I. Now Class G is shown, is it not, at the upper left of page 5?

A Yes.

Q That is the cenosphere that is shown here in this documentation of the figure on page 5, is it not?

A Yes.

Q What do these things in this figure appear to be to you?

A Well, what I'm looking at looks like a circle, and one of the items in the lower righthand corner of that portion of the figure looks like a donut.

Q And in some of these circles there appear to be maybe splotches, maybe holes on the surface?

A Yes, there are blotches on the surface of the circles; that is correct.

Q Now the Class I, which is the non-opaque solid spheres, is the one that 87 percent of these fine fraction particles around 2.2 microns is composed of, is it not?

mgc 6-9

A It doesn't appear too clear to me. It does say that it is non-opaque. I is non-opaque solid spheres, but the diameter indicated in the figure appears to be 20 microns instead of 2 microns. I guess that's the only thing that confused me a bit.

Q Yes, it does say 20 microns in this figure. And it shows at least two spheres of approximately the same diameter as the distance shown as 20 microns, does it not?

A Yes.

Q And it also shows a couple of smaller spheres, but even they are -- what would you say? -- between five and ten microns?

A Approximately ten microns, yes.

Q Okay. Now if we could just look over all of the figures that are shown here, A through J, briefly, none of these reproduced particles, which appear to be on the order of two microns, as far as you can see, do they?

A No. The smallest particle size that I see reproduced here in these figures on pages 4 and 5 appears to be five microns.

Q Would you agree with that, Dr. Schaffer?

A (Witness Schaffer) Yes.

Q Okay.

MR. EDDLEMAN: I think because of that, I am going to have to await getting better copies of these other things,

mgc 6-10

if I can, to follow along on this.

JUDGE KELLEY: Your original exhibit, the copy there, isn't good enough either?

MR. EDDLEMAN: Pardon?

JUDGE KELLEY: You say you are going to have to wait for better copies, right?

MR. EDDLEMAN: Better copies of the parts that were missing from the original exhibit. That's what the problem is.

MS. BAUSER: Excuse me. Those pages were not missing from the original exhibit.

MR. EDDLEMAN: No, no, no. The other pages that were missing from the original exhibit. These don't show 2-micron particles, Counsel.

MS. BAUSER: I see. I see.

JUDGE KELLEY: When do you think you can fill the gap?

MR. EDDLEMAN: I'm going to try to do it at lunch.

JUDGE KELLEY: Okay.

JUDGE FOREMAN: I have a question for clarification. Are you saying or agreeing that those so-called opaque particles that are listed as comprising 87 percent of the particles are the ones that are illustrated in I on page 5, even though they are indicated as 20-micron size?

WITNESS MAURO: That is correct. Well, I was

mgc 6-11

answering Mr. Eddleman's question. That is correct, that I on page 5 is a photomicrograph of non-opaque solid spheres, which is the same name given to that 87 percentile I. So the answer is yes.

The only problem we have here is, the picture pertains to a 20-micron particle, which is the 25th percentile.

Could we back up a little? Maybe we can clear it up.

On Table 1 on page 7, you will not that under Category I, non-opaque solid sphere, by far it indicates that for each particle size, 25 microns, 6.3, 3.2, 2.2, the percentage of the fly ash which is in that class. We were focusing in heavily on the last 2.2 micron before we found it to be 87 percent. So in effect, it says that 87 percent of 2.2-micron fly ash may be considered to be Class I type particles.

Now from there, Mr. Eddleman went over to photomicrographs to try to see what these look like. And I in the photomicrograph on page 5 is Type I non-opaque solid spheres. However, it is for a 20-micron particle and not for the 2-micron particle. And that is where we left off.

JUDGE FOREMAN: I guess what is not clear to me is the significance of showing us the 20-micron particle.

mgc 6-12

What does that add to the -- to understanding, by showing the 20-micron particle when, indeed, that is not the particle of significance for the purpose of this discussion?

WITNESS MAURO: I would imagine that if there were a photomicrograph of the 2.2 micron particle, it would look a lot like the ones we were just looking at, but smaller.

JUDGE FOREMAN: I see.

WITNESS MAURO: They would be circular also.

JUDGE FOREMAN: The significance is that each of them is circular?

WITNESS MAURO: That's correct.

JUDGE FOREMAN: Thank you.

BY MR. EDDLEMAN:

Q Doctors, let me follow on that a little bit. On some other pages of modified Exhibit 1, modified Eddleman Exhibit 1, I believe on some of those it might be possible to distinguish the size markings on the figures, and unfortunately, on the pages where the page numbers didn't show up -- but I believe it's page 13 in the modified exhibit -- does the page that you are looking at show a 2x3 layout of what may appear to be pictures with the capital letters A, B, C, D, E and F in the lower corners of these six pictures?

A (Witness Mauro) Yes.

mgc 6-13

Q Can you read the figure number down at the bottom where that figure is described?

A It is a very poor copy. It may be Figure 6.

Q That's what it looks like to me, too. I can't really read it. This 6, I might note, is actually made up of three dots and maybe just a little streak; it's hard to tell.

But, Doctors, it is possible, is it not, if you look at the F part of this figure, to see a scale over on the lower righthand side, is it not?

End 6

7pb1

And that scale is one micron, isn't it?

A (Witness Mauro) I believe that one micron scale refers to F.

Q Right. And in D immediately above that in the lower left part of the D portion of this figure, there is a scale of three microns laid out, is there not?

A Yes.

Q And then in B immediately above that there -- you cannot see the scale mark but you can read a number of two microns, can you not?

A Yes.

Q Can you see the scale on your copy, the length of that scale?

A No, I cannot.

Q Okay. We can presume that it would fit into the space that is whited-out around the two, as the others do, can we not?

A I would assume that, yes.

Q But we cannot tell from the quality of this copy what length that scale is.

A That's correct.

MR. EDDLEMAN: This is the thing that I'm going to try to get a better reproduction of as quick as I can.

BY MR. EDDLEMAN:

Q Let me turn back in your testimony to the bottom

7pb2

of page 2. The last full sentence on that page says that, "It is contended that this particle adsorption" -- with a "d" -- "would cause more of the radionuclides in the gaseous effluent" -- with an "e" -- "to penetrate deeper into the lungs and be retained for longer periods of time."

Now that is your interpretation of the contention, is it not, that part of the contention?

A (Witness Mauro) That's correct.

Q Okay. And that is the part that is dealth with in Section II of your testimony beginning on page 3.

A That's correct.

A (Witness Schaffer) I'd like to add some clarificatio that when developing this Section II of the testimony we really were talking about attachment to particles and were not that concerned about the mechanism of the attachment.

Q Is that all of what you wanted to say?

A That is what I wanted to say.

Q All right, let me ask you about that. I had asked earlier about adsorption and absorption and you said, well, however it got onto or into the particle didn't make much difference in the way that you calculated. That is still true in light of what you just said, isn't it?

A Yes. In fact, I hope that is just a restatement of that.

Q Okay. So when you say adsorption here in this

7pb3

Section II, you really mean any method of attachment that makes -- or you can be read to have meant, any method of attachment that takes the radionuclide onto the coal particle and carries it along with it, can't you?

A Yes.

Q Okay. You say that radionuclides -- this is at the bottom of page 4 in Section II -- you say that the radionuclides that cannot take particulate form will not stay in the lung -- that's what you say, is it not, down toward the bottom of page 4? I believe it's in the beginning of the second full sentence.

A (Witness Mauro) I believe if you read it we make two statements. Cannot stay in the lung, but will be immediately exhaled or absorbed into the body fluids.

Q Suppose that the radionuclide is adsorbed on a particle of fly ash, you would agree, wouldn't you, that some of those particles of fly ash can stay in the lungs?

A Yes.

Q And indeed, on Figure 1 that you reproduced in your testimony, that portion might be as high as 65 percent, might it not?

A (Witness Schaffer) Depending on the breathing conditions it might be as high as 60 percent in the deep lung.

Q I believe we agreed that the top of that upper curve is 65 percent or so, didn't we?

7pb4

A Between 60 and 70 percent in the deep lung.

Q Okay. Now, even if the radionuclide didn't take particulate form, if it were attached to or in one of these fly ash particles, we have agreed that it would have the same effect in the lung as if it were just there by itself, staying where the particle is, haven't we?

A (Witness Mauro) I think you may have misunderstood. We treat the radionuclide as a particle. That is, it is a particle upon inhalation.

Q Yes.

A So are you asking the question, is that particle attached to another particle?

Q Yes. In other words, the contention is about particles attached in whatever way to fly ash particles, is it not? That is your interpretation.

A The contention is radionuclide binding to fly ash particles.

Q Right, okay. So the radionuclide, whether it is a gaseous atom or a particle, or whatever form it may physically be taking that has been released into the exhaust from the Shearon Harris plant into the air, whatever form it takes in that power plant exhaust, we are concerned here with it then being attached to a coal particulate, are we not?

A Yes.

7pb5

Q And didn't you say as we were starting out into this set of questions, you know, back at the beginning or near the beginning, that in your consideration of the radionuclide's effect in the body that it didn't make much difference whether it was on the outside of a coal fly ash particle or on the inside of a coal fly ash particle? It's method of attachment didn't make a lot of difference?

A I think perhaps I could help clarify this. I was more referring to our modeling of the lung dosimetry. There is a standard method that is used for performing inhalation dose calculations. And what is done is, for every unit of activity inhaled we model the behavior of that radioactivity in a certain fashion; notwithstanding whether or not the particle is assumed to be adsorbed or absorbed onto the particle. Or in fact, is itself a particle. The model is transparent to that.

Q The model, you're saying, treats these nuclides' effect on the lungs alike whether the particle is -- the radionuclide particle or radionuclide atom is in the lung by itself or attached to the outside of a coal or other particle, or attached to the inside of that particle. It doesn't make any real difference to the model, does it?

A That's correct. The model does not explicitly address the phenomenon that you are referring to.

Q All right. And what you have done then is to try

7pb6

to make an investigation of this phenomenon and relate it to that model, have you not?

A That's correct.

Q And to go back to what you're saying here at the bottom of page 4, you say radionuclides that cannot take particulate form will not stay in the lung. But isn't it true that if it is adsorbed onto a fly ash particle that it will stay where that particle is?

A But then that radionuclide cannot take particulate form.

Q Okay. So it is taking on the form of the particulate that it's attached to?

A That's correct.

Q So effectively, regardless of the physical form of the nuclide, if it is attached in some way to one of these coal particulates, it is in particulate form for your purposes.

A That's correct. If it can. But if it cannot do that, that is, if it cannot bind up and tenaciously stay with a particle, then we do not treat it as a particle.

Q All right. You then go on to say -- this is pages 4 and 5 -- tritium is not in particulate form. Now

side 2 bu

what do you mean there? What is the nature of tritium?

A Tritium takes the form of water vapor as opposed to a solid particle.

7pb7

Q Is all the tritium released from the Harris plant in your source term in the form of tritiated water?

A That's correct.

Q Okay, it's all water. Do you know anything about the adsorption or absorption of water on coal particulates?

A (Witness Schaffer) Only to the fact that coal particulates can grow in size due to water attaching to it.

Q Isn't it true, Doctors, that when you have a fine particulate as some of these coal particulates are, that they can, through a process called nucleation attract water out of the atmosphere and form water droplets around themselves?

A Yes, that's what I just said.

Q Okay. And in, let's say, where it's actually not raining or snowing or some sort of precipitation is going on, the particles, water droplets with these particles in them so formed can remain suspended in the atmosphere if they are not too large, can they not?

A Yes.

Q And the critical size for such a particle to be deposited out of the atmosphere would relate to its aerodynamic diameter, would it not?

A Yes.

Q To the extent that the particle were containing a coal particulate and some tritiated water, and there may

7pb8

be other things, and were say, less than five microns in aerodynamic diameter, how long could that particle remain suspended in the air? It's got kind of a mean lifetime of suspension in air.

A What was the total size of the particle?

Q Aerodynamic diameter of five micron, let's say, just for an example.

A It would probably be suspended on the order of a few hours.

Q And if it were down around two microns, what sort of suspension lifetime are we talking about?

A On the order of hours to days.

Q Suppose we were down smaller than that, say smaller than one micron, what kind of time are we talking about?

A Days.

Q Several days? Perhaps, one to three days. Something like that?

A Perhaps.

A (Witness Mauro) I couldn't speak for that size. I would say that in the particle range around two microns, of a few microns, the particle would stay airborne on the order of hours. I couldn't go well beyond what would happen -- when you get to a smaller particle. You were referring to particles less than what? Around .1 micron?

7pb9

Q Well, less than one micron.

A Oh. Well, I would say that one would be in the area, on the order of several hours and getting smaller than that would be difficult to speculate because the particle itself may begin to agglomerate and behave differently.

Q All right. Isn't it so that the smaller particles generally tend to have longer suspension lifetimes if they do not agglomerate?

A (Witness Schaffer) We have a discussion of this thing in our testimony. Let me see if I can find the page.

Q Dr. Mauro, if you want to make an additional answer --

A (Witness Mauro) A general statement that is the smaller the particle it remains small, everything else being equal will tend to stay airborne longer than a larger particle.

Q Yes.

A Yes.

Q Now, Dr. Schaffer, have you found --

A (Witness Schaffer) Yes, on page 11 we talk about three basically size modes of particles in the atmosphere, and the first mode is the nuclei mode below tenth of a micron usually stays, has residence time on the order of hours because it starts to grow.

And the second size mode is between .1 microns

7pb10

and two microns. And these particles typically remain airborne for several days. And then I go on to say, the third and final mode includes particles above two microns and generally produced through a mechanical. And these are easily by wash-out and sedimentation. So they only exist in the atmosphere for several hours.

Q Okay. Now let me go through that with you. I'm glad you brought me to it because I would have gotten there soon enough myself. Let us first consider the third mode above two microns.

You say they are generally produced by mechanical action. Does that mean bumping into each other, or does it mean by grinding?

A Grinding, abrasion.

Q Okay. So these particles in a sample of suspended particulates, what you're saying is that most of the particles above two microns would generally be produced by grinding or abrasion, is that a fair characterization of your statement?

A In an industrial situation, yes. You might have particles of that size range from natural sources, such as pollen, and that is in that size range also.

Q In dust, say, blown up from a plowed field or a dusty road, would many of the particles also be in this size range?

end 7.

A I would expect that, yes.

mgc 8-1

Q So the first mode, the nuclei mode, very tiny particles below a tenth of a micron, in these you mention that they are generally primary particles emitted as a result of fuel combustion, and the fuel combusted includes coal, does it not?

A Yes, it does.

Q Do you have any idea what fraction of those particles in the ambient air are produced by the combustion of coal?

A What fraction? I'm a little confused. Do you mean what fraction of this small mode in the ambient atmosphere?

Q That's correct.

A And small mode also referring to --

Q Nuclei mode.

A Due to the combustion of coal?

Q I beg your pardon?

A You sort of have two qualifiers, one being the size, and the source of combustion. Do you mean coal -- particles emitted from coal combustion at the size below .1 micron?

Q Let me just ask my question again, if I can. You say that this nuclei mode below a tenth of a micron generally consists of primary particles emitted as a result of fuel combustion, don't you?

mgc 8-2

A That's what I say.

Q All right. And then you list various fuels that can be combusted to make these particles, do you not?

A Yes.

Q Okay. Oil, gasoline, and natural coal are the ones that you list, correct?

A Correct.

Q What I'm asking is, do you know, or have any data that you have examined on what fraction of the particles in this nuclei mode result from the combustion of coal?

A It depends upon many, many factors, and I don't know, because of all the confounding situations.

Q Did you examine any data concerning this in preparing this testimony?

A No.

Q Now let's go the middle size of particles. When you have rapid coagulation and aggregation of the nuclei mode particles, as you describe in the third sentence of the first full paragraph on page 11, if I am reading my sentences correctly, rapid coagulation and aggregation of these nuclei mode particles, what you are doing is making the second size mode between a tenth of a micron and two microns, are you not?

A Yes.

Q So these nuclei mode particles coagulate and

mgc 8-3

aggregate to form particles in the middle-sized range, between a tenth of a micron and about two microns. That is where they go. Is that more or less correct?

A Yes.

Q What are some of the mechanisms of coagulation and aggregation of particles like these?

A Particles -- you could have two particles of this small size coming together --

Q Colliding?

A Colliding. You could have a small solid particle having water vapor attached to it and growing.

Q Okay. Could also electrostatic attraction be one method of these particles beginning to clump together?

A Yes, it could.

Q Do you know anything about the electrostatic nature of small water droplets in the atmosphere?

A I don't.

A (Witness Mauro) No, I don't.

Q Okay. Then I guess I cannot pursue that. Since you don't know anything about it, you didn't take this phenomenon of electrostatic phenomena related to water droplets in the atmosphere into account in preparing this testimony?

A (Witness Schaffer) That's correct.

Q You did not?

mgc 8-4

A We did not. I guess in preparing this section of the testimony, we relied on studies that have looked at ambient atmospheric particles, and we found these size modes. And whether or not electrostatic attraction is working in the ambient atmosphere when these studies were taken, I don't know.

Q You don't know either, do you, Dr. Mauro?

A (Witness Mauro) No.

JUDGE CARPENTER: Is there any basis for believing it was not?

WITNESS SCHAFFER: I don't have a basis.

JUDGE CARPENTER: From your knowledge of the studies, is there any statement?

WITNESS MAURO: No.

BY MR. EDDLEMAN:

Q So I think we have agreed that electrostatic attraction could play a role in the agglomeration of these particles. It is just that you all did not explicitly consider it in preparing this testimony.

A (Witness Schaffer) That's correct.

Q Now suppose that we have a little droplet of tritiated water, and just for the heck of it, let's suppose that we have a picogram of tritiated water there -- a relatively small amount, in other words. Do you understand what I'm talking about here, one-trillionth of a gram?

mgc 8-5

A (Witness Mauro) Yes.

Q That particle, that water droplet, would still have a relatively large or could have a relatively large number of atoms of tritium in it, could it not, and it could have hundreds or thousands or even perhaps millions of atoms of tritium and still not weigh more than a trillionth of a gram as water?

A I'm not following you. You are saying pure tritium?

Q Well, let's take that as a first example. If I have a trillionth of a gram of pure tritiated water in a particle, as a droplet, -- you see what I'm getting at?

A Pure tritiated water, okay.

Q Right, or at least pure TOH, let's say; it doesn't have to be T_2O.

That would have a fairly large number of tritium atoms in it, would it not?

A That's correct.

Q And actually would have on the order of billions of tritium atoms in it, wouldn't it?

A I couldn't say offhand. I would have to do the calculation.

Q But, Doctor, the way you would do that calculation is that you know the molecular weight of tritiated water, and you also know you have an Avogadro's number, which is

mgc 8-6

the number of molecules or atoms in one-gram atom or one-gram molecule of the substance.

A That's correct.

Q And what you would do is, you would take, if you wanted to know how many molecules there were in a certain weight of the substance, then what you would do is figure out how many times that weight of substance goes into the weight of one-gram atom or one-gram molecule of substance, and then that same fraction of Avogadro's number would be the number of atoms or molecules in the weight of the substance that you had, would it not?

A I agree.

Q Now Avogadro's number is about 6×10^{23}, isn't it?

A 6.023×10^{-23}.

Q Thank you, Doctor. And if tritiated water has a molecular weight of about what? 18?

A That's correct.

Q So just in order of magnitude terms, if I had -- well, 18 grams of tritiated water, therefore, would be a one-gram molecule of tritiated water.

A That's correct.

Q Then if I say that I have 10^{-12} grams of this tritiated water, that is something on the order of 10^{-13} -- in rough terms about 10^{-13} or $10^{-13.5}$ of gram molecules of tritiated water, isn't it?

mgc 8-7

(Pause.)

A I just looked at the exponents, and we are talking on the order of 10 to 11 atoms.

Q 10^{10} is about ten billion, isn't it, Doctor?

A That's correct.

Q So if it were pure tritiated water, even in a trillionth of a gram, we would still have over a billion atoms of tritium, wouldn't we?

A That's correct. That's what these calculations would appear.

Q All right. Now still taking this example of relatively pure tritiated water, tritium has a certain halflife, and that means in a certain time period each of these atoms has a 50 percent probability that it will decay. Isn't that what halflife means?

A That's correct.

Q Okay. And the halflife of tritium is about twelve years?

A That's correct.

Q It is possible to calculate, isn't it, an expected decay rate of how many disintegrations you would have per sector and per hour in a certain mass of radioactive material if you know the halflife of the material, isn't it?

A That's correct. You would multiply the number of atoms times the decay coefficient, lambda.

mgc 8-3

Q And would you explain what that decay coefficient is?

A It's .693 over the halflife equals lambda.

Q And the .693 comes from a natural logarithm?

A That's correct.

Q So taking this constant, .693 over the halflife, this lambda constant, multiply that times the number of atoms, and you have an expected decay rate?

A Yes. You have to convert -- to get into disintegrations per second, you have to do some unit conversions for time.

Q Right, because the halflife might be in years, and you would have to express the halflife in seconds to get disintegrations per second. And if you wanted disintegrations per hour, you would have to express the halflife in hours, and likewise for days or years or months or any other figure of time.

If you express the halflife in that unit of time, then what you get from this calculation of multiplying atoms times the lambda coefficient is the number of disintegrations per unit of time.

A That's correct.

Q Same units.

A That's correct.

Q So we make that calculation for a particle. Now

mgc 8=9

in your testimony, you mention the amount of tritium that comes out of the plant as being -- or do you mention that? Let me see if I have that.

You say on the top of page 5 that tritium is inhaled as water vapor, and hence that fraction not exhaled is immediately absorbed.

Now is the fraction that is determined to be not exhaled computed by some chemical method; that is, if you take in a certain concentration of water vapor, how much of that is coming back out of your lungs? Is that how you do that?

A No. We assume that 75 percent of the inhaled tritium is immediately absorbed into the body fluids and distributed throughout the body.

Q Okay. Is the source of that assumption in your ICRP No. 2 paper?

A Yes, that's correct.

Q Do you have a copy of that with you?

A No, I don't.

Q You don't either, Dr. Schaffer?

A (Witness Schaffer) No.

Q Okay. Well, if some of the tritium comes into the body as water vapor, and some other tritium comes in as water droplets or even water molecules attached to these coal particulates, your analysis assumes 75 percent

mgc 8-10

is absorbed in to the body?

A Yes. That's correct.

A (Witness Mauro) Yes. That's correct.

Q If the tritium were attached to a particle, do you know if that would have any effect on the likelihood of its being absorbed by the body or not?

A We treat it as if the tritium -- the particle, this wet particle, when deposited in the lung, that the fluids in the body would commingle with the wet surface, and the tritium would be taken up and behave as if it came in not attached to the particle, but just as a water droplet. That's how we basically treated this problem.

End 8

9pbl

Q Did you make any analysis of the surface tension of attachment to water of very fine particles or any other physical transport phenomenon in making in that assumption?

A No.

Q Okay. And you don't know for a fact whether being attached to a particulate of coal fly ash has an effect one way or another on the likelihood of tritium being taken up in the bodily fluids, do you?

A Except that we would expect a wet particle, any water on the particle to commingle with other water that may be in its vicinity which would be the case. But we haven't gone further than that in our treatment.

Q So the brief answer to my previous question is no, isn't it?

A Could you repeat the question again?

Q You don't know directly whether being attached to a particle of coal fly ash has any effect one way or another on the likelihood of tritium being taken up in the bodily fluids, do you?

A Directly -- I guess I'm quite sure what you mean by directly.

Q Other than from the rationale you just gave me you don't have any other evidence.

A That's correct. Other than the rationale I just gave you I have no other evidence.

Q Okay. And I think you have already said that in dealing with the wet particle you didn't consider any physical data or physical phenomenon as to the uptake of tritium attached to particles in bodily fluids.

A No, what we did do though in looking at our analysis was to say, although we couldn't conceive of a situation where the tritium would remain as a particle, we did look at -- and this is not contained in the testimony -- we did look at, well, let's just create an arbitrary situation. One that is counter to what we believe would occur. What influence that could have on a calculation.

And it really isn't that great. It's just a postulate that the tritium behaves as a particle, which in my judgment would be quite extreme. Now we looked at the doses there also, but that is not contained in this testimony.

Q It's not in the testimony. I think we have agreed, haven't we, that if something is attached to the particle then it behaves like the particle as long as it's attached to it.

A As long as it remains attached.

Q Okay. So if tritium were attached in some way to one of these particles, and not taken up directly into the bodily fluids, then that is the sort of thing that you were analyzing in this analysis. You just mentioned

that's not included in your testimony.

A Yes, we looked at that also. But it's not explicitly treated. We consider it to be a little farfetched.

Q Can you tell me what sort of assumptions you made about tritium as a particle in this analysis?

A Well, basically what we did was -- well, we said that would mean that the tritium, rather than being distributed throughout the body, the whole body, which would remain in the lung and deliver its dose to the lung as opposed to the whole body. And effect of that would be the whole body dose would go down considerably because it's not in the whole body, it's in the lung.

However, the lung dose would go up. ANd the difference in the doses would be really the relationship between the mass of the whole body, the mass of the lung. The mass of the lung is approximately 1,000 grams or one kilogram. While the mass of the whole body that we treat in our model is 70 kilograms.

So what would happen is the whole body dose would disappear, in effect, for the tritium, but the lung dose would go up by about a factor of 70 from the dose from tritium. So that's the extent to which we addressed this matter.

But as I pointed out before, I consider it to be just like a scoping analysis and a really farfetched

assumption.

Q All right. But isn't it true that if you reduced the dose to 70 kilograms by a certain amount and then you increased the dose to 1 kilogram by 70 times the same amount, you are just balanced off. It's the same dose, isn't it?

A Well, no, no. You're delivering the dose to the lung, as opposed to the whole body.

Q Right, and the lung is one kilogram, and I thought you said the body was 70.

A That's correct.

Q So if you get over 70 times the dose to the lung that you would deliver to the whole body you come out with the same dose, don't you?

A No. It's 70 times higher dose.

Q Yes, that's what I'm saying.

A To the lung.

Q 70 times the dose to one kilogram in terms of dose per mass or dose absorbed.

A No, dose is a per unit mass expression. I think you misunderstand --

Q All right, so you say dose per unit mass, okay. You apply 70 times the dose per unit mass to one kilogram that you would have applied to 70 kilograms. Don't you then end up with the same dose?

A The same amount of energy is deposited. Not the

same dose.

Q All right. Same amount of energy deposited. That's right, isn't it?

A Yes.

Q Now this also assumes, does it not that the particle once absorbed into the deep lung remains in the lung, right?

A In that assumption, yes.

Q Did you in your analysis treat the uptake of these coal particulates by a macrophages or other parts of the body's immune system?

A Well, now you're referring to -- we just covered the question on this hypothetical tritium --

Q If it all stays in the lung and the particle stays there. That's what we just covered. Now I'm asking you, if the tritium stays on the particle but the particle gets eaten by a macrophage of some other part of the body's immune system, did you consider whether that might then lead it to be carried out of the lung?

A For the tritium, the analysis we just talked about, the scoping calculation regarding tritium, the "what if" calculation we did not explicitly address the way in which it would be cleared.

Q And in the other calculations you made regarding tritium in your testimony did you consider such a phenomenon?

A No, sir. As pointed out in the testimony, we did not consider tritium as a particle. And clearance by penocytosis or endocytosis is not really relevant.

Q But did you say on page 5 that the tritium makes up over 98 percent of the whole body dose from inhalation from these nuclides that are laid out in your Table 1?

A 98, that's correct. 98 percent.

Q So if you had some increase in the tritium dose, that would certainly tend to be larger -- well. let's say this. A 3 percent increase in the tritium dose would be larger than a 100 percent in the 2 percent of dose that comes from inhalation of all other things, wouldn't it?

A Yes.

Q And you can make calculations like that for any particular increases in the tritium dose and the non-tritium dose and compare them.

A Yes, sir.

MR. EDDLEMAN: Judge, this is a good stopping point for me.

JUDGE KELLEY: Okay. Any questions?

JUDGE FOREMAN: Yes. I would like to sort of get onto the record the differences in terms of detriment to the body and to different tissues. And having the tritium go absorbed into the lung versus having it absorbed to other organs in the body. And I wonder if you could speak to that.

WITNESS MAURO: Yes, the risk per rad, or the risk per rem to different organs in the body, the whole body is quantified in several places. And the whole body risk co-efficients. It's more detrimental to deliver the dose to the whole body than to localize and deliver the dose to the lung. The potential, or the risk of developing an adverse health effect is greater per rem to the whole body than it is per rem to the lung.

JUDGE FOREMAN: And therefore, in that hypothetical situation that you had postulated, wherein the tritium remained in the lung -- am I right? I think I am -- that that is less detrimental over all to the body than having the tritium absorbed and distributed to the body.

WITNESS MAURO: We stopped at the dose calculation. We didn't take it to the next step to determine what the change in risk would be, the health risk.

JUDGE FOREMAN: I'm asking you, based on your general knowledge whether that is --

WITNESS MAURO: In effect what we're saying is a 70-fold -- I believe if you assume that the tritium is in the lung -- and let me qualify again, that's quite an extreme assumption -- the overall risk to the person compared to the whole body -- no, I think they about balance off each other.

That is, perhaps the risk would even go up slightly from the lung dose because you have increased the

lung dose by about a factor of 70, but eliminated the whole body dose. The question then is, is the risk per rem 70 times higher to the whole body than it is to the lung? I believe the difference is not that great.

That is, the risk per rem to the whole body is higher than the risk per rem to the lung, but not by 70-fold. I don't know the exact difference though.

MR. EDDLEMAN: I just want to ask one clarification about that.

BY MR. EDDLEMAN:

Q In the things that you were just discussing with Judge Foreman, these are all predicated on the amount of tritium coming into the lung and being absorbed either by staying in the lung or being distributed to the whole body as being 75 percent of that inhaled?

A That's correct.

Q It doesn't take into account any possible increase in the amount of tritium uptaking by the body due to the coal particulates?

A --

MS. BAUSER: I didn't hear the question.

BY MR. EDDLEMAN:

Q These answers that you have given here do not take into account any possible, or let me say even hypothetically possible increase in tritium uptake beyond

the 75 percent that you assume due to it being attached to coal particulates?

A (Witness Mauro) We assumed 100 percent -- 75 percent of the inhaled material; 75 percent remains. All of that 75 percent is absorbed within the body.

Q Right. But what I'm saying is, if coal particulates should cause more than 75 percent of what is breathed in to remain in the body, that would not be included in the calculations you were just discussing with Judge Foreman?

A That's correct. In other words, you're saying, you are postulating that absorption of the particles may increase the 75 percent for some reason?

Q Yes.

A We did not address that.

A (Witness Schaffer) I would like to also state that within that inhalation dose conversion factor for tritium it is multiplied by -- increased by 50 percent due to absorption through the skin. So even though 75 percent is getting in through the lung, the 50 percent absorption through the skin is more than including anything greater than the 75 percent.

Q Okay. So what you're saying is that with that dose conversion factor, it's assumed that 125 percent of what you breathe in is in the body, because 50 percent of what you breathe in also comes into the body through the skin.

A Exactly.

Q But that's an independent pathway, right? It doesn't depend on what happens in the lung --

A It doesn't depend on what's in the lung, but the numbers we used in our calculation to develop the whole body dose includes that 50 percent increase.

Q Okay. So if I were, say, breathing pure oxygen from which somehow all tritium had been removed, I don't know if that's possible, but just hypothetically. I would still be getting a dose from tritium absorbed through my skin, equal to the dose from 50 percent of the tritium that I'd be breathing in if I were just breathing air around me that had that same concentration of tritium in it?

A Well, if you remove the tritium from the atmosphere around you --

Q No, just from what I'm breathing. I've got a tank of it here.

A (Witness Mauro) I think the best way -- the dose that we have here, if you were to isolate, take out the tritium being inhaled, the doses here for tritium would go down by a factor of two. Half the dose is due to the tritium that's inhaled, and the other half of the dose is due to the tritium that's absorbed through the skin. That's probably the best way to look at it.

Q All right. But the skin absorption tritium dose

is not affected itself by what happens in the lungs, is it?

A No.

A (Witness Schaffer) No.

Q It doesn't go up or down regardless of what's in the lungs?

A No.

A (Witness Mauro) No.

MR. EDDLEMAN: Okay, I am done now.

JUDGE CARPENTER: Gentlemen, some food for thought over lunch, in the spirit of think assignments, sometime this afternoon I would like to ask you to consider the following question.

Consider a hypothetical individual in an environment which contains tritium in the form of water. And by all the routes possible, that individual becomes to have the same specific activity in every organ of his body as his environment. I'd like you to answer that later, and see whether that thinking experiment includes all the considerations in your model.

JUDGE KELLEY: Shall we get a whole body dose of lunch?

MS. BAUSER: Excuse me. Could I just ask, Dr. Mauro, did you understand the question?

WITNESS MAURO: Yes.

JUDGE KELLEY: You didn't?

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MS. BAUSER: I did not.

JUDGE KELLEY: Neither did I. Lunch until 1:15.

(Whereupon, at 12:15 p.m., the hearing was recessed, to reconvene at 1:15 p.m., this same day.)

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AFTERNOON SESSION

(1:30 p.m.)

JUDGE KELLEY: We are back on the record, and we can resume the cross very shortly. We have a couple of comments that we want to make first on the subject of time and contentions and when we expect to get finished here. And let us share a few thoughts with you, and then we will ask for counsel to comment on our comments and make your own comments on the same subject.

It seems to use that the way things stand, we have some flexibility. We are not in a situation where we are obliged to adopt any fixed time allocations in order to get where we want to get to, and we would like to retain that.

We do have in our minds one pretty definite parameter, and that is, as previously indicated, we expect to complete Contentions II(e) and II(c) by the close of business on Wednesday. It seems to us that given the relatively narrow scope of these contentions and the fact that we only have a few witnesses, that is certainly a reasonable expectation.

We did start a half-hour later than usual today. We are prepared to go to six instead of five-thirty tonight, and perhaps somewhat later depending on how things are going, but at least until six. It is our understanding

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that we will not be locked in and that the logistics of running up to six-thirty or seven are not complicated.

Similarly, tomorrow we normally would go nine to five-thirty. We will start at nine, but we could go to five-thirty, and if we aren't where we want to be at the end of the day, I suppose we can start at eight-thirty, but we will look at that when we quit tonight.

We expect, based on experience in the few days of this hearing and other hearings too, Intervenors' cross will take most of the time, and that's the way the system is really structured, and we expect that.

Having made those general comments, we would anticipate that we would finish up on (e), the contention we are on now, around midday tomorrow or early afternoon, and then move into (c).

Now I qualify that, since Intervenors' cross takes most of the time. If the Intervenors are a lot more interested in (e) than they are in (c), they can let us know that, and we can allocate more time for (e) and less for (c). But that's something for you to tell us about, if that's what you want to do.

Those are general comments on the general subject of timing and getting it finished. Again, we can set time limits, three hours for this and an hour for that and so on, and we will do it if we need to, but we don't think

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we have to. We would rather leave it a little looser than that.

So those are our views on it at this point, and needless to say, we will have to see how things develop as we go along and where we are tonight and where we are tomorrow noon and so forth.

Applicants, do you have any comment?

MS. BAUSER: We would assume that if we were done earlier, that would be fine, too, but we have no comments.

MS. MOORE: No comment.

JUDGE KELLEY: Mr. Eddleman?

MR. EDDLEMAN: It looks like I will probably be doing most of the cross on II(c) also. I'm not absolutely certain how much the other Joint Intervenors might have. I think it is likely that we will finish II(c) at or before the time that you mentioned.

JUDGE KELLEY: II(c) or II(e)?

MR. EDDLEMAN: II(e).

JUDGE KELLEY: II(e) is the one we are on now.

MR. EDDLEMAN: Right, this one, at or before the time you mentioned tomorrow, and I don't anticipate II(c) taking as long as this one.

JUDGE KELLEY: All right. I will put it into operational terms. I have a 3:15 plane on Wednesday, but I am prepared to change it. But I appreciate that.

mgc 10-4

Would you guess, other things being equal, that we will probably get through II(e), you say, about midday?

MR. EDDLEMAN: Judge, we might do it considerably before that.

JUDGE KELLEY: That's fine. Okay. Well, then, hearing no dissent, I guess we can go ahead.

Mr. Eddleman was in the process of cross, and you may resume.

Whereupon,

JOHN J. MAURO

STEVEN A. SCHAFFER

resumed the stand and, having been previously duly sworn, were examined and testified further as follows:

MR. EDDLEMAN: Did Judge Carpenter want to take his matter up now or later?

JUDGE CARPENTER: Mr. Eddleman, I intruded just for some food for thought. You are still crossing them now, and I will come to it in due time.

MR. EDDLEMAN: Okay. I just wanted to make sure I wasn't cutting you off.

JUDGE CARPENTER: Thank you very much.

CROSS-EXAMINATION (RESUMED)

BY MR. EDDLEMAN:

Q First let me state on the record, that I was not able to find a copy here with a better reproduction of those

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figures in Eddleman Exhibit 1, so therefore I won't have any more questions for you about those figures, since we cannot read the ones we have.

If you will turn to page 7 of your testimony, I believe the sentence begins right at the end of page 6, referring to ICRP-2 again, it distinguishes three outcomes for material that is inhaled, any material that is inhaled -- that is, it may be immediately exhaled or deposited in either the lower or upper respiratory passages.

Now what is meant by "upper respiratory passages" there?

A (Witness Schaffer) It is normally assumed to be from the top of the pharynx -- excuse me -- the epiglotis down to the terminal trachial bronchial tubes.

Q Okay. So then the lower respiratory passages would be what?

A That would be the gas exchange areas of the lungs.

Q The alveoli?

A The alveoli, yes. Any area without the mucociliator membrances.

Q Okay. Now when we refer to the deep lung, how does it relate to these two terms, upper and lower respiratory passages? Which part is the deep lung in?

A The deep lung relates to the lower passage.

Q And would it mainly relate to those gas exchange

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areas?

A Correct.

Q Okay. Then beginning on page 6, the last sentence starts, "Once deposited in the two compartments of the respiratory system, the material is cleared at varying rates depending on the chemistry of the particle and the site of deposition."

Now you have mentiioned the mucociliary in the upper compartment. That is a clearing mechanism, among other things, isn't it?

A That is its main function, yes.

Q Okay. But that system does not exist in the deep lung, does it?

A That's correct.

Q Okay. Now how is material cleared from the deep lung, Doctors?

A There are several mechanisms of clearance from the deep lung. One mechanism is, basically if the particle is not deposited and remains in the airstream, it will be breathed back out. Another aspect is, if the particle is deposited, you have macrophage clearance where they would phagocytize the particle and take it up to the mucociliator membranes and then have that removed from the lung.

Particles could also, depending upon their solubility, pass through the gas exchange membranes in the

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deep lung and get into the blood and be cleared that way.

Also the macrophage may also carry particles to the lymph.

Q Okay. Are those the main mechanisms?

A Those are the main mechanisms, yes.

Q By phagocytize, in laypersons' terms, does that mean swallow up?

A Being a biologist, I will have to say it means having the cell membranes surround the particle and bring that particle inside the cell.

Q Okay. So the macrophage actually takes this particle into itself when it phagocytizes it.

A That's correct.

Q Now what role, if any, does a possible rupture of the gas exchange membranes play in removing material deposited in the deep lung?

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A I don't know of any role that it would play.

Q Are you familiar with any materials which, if inhaled into the deep lung, could result in rupture of those membranes?

A No I am not familiar with any.

Q Okay. Do you have any idea what proportion of the macrophages that take in or surround particles deposited in the deep lung move upward into the mucociliary area and what proportion might move into the lymph system?

A I know that the macrophages that move up to the mucociliary area are a significant proportion, but the actual percentage I am not aware of.

Q Are the lymph nodes near the lung counted as part of the lung by the ICRP in this publication you refer to?

A No.

Q So a particle which was transported out of the lung by a macrophage into the lymph system would have gone to a place that's not directly covered in your calculations?

A (Witness Mauro) That is correct.

Q Okay. Now just for completeness, if the macrophage carries it up into the mucociliary system, that is still in the lung, isn't it?

A (Witness Schaffer) It is still in the lung until the system removes it.

Q Clears it out of the top of the lung?

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A Yes. Quite rapidly.

Q About how rapidly?

A On the order of hours to a day.

Q And once it came out the top of the lung, would it be swallowed?

A It can be either swallowed or coughed.

Q Okay. Would it be fair to say that that which is not expectorated is eventually swallowed?

A Yes.

Q Did you make any assessment of -- well, first let me ask you about ICRP-2. How does ICRP-2 treat this phenomenon -- that is, that some proportion at least of the material deposited in the deep lung is actually carried out of the lung by the combination of the macrophages and the mucociliary system, and if not expectorated, would be swallowed and then passed through the intestinal tract? How does it treat that phenomenon?

A (Witness Mauro) It includes it in the model. It now becomes part of the GI tract model.

Q So it is not just a dose to the lung that would have to be computed using the ICRP-2 model.

A No. The ICRP-2 model is the model that looks at the whole body as a system where you have the transport of this material, and, in fact, if you look at our inhalation dose conversion factors that we use and the

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inhalation doses that were calculated, it is not just the lung dose presented there, but there are many organ doses.

Q All right. Now let me just look at those dose conversion factors. That's Table 1 of your testimony following page 5, is it not?

A (Witness Schaffer) No. Those are the doses that are in the calculation.

Q Okay. Well, maybe you could point me to where those dose conversion factors show up?

A They are in Reg Guide 1.109, Tables E-7 through E-10.

Q And those tables don't actually appear in your testimony or are attached to it, are they?

A No, they are anot.

Q But you drew from the Commission's Regulatory Guide, the numbers?

A That's correct.

Q And if I may reask one of my past questions with maybe a little more precision, when a material is deposited in the lung in this model, the dose that results from that deposited material being cleared from the lung by the mucociliary system, with or without help from macrophages, and passing through the gastrointestinal tract is included in those dose conversion factors?

A (Witness Mauro) Yes.

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Q What about the particles or radioactive materials that may be removed by the macrophages into the lymphatic system? How is that treated in this model?

A The doses are not calculated to the lymph nodes.

Q Okay. From the lymph nodes, where would it go if it were not retained in the lymph nodes?

A More recent models treated many of the unsoluble radionuclides as if it remains there indefinitely and just is removed with the radioactive decay halflife of the radionuclide.

Q Are macrophages sometimes removed further in the lymphatic system, past the lymph nodes?

A (Witness Schaffer) I'm not aware of any.

Q Do you know, Dr. Mauro?

A (Witness Mauro) No.

Q You don't know one way or the other?

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A No. I believe they are removed out the lymph nodes.

Q Okay. I guess that's about as far as I can take that.

JUDGE KELLEY: Excuse me. Could the witnesses raise their voices perhaps just a bit?

Thank you.

BY MR. EDDLEMAN:

Q Are either of you familiar with any cancers are known to arise in the lymph nodes around the lung, any kinds

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of cancers or any cases of cancer?

A (Witness Mauro) In general terms?

Q Yes.

A I know of, probably through the same sources as you do, that there is cancer of the lymph nodes. But to specifically say where they are located, I couldn't say.

Q And you did not -- did either of you make any review of cancers arising in the lymph nodes near the lung to which these macrophages might clear particles like we have been talking about here, coal particles and radioactive particles, in preparing your testimony?

MS. BAUSER: Objection. I don't see how this is relevant.

JUDGE KELLEY: Could you repeat the question?

MR. EDDLEMAN: The question is, did either of them make any review or consideration of cancers arising in the lymph nodes to which the macrophages would clear some of these particles deposited in the lung that we have been dealing with in the testimony.

MS. BAUSER: Judge Kelley, if I might elaborate, this contention is concerned with whether the dose model considers properly the attachment of radionuclides to fly ash, not the consequences thereof.

MR. EDDLEMAN: Well, he has already testified that the dose model doesn't look at those lymph nodes, so there

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is a piece of it that his dose conversion factors doesn't take into account, and I think I'm entitled to explore that a little bit.

JUDGE KELLEY: Your question goes to how many cancers?

MR. EDDLEMAN: Well just to whether they made any consideration of cancers. See, he has also said that some of these particle are transported by macrophages to these lymph nodes. So I have a mechanism for the material getting to these lymph nodes where cancers arising from that were not considered.

What I am asking is, did he make any consideration of those cancers in preparing his testimony? It's a very simple question, and that's all there is to it.

JUDGE KELLEY: Sustain the objection. It seems to me this has to do with how things get to places and not the results.

MR. EDDLEMAN: Judge, can you clarify that just a little for me? Is cancer a result?

JUDGE KELLEY: Is cancer a result of the dose?

MR. EDDLEMAN: Yes.

JUDGE KELLEY: I thought we all thought it could be, or we wouldn't be worried about this.

MR. EDDLEMAN: That's what I thought, too. That's why I don't understand why you overruled it.

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JUDGE KELLEY: I ruled -- let me find the text of your contention.

(Pause.)

It's repeated at the top of page 2 of the witnesses' testimony, and you say that various health effects are underestimated because the models underestimate the means of concentrating radionuclides, specifically radionuclides that get attached to fly ash.

We are talking about fly ash and radionuclides getting attached to it and getting into the body in one way or another and delivering some kind of dose. It seems to me that is the outer limit.

MR. EDDLEMAN: Well, Judge, the lymph nodes, as I understand it, are in the body --

JUDGE KELLEY: Yes.

MR. EDDLEMAN: -- yet the dose to them is not included in their model.

JUDGE KELLEY: Ask them why it isn't.

BY MR. EDDLEMAN:

Q Why isn't the dose to those lymph nodes included in your model?

A (Witness Mauro) At the time of the development of this model, the lymph nodes were not included as one part. Subsequent to that, when the model is enhanced and looked at more closely -- and it's a publication, Health

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Physics, 1966 -- which goes into greater detail, a more sophisticated model where they look at the lymph nodes. The analysis was done on the significance of not explicitly treating lymph nodes in this older version of the model, and the conclusion was that the dose to the lung was more important or comparable to the dose and risk to the lymph nodes. So therefore the model we are currently using still remains valid, even though it does not explicitly treat lymph nodes.

So it would be incorrect to say that we are not cognizant of the lymph node dose when using this model. We are cognizant of it, and it's not explicitly treated here, and it's considered an appropriate approach, since the lymph nodes, when you go through the rigorous calculation using the more sophisticated models, the lymph node dose is not the limiting factor when dealing with the dose to the lung.

Q Did those more sophisticated models that you refer to take into account nuclides deposited on fly ash explicitly?

A It took into consideration particulate material deposited in the lung which was not rapidly cleared by the other mechanism, but cleared by phagocytisis to the lymph nodes which would thereby envelop and include, have nested within it, coal particulates.

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Q But did it explicitly treat the question of whether those coal particulates might carry more nuclides into the lung, into the deep lung?

A No. It addressed, given a certain amount of radioactivity deposited in the lung, what the dose would be to the lymph nodes. It never mentioned coal particulates at any time.

Q Does your model, then, consider that that dose which might be carried out by the macrophages to the lymph nodes, the dose from the material that might be carried out by the macrophages to the lymph nodes, is actually just delivered to the lung? Is that how your model treats it?

A No. Our model, the model you have before you, treats the organs listed in Table 1, does not include any other organs.

Q But does your dose conversion factor -- I thought you said your dose conversion factor did not include the dose to those lymph nodes.

A No, it does not. I am saying that subsequent to the development and application of this model, this question has been raised, and more refined models, much more sophisticated models -- and one of them is described in the Health Physics aricle in 1966 -- did look at additional organs, including the lymph nodes, and it did look at a

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more sophisticated treatmet of the clearance process for soluble and insoluble particles, and in effect validated that this is still -- this approach that precedes the 1966 version is still a reasonable approach to modeling doses from inhaled soluble and insoluble particulate material.

Q Well, how much difference in dose do you get between those two models?

A I did not do the numbers in this particular application.

Q Okay. So you don't know how much different a dose you might have gotten if you had used one of these more sophisticated models?

A I could very readily speculate on it, simply because the tritium dose is by far the limiting factor, and tritium is treated basically the same in the two models, so nothing would really change.

Bear in mind, one of the points we tried to make in our testimony is that 98 percent of the dose presented in the FES is due to inhaled tritium. Now tritium is treated as a soluble radionuclide, which means that upon inhalation, 75 percent is immediately absorbed into the body. This part of the model is unaffected by the more recent developments.

Q But you testified, didn't you, that you thought it might even increase the dose to a person if the material,

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the tritum, were held in the lung rather than distributed throughout the whole body, didn't you?

A Yes. I created a hypothetical situation on my own, just to take a look at what would happen if we assumed that. That has no bearing -- at no time in the 1966 update of the lung dynamics model did they ever consider it feasible that tritium would, in fact, behave that way.

Q But to the extent that any tritium does behave that way, your calculations show that it might increase the dose to the person who inhales the material, don't they?

A Given that tritium behaves as a particle, notwithstanding the fact that I don't believe that is at all the case, the dose to the lung from inhaled tritium under those circumstances would increase, and the dose to the whole body would decrease.

Q And I believe you said that the effect on the lung of that increase might even be more than -- might more than offset the effcct of the decrease on the whole body.

A That's correct.

Q I think we have also established, have we not, that you gentlemen don't know for sure one way or another whether these coal particulates tend to hold tritium on them when they are in the lung.

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A There is no reason to believe that tritium would bind tenaciously to a particle. You would expect that any tritium associated with a wet particle would commingle with other waters in the body and exchange with it, so that it would rapidly become part of the body fluids, as opposed to being held tenaciously to the particle.

Q And you also don't know one way or another whether the --

MS. BAUSER: Objection. Objection, he said you also don't know and that is not what Dr. Mauro just stated.

JUDGE KELLEY: I think it's a mischaracterization.

MR. EDDLEMAN: I will rephrase the question.

JUDGE KELLEY: He said he did know, I thought.

MR. EDDLEMAN: I thought he earlier testified that he did not. But the record can speak for itself. Let me ask the next question in a different form.

BY MR. EDDLEMAN:

Q Do either of you know whether adsorption or absorption of tritium on coal-fired power plant fly ash particulates would or would not increase the amount of tritium that is absorbed in the body through the lungs?

A (Witness Mauro) It would not have any effect on the calculation.

Q Well, that's not exactly the question I asked. Do you know whether it would increase or decrease the amount

of tritium that's absorbed into the body through the lungs?

A Do I know? What do I believe to be the case? I believe that any attachment or association between tritiated water vapor in the air and airborne particulates including fly ash would not have an effect on the doses that were calculated here.

Q All right, that's your opinion. But let me ask you just a very slightly different question. Do you know, know as a fact, rather than your opinion, that that is the case?

MS. BAUSER: Objection. I think that's argumentative. I don't see the distinction. They're testifying as experts.

JUDGE KELLEY: Do you want to comment, Mr. Eddleman. I have a little trouble with it myself.

MR. EDDLEMAN: I understand that as an expert his opinion counts for something, depending on the weight of his expertise and so on, and all of these things. But what I'm trying to distinguish is whether that's his opinion based on whatever facts he might have or whether he knows it as a fact.

If he knows it's a fact, it's even stronger, isn't it?

JUDGE KELLEY: Well, do you mean it in the sense of have you ever performed an experiment with his very own

eyes?

MR. EDDLEMAN: Yes. Has he performed an experiment or calculation to demonstrate that his opinion is correct or not That would be the question I could refer.

JUDGE KELLEY: Well, I think that's okay. Go ahead.

WITNESS MAURO: I have never performed an experiment to make a distinction between how tritium would behave when inhaled as a vapor or when inhaled as associated with a wetted airborne particle.

BY MR. EDDLEMAN:

Q Have you ever made any calculation as to the amount of tritium that would be deposited in the lung depending on what fraction of it comes into the lung associated with coal fly ash particulates?

A (Witness Schaffer) We could basically do the same thing as we have done in the attachment to our testimony and show that --

Q You mean Attachment 2?

A Attachment 2 dealing with the noble gas absorption. Yes, that is Attachment 2.

Q You could do that for tritium, you say?

A We could assume that the 100 micrograms per cubic meter of particulates was all water and show that that is an insignificant fraction of the water vapor that contains

tritium released from the plant, just due to the fact of the tremendous amount of water vapor already in the ambient atmosphere.

Q Doctor, do you know whether when measurements of total suspended particulates are taken if water is included in the weight that is measured? The weight.

A I don't know.

Q Okay.

JUDGE FOREMAN: Mr. Eddleman, could I interrupt? Could you repeat your statement about the amount of tritium being absorbed in relationship to the total amount of water that's absorbed? I didn't quite understand your point.

WITNESS SCHAFFER: I had made the relationship saying that if there's about 100 micrograms per cubic meter of respirable size suspended particles in the air. Now, if I want to know what fraction of the total water vapor in the air that that 100 micrograms of particles can hold, it would be an insignificant fraction. And it would be the same fraction applied to releases from the plant.

WITNESS MAURO: Perhaps I could help a little further. Typically a cubic meter of air has eight grams a cubic meter of water vapor in the ambient environment. We're talking about 100 micrograms of particles. So even if the particles were all water, it would still be a miniscule fraction of the total amount of water vapor in the air.

So the amount of water that is associated with particles in the air cannot be very large.

JUDGE FOREMAN: But the meaningfulness in terms of contribution to the dose is the specific activity of that tritium in the water is how much tritium there is, not the weight. In other words, how radioactive that water is, and it may be a very, very small percentage of the total water and still be able to give a dose to the lung.

WITNESS MAURO: Yes, but that would also mean, whatever the fraction of water is on the particles they're associated with particles. That's the same fraction of the tritiated water vapor that would be associated with it because they would partition the same way.

So a very, very small fraction of the water vapor in the air is associated with particulate material. It would also be true that the same fraction of the tritiated water vapor in the air is associated with those particles.

JUDGE FOREMAN: It is still not clear to me in terms of the meaningfulness of that to the dose that might be delivered to the -- maybe a hypothetical situation where the fly ash particles absorb water and therein act as a particulate conduit for tritium.

WITNESS MAURO: I'll try to do through it. I thought through this question before. If there is eight grams of water typically in the ambient environment, but

there's only 100 micrograms per cubic meter of particles, so the water -- all the eight grams of that water cannot be associated with 100 micrograms of particles.

JUDGE CARPENTER: Eight grams per cubic meter?

WITNESS MAURO: Yes, per cubic meter. So I guess as sort of a physical possibility to start thinking in terms of a large fraction of the water vapor in the air, including being associated with a particle, if you have eight grams of water in the air per cubic meter and only 100 micrograms of these particles.

So you would have to have all these grams of water on micrograms of particles. It is just a physical impossibility. And the tritium would behave just like water vapor.

JUDGE FOREMAN: I don't understand why you would have to have all of the -- bear with me, I'm not trying to challenge you -- why all of the eight grams would have to be on the particle. Why, even if it's a small portion of that water that comes to dissolve in the particle, what's important is the amount of radioactivity that is stuck there, not the amount of water.

WITNESS MAURO: Well, the particle -- if you have eight grams of water in the air you are asking how much of that -- how many microcuries per cubic meter -- I guess there are several questions that I am trying to unravel here.

We looked at it as being a physical impossibility to have eight grams of water being thought of as bound up to these two-micron particles, absorbed in it or wetted by it, because you only have 100 micrograms of these little particles. So I guess that's as far as you carry it. I'm trying to visualize this.

So you really cannot expect to have the water, the eight grams of water bound to a two-micron particle because there's just too much water out there to be bound up and wetted. If anything, the particle would dissolve in the water.

JUDGE FOREMAN: I understand that all the water cannot be bound up, but some of them might be bound up, and some of it might have radioactivity in the form of tritium on it.

WITNESS SCHAFFER: Yes, but that portion is the same fraction, because the tritiated water vapor and the stable water vapor constitutes the total water vapor in the atmosphere. And if that is eight grams, then a very small fraction of that can be associated onto the 100 micrograms of particulate matter suspended in the air.

JUDGE FOREMAN: But are you saying then, were the tritium just being inhaled in the form of water vapor all eight grams would get in?

WITNESS SCHAFFER: 75 percent of the eight grams.

JUDGE FOREMAN: I see. And therefore, the amount that might stick to the particles is a tiny, tiny fraction of what might be taken into the lung by adherence to particulate matter as compared to what is taken in in the form of water --

WITNESS MAURO: That's correct. And any addition, any of that may be wetted, any particles that may be wetted particles, we believe that any tritium in that water, wetted particle would very rapidly commingle with the fluids in the lung and just become part of the body fluids and behave as if it was inhaled, as if it was a water droplet.

JUDGE FOREMAN: Do you have any idea how fast that mixing with ordinary water takes place under those circumstances?

WITNESS MAURO: It's treated in the model as immediately.

JUDGE FOREMAN: And it takes some time for the model to exchange, depending upon the access of ordinary water to that. But you're saying, it's immediately?

WITNESS MAURO: It's modeled as immediately, and that's based on empirical data which shows that it's so quick that for the purpose of modeling it's, mathematically it suffices to treat it as absorption into the body.

JUDGE FOREMAN: Gentlemen, I want to take another minute, if you don't mind, to a point that you brought up.

It wasn't entirely clear to me, and I appreciate your clarifying again why you think that the dose that might be provided to lymph nodes by virtue of agglomeration of particles brought there, say, by a phagocyte, why that isn't a dose worth calculating?

WITNESS MAURO: Oh, I guess it is not built into these models. Subsequent to the development of this model, the original model used here, the whole question of inhalation, modeling of inhaled particulates has been an ongoing process. And the ICRP in connection with the Committee on Rad Health, has come up with more sophisticated methods of modeling which are improvements on this method, where they do treat the lymph nodes as an explicit part of the model.

And of course at that time when that model was developed the question became, well, does that invalidate the models we currently use as standard practice in our regulatory guides. This type of question is always raised because there's always new information where you have to go back and question your generic approaches or your standard methods.

And this is one case of a more general question. There's this new model that somehow invalidates, and it was looked into on a generic basis. That is, can we still use the old models in light of this new information. And this was done on a generic basis. And it was decided yes

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we can.

JUDGE FOREMAN: Maybe I can shortcut this. Are you saying that one can still use the previous model but one would not be better off by -- in terms of determining the dose to the lung area by including a calculation of dose to the lymph nodes too?

WITNESS MAURO: Well, I guess the answer to that in its purer sense is yes. Always use the best information available. But there's also a practicality because new information is being developed continually, and you would not selectively go in and change one part of your model.

The methodology is before us where we couple source term meteorology, the entire dose process. It represents an overall best estimate of how to model the behavior of radionuclides. Now the question comes up, here we have this methodology, which is laid out very nicely in Reg. Guide 1.109.

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There's always new information coming out on all aspects of the models, including the lung model, including deposition velocities, including atmospheric transport, biocumulation from soil to the plant. There's continually research going on and literally thousands of papers coming out on the subject. To selectively go in at intermittent times and change pieces of it -- it is taking the overall model and selectively changing parts out of context.

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I think the best way to go about questions like this is to look at the overall process, the entire Reg. Guide 1.109 model and periodically review it in total and say, what can we do now to make the overall model improvement. And at that time incorporate questions such as the one you raised regarding this specific aspect, namely the lymph nodes.

JUDGE FOREMAN: But is it really important that you stick to the model when you are trying to give a specific answer to a contention? Namely, the answer as to whether considering fly ash as a vehicle for radioactivity in the body will affect the dose to the lung region.

Nothing says you have to stick to that model. Why you can't modify part of it, say, in order to provide an answer to that question.

WITNESS MAURO: I agree, but I couched my entire testimony in terms of really a challenge to the FES and the ER where we presented our doses. And I saw this really as a challenge to what we prepared as our license application. And this is what we used.

So I went back to those models and justified them on the basis -- within that context we used the models we've been using. The question is do they adequately account for the behavior of particles. And that's how I approached it.

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Now I see your question as certainly another level of analysis, namely, looking at the question of lymph nodes and possibly other matters that have come up in the newer lung models could be rigorously and quantitatively addressed. But we didn't elect to do that here.

JUDGE FOREMAN: But on the basis of your intuitions and long experience in calculating doses and radiobiological effects, would that calculation be a meaningful addition to an answer to the question that's being raised at this hearing? Would that calculation -- meaning the calculation of the dose to the lymph node?

WITNESS MAURO: I believe it will show that the numbers that we calculated here are conservative. In other words, the dose to the lung that we calculated using the old method is higher than you would get to the lymph nodes or the lungs if we use the newer methods, and the overall approach we're using here.

If anything, by going to a new refined model, the numbers will come down.

JUDGE FOREMAN: Why?

WITNESS MAURO: It is more realistic treatment of the behavior of radionuclides. In developing this original model there was a limited amount of data. In fact, one of the points made in our testimony is regarding deposition, the assumptions regarding deposition and behavior

of radionuclides. And at the time those models were developed, assumptions were made regarding limited data on the behavior of radionuclides. There is more data available now, and typically, when they made the original assumptions, in order to err on the safe side, they made assumptions which were of a general conservative nature.

As more information is acquired and research is done we usually confirm that and find out that yes, at the time we were forced to make conservative assumptions because we lacked at that time the level of precision that we would have liked to have had. Now that we have more information, and typically this is always the case, we go back in and redo the analysis and we usually find out that the original models we used were conservative, and appropriately so at the time because of the lack of precision of information we had at the time.

JUDGE FOREMAN: Let me ask you again, to your mind then, this model and the results you obtained therefrom is more conservative than taking other considerations into account?

WITNESS MAURO: Yes, sir.

WITNESS SCHAFFER: I would just like to add that looking at the dose conversion factors, using the new models, new lung models they're actually for radionuclides like tritium and iodine have decreased compared to the dose

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conversion factors used in Reg. Guide 1.109.

JUDGE FOREMAN: Let me take a couple more minutes on this. There is, to my mind -- well, let me ask the question this way. The detriment of a given dose to lymph nodes, say the higher lymph nodes is greater than say the detriment to the lung for the same dose? That's the question. Is it?

WITNESS MAURO: I don't have an answer to that question. I don't know the risk co-efficient for lymph nodes. I don't believe a separate risk co-efficient would develop for lymph nodes so I can't answer your question.

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JUDGE KELLEY: I think you are walking into where we said Mr. Eddleman cannot go.

JUDGE FOREMAN: But the sense of that is, when you say your calculations are conservative, if indeed the answer to the risk coefficient is that the risk coefficient for lymph nodes is higher, then your calculations are not conservative.

WITNESS MAURO: Our calculations with regard to dose. Unfortunately, I don't have the information at my fingertips regarding the conversion of dose to risk. I just could not answer what the results would be in terms of expression of risk.

JUDGE FOREMAN: So legally I cannot ask that question?

JUDGE KELLEY: Well, the contention speaks to radionuclides going along with fly ash and where to they get, and I guess what is the dose. But then when you get to dose, to what happens next, you get cancer or not, I don't think we're in that stage.

That was the objection, as I understood it previously.

JUDGE FOREMAN: Yes. Thank you.

JUDGE CARPENTER: Can I ask just one question to be sure I'm following what is being said?

You used the expression "modeled." I am not a

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health physicist or a biologist. I want to be very clear in my mind that the next step from that word is to say you conceptualized something and express it in an equation with a series of terms.

Am I correct in saying that you are looking at sum of the old terms vis-a-vis the refinements by adding terms to that equation, just like bank accounts, and the increment if you change the values of the terms, the sum is smaller; is that exactly what you said?

WITNESS MAURO: The results, the results, yes, using the model greater refinements, greater number of terms and constants and new parameters for many of the constants, the result would be lower doses.

JUDGE CARPENTER: Thank you very much.

BY MR. EDDLEMAN:

Q Gentlemen, I think you may have answered this, but I want to tie it up at this line of questioning from the Judges.

Neither of you has actually made the calculation of dose with any of these newer or more sophisticated models beyond Reg Guide 1.109, have you?

A (Witness Mauro) I have, but not in this particular application.

Q You have not made it for the -- relative to particles, radioactive materials which may be deposited on

mgc 13-3

or with coal fly ash?

A That's correct. We have not.

Q Let me turn to this question of partitioning again. I believe we also established that when you weigh a certain amount of total suspended particulates, say 100 micrograms per cubic meter that you use in some of your calculations, that you don't know whether that is wet weight or dry weight?

A (Witness Schaffer) That's correct.

Q Okay. Now doesn't the sort of calculation that you were describing to Judge Foreman about the tritium in that 100 micrograms depend a good bit on whether it was wet or dry weight?

A We, in our discussion with Judge Foreman, we assumed that that 100 micrograms was all water.

Q And that would be a wet weight, wouldn't it, if it was all water?

A That's right.

Q Now let me ask you this. Doesn't your argument also assume that the tritium is more or less evenly distributed in all the water vapor and droplets that are in the ambient atmosphere?

A That's correct.

Q But it doesn't come out of the plant that way, does it?

A It comes out as water vapor, predominantly water.

mgc 13-4

Q Okay. But what I mean is, when you come right out of the stack from the plant, the tritium is more concentrated than the water vapor and the water droplets that are coming out of the stack than is assumed in your answers to Judge Foreman's questions.

A No, sir. We calculate the concentration of the tritium in the air coming out of the stack, and we didn't explicitly treat the fact that -- the influence the water vapor may have in the environment. We treated transport of tritium as we treated the transport of any radionuclide coming out of the plant stack, applying just atmospheric dispersion constants to it.

Q But atmospheric dispersion is the phenomenon by whereby things are dispersed in the atmosphere, isn't it?

A That's correct.

Q And that means that the concentration per cubic meter, let's say, of tritium is higher at the stack than it is anywhere else around it in your model, isn't it?

A The calculated concentration per cubic meter is higher the closer you get to the plant.

Q All right. Let me ask you this. Do you have any idea how many coal particulates might come by that stack while that tritium is coming out, what concentration of coal particles the water vapor and tritium see as it comes out of the stack from the Harris plant?

mgc 13-5

A As we pointed out in our calculations or testimony, we presumed that the ambient particulate concentration was 100 micrograms per cubic meter, which we believe, based on the information provided in our testimony, is a fairly conservative estimate.

Q Where do you discuss the conservatism of that estimate, if you could point me to it?

(Pause.)

A (Witness Schaffer) It is discussed on page 2-1 in Attachment 2, the last sentence on the page, which reads, "It should be noted that the actual fraction will probably be lower than the quantity calculated, because calculations assume a fly ash concentration representative of the maximum total respirable airborne particle load for Northeastern cities, which is a higher concentration than exists in the vicinity of the Harris plant." And it is based upon that PEDCO and EPA record.

Q Now PEDCO, have you ever seen the document that you are referencing there?

A I have a copy of it here.

Q Okay. Well, let me get my copy and your copy together here, if we can.

First, I want to ask you what monitoring station or stations is the one that you used in that report as representative of the Shearon Harris plant? This is a

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PEDCO report of January 1982 that you have?

A Yes.

Q Okay. And I have a PEDCo report of March 1982 here. Let me look at your document, then, and I will put mine away.

Would you read the title of your January 1982 report, please?

A The title is "Compilation of Ambient Particulate Matter Size and Composition Data."

Q Okay. Can you find in there where --

JUDGE FOREMAN: Could you say who put it out?

WITNESS SCHAFFER: It's prepared by PEDCo -- P E D small o (spelling) Environmental, Inc., and their address is 505 South Duke Street, Durham, North Carolina, Zip Code 27701.

JUDGE FOREMAN: Excuse me. Prepared for what purpose? Was it prepared for the EPA?

WITNESS SCHAFFER: Yes, it was prepared for the EPA.

BY MR. EDDLEMAN:

Q Would you read the first line, what it says it was prepared for?

A (Witness Schaffer) Prepared for Monitoring and Data Analysis Division, U.S. Environmental Protection Agency, Research Triangle.

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Q You are referring to Table 3 on page 36 of this document, are you not?

A Yes.

Q And you are pointing at a figure that says SE with a little supercript C.

A That's correct.

Q And the supercript C reads, "Only one site with data less than 2.5 or less than 15 microns."

A That's correct.

Q Okay. And the superscript is on the letters SE. What does that mean, Doctor?

A That means it is a southeastern site, and in fact, if you go back to the original data, it is a rural non-industrial area outside of Durham.

Q Can you be more precise? Do you know where in this document that site is identified?

A We are looking at Table 5, which gives --

Q This is a listing of various sites.

A Particle distribution by site classification -- oops, sorry. It is "Summary of Particle Size Data by Site Type/Area."

Q And we are looking for a southeastern site?

A Southeastern site right here (indicating).

Q Page 45?

A Yes.

mgc 13-8

Q This says "R-B Elkmont, Note 3," does it not?

A Yes.

Q And this reports in various columns diameters less than one micron and diameters less than 2.5 microns, doesn't it?

A That's correct.

Q It doesn't give a figure for total suspended particulates at that site, does it, Doctor?

A It does not.

Q Okay. Let's take a look at Note 3 to this table. Well, let's look at the top and see if we can figure out what that 3 means. I don't see any explanation for these. There are different numbers like 1 and 16 and 22 and 43. I don't know what that 3 means.

A I can't find an explanation.

Q Okay. Well, at any rate, whatever this note means, it is not obvious.

A That's correct.

Q Okay. We have one site, it has an average there for it but not standard deviation.

Now, Doctor, it does give in a column labled D_{50} less than 2.5 microns concentration micrograms per cubic meter, the number 56.0, does it not?

A That's correct.

Q What does D_{50} mean? What does that mean?

mgc 13-9

A I believe it means the median diameter.

Q Okay. So median diameter less than or equal to 2.5 microns.

Can you tell me how that relates to a measure of total suspended particulates?

A This would be a subpart of total suspended particulates, and in fact, this would be the subpart that would be relevant to someone worrying about the health effects of particles, because this is the inhalable size range.

Q This is the fine particulate size range, really, within the inhalabe range, is it not?

A That's correct.

Q Now the inhalables would go all the way up to about 15 microns, I believe you gentlemen have said.

A Yes.

Q But there is no date for ranges, size ranges between 2.5 and 15 microns reported for this site in this table, is there?

A Well, let me check something. This might be a slight contradiction to Table 1, which says 15 percent or 15 microns -- excuse me -- Table 3, "Particle Size by Geographic Area," has again 56 microns -- 56 micrograms per cubic meter at D_{50} less than or equal to 15 microns.

Q And does not the same Table 3 on page 36 report

mgc 13-10

D_5? And I'm reading it; it says D_5. I think it means D_{50} -- less than or equal to 2.5 microns for that same southeastern site as 24.0?

A That's correct.

Q Okay. So the contradiction between these two tables is that in Table 5, the 24.0 is applied to a D_{50} less than or equal to 1 micron.

A And in Table 3, it's applied to less than 2.5 microns.

Q Right. And likewise, in Table 3, the D_{50} less than 15 microns is reported as 56.0, but in Table 5, the D_{50} less than 2.5 microns is reported as 56.0.

A That's correct.

Q So -- well, let me ask you directly. You said you looked at the contradiction between these two tables, and there is a contradiction between these two tables, is there not?

A That's correct.

Q And you wouldn't know which table is correct, would you?

A I wouldn't, but neither one of them would equal 100 micrograms per cubic meter, is what I assumed.

Q Well, Doctor, what fraction of total suspended particulates is typically fine particulates?

MS. BAUSER: What was your question?

mgc 13-11

MR. EDDLEMAN: What fraction of the total suspended particulates is typically fine particulates?

MS. BAUSER: I object. It is too vague. What fraction where? Anywhere in the United States?

MR. EDDLEMAN: As he uses it in his work. But let me explain to the Judges where I'm going with this.

JUDGE KELLEY: Okay. Let me ask you how long it's going to take. We need a break here pretty soon.

MR. EDDLEMAN: Five minutes at the most.

JUDGE KELLEY: All right.

MR. EDDLEMAN: Where I'm going is, they talk about using 100 micrograms per cubic meter TSP as the conservative assumption about how many particles there are around for these nuclides to grab onto near the Harris plant.

If these data were correct at either of these ranges, and you know in general some fraction of the particulates that -- in other words, if you know that TSP is 100, then if the typical fraction that is fine particulates were, say, 30 percent, then your fine particulates would be about 30, okay?

Likewise, if, say, half of them were less than half a micron, then you could take the amount less than half a micron and roughly double it, and that would give you some rough guess as to what your TSP is.

mgc 13-12

What I am trying to get at is whether these data that he says he relied on are consistent with the assumptions he has made.

JUDGE KELLEY: Do I have an objection pending?

MS. BAUSER: I don't understand how his question gets in there. I have no objection to his going there.

JUDGE KELLEY: Why don't you go ahead in that direction?

BY MR. EDDLEMAN:

Q Doctors, do you have any idea what proportion of total suspended particulates would typically be fine particulates?

A (Witness Schaffer) It depends upon the area that you are talking about. And as I have stated before, we assumed 100 micrograms per cubic meter fine particulates, and that is about the highest that anyone has observed on an annual average.

Q All right. Your testimony -- let me look at that.

In Table A-1 on page 2-3 of Attachment 2 to your testimony, Doctors, it refers at the top of that table, the first item, to a fly ash concentration, does it not?

A I was looking for the table. Could you repeat the question?

JUDGE CARPENTER: Just a minute and give the witness a chance. Can you find the table?

mgc 13-13

WITNESS SCHAFFER: Yes, I have the table.

BY MR. EDDLEMAN:

Q You have Table 1 before you?

A (Witness Schaffer) Yes.

Q Now in that table, Doctor, the top line, top item, refers to fly ash concentration, does it not?

A Yes, it does.

Q And the value, 1×10^{-4}, is equivalent to 100 micrograms per cubic meter, is it not?

A Yes.

Q And it says the Note No. 1 applies to that, doesn't it?

A Yes.

Q Now Note No. 1 actually says, "The concentration of all respirable particles in large industrial northeastern cities can be as high as 1×10^{-4} grams per cubic meter. Reference PEDCo 1982." That is the same reference that we have just been looking at, isn't it?

A That's the reference that I have, yes.

Q Right, the one you had, January 1982 report, right? Is that right?

A That's right.

Q Okay. It says all respirable particles, doesn't it?

In your minds, Doctors, is there any distinction

mgc 13-14

between fine particulates and respirable particles?

A That 1 x 10^{-4} micrograms per cubic meter in that PEDCo reference comes from the number that they give for 2.5 microns or less.

Q All right. But you referred to them as respirable particles here, didn't you?

A I refer to them as respirable particles.

Q And somebody who didn't have that report, which has no page reference in your testimony, without that report in front of me, would you expect me to read the words "respirable particles" as "fine particles"?

A No, I would not.

Q Okay. But what you are saying is, in fact, you assumed that they were fine particulates less than 2.5 microns. So if I wanted to make your testimony at least as accurate as it was written, I could just replace the word "respirable" with "fine" particles in this footnote, couldn't I?

A Yes.

A (Witness Mauro) Well, let me see if I understand. You are saying that -- we are just making a statement of fact. We are looking at the large list of data in that table. If you look at the numbers in the table --

Q Which table are you referring to, Doctor?

(The witnesses confer.)

mgc 13-15

A (Witness Mauro) You can see that we are just making a statement, characterizing the information that has been summarized by PEDCo, saying that 100 micrograms per cubic meter for all particles less than 15 microns, which includes all the way down, 100 micrograms would certainly be an upper estimate.

Q All right. You are still on that Table 5 of the January 1982 PEDCo report?

A That's correct.

Q Specifically, you are in the middle column of that, the D_{50} less than or equal to 15 micrograms.

A That's correct.

Q And what you are saying is, if I look down that column, I am not going to see any numbers that are bigger than 100?

A I don't think too many, or I don't see any right now.

Q Let's just look through it and see.

A (Witness Schaffer) Why don't we look at the northeast cities like I cite?

Q I believe the highest values are in those northeast cities.

A (Witness Mauro) Yes. In northeast cities, we get -- there are several values that are above 100. We have a number cited here, 101.6; another one, 103.1, and

mgc 13-16

we have another one, two more on the far righthand side, of 105.8 and 104.7.

So these are the highest values that we see here.

Q You have a 115.5 in the 30-micron number, don't you?

A Yes, sir.

Q So you have a few over 100. But you are saying that you assumed that 100 was a good upper limit to use here in your calculations, and you further assumed, I take it, that that 100 micrograms was all fine particulates less than 2.5 microns.

A That's correct. Bear in mind that we have done that for the specific purpose of this calculation that we have in Appendix 2.

Q Right, okay. Now how does your calculation in Appendix 2 take into account the surface area of those particles being fine particles, very small?

A (Witness Schaffer) It assumes the surface area to be a sphere with a 1-micron diameter.

Q Okay.

MR. EDDLEMAN: This is a good place to break, I think.

JUDGE KELLEY: Ten minutes or so.

(Brief recess.)

End 13

14pb1

JUDGE KELLEY: We're back on the record. Dr. Carpenter has a question.

JUDGE CARPENTER: Mr. Eddleman, earlier I declined your invitation to continue my questioning. If I may intrude for just a moment before we get such a big gap in the record.

Before lunch, gentlemen, I asked you a very broad question. Now I would like to go with that broad question and make it very sharply focused. I believe from what I have heard that tritium -- we were talking before lunch about tritium and it being the major contributor of dose to the lung. So I will restrict the question to tritium and either HOT or even T2O. But that is the only element or isotope of an element that the question applies to.

And the question was, have you considered over any appropriate period of time, but without time variations during the time the resulting energy transfer to various tissues of the body including the lung and all of the organs as a bounding value? Just a what-if kind of number.

WITNESS MAURO: Yes, I understand your question. Is there more?

JUDGE CARPENTER: No, I just want to restrict it to tritium and I did not specify any time. But I suggested a time and that's all.

WITNESS MAURO: Okay. Yes. What I interpret

14pb2

your question is the concentration of tritium in water vapor in the air can be expressed as microcuries per milliliter of water. And that is referred to as a specific activity of tritium in the water vapor in the air.

That specific activity under microcuries of tritium per gram of water in the air is a bounding concentration You could not have a concentration of tritium in the body greater than the concentration in the air. It's referred to as the specific activity approach for tritium.

So in effect, what one could do is calculate the concentration of tritium in the water vapor in the air expressed in units of microcuries or picocuries per gram of water and assume that your body has the same concentration. If you do that you would basically establish an upper bound of the physical limit of what of the dose that could occur.

And we have done that calculation. And the calculation would be approximately four millirem per year delivered to the whole body. Four millirem per year.

JUDGE CARPENTER: Thank you. That is for all organs?

WITNESS MAURO: That would be whole body dose for all organs. All organs would receive that dose.

JUDGE CARPENTER: Thank you.

BY MR. EDDLEMAN:

Q Dr. Mauro, what amount -- well, let me ask you

this. The specific activity of tritium in water depends basically on how much tritium is in the water, doesn't it?

A (Witness Mauro) That's correct.

Q So, if we had pure T2O that would be the highest specific activity of tritium we could get in water, wouldn't it?

A That's correct.

Q And on the other hand, if I took a certain amount of tritium and just kept diluting it and diluting it and diluting it with water, assuming that I got perfect mixing by a random mixing, I would be lowering and lowering and lowering the specific activity of that water.

A That's correct.

Q When the tritium comes out of the stack at Harris what is its specific activity in the water?

A I don't have that number. I could give you what it is, for example, in the primary coolant, but not in the stack. It's probably on the order of -- I'm not sure, I'm sorry, I'm not sure.

Q You say you could tell me what it is in the primary coolant?

A I was thinking one microcurie per gram, but I'd have to check that.

Q You'd have to check any of these figures.

A Yes, I'd have to check.

Q Well, what specific activity did you use in making the calculation, the results of which you just reported to Judge Carpenter?

A I assumed -- well, the actual number, I'd have to go through the calculation and back up. Could you give me a minute?

Q Sure.

(Pause.)

A On the order of 10^{-11} curies per gram of water.

JUDGE FOREMAN: How did you happen to pick that number?

WITNESS MAURO: Okay. What I just did, we have an estimate of what the tritium release rate is, average annual release rate from the plant. It's 780 curies per year.

JUDGE FOREMAN: I understand that, okay. Give me that final number again, please.

WITNESS MAURO: On the order of 10^{-11} curies per gram.

MS. BAUSER: Could I have a clarification? Where in the air is that.

WITNESS MAURO: That would be at the off-site location with the highest annual average Chi over Q. That is, the off-site location that has the highest potential to have airborne levels of radionuclides.

BY MR. EDDLEMAN:

Q That is where the 10^{-11} curies per gram applies? That location?

A (Witness Mauro) Yes, that's correct.

Q And you calculated this assuming that 780 curies per year are released from the plant, from the stack.

A That's correct.

MR. EDDLEMAN: Judge, have you finished your line on this?

JUDGE FOREMAN: Yes.

BY MR. EDDLEMAN:

Q I think you already said you didn't know what the concentration was near the stack.

A (Witness Mauro) Pardon me?

Q That you didn't know for sure what the concentration -- what the specific activity of tritium in the water vapor released from the stack was. You would have to look that up.

A That's correct.

Q Okay. But we have established that it would be higher at the stack than, say, at this place where you have the highest Chi over Q away from the plant.

A Yes, sir. The concentration or the specific activity?

Q Both.

A Well, certainly the concentration in terms of microcuries per cubic meter would be higher close to the stack. As far as its specific activity, it would probably be higher also, yes.

Q Okay. Now, the mechanism of lowering the specific activity as the stuff moves away from the stack would be its mixing with other water vapor. Would that not be so?

A That's correct.

Q We have established, have we not that one of the things water vapor can do is nucleate around particulates, haven't we?

A I believe that that's something that may occur. I don't know if we have established it.

Q Well, you don't know for sure the extent to which water vapor might nucleate around particulates, but you think it may occur.

A That's correct.

Q Do you concur in that, Doctor?

A (Witness Schaffer) I agree.

Q Okay. Well, let me ask you as something of a hypothetical, if I have some water vapor coming out of this stack, just water vapor, regardless of whether it is tritiated or not, it's coming out of a stack, cooling off. Is that the same sort of process that would happen to the water vapor coming out of the Harris plant stack? And is it

typically released at a temperature that's greater than that of the ambient air around it?

A I believe not very much so, no. It is not a heated plume.

Q So the water vapor would be released at close to ambient temperatures.

A Yes, I believe so.

Q Now then, to the extent that there are coal particulates or other particulates passing by the stack when this release happens, this tritiated water released at the stack could come into contact with those particulates, couldn't it?

A That's correct, it could.

Q Okay. And to the extent that nucleation might take place around the particulate then, this tritiated water could also nucleate around these particles to form water droplets, or perhaps even ice crystals under certain conditions.

A Yes, sir.

Q In your calculations for your testimony, in the work in preparing your testimony, did you consider the phenomenon of nucleation or adsorption or absorption of water on or around these particulates?

A To the extent it could influence our doses, we considered it, and we rejected it as being an important contributor. That is, we considered the possibility. In

preparing our testimony we considered the possibility of tritium behaving more like a particle than water vapor. And we rejected that as an unfeasible way to characterize the behavior of tritiated water vapor in the environment.

So yes we have considered that and rejected it.

Q Well, isn't it true though, that to the extent that the water vapor containing tritium coming out of the stack, or water droplets coming out of the stack at Harris which would contain tritium, nucleate around particulates passing by that that would tend to inhibit the dilution of -- or would carry away water with a higher specific activity on that particulate? Higher than you would find than if the particle ran into some place way away from the plant where the tritium is dispersed.

A (Witness Schaffer) I'm not too sure of what you're saying. However, I think that as it is carried away from the plant it is given more opportunity to exchange with other water vapor outside the plant area. And therefore, it would be -- the radioactivity would probably be diluted on the particle, because it's exchanging a higher concentration of tritiated water with a lower concentration of tritiated water as you move away from the plant.

Q Now is there any difference between what you have just said for tritiated water being carried away and nucleated on a particle, and tritiated water that's just

moving off as a droplet itself, or as a single molecule? Would there be any difference --

A I imagine there would be exchange between both.

Q All right. Now are you saying then that in terms of the dilution or reduction of specific activity of tritiated water that might have been nucleated into a droplet as a particulate and was passing by the Harris plant, there's no difference in that process than if the water never ran into a particle? Is that your opinion?

A Can you rephrase that please?

Q Well, I'll try. We are comparing the effect on specific activity, comparing effects on specific activity here and what I am asking you to do is to compare the effect on specific activity of these exchange phenomena for, number one, some tritiated water that is nucleated into, you know, a droplet around the particle as it comes out of the Shearon Harris stack.

So initially you start off with a particle and the triated water at the specific activity just as it came out of the stack. Are you clear so far on that assumption?

A Yes.

Q What I'm asking you to do is to consider a comparison between that particle with the tritiated water adhering to it, or nucleated around it and some tritiated water that just came out either as vapor or a droplet and

never ran into a particle at all. So it is maybe a smaller droplet, but it's just loose in the atmosphere. Or maybe it's even a loose molecule on its own.

Now among those three things, the droplet nucleated around the particulate, the droplet by itself and the loose molecule of tritiated water, I'm asking if there's any difference in the effect of these exchange phenomena on the specific activity of the tritium as you move away from the plant.

mgc 15-1

A (Witness Mauro) Yes, given that the tritiated water vapor leaving the plant stack -- what you are doing is really saying a truism. You are saying, let's assume the tritiated water vapor leaving the plant stack does not change its specific activity as it moves away from the plant, so you are really asking a question that has its own answer in itself. Yes, assuming that it does not dilute and therefore reduce specific activity, it will have the same specific activity.

Q Well, I understand that this might happen, for example, if that tritiated water from right out of the plant stack grabbed or nucleated onto a particulate going by, and then as it moved away from the plant, that droplet itself didn't interact with other water. That would then be a real case of the thing that you were just mentioning, wouldn't it?

A I think that would be a kind of unusual process for the water not to -- you know, nucleated water -- bear in mind, though, there is a difference between tritium binding to a particle, as we originally discussed, and this concept of nucleation having a water droplet with this tiny particulate in the center. There's a difference in the nature of the characterization of nucleated water and binding of tritium into a particle.

We are using the term nucleation as if it had the

mgc 15-2

same definition we used earlier --

Q No, it is not.

A All right. I want to make sure that's clear.

Q Yes, I agree with you. And what I was getting at is a point I think you are partly raising in your last answer, and that is, I had understood Dr. Schaffer to be saying that really as the water droplet moves away from the plant, whether it's nucleated around the particle or not, it's going to be undergoing some exchange with atmospheric water.

Is that what you were saying?

A (Witness Schaffer) That's what I was saying.

Q Okay. So now again the question I was trying to get at before is, would there be any difference in this process that depended just on having nucleated together a larger droplet as you came by the plant, by virtue of having this coal particulate there.

MS. BAUSER: Objection. I don't understand the question, and I also am not sure if I understand its relevance. I may simply not understand what he's driving at. But it seems to me that what he's talking about is tritium unattached particles. That is outside the scope of this contention. And maybe he's using that as a way to understand interaction with the particle. I'm just not sure.

mgc 15-3

MR. EDDLEMAN: Well, as I understood the calculation Judge Carpenter asked for, that assumed just dispersion of the tritium without regard to particles, and I think I went through that with him.

And then what I'm trying to get at is, if you come by the plant with a particle and it interacts with this tritiated water coming out, the only effect I can see of having a particle there is, it wouldn't happen if there's no particle, is this nucleation of droplets. When you nucleate the droplet, it makes a bigger droplet, and my question is, what effect does this have?

We're going to get back in to surface-to-volume ratio if we go into this.

What effect does this have on the exchange of the tritium in that droplet with the other water in the atmosphere? That's where I'm going. It could conceivably be delivering a higher specific activity of tritium, because it had a particle associated with it, because it nucleated a bigger droplet which doesn't interact as much with the environment. That's where I'm going to go, you know, to the extent that these gentlemen answer whatever they will.

MS. MOORE: Your Honor, I'd like to interpose an objection at this point. I would object on the grounds of the relevance of this line of questioning to the contention. Relevance is not readily apparent.

mgc 15-4

JUDGE KELLEY: Are you essentially joining -- Ms. Bauser, were you satisfied with Mr. Eddleman's explanation?

MS. BAUSER: I'm afraid I cannot follow his explanation. I'm not sure why this information would tell him anything more about this contention. I just don't follow his explanation.

JUDGE KELLEY: How do you tie it to the contention, Mr. Eddleman?

MR. EDDLEMAN: Well, I think as we were going through this stuff before, we established that to the extent -- at the extent to which tritiated water adhering to particles might increase the amount of tritium deposited in the lung, that hadn't been taken into account in these gentlemen's analysis.

I then believe that Judge Carpenter asked what may have been intended -- I don't want to presume -- but as a kind of a bounding question about that, which is basically, what if all the tritium that's on the loose in the environment comes into equilibrium with your body? What kind of dose do you get?

What I'm getting at is, there may be a way that the particulates can deliver a higher dose than that by delivering or by causing water droplets with higher specific activity in them to get into people's lungs. That's

mgc 15-5

where I'm going.

JUDGE KELLEY: Maybe I am way back in the dust, but did we establish that the tritium is conveyed by particles? I thought tritium was out of the picture, and it was 98 percent of what was to be worried about, and that it wouldn't go with particles or adhere to particles, be adsorbed by particles.

MR. EDDLEMAN: They said that didn't have anything to do with that, but I challenge that, and I think I got them to admit that it could be associated with the particles. The record will speak for itself, but I have been going into that question.

MS. BAUSER: I object. Mr. Eddleman mischaracterized the witness' testimony. He said they did not take it into account. They did take it into account. They just rejected it as a viable mechanism for increasing the dose to the lung.

He then wants us to proceed on the hypothetical, which they don't agree with to begin with, in order to -- and I'm not sure that that's proving another hypothetical.

But I just think we are removed from the substance of their testimony.

JUDGE KELLEY: Excuse me a minute.

MR. EDDLEMAN: Judge, I'm not hypothesizing. I've been challenging their judgment as to the viability

mgc 15-6

of the mechanism. That's all I wanted to say.

(The Board confers.)

JUDGE FOREMAN: It might be relevant, but I think it's trivial.

JUDGE CARPENTER: I do believe that Mr. Eddleman is pursuing intellectually a line that derives from the question that I asked, and he is going to come perhaps in a little while to the words "rate of exchange." We might begin there again, if that is where you are going or not.

JUDGE KELLEY: Well, can you restate the question? That's where we always end up on these judgments.

MR. EDDLEMAN: Judge, I'm sorry. I think I may have lost it in my memory. Let me see if I can dredge my memory, rather than forcing the court reporter to go back.

JUDGE KELLEY: Yes. That's kind of hard to do.

MR. EDDLEMAN: Okay.

BY MR. EDDLEMAN:

Q Well, let me start to lay this out. I think I can do it quicker than trying to remember the whole question.

JUDGE KELLEY: Please do.

BY MR. EDDLEMAN:

Q Doctors, when the tritium is released from the Harris plant stack, it comes out as both the water vapor and possible water droplets, does it not?

A (Witness Mauro) That's correct.

mgc 15-7

Q Okay. Now when droplets nucleate on a particle, they simply merge themselves, do they not -- that is, they have a common surface now instead of two separate surfaces?

A Yes, that's what I understand to be the nucleation process.

Q And typically, surface tension would make a small droplet tend to be more or less spherical in shape, would it not?

A Yes, sir.

Q Now if, therefore, a nucleation process brings, say -- I'm going to use eight droplets of exactly the same size as a hypothetical example to illustrate -- if I have eight droplets, say, of 1 micron in diameter, and somehow they all get nucleated together, perhaps all on a coal particulate of a very small size, now I have the equivalent volume of one droplet of 2 microns diameter, do I not?

A Okay.

Q That's correct?

A Yes.

Q All right. Now but having gotten eight -- well, the surface of a sphere is proportional to two-thirds the power of its volume, isn't it?

A The surface area of a sphere, 4 pi r^2?

Q Right. And the volume is proportional to r^3, is it not?

mgc 15-8

A That's right.

Q So we can say that the area is proportional to the 2/3 power of the volume, can we not?

A Okay, yes.

Q I can draw it out for you.

A I will go with that. Yes.

Q All right. Now having increased the volume by a factor of 8, which happens to be 2^3, which is why I picked that number, we therefore have only increased the surface area by something proportional to the 2/3 power of that, which is 4, correct?

A Could we back up. You are going through the mathematics in your head, and you are asking me to agree with you.

Q Can I draw it out for you on the board? Is that acceptable?

JUDGE KELLEY: Have we ever gotten back to your objection? I mean, the question you are objecting to, are we still working up to that?

MS. BAUSER: He's going into a completely different area now.

MR. EDDLEMAN: No. We're getting right back to that question.

JUDGE CARPENTER: Excuse me, Mr. Eddleman. I interrupted you. You were asking about tritium water vapor

mgc 15-9

emerging from the stack, encountering particles and the subsequent events. You were right there, and that's when the objection came.

Could we go back to that?

MR. EDDLEMAN: Okay. Well, what I thought I was doing was starting with the tritiated water coming out of the stack and allowing it to nucleate around a particle. It encounters the particle and it nucleates water vapor around it. It forms a droplet.

And I think we established or I was trying to establish that it then will form a bigger droplet than it would in the absence of this nucleation phenomenon, and then that bigger droplet has a smaller surface area in relation to its volume than do the independent smaller droplets.

JUDGE CARPENTER: Stop. That's the point intellectually where the objection occurred.

JUDGE KELLEY: Is it established also that tritium in vapor form does that -- namely, nucleates around the particle? Has that been established?

MR. EDDLEMAN: Judge, I can't testify, but let me ask them.

BY MR. EDDLEMAN:

Q Does tritiated water behave generally physically like regular water?

A (Witness Mauro) It will behave virtually

mgc 15-10

exactly like water. It will evaporate and recondense and evaporate and recondense and disperse, as would water vapor.

Q And hypothetically, since you said you don't really know for sure, should ordinary water vapor display this sort of nucleation phenomenon around small particles? Tritiated water vapor you would expect to display the same phenomenon?

A That's correct.

JUDGE KELLEY: So perhaps I misunderstood what you said on pages 4 and 5. I thought you, in effect, said you don't worry about tritium in this calculation, right?

WITNESS MAURO: It's not behaving as a particle. If you would, I would like to explain that.

JUDGE KELLEY: I thought -- when I read your testimony, I thought tritium was out of the picture entirely, as far as you were concerned, and if we're talking about it now, there must be some reason we are talking about it. What is the reason?

WITNESS MAURO: I believe the reason we're talking about it is, Mr. Eddleman believe that once the tritium is associated or nucleated around the particle, upon inhalation it will behave as a particle and stay lodged in the lung like a small insoluble piece of particle.

But it won't do that. It is water vapor. And

mgc 15-11

when it is absorbed or when it's inhaled, it will be immediately absorbed into the body fluids. For that reason, we did not treat it as a particle. We treated it as water vapor that does not move through the body as a particle would. It is not phagocytized as a particle would be. It is not cleared with the 120-day halflife as we described, as a particle would. It's absorbed whether it comes in as water vapor nucleated around a particle or it's just a vapor as atoms. When taken into the body, it's rapidly absorbed. It does not behave as a particle would behave.

So for that reason, we almost set it aside.

JUDGE KELLEY: I thought you did set it aside. If I accept your testimony, why should I worry about nucleation of tritium in vapor form around particles? Why shouldn't I just dismiss it?

WITNESS SCHAFFER: I think that's the point.

MR. EDDLEMAN: Judge, I don't want to get into a dispute with the witnesses. They are discussing one of the other points I raised about the tritium, which is, what if it's associated with a particle when it gets into the lung? This point is a challenge to their assumption that you are not going to increase the amount of tritium that comes into the body by having particulates on the loose.

That's where this ties in. It's a different question.

mgc 15-12

JUDGE KELLEY: But if they are right, and once it gets into the body, it takes a quick trip through and disappears, what difference does it make?

MR. EDDLEMAN: Well, Judge, the more that you put in -- the quick trip through and disappearing only applies if it comes in, as I take it, in the vapor phase. I believe they testified that if it came in as water, it would be mixed with bodily fluids and therefore three quarters of it was assumed to be absorbed into the body fluids. And therefore if more tritium comes in with the water, then -- in other words, if a higher dose of tritium is delivered in the water that is brought into the body, because these particulates, by nucleating larger droplets, are carrying out water with a higher specific activity from around the plant, then you are delivering a higher dose -- I mean, a higher amount of tritium into the lung, and three quarters of that is assumed to stay in the body by their calculations. So their numbers would be low.

MS. BAUSER: Mr. Chairman, this has nothing whatsoever to do with Contention II(e), which is talking only about radionuclides adsorbing or attaching to fly ash, and through that mechanism increasing the dose to the lung. And this is not --

JUDGE KELLEY: The particle that you refer to, is that fly ash?

mgc 15-13

MR. EDDLEMAN: Yes, Judge.

MS. BAUSER: But he's trying to get an increased quantity coming into the body. The question is whether that increased quantity, assuming even that it exists in the first place, can in effect be a challenge to the concentration models, because it means that the concentration models do not take into account radionuclides absorbed in or attached to fly ash, which means that the necessary element of it has to be that that increase attaches to particles which somehow stay in the lung.

Without that element to it, it's not relevant.

JUDGE KELLEY: If I follow this, and I'm not at all sure I do, you get these agglomerations of water vapor with tritium in it, and they somehow form around a piece of fly ash, right? The fly ash is what -- inhaled?

MR. EDDLEMAN: The whole droplet.

JUDGE KELLEY: The whole thing is inhaled -- fly ash, tritium, water and all that is inhaled, and then you say that three-quarters of that stays in the body?

MR. EDDLEMAN: That's what they say.

JUDGE KELLEY: Is that --

JUDGE FOREMAN: I hate to intervene, but I think I can help clear this up.

Why don't you ask the question again, if you haven't asked it, is it likely that tritium associated

mgc 15-14

with fly ash can come in with a higher specific activity than if the tritium, the same amount of tritium, came in not associated with fly ash? That would be one question on the way.

MR. EDDLEMAN: Judge, that's not quite the question I would ask.

JUDGE FOREMAN: I thought I would be helpful.

JUDGE KELLEY: Let's ask it anyway.

MR. EDDLEMAN: If you gentlemen will anwer the Judge's question.

WITNESS MAURO: It would not change. The association of the tritium and fine particulate that is somehow wedded, as opposed to a molecule, we would still model atmospheric the same way as we would apply the atmospheric dispersion factor, because the atmospheric dispersion factor applies equally to gases or suspended particulate material. So we would not change the way in which we model the dispersion of the source term, and as a result, the specific activity would remain unchanged.

MR. EDDLEMAN: Now he set up the question I want to ask.

JUDGE KELLEY: Can I come back with my little one? The three-quarters that stay in the body -- and you say that things like tritium are immediately exhaled or absorbed into body fluids, but it doesn't stay there very long,

mgc 15-15

does it? Isn't that extreme?

WITNESS MAURO: It is absorbed immediately throughout the body, and then the body eliminates it with a halflife of about ten days. So it does build up, and it builds up and reaches a level that corresponds to a 10-day effective halflife.

JUDGE KELLEY: So it's not excreted?

WITNESS MAURO: Not immediately, no.

JUDGE KELLY: It's in the body for some period of time.

WITNESS MAURO: Yes.

JUDGE KELLEY: And if this mechanism that Mr. Eddleman is talking about did occur then, couldn't the fly ash which forms the core of this expanded mass of water and tritium deliver more into the body and raise the dose?

WITNESS MAURO: No.

JUDGE KELLEY: No? Why not?

WITNESS MAURO: We didn't even look at the behavior of the tritium in the atmosphere. It's going to disperse according to the atmospheric dispersion, whether it's on particles or not. It's going to disperse the same way.

In other words, picture -- to visualize it, perhaps picture the tritium water vapor leaving the plant

mgc 15-16

stack, and in one case it stays as vapor, not associated in any way with any type of particle. Then we apply our atmospheric dispersion factor. We calculate a standard Gaussian distribution, and it will move it out and open it up.

Then let's step back to the stack again and say, okay, now let's assume that for some reason it is affiliated somehow with some kind of particulate material. I wouldn't change the way in which I disperse that either. Each one of those little particles will disperse out in the same fashion.

The only thing that could possibly occur is, if you wanted to postulate that you had very large droplets formed to the point that it actually falls out, and if that were to occur, if you wanted to presume that occurred, that would lower the specific activity at the point of exposure of the individual.

JUDGE KELLEY: Why?

WITNESS MAURO: Because it wouldn't be airborne. It would have condensed out.

MR. EDDLEMAN: Judge, if I may, I want to ask him about my fourth alternative to this. Let me go back and ask my version of Judge Foreman's question, if I may.

JUDGE KELLEY: You may provoke an objection, but go ahead.

mgc 15-17

MR. EDDLEMAN: Okay. If they want to object, that's up to them.

BY MR. EDDLEMAN:

Q My question is, if it were so that water vapor nucleated around coal particulates that pass by the Shearon Harris stack as this tritium is released at a higher specific activity of tritium associated with it as they move out through the atmosphere, then would just ordinary tritium vapor, tritiated water vapor -- pardon me -- diffusing from the stack -- couldn't that deliver a higher dose to the lungs of somebody who breathed those droplets in?

A (Witness Mauro) No, because those droplets will also disperse. So to perhaps to help out here, perhaps that particular droplet, to follow your line, has a higher specific activity, but then some other droplet nearby does not have any tritium. And what you inhale is not a -- it is both that come in. So in effect, it doesn't have any effect. So what you are really saying is, let's put a little more activity on one of these droplets. But that means at the same time you are putting less someplace else, and when you inhale, no distinction is made between the two.

So the net effect is that the total quantity of tritium inhaled is the same.

Q But doesn't that assume that you are going to have the same dispersion in all directions? For example, that

mgc 15-18

doesn't take into account that you might have a higher concentration of particulates coming by the Harris plant from a certain direction, like the direction of the Cape Fear coal plant, for example.

MS. BAUSER: Objection.

JUDGE KELLEY: Finish the question. And then I have an objection.

Do you want to state it?

MS. BAUSER: I'm sorry. I was objecting to his challenging the dispersion models that we used, which I understood to be the nature of his question.

MR. EDDLEMAN: Well, let me ask it without saying "dispersion," then.

JUDGE KELLEY: All right.

BY MR. EDDLEMAN:

S2BU

Q In this last answer that you gave, Doctor, do you take into account whether there might be some preferred direction from which coal particles come by the Harris plant and pick up tritium, and whether they would tend to carry more tritium in that direction?

16pb1

A No, sir.

Q Do you know what the closest coal-fired power plant stack at the Shearon Harris site is, either of you?

A (Witness Schaffer) Cape Fear's units I think are 9 and 10. They are about 12 miles slightly southwest of the plant on the Cape Fear River.

Q Could that be Cape Fear Units 5 and 6 perhaps?

A I'm not sure.

Q Okay, but two Cape Fear units are over there about 12 miles slightly southwest of the plant. Slightly southwest?

A Slightly southwest. It's not directly south, it's over to the west side.

Q Now let me try to be clear on this, are you saying, here you have south this way and west 90 degrees away from it. Southwest right between. Now are we talking in a direction that's more nearly south than southwest, or more nearly west than southwest?

A More nearly south.

JUDGE KELLEY: South-southwest.

BY MR. EDDLEMAN:

Q Are you gentleman familiar with the wind rows

16pb2

around the Harris plant? Directions of the winds?

A (Witness Mauro) If I recall it's fairly uniform. But there is a predominant wind coming out of the southerly areas. That's my recollection of the general direction of the wind at the site, but it's fairly uniform.

Q If I may, I may be doing something improper here and you could just stop me, but let me ask the Staff, is that wind rows anywhere in the final environmental statement, do you know?

MS. MOORE: That is something that's a little bit improper, Your Honor. There is no Staff witness on the stand at the moment .

JUDGE KELLEY: Well, that's true. The FES is in evidence. You could ask for a recess and we'd all go look for it. I don't know.

MS. MOORE: Mr. Eddleman has had the FES and should be prepared for this cross-examination.

MR. EDDLEMAN: I will withdraw it.

MS. BAUSER: I have a question.

Based on Mr. Edleman's interrogatory answers to us, We did not understand his analysis to be focused on coal releases from plants in the particular vicinity of the Harris plant. Quite the contrary.

MR. EDDLEMAN: Well, they asked me a question, and this may be probably literally answering a question, they

16pb3

asked me, are you focused on one specific plant where these particles come from. And I said, no, particles come from any plant. But I didn't mean by that to exclude a specific plant, but rather to include all the other plants from which particles might come.

JUDGE KELLEY: Which question did you withdraw?

MR. EDDLEMAN: The one to the Staff about the FES. I can look at it.

JUDGE KELLEY: All right. So you have a pending question?

MR. EDDLEMAN: I don't believe so. I think they had answered that the prevailing winds come out of the south, as to the Harris plant.

JUDGE KELLEY: All right. Go ahead.

BY MR. EDDLEMAN:

Q You just testified that there is a coal-fired power plant located about 12 miles in that direction, did you not?

A (Witness Schaffer) Yes.

A (Witness Mauro) Yes.

Q Do you have any idea what the height of the stack on the Cape Fear plant is, as compared to -- well, let me say elevation of the stack above sea level of Cape Fear plant, compared to the elevation of the stack above sea level at the Harris plant?

16pb4

A I could only speculate.

Q Well, Doctor, do you know?

A I just know stack heights for coal burning plants are typically quite a bit higher. But that's about as far as I could go.

Q So to make this comparison, we'd have to know not only the heights of the stacks, but also the elevation above sea level at which each plant sits, wouldn't we?

A That's correct.

Q Okay.

MR. EDDLEMAN: If we're coming up for a break, this is as good a point for me to stop as any.

JUDGE KELLEY: Well, we've only been back about 40 minutes. I'm not saying we can't break now. How do other counsel feel about it?

MS. BAUSER: We would just as soon continue.

JUDGE KELLEY: Ms. Moore?

MS. MOORE: I think we should still continue.

JUDGE KELLEY: Can you go on?

MR. EDDLEMAN: I'm going to have a physical difficulty in a minute, Judge.

JUDGE KELLEY: All right. In that case, why don't we just make it five minutes.

(Recess.)

17pbl

JUDGE KELLEY: We are back on the record and will resume cross-examination.

BY MR. EDDLEMAN:

Q Gentlemen, I want to go back to -- we established that we had a source of coal particulates rather in the upwind direction of the Shearon Harris plant within about 12 miles of it, didn't we --

A (Witness Mauro) Yes.

Q Namely the Cape Fear plant, coal plant.

A Yes.

Q Do you gentlemen know what other power plants might be located in that general direction from Harris that produce particulate loading around Harris?

A (Witness Schaffer) No.

A (Witness Mauro) No.

Q Okay. Now I want to turn back to this question of specific activity of these droplets. If droplets of -- well, the tritiated water that comes out of the stack I think we agreed had a higher specific activity than that you assumed in the calculation you made for Judge Carpenter; isn't that right.

A Yes. I didn't do the calculations but I think that's a safe assumption. That is, you would expect to have higher specific activity at the point of release than after dispersion in the environment.

17pk2

Q All right. So if you have a vapor and it's being dispersed in the environment, it's fairly straightforward how the specific activity goes down, isn't it? That is, the vapor is simply getting out farther from the plant where there is more and more vapor which is not tritiated.

A That's correct.

Q Okay. And I took it from your earlier answers to say, well, suppose you're dispersing a particle from around the plant, that it is going out into an area where there are fewer and fewer particles relatively speaking which have tritiated water on them.

A That's correct.

Q Okay. Isn't it also true though that if you have a tritiated water particle moving out away from the plant, it's exchanging water vapor with the atmosphere. That is, there's an equilibrium between the droplet surface and the atmosphere for the water. That's true for a water droplet, isn't it?

A I'm sorry. Could you repeat the question?

Q Isn't it true that a water droplet containing tritiated water at the surface of the droplet is an equilibrium with the water vapor in the atmosphere surrounding it?

A Yes, I would expect that.

Q And you would expect that on the basis of your knowledge of physics and chemistry?

A Yes, sir.

Q Okay. If a certain volume of tritiated water were inside a relatively smaller surface, then it would have less exchange of water vapor with the atmosphere surrounding it, wouldn't it?

A If it had a smaller surface area?

Q All other conditions being equal. That is, you take at the same temperature, pressure, and concentration of tritium droplets, and also same concentration of tritium in the air around the droplet are virtually the same, you'd have more exchange through a larger surface area, would you not?

A The larger the surface area the greater the total exchange. That's correct.

Q And conversely then, the smaller the surface area in which a given volume of tritiated water were confined, the smaller the exchange would be.

A That's correct, everything else being equal.

Q And we've established, have we not, that the nucleation phenomenon leads to a reduction in the surface area of a given volume of tritiated water if that tritiated water is coming out as droplets from the power plant stack.

A The nucleation process does what?

Q Reduces the surface area of a given volume, a certain volume of tritiated water released from the Harris

plant stack. That is, if you take the particles coming out of the plant stack, tritiated water droplets, okay? And you nucleate them, Doctor, don't you end up with the tritiated water confined in a smaller surface than if those droplets had not been nucleated?

A Yes, sir.

Q Okay. I guess that's all I have on that point. Let me turn in your testimony again, gentlemen --

JUDGE CARPENTER: Mr. Eddleman, I'd like to ask one more question. Mr. Eddleman has been asking you a series of questions of quality. Can you help the Board in a quantitative sense? The Board hasn't had a chance to study the record, but assuming -- could you tell me what the difference in time to come to equilibrium would be as a function of particle size over a range of realistic water vapor particles?

The line of questioning now has gone into the gas phase, the nucleation and/or adsorption on the particle. And then the question about specific activity. And the line of questioning has not included the element of time as the particles moves from the point of origin.

WITNESS MAURO: I think one of the things that is happening, if you'll bear with me for a minute is we are going into a microscopic ground while we're dealing with dose, which is a macroscopic phenomenon. The tritiated water

vapor as it leaves, whether it's on the very, very small or very large will disperse in the atmosphere. And the results of the certain concentration at the site, at the location where people are residing. And the question becomes, will that concentration change depending on some of the processes that Mr. Eddleman has been referring to. And the answer is no.

The concentrations will remain primarily the same because the vapor or vapor associated with the particle would disperse in the atmosphere in a similar fashion. The concentration at the point of the receptor doesn't change which means that the total quantity of tritium inhaled per unit time doesn't change.

So I guess I feel as if we are looking at, we're going into this fine structure of the behavior of these microscopic particles, but it really has no bearing on how it's going to influence the concentration of the radionuclide at the point of exposure.

And to get back to the time question then, you were referring to like a rate constant. How quickly does -- as I understood it -- does the tritiated --

JUDGE CARPENTER: No, I misspoke if that's what I said. You said by the time it reaches people it will have a certain value, and I asked you about time. And that is all I meant to do, and I would stop questioning at this point.

Mr. Eddleman?

BY MR. EDDLEMAN:

Q First, isn't it true that the maximum exposed site is located somewhat to the northeast of the Shearon Harris plant?

A (Witness Schaffer) Yes.

A (Witness Mauro) Yes.

Q So that a wind blowing out of the slightly to the west of south will go somewhat in that direction, wouldn't it?

A That's correct.

Q Basically in that direction.

A That's correct.

Q Let me ask you this, have either of you conducted any study or made any calculation of the time it takes for the specific activity of tritium in water released from the Harris plant to get from whatever level it is at the stack to the level that you assumed in the calculation that you made for Judge Carpenter about coming into equilibrium with the tritium around one's self?

A It's basically the time it takes for the release to reach the receptor, assuming an average wind speed of about five meters per second, which is probably representative. And we're talking a distance on the order or 1.7 kilometers, or 1.7 miles -- hold on a second.

(Pause.)

A It would take on the order of an hour or so at that wind speed for the plume to reach the receptor located at the site boundary.

Q All right. Now I think you already said that you didn't know exactly what the specific --

A I'm sorry, it's not an hour. On the order of a minute. Hold on a second. About ten minutes.

Q Okay. I believe you already said that you didn't know exactly what the specific activity of the tritium released from the Harris stack was at the stack but you could look it up.

A Yes, sir. But bear in mind, that would not influence the way in which we calculated our doses.

Q Well, how did you get the specific activity to change? Is it simply because there's more other water vapor around the site that you're looking at?

A In our calculation that's in our testimony we calculated the dose to any organ in the whole body from the inhalation of tritium. We did not use the specific activity approach.

Q But you used it in the calculation you made for Judge Carpenter.

A Yes, sir. Now with regard to Judge Carpenter's calculation, we did use a specific activity approach. What

we basically did was to calculate what we expected to the concentration of tritium in the air per cubic meter at the location of the nearest resident, or at the site boundary and got a number expressed in units of microcuries per cubic meter. Then we said, okay, that's the tritium in the air, and we also know there's approximately eight grams per cubic meter of water vapor in the air. That's a typical number.

And as a result we got a concentration of tritium specific activity at that point of on the order of 10^{-11} curies per gram. Then we assumed that a person living there at that location for some reason, which really cannot happen achieved equilibrium. That is, his specific activity curies per gram is the same as this water.

And that is how we came up with our calculation. So, in effect, we are assuming that the microcuries per cubic meter commingles uniformly with the stable water, eight grams that's in the atmosphere at the same location.

Q You've assumed --

JUDGE CARPENTER: Just a moment. I believe the witness misspoke during the course of that. He made reference to Judge Carpenter's calculation. I have made no calculation. It was a slip of the tongue.

MR. EDDLEMAN: You meant the calculation that you made in response to Judge Carpenter's questions, didn't you?

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JUDGE CARPENTER: Just a moment. I believe the witness misspoke during the course of that. He made reference to Judge Carpenter's calculation. I have made no calculation. It was a slip of the tongue.

MR. EDDLEMAN: You meant the calculation that you made in response to Judge Carpenter's questions, didn't you?

WITNESS MAURO: Yes, that's correct.

MR. EDDLEMAN: Judge, do you have something further on that?

BY MR. EDDLEMAN:

Q In the calculation that you made for the judge then, you're saying you effectively assumed that the tritium is dispersed as a gas would be dispersed from the stack. And then, having been dispersed to the site that you're looking at, you take that as a fraction -- that tritium that is present per cubic meter at the site as a fraction of the water vapor present in the air at that site, which you take to be eight grams per cubic meter, did you not?

A (Witness Mauro) That's correct.

Q If there were a mechanism whereby more of the tritiated water carrying its specific activity as it came out of the stack came in that direction, there would be more tritium in the air around that site, wouldn't there?

A Excuse me? Could you repeat that again?

Q If there were a mechanism whereby more of the water at the specific -- tritiated water at the specific activity that comes out of the Harris stack were carried in the direction of the site, that would increase the amount of tritium, concentration of tritium in the air at that point, wouldn't it?

MS. BAUSER: Objection, Your Honor. More than

what? I think that's an incomplete hypothetical.

MR. EDDLEMAN: Compared to the method he just described in his last answer.

WITNESS MAURO: You're saying, if the tritium did not disperse the way I assumed it dispersed?

BY MR EDDLEMAN:

Q Well --

A (Witness Mauro) Would the concentration be higher? Yes, if I assumed the higher atmospheric dispersion factor for my tritium in doing my calculation, yes. The concentration of tritium at the point receptor location would go up. Yes, the concentration is directly -- the calculated concentration is directly related to the assumed atmospheric dispersion factor.

Q And if in fact there were a transport mechanism that did not disperse the tritium the way it disperses as a gas, but brought some tritiated water with higher specific activity directly to this site in about ten minutes, which is how long you said it takes the wind to get there, then you have a higher concentration of tritium around that site, wouldn't you?

MS. BAUSER: I'm going to object. I think, first of all, we are way off from the subject of the contention. Second, we're challenging the dispersion model which is not at issue here, at all. And Mr. Eddleman has postulated a

hypothetical without any foundation whatsoever.

MR. EDDLEMAN: Judge, the foundation of the hypothetical is all that stuff I went through them about the direction of the Cape Fear plant and nucleating water and so on, water with higher specific activity. I'm just challenging his answer. He says it's tied to dispersion. I say, maybe it's not.

JUDGE KELLEY: Would you also repeat the question?

BY MR. EDDLEMAN:

Q If you had a mechanism bringing tritiated water with a higher specific activity over about a ten-minute flow time or moving time in the wind from the Harris plant to the site of concern that we are dealing with here, wouldn't that produce a higher concentration of tritium around that site of concern?

MS. MOORE: Objection, Your Honor. I would like to join Ms. Bauser. I believe it's incumbent upon Mr. Eddleman at this point, since he is attempting to establish a hypothetical to show that there is such a mechanism in existence. And not require the witnesses to speculate.

MR. EDDLEMAN: I think I've already gotten the witnesses to say that such a mechanism exists.

MS. MOORE: I never heard it if you did.

JUDGE KELLEY: As I understand your question, it keys to this nearby coal plant to the south-southwest of

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the site. Is that right?

MR. EDDLEMAN: Yes, because that's the only one they knew about.

JUDGE KELLEY: Well, okay.

Ms. Bauser, are you saying it's outside the scope? I gather you are.

MS. BAUSER: I don't think his assumption, in fact, ties to the existence of the coal plant, although he's claiming it does. I think if he were to ask the witnesses how the existence of a coal plant there might affect the calculation I would not have an objection. That seems to be his assumed foundation. I don't think that is, in fact, a foundation for a hypothetical like this.

If he wants to go ahead and try to lay the foundation, I have no objection.

JUDGE KELLEY: Do you intend to tie the line of questioning to the existence of this particular plant?

MR. EDDLEMAN: Well, as I saw it, the mechanism that does this -- it depends on the answers to a lot of questions, because I've had to go through it step by step.

The coal plant is down there in the direction. It is upwind, not only of the Harris plant, but also the site of concern. The wind blows from the coal plant past the Harris plant, toward the site where the maximum deposition of these nuclides is, you know, the closest people.

That's the site that was used in the calculations here.

And I think that's both in the calculations in the testimony and the in the calculations made for Judge Carpenter, that that same site was used as the place of maximum exposure. Is that not correct?

WITNESS MAURO: That's correct.

BY MR. EDDLEMAN:

Q So, we've gone through all this stuff about nucleation and the fact that the specific activity, pardon me, is higher at the plant stack. I guess maybe I do need to go through one other thing which is the question of coming to equilibrium of the specific activity in a droplet in ten minutes.

Maybe that's the best thing to ask, if I'm going to have to lay a better foundation. Let me ask you, if you have a droplet at the specific activity that comes out of the plant stack, in ten minutes of interaction with the atmosphere, assuming that that droplet were in a size range around, let's say 100 microns or under, would either of you be able to calculate or estimate how much that specific activity would drop off or come toward equilibrium with the air around it?

MS. MOORE: Excuse me, Your Honor. There's an objection pending.

JUDGE KELLEY: I thought there was an objection

to a different question, and we are now feeling our way in a somewhat different direction, I believe.

MR. EDDLEMAN: That's right. Ms. Bauser said if I could lay a foundation then she wouldn't object. So I'm trying to lay a foundation.

JUDGE KELLEY: This line of questioning then is going to raise questions about their model and their conclusions as it relates to this coal plant to the south-southwest; is that right?

MR. EDDLEMAN: Among other things, yes, Judge.

JUDGE KELLEY: Well, your objection as I understood it is that it was a hypothetical not tied to anything, right?

MS. BAUSER: Well, I'm a little confused I have to confess. Originally Mr. Eddleman asked the witnesses, I believe, whether if he made some different assumptions about dispersion that that would change the dose received at the site boundary in that case.

JUDGE KELLEY: Site boundary?

MS. BAUSER: I think the maximum location that they had analyzed. And they said, yes. He then switched gears and I'm not sure where he is right now.

MS. MOORE: Your Honor, I believe the Staff's objection to the same line of questioning was that Mr. Eddleman had hypothesized a transport mechanism and hadn't defined the transport mechanism. It's unclear to me that

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the mere existence of a coal plant is an alternate transport mechanism than the one assumed in the testimony.

MR. EDDLEMAN: Judge, if I may comment. It's not the mere existence, it's that whole of questioning I went through with them about those coal particulates can produce nucleation of the tritiated water droplets.

JUDGE KELLEY: Ms. Moore, let me be clear. You say that there is one transport mechanism assumed in the testimony and now we're getting into a different one?

MS. MOORE: As I understood it, that was Mr. Eddleman's hypothetical.

JUDGE KELLEY: Well, it's not entirely hypothetical. He's found a coal plant to the south-southwest. Right? You're talking about the wind blowing past the plant -- from the plant in the south-southwest. And the wind rows indicates that the wind blows in that direction up over the Harris stack and on over to this other spot where there's maximum deposition, right?

MR. EDDLEMAN: That's right.

JUDGE KELLEY: That's in the real world, more or less.

MR. EDDLEMAN: Yes, they say so.

JUDGE KELLEY: What's the problem with that?

MS. BAUSER: I don't have an objection. They have a discussion in their testimony about the size particle

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that they assume for the area around the plant. And why they assumed that. Mr. Eddleman now appears to be questioning that. If he wants to ask them and say if he can lay a foundation for the assumptions he then wants to draw, I don't have any problem.

I haven't heard him doing that. That's my only problem.

JUDGE KELLEY: Maybe just for my sake at least, in your testimony here, when you talk about fly ash and deposition and doses, did you assume any particular coal plants?

WITNESS MAURO: No, sir. We assumed particle sizes based on our analysis of what the particle size distribution. We assumed they are all fine particulates, which we felt to be quite a conservative assumption.

JUDGE KELLEY: But you didn't do, if I may call it that, a site-specific study in the sense of coming down here and trapping samples?

WITNESS MAURO: No, sir.

JUDGE KELLEY: But that's what you're asking about, right?

end 17

mgc 18-1

drop

MR. EDDLEMAN: Well, they use that assumption about the fine particulates more without respect to tritium, and what I'm trying to do is tie in a particulate effect on tritium dose delivered to that site, or tritium concentrations delivered to that site of concern. That's what I'm trying to do. It's a little bit different.

JUDGE KELLEY: Gentlemen?

JUDGE CARPENTER: I would like to hear the answer.

JUDGE FOREMAN: I would also.

JUDGE KELLEY: Go ahead, Mr. Eddleman, subject to the possibility of being stopped. Go ahead.

BY MR. EDDLEMAN:

Q Again, I've been thrown a little bit off, so I'm not quite sure where I was.

Gentlemen, if -- I think I was asking you if you could calculate or quantify -- let me lay this out in a few steps, if I may.

First, we have a higher specific activity of tritium in the water vapor that's released from the stack than we do in the surrounding ambient water vapor that hasn't come through the Harris plant, don't we?

A (Witness Mauro) Yes, sir.

Q Now as that triated water vapor and tritiated water droplets -- well, we established also, didn't we,

mgc 18-2

that triated water vapor and tritiated water vapor -- pardon me -- triated water vapor and tritiated water droplets would be released from the stack, didn't we?

A Yes, sir.

Q Now as the droplets move away from the plant, they physically disperse. That's what you've been talking about.

A That's correct.

Q Okay. Do they not also exchange water vapor with the atmosphere through their surfaces?

A You would expect so, yes.

Q Okay. Now given that we have a source of particles upwind of the Harris plant, which particles can nucleate those tritiated water droplets to make them have a larger surface in relation to their volume, then those larger droplets also will be exchanging water molecules with the air through their surfaces, will they not?

A It's quite likely, yes.

Q Okay. And if those droplets of nucleated tritiated water then move from the Harris plant toward the site of concern, two mechanisms will be reducing the specific activity of tritium that might be picked up from those droplets at the site -- namely, first dispersion of the droplets themselves, and second, exchange of water molecules with the atmosphere while they are moving from

mgc 18-3

the Harris plant to the site of concern; isn't that so?

A That's correct.

Q Let me ask you another thing. It's true, isn't it, that a plume can have a good bit more coherence than just pure Gaussian dispersion from a point, can't it?

A In general, assuming that a plume behaves as a Gaussian, and it's dispersion properties are fairly conservative, it's been shown that because of terrain factors, Gaussian treatment of dispersion is a conservative way to treat. So if you calculate concentration offsite using the Gaussian model, as we have, it tends to overestimate the concentration as opposed to underestimate.

So the answer to your question, I would say is, regarding the coherence, we probably have overestimated the amount of coherence going on within the plume.

Q All right. Well, regardless of the coherence of the plume, you have the other mechanism of reducing a specific activity of that tritiated water, which is exchanged water molecules with atmosphere, do you not?

A Yes, sir, but that's not part of our model. We just took credit for the fact that the water vapor will disperse in the atmosphere according to Gaussian principles, and the rate of exchange of existing water vapor is not part of the calculation. So in the end, the concentration, the specific activity concentration at the point is

mgc 18-4

transparent to all of the processes that you have been referring to.

Q Does Gaussian dispersion happen at the same rate for particles of different weights or sizes?

A In general, when you are dealing with smaller particles, there isn't very much deposition occurring. That is, when particles are on the order of one or two microns, they will behave almost as if they are airborne as a gas. Particles, as they start to get larger, they will settle out, and therefore you will deplete your plume, thereby reducing the concentration.

When we deal with tritium, we do not take credit for depeletion. And at that location, nevertheless, about a mile or so away, depletion doesn't have very much effect. So in treating the transport of tritium, particulates and noble gases, straight Gaussian dispersion without depletion is a reasonable assumption and certainly conservative.

Q So, then, to the extent that the nucleation phenomenon caused by coal particles from this plant that is upwind the Harris plant, which in turn is upwind from the site of concern, might cause, let me say, a greater deposition velocity out of the atmosphere. It might bring more tritiated water close to the ground of the site of the concern, might it not?

A No, sir. It would not have any influence. The

mgc 18-5

way in which we have modeled it is transparent -- at that closeness to the plant, deposition is not very influential, because the particles, we assume, are quite small.

Q Well, what size does a water droplet have to be to have a significant deposition velocity in ten minutes?

A I would imagine it would be very similar to other particles that are not water. That is, when particles begin to get above 15 microns, they will start to settle out fairly rapidly. Below that, they will remain -- they have a tendency to remain airborne.

Q All right. If you go much above -- say you went up to 30 microns, they would settle out even more rapidly than those of 15 microns, wouldn't they?

A Yes, sir.

Q Did you in any of your studies in preparing for this testimony figure out what kind of upper limit of particle size might be achieve of nucleation of water droplets around a coal-fired particulate?

A No, sir.

MR. EDDLEMAN: I think I'm at the end of that line.

JUDGE KELLEY: Okay.

MR. EDDLEMAN: And I'm also having my water effect, Judge, again. I'm sorry.

JUDGE KELLEY: Sure. We'll take five minutes.

mgc 19-1

(Recess.)

JUDGE KELLEY: We're back on the record. Cross-examination will resume.

BY MR. EDDLEMAN:

Q Gentlemen, I would like to turn to something completely different. In Section 3 of your testimony on pages 14 and 15, between which there intervenes your Table 3, you say in the last sentence on page 14 that, in general, the greater the depsotion rate, the higher the dose from the food ingestion pathways; is that correct, gentlemen?

A (Witness Mauro) That's correct.

Q All right. And then you say, "Analysis of deposition velocity establishes" -- not indicates, but establishes -- "that the food pathway dose calculation conservatively accounts for the attachment of radionuclides to fly ash particles and the effect this phenomenon may have on the rate at which radionuclides deposit on the ground."

Isn't that correct?

A That's correct.

Q Now, however, when you come down in your second full paragraph on page 15, you refer to EPA data on deposition velocities, do you now?

A That's correct.

Q And in fact, these velocities are 0.015

mgc 19-2

centimeters per second for a particle of 0.1 microns in diameter, isn't that correct?

A That's correct.

Q And for a 1.0 micron particle, the deposition velocity corresponding is .21 centimeters per second, correct?

A That's correct.

Q And finally for a 10-micron diameter particle, the corresponding deposition velocity is about 4 centimeters per second, 4.0; is that correct?

A That's correct.

Q Now, then, you say, "The median size of fly ash is about 2 microns," don't you?

A Yes.

Q Now given the broad variation in deposition velocities over this two orders of magnitude of diameters, how representative is the median velocity for gauging the actual amount of material that is deposited due to attachment to these particles?

A I believe you are asking a question which pertains to the validity of our models -- namely, we assumed a certain deposition rate in trying to characterize the behavior of radionuclides in the environment. And certainly one may reasonably ask, "Well, is it possible that the real or actual deposition rate would be somewhat different?"

mgc 19-3

And certainly that's true. And that is one of the reasons why we implement an environmental radiological surveillance program -- that is, to go back and gather data once the plant begins operation to confirm the validity of our models as applied to this particular site.

So I could not argue that there is some uncertainty regarding deposition velocities, and we have made our best estimate to predict what that will be and characterize it. And I believe the data we show here demonstrates that it is -- that the values we use are reasonable, they are within experimental and observed values.

However, of course, there will be verification of this. That is the reason for the environmental surveillance program.

Q Doctor, apart from any monitoring that you might do afterwards, in this calculation isn't it important to know -- well, let me go back and lay a foundation.

The range of deposition velocities in Reg Guide 1.111 in the first full paragraph on page 15 have a maximum of 1.81 centimeters per second, do they not?

A That was the input into a mathematical model that was developed for 1.111.

Q But that maximum input for deposition velocity is 1.81 centimeters per second?

A That's correct.

mgc 19-4

Q And that is in line 8 on page 15, isn't it?

A That's correct.

Q Okay. Now isn't it likewise true that for a 10-micron diameter particle, the corresponding deposition velocity is 4.0 centimeters per second, according to the reference you cited in the second full paragraph of page 15?

A That's correct.

Q Now if we wanted to get into the real world, do you gentlemen have any idea what fraction of the particulates coming by the Shearon Harris plant stack are as large as 10 microns in diameter or larger?

A (Witness Schaffer) From major industrial sources like the Cape Fear plant?

Q Well, just in general. Do you know at all from any analysis of air quality or any measurements that have been taken, do you know what proportion of those particles passing by the Harris plant stack are greater than 10 microns in diameter or equal to 10 microns?

MS. BAUSER: I'd like a clarification. Are you talking about coal particles specifically?

MR. EDDLEMAN: Well, let's say coal particles.

WITNESS SCHAFFER: Then we would have an indication, yes.

BY MR. EDDLEMAN:

Q What indication do you have, Doctor?

mgc 19-5

A (Witness Schaffer) That's the indication that I give in the testimony that said it would probably be in the size range of about .1 to 2 microns, because that would be the size range most easily transported from a coal-burning facility distant from the Harris facility.

Q So if the fly ash came from distant coal plants, you would expect that the median diameter would be about 2 microns?

A No. I would expect that to be the maximum diameter. The median would be the midpoint between .1 and 2 microns.

Q All right. Now if the windspeed around the Harris site is about five meters per second, as I believe one of you gentlemen said, how long would it take the particles in the plume from the Cape Fear plant twelve miles away to reach the Harris site when the wind from the Cape Fear plant is blowing in the direction of Harris?

S2BU5

(Pause.)

A (Witness Mauro) Approximately an hour.

Q Okay. I believe you stated that the median airborne lifetime of particles up around the 10-micron range was in the order of hours, did you not?

Q Which size range again? 10 microns?

A Ten microns is about on the order of a few hours, correct.

Q All right. Now let me show you Figure 8,

mgc 19-6

appearing on page 17 of Eddleman Exhibit 1, the Fisher and Natusch article, if I may.

Do you have it? Would you like to look at your copy or mine? I can show it to you quickly (handing document to witnesses).

This is a graph, is it not, of size distribution for boiler particulate emissions from coal combustion: isn't that what it says?

A (Witness Mauro) Yes.

Q And in fact, you made reference to this very distribution, did you not, in your testimony?

A (Witness Schaffer) No.

A (Witness Mauro) No, sir. We refer to another figure that may be in here also.

A (Witness Schaffer) No, we don't.

A (Witness Mauro) No, sir. We used a different figure to characterize size distribution.

Q Can you point out to me in your testimony where your figure characterizes size affecting size distribution appears?

A (Witness Schaffer) I believe it's Figure 2. It is from Natusch, 1978.

Q Okay. So it's a different article by one of the articles of this paper.

A That's correct.

mgc 19-7

Q Now having these two things here side-by-side, Doctors, let me ask you first, for the 1-micron particle diameter, what percentage, weight percent less than stated size does the Natusch 1978 reference that you used give for particle diameter of 1 micron?

A About 30 percent.

Q About 30 percent?

A About 30 percent for less than 1 micron in diameter.

Q All right. In this Figure 8 of Eddleman Exhibit 1, if we take the 1-micron diameter and come out to 30 percent, that's not on any of these lines, is it?

A I'm not sure that these figures are comparable. You have to realize, this is stack emissions for a plant with electrostatic precipitators, and I am not sure what the figure in Eddleman Exhib it 1 -- where these particles were collected.

Q All right. Let me see if I can find in this the reference on that.

JUDGE FOREMAN: What page is that?

WITNESS SCHAFFER: It's the figure right after page 12 in the testimony.

(Pause.)

BY MR. EDDLEMAN:

Q What I needed to get was the improved

mgc 19-8

Eddleman Exhibit 1 that has the pages right before page 17 in it.

End 19

Your suspicion is correct, Doctors. I believe you referred to page 16 here of Eddleman Exhibit 1, and would you read this characterization of Figure 8 that appears at the bottom of the second to the last paragraph on that page?

Why don't you start here (indicating).

A (Witness Schaffer) This latter dependence is illustrated in Figure 8 for fly ash derived from coal burning burned in a chain grate stoker unit, a pulverized coal-fed unit and a cyclone-fired unit. Southern Research Institute, 1975.

In each case, the fly ash was sampled upstream from control equipment so it is representative of that generated by combustion.

Q And since we're concerned in the real world with fly ash as it's emitted after the precipitators, let's use your Figure 2 to consider this further, if you will. Did you say that appears after Page 12?

A That's correct.

Q On this, do you know what efficiency of precipitator is used in deriving the data for this graph, your Figure 2?

A I don't know the efficiency of the precipitator, but I do know the efficiency of the collection device that captured these particles.

Q T hat would be an impacter, would it not?

A No, it was a thermal precipitator, and for

everything below 5 microns it's virtually 100 percent efficient.

Q Okay. What is its efficiency for particles above 5 microns?

A I don't know.

Q Less than 100 percent?

A I don't know.

Q So you don't know whether the device which captured the particles on which this graph is based has any particular efficiency for capturing particles in the 10 micron size range, do you?

MS. BASER: I'm going to object. The witness has answered the question with respect to the 5 microns or less, which I think is what we're concerned about in any event here.

JUDGE KELLEY: The pending question is 10? It was asked and answered; he doesn't know. Right.

MR. EDDLEMAN: Okay, I'll take it. I withraw the question.

BY MR. EDDLEMAN:

Q Do I understand correctly that for sizes above 5 microns you just don't know?

MS. BAUSER: Asked and answered, objection.

JUDGE KELLEY: Let's make it easy. Isn't that right?

WITNESS SCHAFER: That's right.

JUDGE KELLEY: Fine.

BY MR. EDDLEMAN:

Q Thank you, Judge.

So then, as to the assumptions of your page 15 about the appropriate deposition velocities, your Figure 2 is based on a capturing method which may not have picked up particles up in the 10 micron size range, isn't it?

A (Witness Schaffer) There might not even be 10 microns there because of the electrostatic precipitators.

I was under the opinion that electrostatic precipitators remove larger size particles, around 10 microns.

Q Well, Doctor, I think you already stated that you didn't know what precipitation efficiency your Figure 2 was based on.

A I didn't know what efficiency of collection of the thermal precipitator was. That was the collection device of the particles above 5 microns. But the electrostatic precipitator is supposed to remove 10 micron particles that are at a relatively high efficiency.

Q Do you have a specific number for the efficiency of the electrostatic precipitators used in preparing this Figure 2 of yours?

A No, I don't.

Q You don't. Not for any size of particles.

A You state for this figure.

Q Right. And you said you don't for 10 micron

particles. I'm asking you now do you know its efficiency in removing any size particles.

A In general terms I know it is less efficient at removing particles of respirable size.

Q I agree with you about that, but just to try to pin this down -- no offense intended -- you do not know what percentage of particles of any particular size or sizes this precipitator removes, do you?

A Would you repeat that once more, please?

Q Let me rephrase it since I probably can't repeat it. Do you know what percentage of the particles of any specific size or sizes are removed by the precipitators that were used in getting the data reflected in your Figure 2?

A Are we talking about the electrostatic precipitator now?

Q Yes, sir.

A I don't know the exact numbers.

A (Witness Mauro) Could I interject here? I'm listening to this and I may have misunderstood, but what I see here is -- this is what was measured in the effluent after. So this is the actual measured values. So no assumption regarding efficiencies is really pertinent here, as I understand -- . This is the experiment that sampled and observed this -- actually observed this particle size distribution after the filter. In other words, after the

electrostatic precipitator has had its opportunity to clean up the stream.

So we are effectively using this curve to show what we would expect to be the particle size distribution of particulates leaving coal plants, within an electrostatic precipitator.

Q Right, sir. But wouldn't you agree also, though, that the precipitators are more efficient at removing the larger particles than they are the smaller particles?

A Yes, sir.

Q All right. Now suppose I have a precipitator that has an overall efficiency of 90 percent. That is, of a certain weight particle that starts up the stack, -- let me start over.

Suppose I have an electrostatic precipitator, Doctors, which is 90 percent overall efficient, according to the following outline: and that is, if a certain weight of particle starts up the stack, is airborne fly ash, goes through the precipitation system, then 90 percent of that weight shows up in the hoppers. It's caught by the precipitators, and only 10 percent of it escapes out the top of the stack. Do you follow me?

A Yes, sir.

Q So I'm going to call that 90 percent overall precipitation efficiency, as defined for the purposes of the

questions I'm going to ask you.

A Okay.

Q Now, even at that 90 percent removal efficiency, you would expect, wouldn't you, that the larger particles would be more efficiently removed?

A Yes.

Q So that in fact, the efficiency of removal of very large particles there might be virtually 100 percent. Say, if I had a 1000-micron particle, it might be very likely that that one would be trapped in the precipitator; whereas, for very tiny particles like 1/10 of a micron, the efficiency might be as low as 30 percent or something like that, lower efficiency.

A Yes.

Q If I make a better precipitator, or put some more equipment in or improve it, and now I'm knocking out 95 percent of the weight of the particles that started up the smokestack, isn't it still true that in that extra 5 percent I've removed, I'm more likely to be knocking out the larger sized particles than the smaller ones?

A That intuitively would appear to be the case, but I haven't read or reviewed any material that actually said that or demonstrated it. But intuitively, I guess I'd agree.

I would expect that's what would occur.

Q Let me ask you this. Did either of you ever work

with electrostatic precipitators?

A (Witness Mauro) No.

A (Witness Schaffer) No.

Q Have either of you ever read any literature describing the physics or science, if you will, of the removal of particles in electrostatic precipitators?

A (Witness Mauro) IN some general literature, yes.

A (Witness Schaffer) The same with me.

Q Okay. It's true, isn't it, that they removed the particles by means of an electrostatic field at right angles more or less to the gas stream?

MS. BAUSER: Objection. I cannot understand how the fine details of electrostatic precipitation at a coal plant has any bearing on this contention. They have stated what Figure 2 is and what the basis of it is and what the limits of their knowledge is about it, andhow they used the number in their testimony.

MR. EDDLEMAN: Judges, what I'm trying to show is that the overall efficiency of that precipitator has, indeed, a bearing on the kind of size distribution that you get. If you like, I'll go into some more detail about it.

JUDGE KELLEY: I think we would like a little less. Could you pursue the point rather more quickly than you have been?

MR. EDDLEMAN: I'll try my best.

BY MR. EDDLEMAN:

Q If you gentlemen would look at page 17 of Eddleman Exhibit 1, Figure 8, the size at which 50 percent of the weight of these particles before coming through an electrostatic precipitator is less than a given diameter, is 10 microns for a pulverized coal-fired plant on that graph. Is it not?

MS. BAUSER: Clarification, please. I don't understand the question. Could you restate it?

BY MR. EDDLEMAN:

Q All right. This figure we have established shows the size distribution of boiler particulate emissions from coal combustion before the particles go into the precipitator. Isn't that correct, Doctors?

A (Witness Mauro) That's what you read to us before, yes.

Q That's what you read for me out of the exhibit, right?

A Yes, sir.

Q All right. Now what I'm asking you is about the particle size distribution there. Isn't it true that for a pulverized coal-fired plant, 50 percent of the particles by weight are less than 10 microns in diameter, or approximately 10 microns?

A Ten to twenty, yes.

Q All right, sir. Now on the other hand, in your Figure 2 of your testimony, 50 percent of the weight of the particles after this precipitator are less than 2 microns in diameter, aren't they?

A Yes, sir.

Q Now in general, you have said that precipitators remove larger particles more efficiently, and what I want to get at is how they do that, and how that relates to the change of particle size distribution from this uncontroled, pulverized coal-fired distribution of Figure 8 in Eddleman Exhibit 1, over in the direction of the emissions after control by an electrostatic precipitator in your Figure 2.

MS. BAUSER: Objection.

JUDGE KELLEY: Before you agree with the results, why do we care how they do that?

MR. EDDLEMAN: Because the distribution will be different based on the efficiency of the precipitator. And if, in fact, the actual Cape Fear coal plant has a lesser precipitation efficiency, then this figure is not valid for application to the Harris Plant area.

MS. BAUSER: I don't understand. There's no foundation laid, first of all, about the nature --

JUDGE KELLEY: Is anybody here prepared to litigate the details of the precipitator at the Cape Fear plant?

MR. EDDLEMAN: No, Judge, but you can get the

efficiency data right out of the stuff from the Department of Natural Resources, Community Development here.

What I'm saying is this particle size distribution that they use here, that they used in their testimony about deposition depends on the efficiency of the precipitators. And in particular, I think we've established that the Cape Fear plant is sitting there upwind of Harris, so we know there's a real coal plant there.

And if what really comes out of this is not comparable in weight percent less than stated size to their Figure 2, then their conclusions are wrong.

MS. BAUSER: That's not right. Mr. Eddleman has not asked the witnesses why their analysis did not consider releases from the Cape Fear plant, and if it did, whether that would have any impact on their analysis. And I suggest that he ask that before he assumes certain negative impacts and then he draws inferences based on what he knows about the equipment at the Cape Fear plant.

MR. EDDLEMAN: I'm coming at it from what I do know, which is I asked them about the particle size distributions they assumed, and they told me they made this assumption, that .2 microns is the median size and 10 microns doesn't enter into it much.

And I asked them -- well, the 10 micron size particles precipitate out faster than the numbers that are

given in the regulatory guide 1.111 and they agreed. So I'm trying to get at the question of whether of those 10 micron particles are actually present in the ash, the fly ash released from the Cape Fear plant than their Figure 2 indicates.

Maybe I can just go through it that way rather than argue with them about precipitators. Why don't I try that?

JUDGE KELLEY: Let me make sure I understand this, Mr. Eddleman. Having read the testimony filed in advance, I did not know that we were going to be litigating the actual characteristics of the efficiency of precipitators at any particular coal plant. This comes as a complete surprise to me.

It's one thing, it seems to me, to ask a question or two about do you know, at the coal plant 10 miles away, would that affect your conclusions. But if you're attempting to go toward an invalidation of their position based on the hardware at the Cape Fear coal plant -- you don't have any witnesses prepared to testify on that, do you?

MR. EDDLEMAN: No, I'd have to do it with documents.

JUDGE KELLEY: Well, it's a little late for that. The documents were supposed to be filed along with the testimony, right?

MR. EDDLEMAN: Well, I think that's what I understand now, but I don't think I understood it at the filing time.

JUDGE KELLEY: Well, you've got lawyers and they can read. I mean after all, the Applicants are putting on a case, the Staff is putting on a case, and it's sort of an academic case if you want to call it that, but since they haven't gone out and looked at the Cape Fear coal plant -- but that's their case. And you can cross examine them on that.

But I simply don't understand how we can get to the point that you seem to be suggesting we're going toward.

MR. EDDLEMAN: Until I saw their testimony I didn't know they were going to use this approach and just ignore the Cape Fear plant.

MS. BAUSER: I object to that, Your Honor. We asked in the interrogatory, identify the specific coal plants to which you're referring on Contention II.(e), and the answer was: Joint Intervenors do not refer to specific coal plants in Contention II.(e).

We were not adverse; we could have put on testimony that went into detail on the Cape Fear plant, and we saw no need to because that was not the focus of the contention.

You haven't even asked these witnesses whether

that analysis would change. And a minimum, it seems to me, before we pursue the Cape Fear plant for hours is you should see if they considered whether that would have any impact on their analysis.

MR. EDDLEMAN: What we're doing is arguing for hours, so let me take you up on that if I may.

JUDGE KELLEY: I think Ms. Bauser makes a good point. They have come in with their testimony, they have done what they have done, and certainly, you as legitimate cross, as legitimate impeachment, if you will, of their testimony can say: How can you take this position without looking at Cape Fear? And they probably have an answer. Let's try that.

BY MR. EDDLEMAN:

Q Let me ask you this, gentlemen, if you had a source of 10 micron particles upwind of Harris, couldn't that alter this analysis?

A (Witness Mauro) I would I'd expect not.

Q Why would you say that?

A (Witness Schaffer) Can I get a clarification? A source of 10 micron particles upwind of Harris?

Q Let's say 12 miles upwind of Harris.

A The particles would never reach Harris. You mean downwind?

Q No, upwind. In other words, the particle enters

the air upwind of Harris and carried by the wind past Harris.

Now let me ask you again: If the Cape Fear plant, which is 12 miles upwind of Harris, emitted 10 micron particles which were then carried past Harris, wouldn't that change one of the basic assumptions of your analysis, which is that the deposition velocities are within the range of Reg Guide 1.111, as you stated on page 15?

A (Witness Mauro) I'll continue with my answer. My answer would be no, it would not change it because they would be -- the 10 micron particles would not be expected to reach the site.

You see, the particles that remain airborne for long distances like 12 miles and greater are the smaller ones. You wouldn't expect very much of the 10 microns and above to remain. So we would expect the particle size distribution in the vicinity of the Harris plant to be on the order of .1 to 2 or 3 microns.

end 20

mgc 21-1

Q So your testimony now is that these 10-micron particles coming from the Cape Fear plants at the average windspeed would -- around the Harris sight, would have settled out before they got to Harris?

A Given that you assume 10-micron particles and larger are being emitted along with finer particles, I would say by the time any transport to the Harris site, you would predominantly see the smaller particles, and they would be lost in transit, the larger ones.

Q And would you say that is equally true if the particles were mainly right around 10 microns in size, a little below and a little above, but not down towards 2 microns, but, say, from 8 to 15-micron particles? Would your conclusion that you just stated still hold true?

A (Witness Mauro) I gather you question is, would I expect any 8 to 10-micron particles that are emitted from a source twelve miles away to be able to travel about twelve miles before they settle out?

I guess some would. I couldn't quantitatively -- I'm trying to paint the picture. Certainly the preference would be for the smaller ones. In the area of 10 microns and larger, you are starting to not expect them to be transported very far. I could not give you a quantitative estimate of what I predict to be the fraction of removal or the fraction remaining of a 10-micron particle.

mgc 21-2

Q You don't have a numerical estimate, but you said that they virtually all would be removed, and that's why it wouldn't change your calculation, didn't you?

A Well, there were two reasons why we felt that. The site could be treated as a rural site, and the airborne particles would not be influenced by, say, a local combustion source.

One is, particles that may be emitted from coal-burning plants in the vicinity based on these data show that you would expect the median size to be approximately 2 microns. So that's one level.

The next level is, notwithstanding that, since we are talking on the order of twelve miles away, the actual forces at work would be to select, as we pointed out earlier in our testimony, to select more particles of the smaller size -- that is, we describe the nuclei mode, the accumulation mode and -- what was the larger size? -- above 10 microns, you would expect them to settle out. So there would be these forces operating to select more particles on the order of about 2 microns, .1 to 2 microns.

Q You didn't make, then, any analysis of the actual particle size or distribution of particles emitted from the Cape Fear plant?

A No, sir.

Q Let me ask you this. In your Attachment 2,

mgc 21-3

adsorption of noble gases onto airborne fly ash, the fraction absorbed -- now you seem to use absorb and adsorb almost interchangeable here, but I think we tied that up early on -- what I want to ask you is, these concentrations are basically equilibrium concentrations, are they not?

A Yes, sir.

Q And that equilibrium is established without regard to ionization, isn't it?

A (Witness Schaffer) Without regard to ionization? Yes.

Q Okay. Now to the extent that a radioactive atom -- well, let me ask you this.

These radioactive noble gases, they are beta emitters, aren't they?

A (Witness Mauro) Beta gamma.

Q Okay. But they emit, among other things, electrons, don't then?

A Yes, sir.

Q When you emit an electron, doesn't that result in your having an ionized atom after the emission?

A Yes. Every decay, whether we are dealing with a beta or a gamma emitter, would expect to generate ion pairs.

Q And that would hold true also for radioactive atoms where were, as a solid element, decaying. They would

mgc 21-4

also become ionized when the decay happened, wouldn't they?

A Upon decay, the particle will be ionized for a short period of time, and then it will recombine.

Q All right. Now while it is ionized, it would be more likely to be electrostatically attracted to other particles around it, wouldn't it?

A It would be attracted to particles of opposite charge and repelled by particles of the same charge.

Q Do you have any idea what the charge distribution is on fly ash airborne around the Shearon Harris plant, electric charge?

A No.

A (Witness Schaffer) No.

Q Okay. Do you have any idea whether electrostatic attraction among particles of coal fly ash and atoms or particles containing radionuclides would increase the likelihood of attachment of that particle or atom containing the nuclide to a charged -- an oppositely charged particle of fly ash?

MS. BAUSER: I'm sorry. I need to ask him to repeat the question. I just don't understand it.

BY MR. EDDLEMAN:

Q Let me rephrase it. Would a charged particle of fly ash tend to attract atoms or particles which contain a radionuclide which, because of recent decay, has the

m gc 21-5

opposite charge from the fly ash particle?

A (Witness Mauro) In a purely theoretical sense, you couldn't argue with that. You are saying, let's assume we have a postively charged particle here, and let's assume we have a negatively charged particle here. Given that assumption, is it possible that these two may be attracted to each other? And certainly I'd have to agree.

But in the real world, the extent to which that's a real phenomenon that has an influence on the behavior of these particles is another matter altogether.

Q Well, let's go to the real world, Doctors. Do you have any idea what kind of electric charge particles have after they come out of an electrostatic precipitator?

A I believe that the electrostatic precipitator places a charge to increase agglomeration and removal, and what comes out, I would just be speculating. I don't know.

Q Well, if the precipitator places a charge on them, and that charge doesn't, for whatever reason, end up caught inside the precipitator with the particle, then that charge comes out of the precipitator with the particle, doesn't it?

A I don't know.

Q Well, if you place a charge on a particle in an airstream, how fast would that charge leak off of it?

mgc 21-6

MS. BAUSER: Objection. The witness has answered the previous question that he didn't know, and I think Mr. Eddleman is attempting to get him to answer it again, and he's already stated that he doesn't know.

JUDGE KELLEY: Sustained. Move on.

BY MR. EDDLEMAN:

Q Do you gentlemen know anything about the resistivity of fly ash particles?

A (Witness Schaffer) No.

A (Witness Mauro) Just what I've read in some of these articles. That is that it influences the effectiveness of an electrostatic precipitator.

Q You don't know whether resistivity of fly ash particles is high or low, do you?

A High or low relative to?

Q Relative to other materials.

A I don't know.

Q Okay. Since you don't know all this, how can you say that the charges on these particles don't have any significant effect on the adsorption of radionuclides onto such particles?

MS. BAUSER: Objection. That's very argumentative, and I don't know --

MR. EDDLEMAN: I thought he just said it in response to one of my questions. I asked him, "Is this

mgc 21-7

going to affect your model?" He said no.

JUDGE KELLEY: Well, would you restate it?

BY MR. EDDLEMAN:

Q Gentlemen, you've said that in a purely theoretical sense you would agree that electrostatic attraction between a radionuclide and a particle of opposite charge would occur, but you said that in the real world, that was not significant.

Now what is the basis for that statement?

A (Witness Mauro) No. I said I would not be able to comment on how significant it would be. I believe that's what I said.

The kinds of questions you are asking are drawing from some theoretical concept, what influence it could have on how we model dispersion. And you recognize that the atmospheric models that we used in the calculations that we performed have been validated in the real world -- that is, measurements were taken to see what, in fact, is the dispersion behavior. That validation is really what is important. That is, are the dispersion models that we have, can they be relied upon to give an accurate prediction of what the concentrations would be offsite.

Notwithstanding all of these phenomena that you may want to bring up, they are sort of a subset of all this and have been accomodated for in these validation models.

mgc 21-8

So theoretically you are raising issues that are taken into consideration in a macroscopic sense.

Q Well, where in your testimony, Doctors, do you allude to this sort of validation of these models?

MS. BAUSER: Would you repeat that, please?

BY MR. EDDLEMAN:

Q Where in your testimony, Doctors, do you allude to this sort of validation of your models?

MS. BAUSER: I object. The dispersion models are not at issue here. I think that's what Mr. Eddleman is challenging. We use them in our analysis, but they are not at issue here.

JUDGE KELLEY: Well, but he's asking -- the witness said that these models have been validated out in the field, so to speak, correct?

WITNESS MAURO: Yes, sir.

JUDGE KELLEY: So Mr. Eddleman is saying, "Is that in your testimony?" Is it or not?

WITNESS MAURO: Yes.

JUDGE KELLEY: Where is it?

WITNESS MAURO: On page 15 where we describe the empirical measurements of deposition rates that were taken by the EPA to show that the deposition velocity they actually measured in the field, collecting samples in terms of velocities by which particles settle, are in accord with our models.

mgc 21-9

BY MR. EDDLEMAN:

Q We have established, haven't we, that if you have a 10-micron particle, that has a greater deposition velocity than is in accord with your models?

A (Witness Schaffer) That was a hypothetical assumption, if we are dealing solely with 10-micron particles.

Q In other words, yes.

MS. BAUSER: No. Objection. That's not what the witness said. He said, "Have we established, have we theoretically established," I think that was the answer.

JUDGE KELLEY: Was Mr. Eddleman's "in other words yes" accurate? Is that what you meant to say, or how would you say it?

WITNESS SCHAFFER: I would say, if we assume that all we are dealing with is 10-micron particles, then yes.

JUDGE KELLEY: Are you making that assumption?

WITNESS SCHAFFER: I am making that assumption.

BY MR. EDDLEMAN:

Q Now to the extent that there are significant numbers or significant proportions, say, of 10-micron particles in the particles coming by the Harris plant, then these assumptions wouldn't be accurate, would they -- your assumptions wouldn't?

A (Witness Schaffer) I wouldn't assume that there would be a significant number of 10-micron particles from

mgc 21-10

an industrial source near the Harris plant.

Q But you have testified that you don't know what the distribution of particle sizes is from the Cape Fear plant, which is an industrial source near the Harris plant, haven't you?

A I have also testified that I felt that larger size particles, sizes of 10 microns, would settle out fast also. So I will leave it at that.

Q And just to tie this up, you also said, didn't you, that neither one of you knew anything about the efficiency of precipitation at that plant?

A That's correct.

End 21

22pbl

Q Let me ask you if you could look in your copy of Eddleman Exhibit 1 on page 20. Do you have that before you, Doctors?

A (Witness M , Yes.

A (Witness Schaffer) Yes.

Q Under Item C, it says, does it not that the electrical resistivity of coal fly ash is an important physical property from the standpoint of control. Thus, it has been established, and it gives reference that the collection efficiency of electrostatic precipitators increases with decreasing fly ash resistivity.

That's what it says, doesn't it?

A (Witness Mauro) Yes, it does.

Q Okay. And then it also talks about resistivities being inversely proportional to specific concentrations of alkali metals which are thought to act as charge carriers, doesn't it?

MS. BAUSER: If Mr. Eddleman is just asking for a verification of this page of the exhibit, the exhibits are admitted and it speaks for itself.

JUDGE KELLEY: I'm sorry, I couldn't hear you.

MS. BAUSER: I said, I couldn't hear Mr. Eddleman. If he's asking for a verification of the sentence in the exhibit he needn't do that. I said it speaks for itself.

JUDGE KELLEY: I would agree with that. Do you

22pb2

have a question, Mr. Eddleman?

MR. EDDLEMAN: Yes. Well, first I wanted to show the Board that this stuff is in the record. But also, if I could ask you gentlemen to turn to page 22 now, this discussion continues in this exhibit.

BY MR. EDDLEMAN:

Q There at about the fourth line down in the text beginning under Table 4, in the middle of the page it says, "It is apparent that the efficiency of electrostatic precipitation per unit mass of these size-classified fly ashes increases with decreasing aerodynamic particle size," doesn't it?

A (Witness Mauro) Yes, it does.

Q And doesn't that indicate to you that there is some effect that is causing those particles to behave just the opposite of what you expect particles in general to do?

MS. BAUSER: Objection --

BY MR. EDDLEMAN:

Q That is, to be more efficiently precipitated at larger sizes. This says more efficiently precipitated at smaller sizes.

MS. BAUSER: Object again. I don't think the precipitation characteristics of particles is relevant. We have discussed this already.

JUDGE FOREMAN: I would like to ask, do you think

22pb3

it's appropriate fare to just read sentences from a paragraph without having people have a chance to see what was said before? Because a statement like that without knowing what was said before could be quite misleading.

MR. EDDLEMAN: Well, gentlemen, if you will, why don't you take a little time and read this section that begins with C on page 20. But then the text takes off at the bottom of page 20, so it's only about three paragraphs. And that is all of Section C. So I think that would give some context.

JUDGE FOREMAN: I would suggest that you ask your questions so that they could be thinking about what you're driving at while they are reading it.

MR. EDDLEMAN: My question is going to be, is there any effect of resistivity or particle charge that has anything to do with this deficiency of precipitation of size-classified fly ashes having to increase with decreasing aerodynamic size.

MS. BAUSER: I'm going to object. First of all, the question is not coherent to me but --

MR. EDDLEMAN: I'll withdraw the question. It'll save time.

JUDGE KELLEY: All right, that question is withdrawn. I'm going to ask where you are at this point, Mr. Eddleman.

22pb4

MR. EDDLEMAN: Pretty close to done, Judge.

JUDGE KELLEY: How close?

MR. EDDLEMAN: Let me look.

JUDGE KELLEY: I think it's a pertinent question. You've been cross-examining this panel for something in excess of five hours on a fairly narrow topic.

MR. EDDLEMAN: And it looks like I've got about five sets of questions, most of which are fairly short.

JUDGE KELLEY: Sets?

MR. EDDLEMAN: I have five things I want to ask about and most of them probably are about three questions long.

JUDGE KELLEY: Go ahead.

BY MR. EDDLEMAN:

Q If I may refer you to page 7 of your testimony, down at the bottom where you discuss the ICRP-2 model, the second to the last sentence on this page. You say that the model assumes that half of the insoluble particles deposited in the deep lung are removed in 24 hours, and half are retained with a half-life of 20 days, correct?

A (Witness Mauro) Yes.

Q Did you examine information about the solubility of fly ash particles in connection with your testimony?

A (Witness Schaffer) We have examined some data on it, yes.

22pb5

Q And how would you characterize that? The fly ash particles with respect to solubility.

A The particles themselves are relatively insoluble.

Q Okay. On page 8, if you will, down toward the bottom again you're discussing the deposition fraction for most particles in the size range of fly ash, and you say that this fraction can approach 60 percent for sizes near the 2.0 micron diameter. And then you say these fractions can be compared to the 75 percent fraction assumed in the model, don't you?

A Let me read this again, please.

Q Sure.

(Pause.)

A Okay. Repeat the question.

Q That is what it says, isn't it?

A Yes.

Q Okay. Now in the model though, as is stated on page 7 doesn't it say of the 75 percent deposited, 50 percent is deposited in the upper respiratory tract and 25 percent in the deep lung?

A Yes, it still winds up to be 75 percent total lung deposition, which that paragraph is talking about on page 8.

Q You're talking about total lung deposition on page 8, that's what you're saying?

22pb6

A That's correct.

Q But isn't it true that the percent deposited from these EPA studies is a percent of deposition in the deep lung?

A No. On this page the figure relates to deep lung. The discussion on page 8 refers to the total.

Q Now by the figure, do you mean your Figure 1 that follows page 9?

A That's what I mean.

Q Okay. Now this figure on page 9 does give deep lung numbers, is that what you're saying?

A Yes, that is deep lung.

Q All right. Now if we look at the bottom solid curve on that figure in the range of two microns, isn't that bottom curve above 30 percent?

A It seems to be about 30.

Q Take your time and check if you will.

A Yes, it's very close to 30.

Q All right. And that's basically the lower limit of this data, isn't it?

A (Witness Mauro) That is for mouth breathers as opposed to nose.

A (Witness Schaffer) Yes, that the mouth breathers.

A (Witness Mauro) For mouth breathers, that curve shows that around two microns you get on the order of about

22pb7

30 percent deposition.

Q Well, it shows that you get between 30 and 60 percent deposition, doesn't it?

A Oh, for the envelope, yes, sir.

Q But the minimum is about 30.

MS. BAUSER: Objection, he just answered the question.

BY MR. EDDLEMAN:

Q All right. Now that minimum of 30 as shown there is actually greater than the 25 percent deposition in the deep lung that's assumed in the model on page 7, isn't it?

A (Witness Schaffer) It's 5 percent greater.

Q And the upper limit of that, the 60 percent is 35 absolute percentage points greater than the 25 percent used in the model.

A The upper limit was not modeled. The model takes in normal breathing, nose, normal tidal volume, normal breathing rates and those upper limits are very deep, slow breathing through the mouth.

Q Well, let me refer you to this figure again. The black squares and diamonds are the last two studies listed in the upper left-hand corner, are they not, Doctors?

A The black squares and black diamonds? Yes.

Q All right, and those both have a breath permanent rate of about 14, don't they?

22pb8

A Yes.

Q Now is that close to a normal breathing rate?

A Yes.

Q Okay. But these, I take it, are deeper breaths because of the larger tidal volume, right?

A Yes.

Q Now, in the three-micron range you can find some of these black diamonds and squares in the graph, can't you?

A Yes.

Q And they range from about 30 percent deposition up to nearly, well, say the range of 50, don't they?

end 22.

A Yes.

Q All right. Now, the white diamond, the outlined diamond, is the study of Altschuler, et al of 1967, the third one listed in the lefthand corner, isn't it?

A That's correct.

Q And that gives a volume of 500 milliliters, which is about normal, doesn't it?

A Yes.

Q And it gives a breathing rate of 15 breaths per minute, which is also about normal, does it not?

A Yes, it does.

Q And in fact, there's one of those diamonds with an error bar around it at the 2.0 micron diameter in this graph, isn't there?

A Don't forget now, this is mouth breathing, also. It's not nose breathing.

Q You have already asked and answered that, if I may not object but point out.

(Laughter.)

It is there, isn't it?

A It's there.

Q Okay. And the error bars range from about somewhere a little below 30 percent up to somewhere a little over 40, don't they?

A Yes.

Q I think I havethat pretty well covered. Let's see.

On page 10 when you're talking about the noble gases you say, Because of their inert nature, they do not bind significantly to particles or absorbed on the surfaces.

Have you gentlemen made any studies of the adsorption of noble gases on coal particulates?

MS. BAUSER: Could you tell me where you are?

MR. EDDLEMAN: Middle of page 10, first full paragraph.

MS. BAUSER: I have it.

BY MR. EDDLEMAN:

Q The third line of that paragraph. Doctors, do you have it?

A (Witness Schaffer) Yes.

Q Okay. Have either of you made any studies of the adsorption or absorption of noble gases unto coal particulates?

A (Witness Schaffer) I have not.

A (Witness Mauro) No. I have looked into the adsorption of noble gases unto activated charcoal, but not unto coal particulates.

Q All right. Let me flip over here to where you mention activated charcoal in your Footnote 2 to Table A-1 in your Attachment 2 on page 2-3. Do you have that?

A (Witness Schaffer) Yes.

Q Footenote 2 says, "The adsorption coefficient for fly ash was assumed to be the same as for activated charcoal, divided by a reduction factor of 332 to account for the difference in specific surface area."

Now, how did you come up with that factor of 332?

A By assuming that fly ash particles was a one-micron sphere with a density of 2 grams per cubic centimeter. You can basically calculate the -- you can calculate the surface area of a gram's worth of those particles, and it came out to be 332 times less than the lower limit of specific surface areas given in NUREG-0678.

Q For activated charcoal?

A For activated charcoal.

Q Now, all you need to make that calculation is the information that you have just given, and knowing the geometry of the sphere?

A Yes.

Q All right. If your fly ash were significantly smaller than 1 micron, wouldn't you have a change in the reduction factor?

A Yes.

Q In fact, let's just consider if you had a one-tenth micron sphere, its surface to volume in relation to the one micron sphere would be ten times as much, wouldn't it?

A I'm not sure.

(Pause.)

A Okay. Yes.

Q Ten times as much, okay. So that in fact, for the smaller sizes, this factor of 332 would not apply. But a factor basically consisting of 332 divided by the ratio of the particles' actual size to one micron would apply, wouldn't it?

A I lost the train.

Q Well, let me ask you this. If I wanted to look at the surface to volume ratio of a particle of any size less than a micron, I could say that the surface area goes as the square of the radius, and the volume goes as the cube of the radius, couldn't I?

A That's correct.

Q Okay. And if I look at the surface to volume ratio, that ratio is proportional to 1 over the radius, isn't it?

A Yes.

Q Okay. So then, if I want to look at what reduction factor I should use for sizes smaller than a micron, the answer is something -- there might be some constant involved here. I take it back, there is not.

332 over R or something proportionate to that would be the constant that I would need. Oh, I'm sorry, I'm wrong. Let me ask you the question again.

If the surface to volume is the ratio of radii, then isn't it true that the reduction factor that's appropriate to use for a sphere with a radius of 1 divided by X microns, is 332 over X?

A (Witness Schaffer) I'm confused.

A (Witness Mauro) I'm not exactly following your calculation, but are you asking if the surface area would increase per gram of material as the size of the particle gets smaller?

Q That's part of it, yes.

A Well, that's true, but now you're trying to come up with a mathematical expression of that relationship.

Q Well let me ask you this. Would you all agree that if we can calculate the surface to volume ratio for spheres of a smaller diameter, that we could get our reduction factor for those spheres in the same manner as you did for the one-micron spheres?

A Sure.

Q So then, if you could just get the surface to volume ratio between 1 micron spheres and spheres of another diameter, you could apply whatever conversion factor for surface to volume of those spheres you've got to your reduction factor of 332 in a mathematically consistent way, and come up with a reduction factor for the other size of spheres?

A You can, but you have to bear in mind that the

surface area -- if that's in the calculation, assuming perfectly spherical particles -- and it would be a reasonable thing to do, to go through that exercise. But you have to bear in mind that the actual particles themselves, the surface area that has been measured as opposed to calculated, doesn't follow that relationship exactly.

But as a first approximation, you know, to try to get a handle on the surface area per unit weight, your method would be correct.

Q And indeed, your method that you used here for the one-micron particles is that same sort of first approximation, not taking into account the deviation from sphericality of those particles?

A Yes, sir.

end 23

24pbl

Q And it doesn't matter at all to this calculation what the shape of the activated charcoal particles is, because you've got a surface to volume ratio for them in this source.

A That is right.

Q Let me refer you to page 14, the second full paragraph on that page. You state that the inhalation dose model used by Applicants and the Staff effectively accounts for the attachment of radionuclides to fly ash particles in atmosphere around the plant.

Isn't it true that the contention says, the health effects are underestimated because they exclude these means of concentrating radionuclides in the environment. Your statement of the contention is on page 2.

JUDGE KELLEY: Page 14?

MR. EDDLEMAN: I first quote their statement on page 14 and then I asked them to contrast that with the contention statement which is on page 2.

MS. BAUSER: Could I have the question again?

JUDGE KELLEY: How about the quote again on page 14?

MR. EDDLEMAN: It's the summary paragraph, and I began after the second comma -- actually it's the third comma in the paragraph. But the middle of the third line, the inhalation dose model used by Applicants and the NRC Staff effectively accounts for the attachment of radionuclides

24pb2

to fly ash particles in the atmosphere around the Harris plant. And I asked them to compare that to the contention.

MS. BAUSER: I object to the question.

MR. EDDLEMAN: Well, I'll withdraw the question then. Let me ask you this, gentlemen.

BY MR. EDDLEMAN:

Q Let's go back to page 13, you described Table 2 in the third full paragraph on that page, do you not?

A (Witness Schaffer) That's correct.

Q And you say assuming a 60 percent deposition fraction, the whole body dose remains at about 0.075 millirems, and the dose to the critical organ (thyroid) is about 0.16 millirem. That's what you say, isn't it?

A That's correct.

Q And that dose to the critical organ is up by about 1/7th of the dose from Reg. Guide 1.109 that is given at the end of the paragraph immediately above that, is it not?

A (Witness Mauro) The changes for the critical organ from .14 to .16.

Q That's an increase of approximately 1/7th, isn't it?

A Yes. That is correct.

Q Okay. And if I come over to page 14, at the top of that page you say Table 3 illustrates that the dose

24pb3

rate down, assuming all radionuclides except tritium are insoluble.

Now, we have agreed, haven't we, that if tritium were attached to an insoluble particle, that it would then be carried where that particle went, haven't we?

A I think you have to be a little careful here. There's a distinction between attached and associated with as like a condensation nuclide.

Q Either way, it goes where the --

A No.

Q Oh, I see what you're saying. Right.

A If you say that, we're saying that attached -- the word attached, when I hear it you're referring to the tritium as bound very strongly to the particle.

Q Adsorbed or absorbed?

A Yes, in such a manner that upon entering the lung and depositing into the mucosa, it would remain with the particle.

Q Okay, that is what I'm asking about now. I think we've also established that you didn't make a partition calculation for tritium on coal particles in your work for this testimony, have we not?

A (Witness Schaffer) We discussed the significance of it in previous questions today.

Q Well, suppose we just let the record speak for

24pb4

itself since it's late. You say, "This calculation results in a whole body dose of about 0.074 millirem," as your testimony is corrected, do you not?

A (Witness Mauro) That's correct.

Q And the critical organ dose (lung) is about 0.084 millirems. Now in the fifth line at the top of page 14, you haven't actually shown the calculations of any of these things in your testimony, have you?

A The actual equations?

Q The actual calculations that were done.

A No, sir, but they are all followed, as you pointed out, the models and are described in our various references.

Q Were these calculations that you could carry out by hand or did you use a computer to do them?

A (Witness Schaffer) They were carried out both by computer and by hand.

Q Okay. And you checked them thoroughly and there aren't any arithmetic errors in them to your knowledge, are there?

A To my knowledge they are correct.

Q But without seeing them, I couldn't examine that question, could I?

A (Witness Mauro) Without independently calculating them themselves, you probably would have to take it on its

24pb5

merit, on its face value that we did do our calculations correctly.

Q Well, if I look at a calculation that you've done that says this number times that number plus this number times that number and so on, even if I don't know how to make the calculation I could identify an arithmetic error just by knowing arithmetic, couldn't I?

MS. BAUSER: Objection. There is no purpose to be served. He answered the question already.

MR. EDDLEMAN: It may be a slightly different question. He says I have to take it on faith unless I can make the calculation myself.

JUDGE KELLEY: Yes, that's what he says.

MR. EDDLEMAN: And I'm asking, isn't it true that whether or not I know how to make the calculation I could find an arithmetic error in it just by knowing the arithmetic if I had the calculation in front of me.

JUDGE KELLEY: That's kind of rhetorical, isn't that true?

MR. EDDLEMAN: Well, sure it is.

JUDGE KELLEY: So where are you headed, Mr. Eddleman?

MR. EDDLEMAN: Well, he hasn't shown me the calculation.

JUDGE KELLEY: So?

24pb6

MR. EDDLEMAN: So it's kind of hard to cross-examine him on it.

JUDGE KELLEY: We know about the data, right? We know where the data came from. We know the formulas. And you could go home, presumably and reproduce what he did, right?

MR. EDDLEMAN: Well, I'm not sure about that but let me ask him that.

JUDGE KELLEY: How is he hiding the ball, I guess? Let me ask you, making the large assumption if I understood all this, I could go home and do the same thing?

WITNESS MAURO: Yes.

JUDGE KELLEY: Okay, thank you.

BY MR. EDDLEMAN:

Q Let me ask you about your Table 2 which follows page 13. It says, "Inhalation dose, assuming all of the radionuclides .1 microns, AMAD" which I gather is aerodynamic diameter?

A (Witness Mauro) Activity meaning aerodynamic diameter.

Q In other words, they act like the median of them is a .1 micron sphere.

A That's correct.

Q Okay. Now, if I wanted to calculate these numbers, what do I do with this 60 percent deposition fraction in making this calculation, Doctors?

24pb7

A (Witness Schaffer) You would then go to the reference that it cited in our testimony, ICRP-30 and look up the correction equation for correcting for particle size aerodynamic diameter. And what this calculation assumes is you correct by that equation these doses.

Q All right. So rather than actually taking the 60 percent deposition directly, I use an equation that depends on aerodynamic diameter to compute these doses.

A Well, let me add some clarification. The 60 percent is the maximum pulmonary deposition in ICRP-30.

Q Okay. Now is that maximum associated with a given particle size?

A Yes, .1 micron.

Q Okay. Let me ask you this about your testimony on page 14. In the summary paragraph again you summarize about accounting for the attachment of these particles. Does the effect have anything to do with the presence of other mutagens or carcinogens on these particles? The effects that you calculate.

A We calculate doses.

Q Right. So any synergistic effects of mutagens or carcinogens of other sorts, that is not radioactive ones that are already on these particles are not captured in your analysis; is that correct?

MS. BAUSER: Objection, that has nothing to do

24pb8

with the contention.

JUDGE KELLEY: You'll have to restate it for me, Mr. Eddleman. There is an objection.

MR. EDDLEMAN: I'm thinking about whether to argue the objection or just to restate the question.

JUDGE KELLEY: I asked you 25 minutes ago, and you said you were about through. How do you stand now?

MR. EDDLEMAN: This is the last question.

JUDGE KELLEY: Good, okay. Try the restatement and we'll see where that takes us.

BY MR. EDDLEMAN:

Q All right. Now, this contention says that its long term somatic and genetic health effects of radiation releases, does it not? That's at the top of page 2.

MS. BAUSER: I lost the end of your sentence, Mr. Eddleman. Could you repeat it?

BY MR. EDDLEMAN:

Q The long term somatic and genetic health effects of radiation. That's what that starts off saying, doesn't it? And it says, "has been seriously underestimated for the following reasons." So I think this contention is about effects.

Now I'm not asking a question, okay? Now, if a radionuclide is on a particle that has some other carcinogens on it, gentlemen, do you expect that the other carcinogens

24pb9

might also have an effect?

MS. BAUSER: Objection --

JUDGE KELLEY: If a particle is on what?

MR. EDDLEMAN: If a radionuclide is on a particle which happens to have some other carcinogens on it, what I'm asking is may there be a synergistic effect between the radioactive particles, cancer potential and the cancer causing potential of the other carcinogens that are on the particle?

JUDGE CARPENTER: Excuse me for just a moment. I was ill last week, I wasn't here last week would you lay a little foundation for that question?

MR. EDDLEMAN: Sure, Judge.

JUDGE CARPENTER: Just a little bit. Three or four sentences.

MR. EDDLEMAN: Well, you mean you want me to explain what my foundation is?

JUDGE CARPENTER: I just want to hear it. I don't want an explanation, I just want to hear it.

JUDGE KELLEY: This may require a huddle. I'm going to vote to sustain the objection, but go ahead.

MR. EDDLEMAN: Well, now I'm totally confused at this point. What am I supposed to be doing?

JUDGE KELLEY: I just portrayed my view on this question, but go ahead and state it if you want it.

end 24.

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BY MR. EDDLEMAN:

Q Gentlemen, in your making your analysis, did you examine either the mutagenicity or the carcinogenicity of any of the constituents of the coal particles?

MS. BAUSER: I am going to object.

MS. MOORE: Staff joins in the objection.

(The Board confers.)

JUDGE KELLEY: Sustained. We don't see this contention as an effects contention; we see it as a mechanisms contention, if you will. To be sure, the preamble talks about effects, but then it goes on to say that the effects are underestimated because, and that is where you start the contention, as we understand it -- how fly ash particles carry things or fail to carry things to various places. We don't see it as having anything to do with relationships between carcinogens.

MR. EDDLEMAN: Well, I hear you , Judge, and I'll say this. If I ever learn to write a contention that says what I really think it ought to mean, it will probably be a miracle. But on that basis, I have no further questions.

JUDGE KELLEY: Contention writing is a fine art.

Staff, have you got questions?

MS. MOORE: No, Staff has no questions.

JUDGE FOREMAN: At the risk of being very

mgc 25-2

unpopular with all of you, I have a small point that I would like to have cleared up for my own edification and perhaps for the record.

BOARD EXAMINATION

BY JUDGE FOREMAN:

Q I would like to preface it by saying, I know if I had -- and I am looking to page 13, "Inhalation Dose Comparison" -- and I know that if I had the numbers and I had the equation, that I could calculate or run through the calculations and get the results, or if I had the program, I could punch the buttons.

However, could you briefly explain to me -- and I am reading now -- "Notwithstanding the above analysis, the doses calculated from the Harris plant vicinity would not change, even if one assumes greater lung particle deposition or longer lung retention of radionuclide than are assumed in the calculation performed with Reg Guide 1.109."

Intuitively, that doesn't make sense to me. I would think that if there was greater lung particle deposition and there was longer lung retention, that the doses would change. How is it that they don't?

A (Witness Mauro) The reason really comes down to something quite simple. Most of the dose is due to tritium, and it is unaffected by articles in the

mgc 25-3

atmosphere. Now if you were to just limit --

Q I understand. Thank you.

JUDGE KELLEY: Anymore questions?

MR. EDDLEMAN: Judge, I want to ask one about that.

CROSS ON BOARD EXAMINATION

BY MR. EDDLEMAN:

Q You say "unaffected by tritium" -- I mean "unaffected by the particles." You didn't, in fact -- I think we've already established that you didn't, in fact, make a calculation of the adsorption of tritium onto these particles in your analysis, did you?

A (Witness Mauro) No, sir. We assumed tritium would be uninfluenced by the particles airborne in the vicinity of the site in terms of how we modeled its dosimetry.

MR. EDDLEMAN: Okay.

FURTHER BOARD EXAMINATION

BY JUDGE KELLEY:

Q Gentlemen, are you familiar with the testimony of Dr. Brannigan from the NRC Staff?

A (Witness Mauro) Yes, sir.

Q Do you substantially agree with it?

A Basically, yes. The bottomline. He has approached the problem differently than we have.

mgc 25-4

Q I understand that the approach is somewhat different. Do you have any significant disagreement with any aspects of it?

A No, sir.

A (Witness Schaffer) No, sir.

JUDGE KELLY: Thank you. Okay. That completes our questioning of this panel.

MS. BAUSER: Excuse me. I think we --

JUDGE KELLEY: Do you have redirect? Oh, I'm sorry.

MS. BAUSER: Could you give me one minute, please?

JUDGE KELLEY: Sure.

(Pause.)

End 25

mgc 26-1
(6 pm)

(6:00 p.m.)

JUDGE KELLEY: We are back on the record now. Ms. Bauser has some redirect questions.

REDIRECT EXAMINATION

BY MS. BAUSER:

Q Gentlemen, could you explain please why it is that you believe that tritium would not attach to particles in the atmosphere and then be inhaled and subsequently lodge in the lung?

First of all, correct me if I'm wrong, if that is not your understanding.

A (Witness Mauro) We don't believe that there is any evidence that tritium will bind tenaciously to an airborne particulate and remain there upon inhalation. There's just no evidence that that occurs, and there is every reason to believe, based on just an undrstanding of the behavior of water vapor, that it won't behave that way.

Q Would tritium behave as any other -- as regular water vapor?

A Yes. Tritium -- when we say tritium, we are talking about tritiated water vapor, which behaves chemically identical to stable or regular water vapor. So as far as the chemistry or the chemical behavior of tritiated water vapor, it is identical to water vapor in general and would

mgc 26-2

not be expected to behave very much differently in its transport and dispersion and behavior in the body.

Q Let me go on to another point. As I understood your testimony earlier today, you stated -- I think both of you did -- essentially that particles, coal particles in the atmosphere, would not, in effect, select out tritiated water or tritium that might be released from the plant, from a nuclear plant.

Could you explain why it is that you have that view?

A Yes. That was almost implied in my answer, and I could have been clearer on that. Any association that tritiated water vapor may have with a particle, there will not be any preference, preferential treatment or selectivity between tritiated water vapor and the stable water vapor. As far as the particle is concerned, they are chemically identicial, and there will be no selection at work, selective processes at work where you would expect for some reason the tritium or tritiated water vapor to preferentially bind or become associated with than any other stable water vapor.

Q What impact does that have in terms of the quantity of water vapor there is, versus the quantity of particles?

I think you were talking before about the eight grams of water.

mgc 26-3

A Yes. Well, the eight grams of water airborne is stable water, and if there were some tritium molecules or tritiated water vapor in there, it would be completely commingled with it. You could treat it as such. There wouldn't be any discrimination between the way in which the tritiated water vapor would behave and just regular water vapor would behave.

Q One more question.

Dr. Schaffer, I think you stated in response to a question by Mr. Eddleman something to the effect of an assumption you made about particulates, coal particulates being 10 micrometers in diameter. Is that the assumption you make in your testimony?

A (Witness Schaffer) The assumption we make in the testimony is that the particles around the Harris plant from a combustion source away from the plant would be in the size range of .1 to 2 microns in diameter.

MS. BAUSER: I have no further questions. Thank you.

JUDGE KELLEY: Well, at this time, I think -- yes?

MR. EDDLEMAN: I think I have one question on recross.

JUDGE KELLEY: All right.

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RECROSS EXAMINATION

BY MR. EDDLEMAN:

Q Isn't it true that one difference between tritiated water and just plain old water is that when a tritium atom decays, it leaves an ionized particle behind it, or it leaves the particle that was anionized?

A (Witness Mauro) That's correct.

MR. EDDLEMAN: No more questions.

JUDGE KELLEY: Okay. Gentlemen, you are going to be our panel, are you not, on the next contention also?

WITNESS MAURO: I will be.

JUDGE KELLEY: I see.

JUDGE FOREMAN: I really would like to ask a question.

FURTHER BOARD EXAMINATION

BY JUDGE FOREMAN:

Q You had stated that there was no difference between a droplet of water containing ordinary hydrogen and tritiated water in terms of relating to particular fly ash. What if the fly ash did have a charge on it? Isn't it possible that the tritiated droplet would be preferentially attracted to that particle?

A (Witness Mauro) The tritiated droplet -- I guess to relate to this charge question -- upon decay, in the decaying prccess, the hydrogen will ionize and there will

mgc 26-5

be the creation of ion pairs. So there would be a very localized charge upon decay. But that is after it is decayed. But the tritiated water molecule's upon decay is virtually chemically indistinguishable from any other water molecule.

JUDGE FOREMAN: Okay. Thank you.

MR. EDDLEMAN: I am sorry, Judge.

JUDGE FOREMAN: It's quite all right. Go ahead.

FURTHER RECROSS EXAMINATION

BY MR. EDDLEMAN:

Q Then to follow up on this question, isn't it true that water with a relatively higher concentration of tritium in it would be more likely to be attracted to coal particulates by electrostatic attraction?

A (Witness Mauro) I don't know.

MR. EDDLEMAN: No more question.

JUDGE KELLEY: Okay. Applicants?

MS. BAUSER: No.

JUDGE KELLEY: Board members.

(No response.)

JUDGE KELLEY: Okay.

Well, Dr. Mauro is going to be returning, and we have another statement, but not the same one tomorrow.

Dr. Schaffer, we can say good-bye, at least as a witness. We appreciate you both being here and responding

mgc 26-6

so well, and we appreciate it very much.

You are excused.

(Witnesses excused.)

JUDGE KELLEY: Anything else before tomorrow morning at 8:30?

(No response.)

JUDGE KELLEY: Okay, we are adjourned.

(Whereupon, at 6:10 p.m., the hearing was recessed, to reconvene at 8:30 a.m., Tuesday, June 19, 1984.)

End 26

CERTIFICATE OF PROCEEDINGS

This is to certify that the attached proceedings before the

NRC COMMISSION

In the matter of: CP&L & No. Carolina Eastern Municipal Power Agency, Shearon Harris, 1 & 2

Date of Proceeding: Monday, June 18, 1984

Place of Proceeding: Raleigh, North Carolina

were held as herein appears, and that this is the original transcript for the file of the Commission.

Suzanne Young

Official Reporter - Typed

Suzanne Young

Official Reporter - Signature