ILLINOIS POLLUTION CONTROL BOARD
August 21, 2006

IN THE MATTER OF:	)	R06-25
	)	
PROPOSED NEW 35 ILL. ADM. CODE PART 225	)	
CONTROL OF EMISSIONS FROM	)	
LARGE COMBUSTION SOURCES (MERCURY)	)	

REPORT OF PROCEEDINGS held in the above-entitled cause before Hearing Officer Marie Tipsord, called by the Illinois Pollution Control Board, taken before Tamara Manganiello, RPR, a notary public within and for the County of Will and State of Illinois, at the James R. Thompson Center, 100 West Randolph Street, Chicago, Illinois, on the 21st day of August, 2006, commencing at the hour of 1:00 p.m.

A P P E A R A N C E S:

ILLINOIS POLLUTION CONTROL BOARD
100 West Randolph Street
Suite 11-500
Chicago, Illinois 60601
(312) 814-3461
BY: MS. MARIE TIPSORD, HEARING OFFICER
MS. ANDREA S. MOORE, BOARD MEMBER
MR. TIMOTHY J. FOX, ATTORNEY ASST. TO MOORE
MR. NICHOLAS J. MELAS, BOARD MEMBER
MR. G. TANNER GIRARD, ACTING CHAIRMAN
MR. ANAND RAO, SR. ENVIRONMENTAL SCIENTIST
MR. THOMAS E. JOHNSON, BOARD MEMBER;

ILLINOIS ENVIRONMENTAL PROTECTION AGENCY
1021 North Grand Avenue East
P.O. Box 19276
Springfield, Illinois 62794-9276
BY: MR. JOHN J. KIM, MANAGING ATTORNEY
MR. CHARLES E. MATOESIAN, ASST. COUNSEL;

AYRES LAW GROUP
1615 L Street, N.W.
Suite 1350
Washington, D.C. 20036
(202) 452-9200
BY: MR. RICHARD E. AYRES;

SCHIFF HARDIN, L.L.P.
233 South Wacker Drive
6600 Sears Tower
Chicago, Illinois 60606
(312) 258-5646
BY: MS. KATHLEEN C. BASSI
MR. STEPHEN J. BONEBRAKE
MR. SHELDON A. ZABEL;

A P P E A R A N C E S

CHICAGO LEGAL CLINIC, ENVIRONMENTAL LAW PROGRAM
205 West Monroe Street
Fourth Floor
Chicago, Illinois 60606
(312) 726-2938
BY: MR. KEITH I. HARLEY;

DYNEGY MIDWEST GENERATION, INC.
1000 Louisiana Street
Suite 5800
Houston, Texas 77002
(713) 767-0450
BY: MR. JAMES W. INGRAM, SR. CORPORATE COUNSEL

MS. TIPSORD: Good afternoon. This is the sixth day of hearing at our second round of hearings in this proceeding. My name is Marie Tipsord and I'm the hearing officer.

For those of you who may be new, this is R06-25 In the Matter of Proposed New 35 Ill. Adm. Code 225, Control of Emissions From Large Combustion Sources (Mercury).

With me today to my immediate left is Dr. Tanner Girard and to my immediate right is Andrea Moore, the presiding board member. To Ms. Moore's right is her attorney assistant Tim Fox. To Mr. Fox's right is Board member Nicholas Melas. To Dr. Girard's left is Anand Rao from our technical unit. And to his left is Tom Johnson, another of our board members.

Also present today are Kathleen Crowley, our senior attorney and Connie Newman. If any members of the press are present and have questions, they should contact Connie Newman.

Today we're going to start our hearing I understand first with a statement

from Mr. James Ingram; is that correct?

MR. INGRAM: Yes, ma'am.

MS. TIPSORD: And then we'll go to the testimony of Krish Vijayaraghavan, Gail Charnley, Peter Chapman and then we'll decide what order we're doing Richard McRanie, C.J. Saladino and Andy Yaros tomorrow.

At the back of the room there are sign-up sheets for the notice of service list. There is also copies of the Department of Commerce and Economic Opportunity letters indicating that they will not be doing an amicus in this proceeding. And I also see that with us today is Mr. John Knittle, who is Tom Johnson's assistant. With that, Mr. Ingram?

MR. INGRAM: Madam Hearing Officer, Members of the Board, Jim Ingram, attorney for Dynegy Midwest Generation, Inc. If I may, I'd like to provide to the parties present a copy of a joint statement of the Illinois Environmental Protection Agency and Dynegy Midwest Generation, Inc., that I have filed with the clerk of the Illinois

Pollution Control Board in this matter today.

Recognizing that this joint statement comes well after the deadline of July 28 for filing pre-filed testimony in opposition to the proposed Illinois mercury rule, I have not prepared testimony concerning the joint statement and assume that as such it will be received as a comment on the proposed rule.

Under Section 102600 of the rules of the Illinois Pollution Control Board, the Board is allowed to revise proposed regulations before adoption in response to suggestions made at hearing and in written comment. And Dynegy is asking in the joint statement that the Board revise the proposed regulation in this proceeding to include the multi-pollutant standard as revised in the attachment to the joint statement of Illinois Environmental Protection Agency and Dynegy Midwest Generation, Inc., that I have filed today.

Dynegy has pre-filed testimony in opposition to the proposed mercury rule in

conjunction with Midwest Generation, Inc., through our attorneys, Schiff Hardin. To the extent that portions of that testimony contradict the joint statement filed today, I would request that the hearing officer and the Board disregard those portions that do contradict as to Dynegy -- as the testimony of Dynegy. If I may?

MS. TIPSORD: Just for clarification, this has been filed in the clerk's office --

MR. INGRAM: Yes, it has.

MS. TIPSORD: -- as a public comment? Do you want to enter it as an exhibit in the hearing as well or just as a public comment?

MR. INGRAM: I would enter it as an exhibit.

MS. TIPSORD: All right. We'll enter it as an exhibit then, as well.

MR. INGRAM: But it will not be supported by testimony today.

MS. TIPSORD: Understood.

(Documents tendered to the Board from Mr. Ingram.)

MS. TIPSORD: Thank you. If there's no objection, we will mark this as Exhibit No. 125. Seeing none, it is Exhibit 125.

And I would note that the clerk's office, I'm sure, has given it a corresponding public comment number in the six or 7000s someplace. And, actually, I can check at break and get back to everyone what the public comment number is on that as well.

MR. INGRAM: Thank you.

MS. TIPSORD: Thank you. Mr. Zabel?

MR. ZABEL: For the record, Madam Hearing Officer, Sheldon Zabel. At this point in time I would formally withdraw the appearance of Schiff Hardin, which includes myself, Mr. Bonebrake, Ms. Bassi, Mr. Moore and Mr. Gilbert on behalf of Dynegy Midwest Generation, Inc. We would continue to represent the other parties for whom we have appeared in this proceeding.

MS. TIPSORD: And just for the record, can you identify who those other parties are?

MR. ZABEL: Yes. Midwest Generation, L.L.C., Southern Illinois Power Cooperative.

MS. TIPSORD: Thank you. And will you be filing something with the clerk's office?

MR. ZABEL: I can file a formal withdrawal, of course. A written withdrawal

MS. TIPSORD: That would probably be easier for the clerk's office.

MR. ZABEL: I just wanted, before we proceeded today, to make that clear on the record.

MS. TIPSORD: Understood. Thank you very much. With that, I believe we're ready to go to Krish Vijayaraghavan and can we have him sworn?

MR. KIM: Before we continue, I just wanted to give you the last word that I had heard on the Steubenville report.

MS. TIPSORD: That's right.

MR. KIM: Dr. Keeler is on a beach somewhere but he has spoken with us and what he has represented to us is this: That he spoke with the -- he contacted and spoke with the editorial office of Environmental Science and Technology. Apparently what's going to happen next is they are going to or they have

sent galleys or proofs of the article to him. He has two weeks to make -- he's probably had these for a little while. He had two weeks to make any changes he felt were necessary. At that point, if they received nothing, they were going to publish it. The date that he received it from them was a September 7th publish date, you know, with or without, I guess, any comments that he had. So what he was told by the publication was that September 7th would be the last date by which it should be published.

MS. TIPSORD: Thank you. If we could have Mr. Vijayaraghavan sworn in.

(Witness sworn.)

MR. KIM: Could we have just -- and I apologize -- two minutes for Mr. Ayres to arrive? He's going to be conducting the bulk of the questioning to Mr. Vijayaraghavan.

MR. AYRES: Thirty seconds?

MR. KIM: Thirty seconds.

MS. TIPSORD: I'll give you a whole minute.

(Brief pause.)

MS. TIPSORD: I have been handed the pre-filed testimony of Mr. Vijayaraghavan. If there's no objection, we'll mark that as Exhibit 126. Seeing none, it's marked as Exhibit 126.

MS. BASSI: And I had indicated to you that there were a couple of additional references and here they are as well. So this gets tacked onto the end.

MS. TIPSORD: If it's all right with everyone, instead of marking this as a separate exhibit, we'll just make it as an addendum to 126. Is that okay with everyone? We'll do that then.

MS. BASSI: Would you please introduce yourself and then we will have a PowerPoint slide that goes through and kind of summarizes Mr. Vijayaraghavan's testimony and I hope we'll clarify some of the maps that are at the end of your testimony that I just handed out.

MR. AYRES: Ms. Bassi?

MS. BASSI: Yes, sir?

MR. AYRES: Is this testimony that you

just handed out the same as the one that was pre-filed --

MS. BASSI: Yes, sir.

MR. AYRES: -- or in addition to it?

MS. BASSI: No. This is the same as what's filed.

MR. AYRES: So these slides are new?

MS. BASSI: Yes. And I will have copies. Well, the slides are mostly the same as what's in your testimony. There are a couple of additional ones and so I will be handing that out separately.

MR. AYRES: Okay.

MS. TIPSORD: You will be handing out an entire copy of this?

MS. BASSI: Yes.

MS. TIPSORD: The PowerPoint presentation, for the record.

MR. AYRES: Madam Chairman, just before we begin, this is additional testimony which we haven't had a chance to review.

MS. TIPSORD: Understood.

MS. BASSI: I'm sorry, you haven't had a chance to review what?

MR. AYRES: What you're going to add by way of the slides.

MS. BASSI: It won't confound you. I'm sorry, did you give an exhibit number to the testimony?

MS. TIPSORD: One-twenty-six.

MS. BASSI: Thank you.

MS. TIPSORD: When he's ready to start the presentation, we'll move.

MR. VIJAYARAGHAVAN: Good afternoon, Hearing Officer. My name is Krish Vijayaraghavan. I'm a staff engineer at Atmospheric & Environmental Research, AER. We provide the research --

MS. TIPSORD: Hang on. That microphone is not going to work at all.

MR. VIJAYARAGHAVAN: It has too much static. I could speak up.

MS. TIPSORD: Okay. Let's try that or we can also try one of the other microphones.

MR. VIJAYARAGHAVAN: I'm a staff engineer at Atmospheric & Environmental Research or AER, which is a research and consulting firm based in Massachusetts near

Boston. And we provide consulting services both to government and industry. Most of the staff have advanced degrees and a substantial number have PhDs, so the focus is on fundamental research and consulting. For example, we received the American Meteorological Society award for outstanding services by a corporation.

The company has offices around the United States and I represent the San Francisco bay area office that specializes in air quality studies. And my area of expertise is the atmospheric modeling of mercury, ozone and particulate matter. I have a bachelor's degree in chemical engineering from the Indian Institute of Technology and a master's degree in chemical engineering from the University of Kansas and a master's degree in environmental engineering from the Georgia Institute of Technology.

I have conducted numerous studies of the modeling of mercury deposition both over the United States and globally and have

published numerous peer-reviewed scientific papers, made conference presentations and written technical reports. For example, recently I was an invited speaker at the mercury session of the annual meeting of the national atmospheric deposition program. And with that, I conclude my opening brief.

MR. AYRES: Mr. Vijayaraghavan? If I said that properly?

MR. VIJAYARAGHAVAN: You got it.

MR. AYRES: Who are the primary clients of AER?

MS. TIPSORD: Could we wait until he finishes his slide presentation and then we'll do questions?

MR. AYRES: Certainly.

MS. TIPSORD: Let's let him do his opening statement first.

MR. AYRES: Okay.

(Brief pause.)

MS. TIPSORD: We're going to mark this, which is the hard copy of the slide presentation, as exhibit number 127, if there's no objection. Seeing none, it's

Exhibit 127. Go ahead, Mr. Vijayaraghavan.

(Brief pause.)

MS. TIPSORD: Why don't you go ahead and start the preliminary questions while we're waiting on the signal to get fixed. That way we won't be losing much time. Mr. Ayres?

MR. AYRES: Mr. Vijayaraghavan, I asked earlier who the primary clients are of the firm, AER, that you're associated with?

MR. VIJAYARAGHAVAN: AER has clients in both government and industry. For example, U.S. EPA, NASA, and then the utilities from industry, then you have the automobile manufacturers, the CRC, which represents a consortium of research organizations. So we have a range of both private industry and government clients.

MR. AYRES: And what percentage would you say was -- of your revenues, let's say, is from private industry?

MR. VIJAYARAGHAVAN: Well, it's hard to tell because I'm not in the executive management position, but it's -- I don't

think I can put a number on it. It's not -- I don't think one is -- either one is more than 75 percent. But it's hard for me to quantify. So there isn't either one that has a significant competence. By either one, I mean industry versus government.

MR. AYRES: Would the majority of the revenues probably be from industry?

MR. VIJAYARAGHAVAN: That might be likely, but I couldn't quantify it. For example, one of our clients was LADCO for a mercury study that we did for them. So at the same time, we've also done work for the utilities so we've got a balance.

MR. AYRES: Could you tell us a little bit about the TEAM model? Is that a proprietary model or is it available for public review?

MR. VIJAYARAGHAVAN: TEAM is available for public review. It has been published in the literature. But the development of TEAM was funded by EPRI, which is a utility consortium. So as can be naturally expected, they would want to be informed before TEAM is

made use of. However, we have transferred TEAM to state organizations. For example, NYSERDA, the New York State Department, we've transferred TEAM to them and have, in fact, provided training to state officials out there.

MS. TIPSORD: Excuse me, for the court reporter, EPRI is capital E, capital P, capital R, capital I.

THE COURT REPORTER: Thank you.

MR. VIJAYARAGHAVAN: And NYSERDA was N-Y-S-E-R-D-A.

MR. AYRES: And we'll do this to you all afternoon. I'm sorry. So has the TEAM model then been peer reviewed in any event?

MR. VIJAYARAGHAVAN: Yes. The TEAM model has been peer-reviewed. It's been also published extensively in the peer-reviewed literature. I believe we have about seven to eight publications in international journals. It's been critically reviewed by scientific researchers who review such journals.

MR. AYRES: And has it been benchmarked against other models?

MR. VIJAYARAGHAVAN: Yeah. We have compared TEAM with -- we have compared TEAM with models such as CMAQ and other chemistry transport models and we have benchmarked it against data. Now, benchmarking is a tricky proposition because you don't want to really compare apples to oranges when you, say, compare a chemistry transport model to a receptor model.

But as has been cited in my testimony, we did a rough comparison with the results of the receptor modeling study done by Dr. Keeler and we seem to be within the range of uncertainty of his numbers so that serves as a fairly good benchmark.

MR. AYRES: So what benchmark that has been done, has been done internally; is that correct.

MR. VIJAYARAGHAVAN: That is correct.

MR. AYRES: Has it just been done by your staff or has it been done by clients?

MR. VIJAYARAGHAVAN: When they transferred TEAM to NYSERDA, they tested the model, as well. But I'm not aware of

publications that they published that came out of that study.

MR. AYRES: Has it ever been accepted by a regulatory agency for purposes of regulation?

MR. VIJAYARAGHAVAN: I don't think that issue has ever come up. Firstly, mercury regulations have been quite recent, so we are talking about a very specific type of model, chemistry transport models as opposed to other types of models, say, for example, a methylation model or a lake model. So historically, since these regulatory models are relatively new, TEAM has -- the issue has not come up. And we have not received any requests for assistance in, you know, making TEAM to be a regulatory model. So, no, that has not come up.

MR. AYRES: EPA does use the CMAQ model for that --

MR. VIJAYARAGHAVAN: Right.

MR. AYRES: -- purpose, though, don't they?

MR. BONEBRAKE: Just for

clarification, Mr. Ayres, you're referring to U.S. EPA?

MR. AYRES: Yes. Thank you. U.S. EPA uses the CMAQ --

MR. VIJAYARAGHAVAN: Right.

MR. AYRES: No. The CMAC -- CMAQ model?

MR. VIJAYARAGHAVAN: That is correct.

MS. TIPSORD: Even we can't keep track of the acronyms.

MR. AYRES: Are we ready for the slides?

UNIDENTIFIED SPEAKER: No.

MS. BASSI: Are those all of your introductory questions?

MR. AYRES: I don't think --

MS. BASSI: Can you think of more?

MR. AYRES: Perhaps. I would like to pause at this point, if I may.

MS. BASSI: We could go to the other questions, if you want.

MS. TIPSORD: The pre-filed questions?

MS. BASSI: While we struggle with the machinery, let's go ahead with question

number one.

MR. VIJAYARAGHAVAN: Question number one: On Page 3 of his testimony, Mr. Vijayaraghavan states that the relative proportions of Hg0, Hg2+ and Hgp differ in time and location, and the fractions of HG2+ and Hgp can be considerably larger near man-made sources. Is a 20 kilometer by 20 kilometer grid spacing the most appropriate model resolution to assess Hg deposition close to emission sources? Is it true that within the 20 kilometer by 20 kilometer grid cell, the deposition amount at a point of maximum deposition would be averaged together with lower deposition amounts to arrive at the average deposition amount over that large area.

Answer: No. A plume model is actually the most appropriate to assess Hg deposition close to an emission source. However, a plume model is typically not applicable to model a large number of different types of sources. For example, in the case of mercury modeling you also have

area sources. And a grid-based model, such as TEAM, is most appropriate for the simulation of atmospheric mercury deposition over the state of Illinois.

We applied a grid model with 20 kilometer grid spacing because our objective was to assess Hg deposition both close to and far from emission sources. Also, a plume model, if applied, tends to predict lower power plant contributions to mercury deposition than a grid-based model over an area commensurate with the grid size.

This was shown in our work published in the Journal of the Air & Waste Management Association. The reference would be Seigneur, et al., 2006(b). And that's cited in my testimony, as well.

And this lower prediction is typically because a plume model will correctly transport the mercury, SO2 and NOx aloft in the plume, whereas the grid model tends to distribute the plume material closer to the ground. All of the emissions are kind of instantaneously released in the grid cell

and then they're disposed down to the surface by vertical diffusion.

In response to the second part of the question: Yes, the deposition flux reported over a grid cell represents an average over the grid cell area. However, a single point of maximum deposition in a 20 kilometer by 20 kilometer grid cell is a moot issue because deposition over a larger geographic area is really what is needed and not at a single point when you're looking at estimating contribution to water sheds.

Also, the grid cell value itself that was arrived by averaging could be artificially high because the plume material is dispersed to the surface grid cell too rapidly in a grid-based model.

MR. AYRES: Isn't the -- aren't the emissions which are within the grid space in the model emitted at a single point in the model?

MR. VIJAYARAGHAVAN: Emissions are emitted at a single point, that is correct.

MR. AYRES: And that's whether or not

the actual point -- whether there's actually one point at which they're emitted or several points at which they're emitted within that cell, correct?

MR. VIJAYARAGHAVAN: Well, the way we do it is if you have multiple sources within a grid cell. First, you compute plume rise. So you see, because of the temperature, velocity, the height of the stack, et cetera, you see how far out the plume goes and there you release the emissions in that particular grid cell.

So if two different sources happen to be in the same 20 kilometer by 20 kilometer grid cell, they would both be released in the same grid cell.

MR. AYRES: They would both be released in --

MR. VIJAYARAGHAVAN: In the same grid cell. But it is not at a single point in the grid cell because in a grid-based model your grid is one entity. In a sense, you divide up your modeling domain into a 3-D gridded mesh and you release the emissions within a

specific grid cell aloft. So there isn't really one point in the grid cell where the emissions are released. It is in a specific grid cell which encompasses the location of the source.

MR. AYRES: So the emissions are released as if they are evenly released throughout the grid cell?

MR. VIJAYARAGHAVAN: Yeah. And that is a limitation of a grid-based model. And what Mr. Ayres is referring to is known as horizontal dilution where you have the emissions being released and then they are spread across the grid cell. So in this case, a 20 kilometer by 20 kilometer grid cell.

MR. AYRES: Aside from Lake Michigan, do you know the extent of the largest lake in Illinois?

MR. VIJAYARAGHAVAN: I have a -- I think in the context of deposition modeling, waters of interest is actually the water sheds of Illinois and I have a map here that has the water sheds of Illinois and those are

significantly larger -- typically significantly larger than the 20 kilometer grid cells that we're modeling with.

MS. TIPSORD: And what map are you referring to?

MR. VIJAYARAGHAVAN: For the record, the map is titled Major Water Sheds of Illinois. This is a map prepared by the Illinois State Water Survey.

MS. TIPSORD: Is it in your testimony?

MR. VIJAYARAGHAVAN: No.

MR. AYRES: I was asking about lakes rather than water sheds.

MR. VIJAYARAGHAVAN: Yes. The size of the water shed will be larger than the sizes of the lake. And the reason I'm talking about -- and, specifically, no, I do not know the size of the lake. But I bring up the issue of water sheds because we're talking about the same concept, deposition to a water shed initially.

MR. AYRES: It would be surprising, wouldn't it, if the largest lake was 20 kilometers square or 20 square kilometers

in area?

MR. BONEBRAKE: I'm going to object. He's already testified that he doesn't know the answer to the question that Mr. Ayres is yet again asking.

MS. TIPSORD: I think he's asking for his opinion at this point. So go ahead and answer as best you can.

MR. VIJAYARAGHAVAN: Well, outside of Lake Michigan one would not expect lakes to be of the order of hundreds of kilometers, I'm sure.

MS. TIPSORD: Ms. Bassi, could we enter that as an exhibit, please?

MS. BASSI: I do not have multiple copies of this. We will have them tomorrow. I was not anticipating giving it to you.

MS. TIPSORD: Thank you. This is Major Water Sheds of Illinois. We'll mark this as Exhibit 128, if there's no objection. Seeing none, it's Exhibit 128. Go ahead, Mr. Ayres. I apologize for interrupting you.

MR. AYRES: Since your model predicts deposition as averages in 20 kilometer square

grids, doesn't that mean that the model cannot tell us what the deposition is at the average or even the largest Illinois lake other than Lake Michigan?

MR. VIJAYARAGHAVAN: Let me repeat, again. What we do in the model is release the emissions in a grid cell, then you simulate the chemistry and the transport and the deposition of the mercury. So if you use a finer grade resolution, then you're going to get the mercury deposition that falls within that particular grid cell. But one of the problems associated with that is you have what I earlier talked about, which was artificial vertical dispersion. So your plume material is -- in a grid-based model, the plume material is artificially dispersed to the ground too rapidly. That's the first point I would like to make.

And the second point, as I just mentioned, the deposition to a single point is a moot issue because what you're really interested in is deposition to a larger geographic area comparable to a water shed.

MS. TIPSORD: And I would like to note just for the record that Exhibit 128 is prepared by the Illinois State Water Survey.

MR. AYRES: Aren't we also interested in the peak deposition? If a particular lake is receiving deposition from a source that is a point source, as these sources all are, at a high concentration, higher than the average in the 20 kilometer square grid; isn't that of interest?

MR. VIJAYARAGHAVAN: First of all, mercury concentrations are not the issue here. It's mercury deposition.

MR. AYRES: I'm sorry. Deposition.

MR. VIJAYARAGHAVAN: Unlike, say, particulate sulfate. And the HUC, hydrological code, is the typical component that's used when you're looking at estimating the effects of mercury deposition.

MR. AYRES: Deposition actually occurs as a result of emissions from point sources, doesn't it?

MR. VIJAYARAGHAVAN: Deposition arises out of several sources, mercury enriched

soils, point sources, automobiles, refineries and such.

MR. AYRES: Let me ask the question another way. Deposition from utilities comes as a result of emissions from point sources, does it not?

MR. VIJAYARAGHAVAN: That is correct.

MR. AYRES: And it travels, to some extent, in plumes we know as a matter of fact, don't we?

MR. VIJAYARAGHAVAN: That is correct.

MR. AYRES: And your model attempts to model the behavior of those activities in the atmosphere. But in reality, we know that there are places where emissions may be considerably higher because of the fact that they're particularly affected by a plume, don't we?

MR. VIJAYARAGHAVAN: I mean, there is -- I don't know what you mean when you say we know that there are places particularly affected by --

MR. AYRES: Don't we --

MS. TIPSORD: Let him finish his

answer, Mr. Ayres.

MR. VIJAYARAGHAVAN: I was just trying to state your question again. You said do we not know that there are places affected by the plumes? I do not follow your statement. But that seems to be an opinion.

MR. AYRES: It seems to be?

MR. VIJAYARAGHAVAN: It seems to be an opinion that you state.

MR. AYRES: I'm asking you a question which is: Do you not know that, in fact, in the real world as opposed to the model world some places are affected by plumes from power plants more than the average over a 20 kilometer area?

MR. VIJAYARAGHAVAN: By definition, the average is going to be smaller than the maximum, that is correct.

MR. AYRES: So since your model predicts deposition in 20 kilometer square grids, doesn't it mean it can't tell us what the peak concentrations in the real world are within those grids?

MR. VIJAYARAGHAVAN: Again, I presume

you're referring to depositions because mercury concentrations are not at issue.

MR. AYRES: I thought I said deposition. But if I didn't, I stand corrected.

MR. VIJAYARAGHAVAN: Right. So, no, again, let me state deposition to a water shed is what is at issue here. Firstly, if you have grid-based models with a 20 kilometer grid such as ours, you are going to have horizontal dilution, which is what we were discussing just now. At the same time, you are also going to have artificial vertical dispersion. So it is quite possible that this average value that we are talking about is actually larger than the real world deposition or concentration.

MR. AYRES: Are we ready?

MS. TIPSORD: Are we ready?

UNIDENTIFIED SPEAKER: We're still working on it.

MS. TIPSORD: Sorry.

MS. BASSI: Are we ready for number two?

MS. TIPSORD: Question number two.

MR. VIJAYARAGHAVAN: Question number two: On Page 10, Mr. Vijayaraghavan notes that U.S. coal-fired power plants are calculated to contribute 19 percent of mercury deposition in Illinois in 2006. For the Illinois grid cells, only four out of 474 20 kilometer by 20 kilometer grid cells receive more than half of their mercury deposition from U.S. coal-fired power plant emissions.

Question A: How is the 19 percent figure calculated if some cells receive more than 50 percent of their deposition from U.S. emissions?

And Question B: Where are the four Illinois grid cells that receive more than half of their mercury deposition from U.S. coal-fired power plant emissions. What is the maximum percentage for any Illinois cell?

Answer A: To calculate the 19 percent number, we compared two different scenarios. We compared the 2006 base

scenario with our scenario number two where we zero'd out mercury emissions from all coal-fired power plants in the U.S. Then we subtract the total deposition in Illinois between those two scenarios and find that as a percent of the base number.

So we subtract the base and the zero-out scenario and find that as -- and convert that to a fraction of the base number and that's how we arrive at the 19 percent number.

Answer B: Four Illinois grid cells, or less than 1 percent of Illinois area, are calculated to receive more than 50 percent of their deposition from all U.S. coal-fired power plant emissions. These four grid cells are in, one, Wabash County, two, Peoria County/Tazewell County, three, Randolph County and, four, Montgomery County. The maximum percentage is 63 percent.

MR. AYRES: To go back to the 19 percent figure, if I could?

MR. VIJAYARAGHAVAN: Yes, sir.

MR. AYRES: That 19 percent figure

represents the average in all cells; is that what your saying?

MR. VIJAYARAGHAVAN: Yes. We compute the total deposition in all cells and subtract out the zero'd number from the base.

MR. AYRES: Okay.

MS. BASSI: May I insert here? Does everyone understand what zero-out means?

MR. VIJAYARAGHAVAN: For the record, by zero'd I mean we set to zero mercury emissions from all coal-fired power plants in the U.S. and we run our model and compute what the deposition is. So, in essence, you're looking only at deposition from sources other than U.S. coal-fired power plants.

MR. AYRES: I'm sorry. Could you also repeat the four county names? We got a couple of them but not all of them.

MR. VIJAYARAGHAVAN: Right. The four would have been, one, Wabash County, two, Peoria County and Tazewell County, three, Randolph County, four, Montgomery County.

MR. AYRES: Do these counties have

power plants located in them? Can you tell us that?

MR. VIJAYARAGHAVAN: Yes these counties have power plants in them.

MS. TIPSORD: If I may? Just out of curiosity, could you tell us how many, for example, in Peoria/Tazewell?

MR. VIJAYARAGHAVAN: Sure. Let me go ahead and give you the full.

MS. TIPSORD: Okay.

MR. VIJAYARAGHAVAN: The first, Wabash County, is actually the maximum contribution that's in a grid cell that spans the Illinois/Indiana border and includes the Gibson Power Plant, which is in Indiana just across the Wabash River from Mt. Carmel. And the Peoria County/Tazewell County that Madam Hearing Officer referred to has got the ED Edwards/Powerton Plant.

MS. TIPSORD: And go ahead with the rest.

MR. VIJAYARAGHAVAN: Yes. And the other two would be Baldwin and Coffeen.

MS. TIPSORD: Thank you.

MR. JOHNSON: Where did you say the Indiana source was?

MR. VIJAYARAGHAVAN: It's the Gibson Plant, which is across the Wabash River just across from Mt. Carmel. Since you bring it up, I came across an issue where the Illinois attorney general actually filed suit against the Indiana plant for cross-state pollution. It's just across from Mt. Carmel in southeastern Illinois.

MS. TIPSORD: Are we ready for question three then?

MR. VIJAYARAGHAVAN: Question three: Related to the 2010 CAIR/CAMR -- it's an acronym, C-A-I-R slash C-A-M-R -- simulation, Mr. Vijayaraghavan notes that Illinois grid cells show decreases in mercury deposition of up to 51 percent. There is only one grid cell in Illinois that shows an increase of less than 1 percent in mercury deposition.

Question A: Where are the Illinois grid cells that have decreases in deposition that are less than 51 percent?

Question B: Where is the Illinois

grid cell that has no decrease in mercury deposition in 2010 due to CAMR?

Answer to A: All Illinois grid cells but one have decreases in deposition that are less than 51 percent.

Answer to B: The Illinois grid cell that showed no decrease in simulated mercury deposition in 2010 due to CAMR is near St. Louis.

MS. BASSI: Number four. Go ahead.

MS. TIPSORD: I'm sorry. You said the area of St. Louis?

MR. VIJAYARAGHAVAN: Yes.

MS. TIPSORD: You mean East St. Louis?

MR. VIJAYARAGHAVAN: Yeah. Actually, it's a grid cell that spans the Illinois/Missouri border. And the power plant out there is Ameren power plant in Missouri. It's right across the border. May I go on to question four.

MS. BASSI: Yes.

MR. VIJAYARAGHAVAN: Question four: On Page 11 of his testimony, Mr. Vijayaraghavan states that the TEAM

results for 2010 CAMR with 90 percent Illinois controls indicated, in relative terms, most of the Illinois area shows decreases of 1 to 5 percent due to the Illinois 90 percent emission reductions with only a few grid cells with decrease in the 15 to 35 percent range.

Question A: How many grid cells had decreases in the 15 to 35 percent range? Where are they located.

Answer to A: Eleven grid cells, or about 2 percent of Illinois area, are simulated to experience between 15 to 35 percent decreases. These grid cells are located in following counties: One, Mason, two, Randolph, three, Peoria/Tazewell, four, Putnam, five, Montgomery, six, Cook, seven, Will, eight, Will again, nine, Lake, ten, Jasper, and eleven, Cook.

Question 5: According to Mr. Vijayaraghavan, the 2020 CAIR/CAMR simulation leads after 10 years to lower mercury deposition in Illinois than the 2010 CAIR/CAMR simulation with 90 percent Illinois

mercury control except for three grid cells in Illinois where very small increases are predicted.

Where are the three Illinois grid cells where 2020 CAIR/CAMR would lead to 3 percent increases in mercury deposition?

Answer A: The three Illinois grid cells where 2020 CAIR/CAMR would lead to very small, i.e., less than 3 percent, increases in mercury deposition are the following counties; Peoria/Tazewell, Christian and Will.

MR. AYRES: Madam Chairman, I'd like to ask some questions about the modeling method, if I may, to follow-up?

MS. TIPSORD: Please do.

MR. AYRES: Mr. Vijayaraghavan, would you say that the deposition of mercury from the atmosphere is a complex phenomenon, one that is difficult to model with atmospheric models?

MR. VIJAYARAGHAVAN: Yeah. The deposition of mercury, much like transport of sulfate, the deposition of sulfate, all

atmospheric phenomena are complex to model. And, typically, our modeling system we try to keep ourselves abreast of scientific advances and use new laboratory data and such and we try to publish our book as quickly as possible. But overall it is a rather complex science.

MR. AYRES: And the reason why it's so complex is that there are so many variables in play, isn't it?

MR. VIJAYARAGHAVAN: Right. Just as in the modeling of any other atmospheric species or for that matter a chemical species such as ozone, mercury is also quite difficult, that is correct.

MR. AYRES: I think maybe there are some additional complications and I'll try to get to those. But let's start by going through some of the variables that have to be included, as I understand it anyway. And you can inform us.

In an atmospheric model like this to make predictions, first, could you tell us how you set the initial conditions for your

model? In other words, for the contents of the air masses in the grid box at the beginning of the modeling exercise.

MR. VIJAYARAGHAVAN: Right. We actually set our initial conditions from a global mercury model that we run so we have a chemistry transport model that spans the globe and that provides both initial and moderate conditions of mercury for our TEAM modeling.

MR. AYRES: And how did you establish the boundary conditions, the conditions at the exterior of the box that your modeling?

MR. VIJAYARAGHAVAN: Right. Again, the global mercury modeling provides -- (inaudible).

THE COURT REPORTER: Provides what conditions?

MR. VIJAYARAGHAVAN: The global mercury model provides boundary conditions of mercury. And, again, our global mercury model has been well published in the peer review literature.

MR. AYRES: And is there a name for that model?

MR. VIJAYARAGHAVAN: Yeah. It's called CTM.

MR. AYRES: CGM?

MR. VIJAYARAGHAVAN: C, as in chemistry, T as in transport, M as in model. CTM.

MR. AYRES: And is that a model that you developed?

MR. VIJAYARAGHAVAN: Yeah. The model originated out of Harvard University. Originally, it was the G-I-S-S circulation model. And a variation of this model is also used by Harvard University currently. And those are the origins for that model.

MR. AYRES: Is that known as Geos-Chem?

MR. VIJAYARAGHAVAN: That is correct. Yes, sir.

MR. AYRES: Where in the United States is the actual highest observed deposition of mercury in terms of regions?

MR. VIJAYARAGHAVAN: Well, we are talking about observed deposition here and observed deposition is typically wet deposition because dry deposition measurements are harder because they have to measure mercury concentrations and then estimate the dry deposition. Whereas with wet deposition, you measure the mercury content in the rainfall.

So when we talk about observed deposition, we have to necessarily talk about observed wet deposition. And, typically, the higher areas of deposition are Florida, for example, along the gulf coast and part of the northeast.

MR. AYRES: Are you aware that the Geos-Chem model predicts the highest deposition of mercury in the U.S. in the west from Wyoming south toward Mexico?

MR. VIJAYARAGHAVAN: The recent paper by Harvard University on the Geos-Chem actually had a very good performance evaluation against the mercury deposition network. So their highest depositions

correspond well with observed deposition.

MR. AYRES: Is this a change from the earlier version or what?

MR. VIJAYARAGHAVAN: I do not -- this is a model that's used by Harvard University, again, and published by them so, I'm sorry, I do not know the answer to your question.

MR. AYRES: Okay. Then you have to include emissions, some variable for emissions in your model, correct?

MR. VIJAYARAGHAVAN: Yes. That is correct.

MR. AYRES: How do you determine the mercury emissions for purposes of your model?

MR. VIJAYARAGHAVAN: Mercury emissions are obtained from different inventories. For example, you have mercury. Obviously, you have both anthropogenic and natural emissions. In anthropogenic emissions, you have emission from utilities, from automobiles and such. So we tend to go to a variety of sources. There isn't one single source that we use for our information. Again, we've published about two to three

papers that discuss the mercury emissions inventory used in our modeling system.

One of the examples would be, for example, the National Emissions Inventory. For power plants, we have EPRI'S well-documented inventory for mercury -- speciated mercury emissions and such.

MR. AYRES: It is true, though, isn't that, there are very few actual measurements of mercury from -- mercury emissions from power plants?

MR. VIJAYARAGHAVAN: If you looked at a percentage of the total power plants in the country, yes, you do not have a majority of the plants with continuous emission monitors, which is relatively a state of the science. So there is some level of scientific estimation that goes into this emissions modeling.

MR. AYRES: And we know that mercury content in coals varies by quite a bit, don't we?

MR. VIJAYARAGHAVAN: That is correct.

MR. AYRES: And we also know that

pollution control equipment can affect the mercury emissions?

MR. VIJAYARAGHAVAN: That is correct.

MR. AYRES: And we also know, don't we, that the chlorine content of coal can affect mercury emissions?

MR. VIJAYARAGHAVAN: Yes, sir.

MR. AYRES: So there are a number of things which could be affecting emissions from actual power plants, most of which have not been measured? They may have been measured in individual places, but they're not commonly measured?

MR. VIJAYARAGHAVAN: Right. If your question is has every single plant in the U.S. measured actual mercury emissions, the answer would be no.

MR. AYRES: So to some extent, there's guesswork involved in trying to create one of these inventories?

MR. VIJAYARAGHAVAN: Right. There is some level of uncertainty in emissions.

MR. AYRES: So then once you have -- your model has emitted the mercury in the

air, it has to try to simulate the chemistry of those emissions in the atmosphere, doesn't it?

MR. VIJAYARAGHAVAN: That is correct.

MR. AYRES: Where do your assumptions on the chemistry come from for this modeling exercise?

MR. VIJAYARAGHAVAN: Right. As I mentioned earlier, we obtained laboratory data, kinetic data, reviewed the literature, we've published a few papers ourselves. One of the earliest papers on mercury chemistry was published by our vice president, Dr. Seigneur. That would be a 1994 paper. And this is one of the seminal books on mercury chemistry.

So we both actively researched this and at the same time keep ourselves informed about new laboratory data and kinetic data, and that would be as published in the literature. And that would be our primary source of information.

MR. AYRES: That data is not based on measurements in the atmosphere downwind of

power plants, though, is it?

MR. VIJAYARAGHAVAN: Mercury -- we are talking about fundamental mercury chemistry. Mercury chemistry can be determined both in a lab and in the field. And to answer your question, no. There is an example of measurements actually made downwind of power plants, for example, as published by Edgerton, et al., in 2006. There is evidence of --

MR. AYRES: Published by whom? I'm sorry.

MR. VIJAYARAGHAVAN: Spelling, E-D-G-E-R-T-O-N.

MR. AYRES: Okay.

MR. VIJAYARAGHAVAN: (Continuing) -- which shows there is some reduction of mercury -- divalent mercury to elemental mercury happening in power plant plumes.

MR. AYRES: You testified that mercury comes in a reactive form, which you call Hg2, as we've seen in the different notations.

MR. VIJAYARAGHAVAN: Right. Hg2 because that's the correct chemical

nomenclature. But as you rightly point out, it's typically referred to as RGM or reactive gaseous mercury.

MR. AYRES: And then a less reactive elemental form, which you denoted, Hg0, right?

MR. VIJAYARAGHAVAN: Yes. Again, because it's a zero oxidation state.

MR. AYRES: Yeah. So Hg2 or the reactive gaseous mercury is deposited readily through wet deposition while Hg0 or elemental mercury is not readily deposited, correct?

MR. VIJAYARAGHAVAN: That is correct.

MR. AYRES: So your model needs to make assumptions about how much of each species of mercury is emitted and also take account of the chemical reactions that take place once it is emitted into the atmosphere, correct?

MR. VIJAYARAGHAVAN: That is correct.

MR. AYRES: Would you say that those atmospheric reactions are well understood or poorly understood or what?

MR. VIJAYARAGHAVAN: I wouldn't say

they are understood with 100 percent certainty. Mercury chemistry is a dynamic science. And as I mentioned before, both keep ourselves abreast of new data as published in the literature and published a few papers ourselves, as well.

MR. AYRES: In the atmosphere, as I understand it, there are transformations back and forth perhaps from these two species once they are in the air?

MR. VIJAYARAGHAVAN: Yes, sir.

MR. AYRES: And, in particular, there is some transformation of Hg2 into Hg0; is that correct?

MR. VIJAYARAGHAVAN: That is correct.

MR. AYRES: And you need to account for that change in your model?

MR. VIJAYARAGHAVAN: Right. We do. There are two aspects to that. Just very briefly, these transformations that Mr. Ayres is referring to could both happen in the gas phase or in cloud droplets. And we account for the reduction of divalent mercury to elemental mercury in the aqueous phase. But

there is some new evidence that this also happens in the gas phase and that would lower our power plant contributions to deposition -- the simulated contributions. But we do not account for that.

MR. AYRES: So somewhere in your model there is an equation or an algorithm or -- I don't have the right term -- a gadget which attempts to reproduce that rate of the transformation from Hg2 to Hg0, right?

MR. VIJAYARAGHAVAN: Right. There are several such reactions, right.

MR. AYRES: And could you tell the Board whose rate reactions you used in there? Are those ones you generated or are they ones you take from the literature?

MR. VIJAYARAGHAVAN: Yeah. They came from the literature. They've been reported in our paper published, that would be Seigneur, et al., 2006(a).

Mercury chemistry is a dynamic science and there is continuously new data available on whether the oxidation of Hg0 to Hg2 is happening faster or slower. And,

similarly, the reduction, as Mr. Ayres is referring to, is happening faster or slower. There are some papers that show that the reduction is happening slower. But, again, there are other books that point out that even if this reduction wasn't happening, a surrogate reduction or a similar reduction has to happen to justify the measured concentrations of mercury in the atmosphere.

MR. AYRES: Would some of that work have been done by someone named -- I think it's Ariya or Ariyat? I'm not sure I have the name correct.

MR. VIJAYARAGHAVAN: Yeah. Ariya. That would be Dr. Parisa Ariya.

MS. TIPSORD: Could you spell that for the record?

MR. VIJAYARAGHAVAN: Yes. The first name Patrick, Apple, R-I-S-A. The last name is A-R-I-Y-A.

MS. TIPSORD: Thank you.

MR. AYRES: And is it her coefficients that you used in your model?

MR. VIJAYARAGHAVAN: Excuse me.

MS. BASSI: Just one second, please.

(Brief pause.)

MR. VIJAYARAGHAVAN: So the answer to the question would be the use of the data of Behkonen spelled B-E-H-K-O-N-E-N, and Lin, L-I-N.

MR. AYRES: Do you know of the work of a Dr. Heinz or Mr. Heinz on this issue?

MR. BONEBRAKE: Mr. Ayres, do you have a spelling on the name?

MR. AYRES: I believe it's like ketchup, but I'm not sure.

MR. VIJAYARAGHAVAN: No, I'm not familiar with that.

MR. AYRES: You're not familiar with that? Okay. Does your model include halogen chemistry?

MR. VIJAYARAGHAVAN: Yeah we include chlorine chemistry.

MR. AYRES: I couldn't hear you.

MR. VIJAYARAGHAVAN: Chlorine chemistry.

MR. AYRES: Chlorine chemistry.

MR. VIJAYARAGHAVAN: There is also

some evidence that another halogen bromine could oxidize elemental mercury to divalent mercury, thereby increasing the global contribution of mercury to deposition in the U.S., but we do not account for that.

MR. AYRES: And what rate coefficients do you use for the halogen chemistry?

MR. VIJAYARAGHAVAN: So that would be elemental mercury plus chlorine gas going to HgCL2, a rate constant of 2.6 times ten to the negative 18 centimeter cubed per molecule per second. The reference is Ariya, et al., 2002.

MR. AYRES: So you're using the coefficients developed by Ariya?

MR. VIJAYARAGHAVAN: That is correct.

MR. AYRES: And does your model include a variable for the effect of sea salt and its associated bromines and other halogens?

MR. VIJAYARAGHAVAN: Only chlorine.

MR. AYRES: Only chlorine?

MR. VIJAYARAGHAVAN: Yes.

MR. AYRES: Meteorology is another

variable that must be included in an atmospheric model like yours; isn't that correct?

MR. VIJAYARAGHAVAN: That's correct.

MR. AYRES: Could you tell us how that's taken into account in your model?

MR. VIJAYARAGHAVAN: Yes. We use meteorology from the Nested Grid Model which is a model developed by NOAA, the National Oceanic and Atmospheric Administration. We obtained wind, pressure and temperature from the NGM. We also obtained clouds and precipitation from actual observations of several thousand stations both from NCAR and NATP databases.

MR. BONEBRAKE: Can you spell out those acronyms?

MR. VIJAYARAGHAVAN: Yes. The acronyms would be NCAR, N-C-A-R, and N-A-T-P.

MR. AYRES: Dr. Keeler explained in his testimony to the Board that his studies showed precipitation events were very important in determining the deposition of mercury. Does your model include empirical

data on precipitation events and storms?

MR. VIJAYARAGHAVAN: I think I got your question right except for the last two words. Did you say precipitation --

MR. AYRES: And storms.

MR. VIJAYARAGHAVAN: -- In storms.

MR. AYRES: And storms. Perhaps it's the same thing.

MR. VIJAYARAGHAVAN: Firstly, we used clouds and precipitation from actual observations at several thousand stations. In terms of precipitation from storms, all this is accounted for in the meteorology that is not present in the model. And, in fact, there is evidence now that thunderstorms that could penetrate the stratosphere actually wash out the global mercury -- all of global mercury that is up there and deposit it as reactive mercury. And that is something that we did not account for so we underestimate the global contribution of mercury to deposition because of that.

MR. AYRES: So does the model include some sort of algorithm that simulates storm

events or how does it work?

MR. VIJAYARAGHAVAN: No, it does not. And because of that reason, sometimes we tend to underestimate global contributions.

MR. AYRES: But you said there is data there from --

MR. VIJAYARAGHAVAN: Yeah. The data does not account for these intense thunderstorms. I presume you're talking about these severe thunderstorm events --

MR. AYRES: Yes.

MR. VIJAYARAGHAVAN: And, no, we do not account for that.

MR. AYRES: You do not account for that?

MR. VIJAYARAGHAVAN: That is correct.

MR. AYRES: Okay. Now, don't some of these variables we've been discussing vary in a predictable and rather continuous way? For example, the emissions from a power plant probably vary according to time of day because load varies in a predictable way from one time of day to another?

MR. VIJAYARAGHAVAN: That is correct.

MR. AYRES: Would a model such as yours be at its best in dealing with such predictable, continuous phenomena?

MS. BASSI: Would you define what you mean by "at its best", please?

MR. AYRES: I think it says what it says.

MS. BASSI: Well, what is its worst? It doesn't make sense to me.

MR. AYRES: I think the witness understands the question.

MR. VIJAYARAGHAVAN: My understanding is your question is how does the model account for such events? Is that it.

MR. AYRES: No my question is isn't it easier -- I'll put it another way. Isn't it easier for a model such as yours to account for phenomena that are regular, continuous, predictable?

MR. VIJAYARAGHAVAN: Right. Again, by definition of grid-based model, it tends to discretize continuous events. So you're not capturing the exact continuum. Instead, you are replacing it by discrete events. So

you're not -- it's actually capturing -- you're capturing the essence of the event.

MR. AYRES: But some of the phenomena that can affect deposition are very discontinuous and unpredictable, aren't they? For example, thunderstorms.

MR. VIJAYARAGHAVAN: True. And that is a problem you face. But chemistry transport models are the only -- such as TEAM -- are the only type of models that can be used to do a predictive modeling. And even in those situations you're going to run into events where, for example, the state wants to control emissions in 2009 or 2010. Can you predict intense thunderstorm activity in 2009 and 2010? No, you can't. So you have to go with typical events rather than unique occurrences, which could eschew those simulated results but are not representative of typical situations.

MR. AYRES: If thunderstorms are an important determinant of deposition, then that would a limitation on the ability to predict in your model, wouldn't it?

MR. VIJAYARAGHAVAN: Yeah. In fact, the model because of that it tends to under-predict the global contributions because as I mentioned before, you have these intense thunderstorms called overshooting tops. So the atmosphere is typically divided into the troposphere and the stratosphere and then a couple of layers above that. You have these intense thunderstorms that penetrate the upper troposphere and the lower stratosphere and you have -- there's now evidence that there's a global pool of mercury and you're washing out that mercury in thunderstorms. So the model event -- yes, by not capturing these thunderstorms, the model is not capturing that global pool of mercury so it's actually we are over-predicting local or regional contributions.

MR. AYRES: Well, wouldn't it also fail to predict the local or regional contributions, as well, if it didn't take into account thunderstorms?

MR. VIJAYARAGHAVAN: Yeah. That

component, which appears in thunderstorms, that is correct.

MR. AYRES: And didn't Dr. Keeler say in his testimony to the Board in June that most of the deposition he measured in Steubenville occurred during storm events?

MR. BONEBRAKE: Object to Mr. Ayres' characterization. The testimony says what the testimony says.

MR. VIJAYARAGHAVAN: I mean, if you can show me which page I can read it and say, yes, that's what he said.

MR. AYRES: All right. I have no more questions of this witness.

MS. TIPSORD: All right. Then let's do the slide presentation.

(Brief pause.)

MR. VIJAYARAGHAVAN: This presentation is about the modeling work regarding the mercury proposed rule. The atmospheric chemistry of mercury is a tiny size. It's quite complex. Mercury exists in three forms; elemental, divert and Hgp. There's Hg0, Hg2 and Hgp existing in both a gaseous

and aqueous phase. In the aqueous phase they are referring to droplets of liquid droplets in the atmosphere. And as discussed earlier today, we have continuous --

MS. TIPSORD: Excuse me, could you move over here because she can't see your face and she needs to see you. It helps her to be able to see you. Thank you.

MR. BONEBRAKE: Are you hearing him okay?

THE COURT REPORTER: I'll be better now.

MR. VIJAYARAGHAVAN: So these three species of mercury transform between each other in the atmosphere. So we can show mercury is accounted for by gaseous oxidation and reductions between Hg0, Hg2 and also absorption to particulate matter. And these three species of mercury speciation form because they have very different deposition characteristics.

Hg0 is not very soluble in water and has a very low dry deposition velocity so it can be transported globally. There is

some demonstrated evidence of anthropogenic emissions of mercury being transported from Asia to the U.S. and that's largely because of the low deposition characteristic of Hg0. So it tends to be transported globally.

Hg2, on the other hand, is very soluble. It's about a million times more soluble than Hg0 and it also absorbs readily on surfaces so it tends to be rapidly removed both by wet and dry deposition with a relatively shorter lifetime because of that.

Hgp is mostly in the fine particle range and its characteristics tend to be between Hg0 and Hg2 so Hgp will remain in the atmosphere for several days if you don't have precipitation. If you have rain, it's going to wash it out just as in Hg2.

The model of atmospheric mercury that we used is called TEAM, which is Trace Element & Analysis Model. This is part of our multi-scale modeling system that I will be discussing next. The meteorology is from the 1998 meteorology, winds, temperature and pressure from the Nested Grid Model of NOAA,

the National Oceanic & Atmospheric Administration, and clouds and precipitation from observations obtained from several thousand stations from NCAR, N-C-A-R, and NADP, the National Atmospheric Deposition Program.

Emissions from EGUs or electrical generating units were obtained -- were developed by Charles River and I'm going to be discussing that in a subsequent slide. These are developed both for 2006 and future year emission scenarios.

Emissions from non-EGU sources for 1998/1999 meteorology were updates done for waste incinerator emissions. The modeling domain or the grid that we used has a 20 kilometer horizontal grid spacing that is over the central and eastern United States. And the boundary conditions for this model were obtained from our global mercury model that we discussed earlier. And this is of extreme importance because, again, in long range transport of mercury it is important to use good boundary conditions.

The next slide shows a schematic of our multi-scale modeling system. The CTM global model stands alone and has a grid resolution or grid spacing that provides speciated boundary conditions of mercury both temporary and it's widely varying. TEAM, our continental model, this box right there, and that, in turn, provides speciated mercury conditions of mercury to our regional model while in grid TEAM. So all of the maps I'm going to be showing you today are from this regional grid, which has a 20 kilometer horizontal grid spacing.

The modeling system known as TEAM has been published in the literature as being well evaluated both using wet deposition from the Mercury Deposition Network and speciated air concentrations of mercury. The performance evaluation has been published in the peer-reviewed literature.

Also, we have compared the TEAM deposition over Lake Michigan with estimates by Drs. Landis and Keeler. It's called the Lake Michigan Mass Balance Study. And those

are estimates for wet, dry and total deposition are comparable.

The TEAM simulated contribution at Steubenville was 62 percent, which is within the range reported by Dr. Keeler as part of his study which was 70 percent plus or minus 15 percent. And, again, TEAM was part of a multi-scale modeling system which includes global mercury model, which is also being well evaluated against the data.

In this part of the study we used different emission scenarios. All of these scenarios used the same meteorology, boundary conditions and emissions from sources other than power plants. So the only thing different between the different scenarios was emissions from EGUs.

In particular, we did five different emission scenarios. The first was a 2006 scenario, one we refer to as 2006 base.

The second would be a zero-out of all coal-fired power plants in the U.S. In essence, we take all coal-fired power plants

in the U.S. and set the mercury emissions from those power plants to zero and that is our zero scenario or scenario number two.

Scenario number three was a 2010 CAIR and CAMR scenario. So the clean air and the state rule and the clean air mercury rule is applied to all states in 2010.

And scenario number four is an Illinois rule scenario where we get a 90 percent reduction in Hg emissions from all EGUs in Illinois. Note that we do not apply the TTBS.

For EGUs in other states, we used 2010 CAIR/CAMR emissions. Note that mercury emissions for EGUs in all states for all these scenarios were provided by CRA International.

And, finally, scenario number five was a 2020 CAIR and CAMR scenario for all states. So to summarize, again, we have five scenarios; a base scenario, a zero scenario, a 2010 CAMR scenario, a 2010 CAMR with the Illinois rule scenario, and a 2020 scenario.

Here are the results from the base

scenario. What you see on here is wet plus dry deposition of Hg2 in the 2006 base case. These are mercury emissions from all sources and result in deposition that arises because of the transport and deposition of those mercury emissions.

This is figure one in my testimony. The units are not very clear on this graphic. They are micrograms per square meter per year. The yellows and pinks and reds are areas with higher deposition. In general, we find that the mercury deposition that's between 10 to 30 micrograms per square meter over the area here over mostly lakes in the United States were scattered areas between 30 and 50 micrograms per square meter. And I studied the areas higher than 30. If we look closer at Illinois, the mercury deposition ranges from typically between 10 and 20 micrograms per square meter with scattered areas between 20 and 30 and isolated cells higher than 30.

The next graphic is a similar slide of the zero-out scenario number two.

So, in essence, we suspect mercury emissions from all U.S. coal-fired power plants are zero. These are the simulated deposition fluxes of mercury. This corresponds to figure two in my testimony. Again, the units are micrograms per square meter per year. The deposition fluxes in Illinois are between 10 and 20 micrograms per square meter with some isolated areas higher than 20 micrograms.

Moving on to scenario number three, which corresponds to figure three in my testimony, this graphic shows the total, i.e., wet plus dry deposition of mercury in the 2010 CAIR/CAMR scenario. The units, again, are micrograms per meter per year. The deposition of mercury in Illinois ranges for the most part from 10 to 20 micrograms per square meter, but in some scattered areas are greater than 20 micrograms.

So far we've looked at the base scenario, a zero to all U.S. coal-fired power plants, and the 2010 CAIR/CAMR scenario.

Next, we look specifically at the

Illinois rule scenario. Here we use CAIR/CAMR for other states and for Illinois we use the Illinois rule. This corresponds to particular testimony. So, again, what we see here is wet versus dry deposition of mercury in micrograms per square meter per year in the Illinois rule scenario or scenario number four.

The deposition of mercury ranges from 10 to 20 micrograms per square meter over most of Illinois. To get a better sense of what impacts these different scenarios have, I'm going to be showing later different slides so you can see what is the difference from the base to each of these scenarios. That gives us a better idea of how much impacts or how much reductions in deposition we are seeing because it's kind of hard to compare the two deposition slides. So that's going to be coming up shortly.

And, finally, to the next slide we look at scenario number five, which is a 2020 CAIR/CAMR scenario. And that was chosen because this is what was proposed by U.S.

EPA. This corresponds to figure five in my testimony. Given, again, our graphics on here, what you see is where it describes deposition of mercury. Over most of Illinois the deposition is between 10 and 20, but in some isolated areas in southern Illinois there are greater than 20 micrograms.

Moving on to the next slide, this is a big picture or a summary, if you will, of the deposition in Illinois in the different scenarios. So the different rows correspond to the five scenarios. Note that the order is slightly different from the slides shown before. So the order in years is 2006 base, 2010 CAIR/CAMR scenario, then the Illinois rule scenario, 2020 CAIR/CAMR scenario, and the scenario where U.S. coal-fired emissions is zero.

This table was adapted from Table one in the testimony. It has similar information but the units have been changed to pounds per year from milligrams per year. The first column here shows the total wet plus dry deposition of mercury in pounds per

year in each of these scenarios. In the 2006 base, it's 7704 and decreases by 5 percent to the next scenario, which is 2010 CAIR/CAMR.

So the second column you'll see on here is additional benefit or decrease you're going to get going from one scenario to the next. So going from the base to 2010 CAIR and CAMR, you see a 5 percent decrease in deposition.

Going from a 2010 CAIR/CAMR to the Illinois rule scenario, you see an additional four percent decrease in deposition.

Going to the 2020 CAIR and CAMR scenario, you see an extra 5 percent reduction in deposition. And most of this is happening because of the reductions you're seeing in emissions from power plants in other states resulting in a lower deposition in Illinois.

And, finally, the zero-out all U.S. coal-fired power plant emissions is an additional 6 percent. The last column here -- the second column we are looking at additional benefits or a percent difference,

if you will, between any scenario and the next scenario.

The last column, on the other hand, shows the percent it changed from the 2006 base scenario. So you're going with 5 percent in 2010 CAIR/CAMR, 10 percent, that is more like 9.5 percent that's being rounded off to 10 percent for the Illinois rule, and with 2020 CAIR/CAMR we have 14 percent and with the zero we have 19 percent.

This 19 percent, again, is the same number we discussed earlier today, the effect of all U.S. coal-fired power plants on deposition in Illinois. And I have highlighted this 4 percent here and, again, in the box below a 4.4 percent decrease in Illinois mercury deposition is the additional reduction in deposition you get in going from the 2010 CAIR/CAMR scenario to the Illinois rule scenario.

The next few slides show differences in deposition between two scenarios. Here you have the 2010 CAIR/CAMR minus the 2006 base. So the greens, the

blues and the dark blues represent regions where the 2010 CAIR/CAMR results in lower deposition data than in the 2000 base. This is figure six in my testimony. One can see that the model simulates between one and 10 micrograms per square meter, decreasing deposition typically in large parts of Illinois. And I know it's hard to tell, but there are a few areas which are higher than ten. Again, the units are microgram per square meter. So this is a change in total deposition going from the 2006 base to the 2010 CAIR/CAMR scenario.

The next slide is going to show the same thing. So now we are on slide 16, which shows the percent change in deposition of mercury from the 2006 base to the 2010 CAIR/CAMR scenario. This is figure seven in my testimony. The units here are percent. So the model simulates between 1 and 10 or less than 10 percent decrease in deposition over most of Illinois. And in scattered areas shows a decrease between 10 and 30 percent.

The next slide we are comparing the 2010 CAIR/CAMR scenario with the Illinois rule scenario. So slide 17 shows the change in total deposition of mercury between the Illinois rule scenario and the 2010 CAMR scenario. Again, the greens and blues reference areas where the mercury deposition is lower than the Illinois rule. This is figure eight in my testimony.

In terms of decreases, most of Illinois has less than 2 micrograms per square meter of mercury deposition, lower than Illinois rule as compared to the 2010 CAIR/CAMR scenario. Isolated areas have decreases that are greater than two micrograms per square meter.

This is another representation of the same plot, but this time there is a percent change. So slide 18 shows a percent change in deposition of mercury between the 2010 CAMR scenario and the Illinois rule scenario. In essence, this tries to simulate what is the additional reduction in deposition you're going to get when you go

from the 2010 CAIR/CAMR scenario to the Illinois rule scenario. So the additional reductions you will get from the position of the Illinois rule.

Large parts of Illinois have between 1 to 5 percent decreases in deposition. Some scattered areas have between 5 and 15 percent and a few isolated grid cells have between 15 and 35 percent. This is from figure nine in my testimony.

MS. BASSI: Does this also show increases in deposition in some places?

MR. VIJAYARAGHAVAN: Yes. So there are a few scattered areas where you see some increases in deposition and that is because the slides change, suggesting the rate of retrofits at these locations. But we expect most of these increases to disappear by 2015.

This is a representation of another slide, but just so we are comparing slides with the same scale, this one is figure eight in my testimony but with the same color scale as figure six. So I'm going to flip back and forth between this slide and

the next one. So both of them have the same color scale, but this slide shows a difference between the Illinois rule and the 2010 CAMR, and the next slide is going to show the difference between the base and the CAMR. So you're going from base to CAMR and then CAMR to Illinois rule. So if you flip back and forth and focus on --

MR. AYRES: Can I ask a question at this point?

MR. VIJAYARAGHAVAN: Yes, please.

MR. AYRES: Would you say the -- if you could back up slightly there. When you talk about the -- from the map with the CAIR/CAMR impact on it. It was just before you moved to the end, I guess. No, the next one.

MR. VIJAYARAGHAVAN: Comparing base to CAMR.

MR. AYRES: The question is -- it doesn't matter. That's fine. When you say CAIR or CAMR, are you talking about when we reach full implementation of CAMR?

MR. VIJAYARAGHAVAN: Yeah. This is as

implemented in 2010. Not --

MR. AYRES: I was trying to find the next slide.

MS. TIPSORD: Just go to the next slide.

MR. AYRES: That one, number one. That's the 20 -- I'm sorry. I'm looking for the one that's 2020.

MR. VIJAYARAGHAVAN: We haven't gotten to that. Are you talking about a different plot or actual deposition?

MR. AYRES: I thought this was 2020.

MR. VIJAYARAGHAVAN: No. This is 2010.

MR. AYRES: Do you have a 2020?

MR. VIJAYARAGHAVAN: Yeah. I'm sure there's one here. I haven't come to that yet.

MR. AYRES: What is assumed here in terms of mercury reductions? It is assumed that the actual emissions of mercury will be at or below the CAMR cap at that point?

MR. VIJAYARAGHAVAN: Yeah. For all states other than -- are you talking about

Illinois? Yes. This is at or below the CAMR cap, yes.

MR. AYRES: And you recall that that rule provides for banking and trading?

MR. VIJAYARAGHAVAN: Yeah. And if you want, these emissions were developed by CRA International, specifically for 2010 CAIR/CAMR scenario taking into account whatever needs to be taken into account going back into the necessary -- but the question is probably more appropriate for CRA.

MR. AYRES: We don't have them in front of us.

MR. VIJAYARAGHAVAN: Right. But I can just state --

MR. BONEBRAKE: Just so the record is clear, Ann Smith from CRA was available to provide testimony and she was here last week.

MR. VIJAYARAGHAVAN: But I see your question. Yes, it does (inaudible) --

THE COURT REPORTER: I didn't hear you.

MR. VIJAYARAGHAVAN: I said it does take into account.

So, now, again, we're comparing two different situations going from 2006 base to 2010 CAMR and going from the 2010 CAMR to Illinois rule. If you go to look at this in terms of percent, this is slide 21, so if you compare slides 21 and 22, they are the same color scale. This gives you a sense of what are the differences between the two scenarios. So I'm not going to go over this because it's a repeat of what I showed before, that slide 21 is just a repeat of another slide, which is the color scale change. So 21 and 22 are shown together again just for additional comparison.

For example, here in 21, you'll see that the percent decrease is between 1 to 10 percent decrease is going from 2010 CAIR/CAMR to Illinois rule scenario. And if you go to slide 22, you'll find that, again, most of Illinois is between 1 to 10 percent decrease with some isolated areas from 10 to 30 percent decrease.

These slides are shown for reference. Note that we are comparing the

Illinois rule scenario and 2020 scenario. Note that the 2020 scenario is obviously not the same point in time as the Illinois rule scenario, but just to get a sense of how much the change would be.

This is the Illinois rule scenario minus the 2020 CAIR/CAMR. Here, you find up to one to five micrograms per square meter higher in most areas with some isolated areas. For example, in Pennsylvania, they are much higher. In Illinois, the southern part of the state shows between one and five micrograms per square meter per year is higher in the Illinois rule scenario compared to 2020 CAIR/CAMR. And, again, note that this Illinois rule scenario and 2010 so one should keep that in mind when looking at this slide.

The next slide is a similar slide with the sign of the percent change. So this shows you how much higher deposition you're going to get in terms of a percent between Illinois rule and the 2020 CAIR/CAMR rule. This is slide 24 and corresponds to figure 11

in my testimony. Again, keep in mind that the Illinois rule refers to the 2010 scenario.

Moving on, in conclusion, the TEAM mercury modeling system was applied to simulate atmospheric mercury deposition in the central and eastern United States, in particular over Illinois.

Five different emission scenarios for coal-fired power plants were modeled. Ninety percent controls of Illinois EGU Illinois rule are simulated to achieve a 4.4 percent additional decrease in mercury deposition compared to the 2010 CAIR/CAMR scenario.

Most of Illinois experiences a 1 to 5 percent decrease in deposition, but a few areas in the northeastern and central parts of the state exhibit between 5 and 15 percent decreases and a few isolated areas between 15 to 35 percent decrease.

As mentioned earlier, deposition reductions in the vicinity of EGUs are likely over-estimates due to artificial plume

dispersion and there is also potential Hg reduction happening in power plant plumes.

Note that there are no hot spots in the 2010 CAIR/CAMR scenario when compared to the 2006 base. Thank you.

(Whereupon, after a short break was had, the following proceedings were held accordingly.)

MS. TIPSORD: Back on the record. I believe we're ready for question number six.

MR. AYRES: I think there's some questions that occur as a result of the slide show.

MS. TIPSORD: Okay.

MR. AYRES: First, the percentage numbers that you've given in the slides that you've shown to the Board just a moment ago, those numbers are strongly dependent on the size of the grid cell, aren't they?

MR. VIJAYARAGHAVAN: Right. In theory, the percentage numbers change, increase, with the size of the grid cell. But, again, when you go to find a grid cell

at the size of the grid cell because of artificial vertical dispersion you might actually be over-estimating your contribution. So if the model shows, say, 35 percent in the vicinity of a power plant, it may actually in reality may be lower than that.

MR. AYRES: Would it be appropriate to conclude from your slides that the Illinois rule about doubles the reduction over the 2010 CAMR/CAIR rule -- reduction in deposition in Illinois I meant. I believe you say it's about a 5 for CAIR and CAMR and another 5 percent for Illinois rule?

MR. VIJAYARAGHAVAN: Yeah. If you take the first significant digit --

MS. TIPSORD: I'm sorry. I didn't hear all of that.

MR. VIJAYARAGHAVAN: I'm sorry. If we take it to the first significant digit, the 2010 CAIR/CAMR gives you a 5.3 percent decrease in deposition and the Illinois rule gives you an additional 4.2 percent. And that gives us a sense of how much additional

decrease in deposition we can expect given the limitations on the over-estimates that we've mentioned before -- given the inherent uncertainties that have been discussed before.

MR. AYRES: I'd like to get to the uncertainties in a few minutes. So it approximately doubles?

MR. VIJAYARAGHAVAN: Well, 5.3 to 4.2, which is I would say if you went -- so you do not get as much as you get going from the base to 2010 CAMR, but 80 percent of that extent. Does it make sense? So if you get 5.3 percent with the CAIR/CAMR scenario, you get an extra 4.2 percent with Illinois rule scenario.

MS. TIPSORD: Just so I'm clear -- and I'm not a mathematician at all -- you get 5.3 and then plus 4.2?

MR. VIJAYARAGHAVAN: Correct. So the 4.2 is the additional, exactly.

MR. BONEBRAKE: And then just for further clarification, we're talking about comparisons as of 2010 as opposed to any

comparison to the effect of CAIR/CAMR as of 2020?

MR. VIJAYARAGHAVAN: Yes. We are talking about 2010.

MS. TIPSORD: Mr. Harley, do you have a follow-up on that?

MR. HARLEY: Yes. For the record, Keith Harley. My follow-up question to that is that 4.2 percent additional reduction that would be achieved, that would be achieved every year between 2010 and when CAIR/CAMR would eventually be fully implemented in 2020?

MR. VIJAYARAGHAVAN: One would have to model year-specific emissions to actually determine that. And that's what chemistry transport models are used for. What one can state with this information is in 2010 that is the additional reduction that you will see.

MR. HARLEY: Have you modeled the annual reductions that would be expected 2011 through --

MR. VIJAYARAGHAVAN: No, sir.

MR. HARLEY: -- 2020?

MR. VIJAYARAGHAVAN: No.

MR. HARLEY: Thank you.

MS. TIPSORD: Mr. Ayres?

MR. AYRES: Your, I believe it's figure eight, appears to show that most of the benefits of the Illinois rule are in Illinois; isn't that correct?

MR. VIJAYARAGHAVAN: Yeah. But if you look at figure 9, which shows a percent, which is the same figure but as a percent change, one can see impacts in Missouri, Indiana, Michigan and so on. And there is a small -- as the plume gets diluted, you see smaller and smaller impacts so that some of that is hidden in the white color which is not displayed so it's less than a percent change.

MR. AYRES: And if you could look at figure -- I believe it's figure ten, although I'm not sure I kept up with the blur of figures, but it varied --

MR. BONEBRAKE: For clarification, can you tell us what the page number is in the

PowerPoint presentation?

MR. VIJAYARAGHAVAN: Or do you have the title of the figure?

MR. AYRES: No.

MR. VIJAYARAGHAVAN: Which figure are you referring to.

MR. AYRES: Maybe it's in here.

MR. VIJAYARAGHAVAN: It's also in the testimony. Can you tell us what figure in the testimony.

MS. TIPSORD: It's on Page 23 of PowerPoint. It's figure ten.

MR. VIJAYARAGHAVAN: So I have a change in total deposition of mercury between Illinois rule scenario and 2020 CAIR/CAMR.

MR. AYRES: Yes. Figure ten in the testimony, which I guess is on Page 23 of the slide show --

MR. VIJAYARAGHAVAN: Yes, sir.

MR. AYRES: -- which shows a difference between Illinois rule and 2020 CAIR/CAMR.

MR. VIJAYARAGHAVAN: Yes.

MR. AYRES: Would it be correct to

read that as indicating the Illinois rule is essentially providing the benefits of the 2020 CAMR rule in 2010?

MR. VIJAYARAGHAVAN: Pardon me?

MR. AYRES: That perhaps together with figure nine on Page 21.

MR. VIJAYARAGHAVAN: Can you clarify your question.

MR. AYRES: Yes. Would it be appropriate to conclude -- maybe that's the way to put it -- that the Illinois rule is providing the benefits -- largely the benefits of 2020 CAMR rule in Illinois in 2010 comparing the --

MR. VIJAYARAGHAVAN: Well, it's not --

MR. AYRES: -- comparing Page 23 where you indicate what the 2020 CAMR rule does with Page 21 where you indicate what the Illinois rule does.

MR. VIJAYARAGHAVAN: Well, the Illinois rule does not give you the benefits of 2020 CAIR/CAMR because as seen in figure 10, in the southern parts of the state and part of the western areas of the state you

have higher depositions in the Illinois rule scenario.

MR. AYRES: But if you'll look at Page 23 again, figure ten?

MR. VIJAYARAGHAVAN: Yes.

MR. AYRES: It appears to me, at least, that this is a difference in comparison, right? It's the difference between the Illinois rule scenario and the 2020 CAIR/CAMR rule scenario?

MR. VIJAYARAGHAVAN: That is correct.

MR. AYRES: And what it seems to show is that there is essentially no difference in the state of Illinois between those two? Is that a misreading of what it's saying? That's what that white areas means, isn't it?

MR. VIJAYARAGHAVAN: Right. But, you see, several of the areas in the southern part of the state, south central and the western parts of the state that show between 1 and 5 and if you look at the next slide that shows --

MR. AYRES: I do see that. But most of the territory is white, is it not?

MR. VIJAYARAGHAVAN: Right. And if you look at the next slide, which shows the percent change, so now I'm looking at figure 11 in my testimony, you can see there is between a 1 and 5 percent change in almost all of the state and parts of the state are higher than 5 percent. So the 1 to 5 number is an absolute number in figure ten. If you look at a percent change, you'll see between 1 and 5 percent change in most of the state.

MR. AYRES: All right. That's about all we can say based on those PowerPoint presentations.

MS. BASSI: I have a follow-up, please.

MS. TIPSORD: Ms. Bassi?

MS. BASSI: Krish, what is the best use of a deposition model in demonstrating how a control technology will work? Is it in the presentation of the absolute amounts that are being deposited or is it in showing the change that results from the application of controlled technology?

MR. VIJAYARAGHAVAN: Yeah. One would

be more interested in the change or the relative change in deposition that arises out of the controls.

MS. TIPSORD: I only heard part of that. I'm sorry.

MR. VIJAYARAGHAVAN: Sorry. One would be more interested in the change or the relative change in deposition that is arising out of a result of those controls.

MS. TIPSORD: So I guess the bottom line is the figure that you say shows a 1 to 5 percent difference in CAIR/CAMR as in 2020, you're saying that under CAIR/CAMR in 2020 there would be 1 to 5 percent less deposition in mercury in Illinois --

MR. VIJAYARAGHAVAN: Yes.

MS. TIPSORD: -- than under the Illinois rule?

MR. VIJAYARAGHAVAN: Yes, Madam Hearing Officer.

MS. TIPSORD: And that's modeling the federal CAIR rule and CAMR, correct?

MR. VIJAYARAGHAVAN: Yes, ma'am.

MS. TIPSORD: Mr. Harley?

MR. HARLEY: Is that under the Illinois Rule 2010?

MR. VIJAYARAGHAVAN: Right. To clarify, as I mentioned in my presentation, we are looking at the Illinois rule under 2010, so one should keep that in mind when comparing.

MR. HARLEY: So by 2020, if we wait for CAMR/CAIR to fully roll out, we will experience a 1 to 5 percent reduction in mercury deposition in Illinois --

MR. VIJAYARAGHAVAN: Which is more than what you would get going from CAIR/CAMR in 2010 to Illinois rule.

MR. HARLEY: I need to complete my question.

MR. VIJAYARAGHAVAN: Please.

MR. HARLEY: Are you comparing 2010 Illinois rule to 2020 CAIR/CAMR?

MR. VIJAYARAGHAVAN: That is correct.

MR. HARLEY: Thank you.

MR. AYRES: So the conclusions that you can draw to the extent that you believe the predictions of the model are that the

Illinois rule will about -- and I'll say it this way again -- about doubled the deposition benefits of the 2010 CAIR rule when it goes into effect in about 2010 and that by 2020 the federal CAIR/CAMR rule will catch up and slightly pass the impact of the Illinois rule; is that a fair statement?

MR. VIJAYARAGHAVAN: I would rephrase that. No, that would not be a fair statement. Let's rephrase. You are on the right track but let me rephrase it.

MR. AYRES: Please.

MR. VIJAYARAGHAVAN: So we are comparing three scenarios here. We're starting from today in 2006, we are looking at 2010 CAIR/CAMR, and then we're looking at the additional reduction you would get with Illinois rule, and then the additional reduction you would get with the 2020 CAIR/CAMR.

So, again, you would get a 5.3 percent reduction going from now to 2010 CAIR/CAMR, an additional 4.2 percent reduction going to Illinois rule and about an

additional 4 percent going to CAIR/CAMR in 2020.

MS. TIPSORD: Can I ask you a question right there?

MR. VIJAYARAGHAVAN: Yes, ma'am.

MS. TIPSORD: So 5.2 (sic) percent plus four point --

MR. VIJAYARAGHAVAN: Uh-huh.

MS. TIPSORD: So from 2006 to 2010, if the Illinois rule is implemented --

MR. VIJAYARAGHAVAN: 9.5 percent.

MS. TIPSORD: And then in 2020?

MR. VIJAYARAGHAVAN: 14 percent.

MS. TIPSORD: 14 percent?

MR. VIJAYARAGHAVAN: Yes.

MS. TIPSORD: But that 4.2 that we've had from 2010 to 2020 disappears if we don't do the Illinois rule, right? So you come back to -- at 2020 then you would have 10 percent?

MR. VIJAYARAGHAVAN: (Witness nodding.)

MS. TIPSORD: And have had 10 years where you didn't have any additional

reduction from the Illinois rule?

MR. VIJAYARAGHAVAN: That is correct.

MS. TIPSORD: And I'm sorry for interrupting in the middle of your question, but I'm finding myself extremely confused by this. I apologize.

MR. GIRARD: Can I ask a question, though? Going back to figure 9 in your testimony, which was the percent change in total deposition of mercury, Page 18, deposition of mercury between Illinois rule scenario and the 2010 CAIR/CAMR. This figure shows the 4.2 percent reduction in the Illinois area on up where our wind blows. But can you tell me why down in northeast Texas this would show an increase in the mercury deposition?

MR. VIJAYARAGHAVAN: Right. See, you have a slight change in the allowance markets for mercury --

MS. TIPSORD: You need to speak up, please.

MR. VIJAYARAGHAVAN: So a change in the allowance markets for mercury, SO2 and

NOx suggests a delay in the retrofitting of -- retrofits in plants at these locations and that is what's causing these increases in deposition. But they are minimal and they're expected to disappear by 2015.

MR. AYRES: So is that the result then of the training program? Is that what you're saying?

MR. VIJAYARAGHAVAN: At this stage, I think I should state, again, that the emissions were developed by CRA International and these questions are of better interest to them.

MS. TIPSORD: Anything else on the slide presentation?

MR. AYRES: No.

MS. TIPSORD: Mr. Harley?

MR. HARLEY: Approximately, how many grid cells -- 20 kilometers square grid cells are there in the state of Illinois?

MR. VIJAYARAGHAVAN: Between 400 to 500.

MR. HARLEY: Roughly how many grid cells in Illinois would experience greater

mercury reduction under CAMR 2010 than they would under the proposed Illinois rule?

MR. VIJAYARAGHAVAN: There is no such grid cell. You're talking higher in CAMR than -- higher reductions in 2010 --

MR. HARLEY: No. Higher deposition. Higher mercury deposition --

MR. VIJAYARAGHAVAN: Higher mercury deposition.

MR. HARLEY: -- under CAMR 2010 than they would under Illinois rule.

MR. VIJAYARAGHAVAN: Under 2010 CAIR/CAMR, yeah, for that we can look at slide -- or figure eight in my testimony, which would also be slide 17, which compares the Illinois rule scenario and the 2010 CAIR/CAMR scenario. So you can see that there are no such -- we can see that all of Illinois has, on average, between .5 to 2 lower in Illinois rule scenario than in the 2010 CAIR/CAMR scenario. So there is no grid cell there that CAIR/CAMR scenario would result in greater reductions in deposition. Or to put it another way, CAIR/CAMR would be

higher deposition.

MR. HARLEY: CAIR/CAMR would be higher deposition in 2010 for virtually the entire state of Illinois?

MR. VIJAYARAGHAVAN: That is correct. And the changes are minimal in most of Illinois but the answer is yes.

MR. HARLEY: Thank you.

MS. TIPSORD: Anything else on the slides? Why don't we take a ten-minute break and we'll come back after that.

(Whereupon, after a short break was had, the following proceedings were held accordingly.)

MS. TIPSORD: I just want to note that the joint statement that was admitted as Exhibit 125 has been entered in the clerk's office as public comment 6283, so it is in the record.

Also, for those of you who saw that Monday's and Tuesday's transcripts have arrived, Wednesday's and Thursday's transcripts are here and available and, as we

speak, Don Brown is trying to get them linked on the web. So the transcripts from last week up to Friday are available on the web page. And with that, I think we're ready for question number six.

MR. AYRES: Actually, I would like to ask some questions before we get to question number six.

MS. TIPSORD: Please do.

MR. AYRES: Mr. Vijayaraghavan, you testified prior to the slide slow to the assumptions and projections that are necessary in order to run the model that you have run. And those I would just repeat for the Board, if I might, that those are boundary and initial conditions, emissions from power plants, speciation of emissions, atmospheric chemistry and meteorology. At least those are the ones we discussed, correct?

MR. VIJAYARAGHAVAN: That is correct.

MR. AYRES: In your testimony you say that your TEAM model can account for about 50 percent of the variance observed in wet

deposition across the U.S. on Page 8?

MR. VIJAYARAGHAVAN: That is correct.

MR. AYRES: So you are attempting to correlate the output of your model with actual monitored mercury deposition across the U.S.?

MR. VIJAYARAGHAVAN: Yes, wet deposition. That is correct.

MR. AYRES: How many monitors are there across the U.S., by the way?

MR. VIJAYARAGHAVAN: About 50-plus monitors.

MR. AYRES: Fifty?

MR. VIJAYARAGHAVAN: Plus.

MR. AYRES: If you were to correlate the output of your model with monitored mercury deposition over a smaller geographic area, say Illinois, how would that affect the model's abilities to explain the variance?

MR. VIJAYARAGHAVAN: When we compare the model deposition with the measured wet deposition in Illinois, the measured wet deposition is 10.1 micrograms per square meter and the model deposition is 12.7. So

there is an over-prediction by 26 percent.

MR. AYRES: This is for Illinois?

MR. VIJAYARAGHAVAN: Yes, sir. It's the MDN monitoring site in Illinois.

MR. AYRES: How many monitoring sites are there in Illinois?

MR. VIJAYARAGHAVAN: There is one site.

MR. AYRES: One. Okay. And if you were to take the output of your model for a single month and correlate it with the monitor date of, say, August or July, one of the summer months, how would that affect the predictive capability of your model?

MR. VIJAYARAGHAVAN: We have not compared specific months so one would have to do such analysis to see what kind of a comparison is obtained.

MR. AYRES: Wouldn't it tend to reduce the ability to predict?

MR. VIJAYARAGHAVAN: I don't see why.

MR. AYRES: What does it mean to say that your model accounts for 50 percent of the variance?

MR. VIJAYARAGHAVAN: When you compare model deposition with wet deposition, the R-squared or the coefficient determination is statistical quantity that lets you come up with a correlation between the model deposition and measured deposition. So what we are saying is with the level of science and other mechanisms in the model, we're able to capture 50 percent of the measured wet deposition or the variance, if you will. So in essence it's saying you can attribute or know for sure that your model captures 50 percent of the wet deposition. In this particular instance, the wet deposition of the monitored stations.

You know, we should also note for the record that we looked at air concentrations of mercury which have also been published and, again, we've compared with monitoring wet deposition data in Illinois where you get, say, between 10 and 25 percent error. So this gives us a sense of what are the limitations of the model, as all models do, what limitations they have,

and as to when new data becomes available, we try to see how the model can be evaluated against those data.

MR. AYRES: So your statement about the variances is equivalent to saying that you find an R-squared value of about .5?

MR. VIJAYARAGHAVAN: Yes. That is mathematically correct.

MR. AYRES: That's a statistical matter?

MR. VIJAYARAGHAVAN: Yes, sir.

MR. AYRES: Would you describe that in statistical terms as a strong correlation?

MR. VIJAYARAGHAVAN: Strong is a subjective term.

MR. AYRES: I think it's a statistical term.

MR. VIJAYARAGHAVAN: Right. It is a -- I do not know the answer to the question.

MR. AYRES: Okay. Wouldn't an R-square of 90 percent be evidence of a great deal stronger correlation?

MR. VIJAYARAGHAVAN: Yes, sir.

MR. AYRES: Isn't it also true that if you have an R-square of 50 percent, that means that 50 percent of the variance across the U.S. is not explained by your model, correct?

MR. VIJAYARAGHAVAN: That is correct.

MR. AYRES: In your testimony, you provide single point estimates of the effects on mercury deposition of the Illinois control program and the EPA CAIR/CAMR programs and so forth and we've discussed earlier to two decimal -- or two significant figures the numbers that output from your model. Wouldn't it be more appropriate in light of the relatively poor correlation of .5 R-squared to include confidence bands around those point estimates?

MR. BONEBRAKE: I'm going to object to the characterization as to poor correlation that Mr. Ayres has put in his question. I think he's suggesting that the witness agreed with that characterization.

MR. VIJAYARAGHAVAN: And I did not.

MR. AYRES: I'll withdraw the word

poor. But let me just ask the question again, if I may?

Wouldn't you agree that given the R-squared of .5, it would be informative to the reader to include confidence bands around those point source estimates?

MR. VIJAYARAGHAVAN: Yes, it might be informative. I mean, it depends on the situation.

MR. AYRES: If you were to put a confidence band representing the 90 percent confidence level around the deposition numbers in your testimony, would it be likely that they would actually overlap?

MR. VIJAYARAGHAVAN: I would have to do that analysis to give you an answer.

MR. AYRES: So it would, however -- the 90 percent confidence interval would show a range rather than a single point source estimate for each of those numbers, correct?

MR. VIJAYARAGHAVAN: That is correct.

MR. AYRES: And with an R-squared of .5, wouldn't that range be fairly broad?

MR. VIJAYARAGHAVAN: Keep in mind that

this R-squared of .5 that you're talking about represents one particular evaluation model and we also evaluate against air concentrations, also evaluated model output with estimates of mercury deposition over Lake Michigan, for example, done by Drs. Landis and Keeler where the percent difference between the two estimates are within 10 to 20 percent.

MR. AYRES: But it is the one that you offered to the Board in your testimony, correct?

MR. VIJAYARAGHAVAN: I already stated in my testimony that deposition estimates are also comparable with Lake Michigan. And as some pointed out in the hearings today, the contributions at Steubenville are within 80 percent and the contribution at the wet deposition and -- actually, since you bring it up, in response to a subsequent question, I have another comparison. In Chicago, at IIT Chicago, measure wet deposition versus the model wet deposition. We had 23 micrograms modeled versus 20 measured. So

it's within about 10 to 15 percent higher.

MR. AYRES: Since you mentioned Dr. Keeler's work, let me ask you a few questions about that, if I may? When air quality modeling can account for only 50 percent of the variance on the national scale, isn't it useful to examine actual measured data in an attempt to gain insight from that?

MR. VIJAYARAGHAVAN: Yeah. We do look at measured data.

MR. AYRES: That's what Dr. Keeler and his group have done, isn't it?

MR. VIJAYARAGHAVAN: Pardon me?

MR. AYRES: That is what Dr. Keeler and his group have done, isn't it?

MR. VIJAYARAGHAVAN: What is it that they have done? I'm not asking a question. Could you rephrase.

MR. AYRES: Well, in the work that he testified to, he measured actual deposition, did he not?

MR. VIJAYARAGHAVAN: That is what he said in his testimony, yes.

MR. AYRES: At Steubenville?

MR. VIJAYARAGHAVAN: Yes. That is in his testimony, correct.

MR. AYRES: And that is what he did, isn't it, to your knowledge?

MR. BONEBRAKE: Objection. He already commented on what he testified to. Now Mr. Ayres is asking for this witness to talk about what Mr. Keeler has done beyond and above what's in his testimony. I think that's unfair of this witness. And there's no foundation that this witness could testify about what Mr. Keeler has done above and beyond what Mr. Keeler testified to.

MR. AYRES: Isn't this witness an expert in this area?

MR. VIJAYARAGHAVAN: Right. Unfortunately, there is --

MS. TIPSORD: Excuse me. We're arguing over the objection right now. Just wait one moment.

MR. AYRES: Isn't this witness an expert in this area and wouldn't he, therefore, be familiar with the work done by

Dr. Keeler and others in the area?

MS. TIPSORD: And if I may ask a question? Were you not present during the testimony of Dr. Keeler in Springfield?

MR. VIJAYARAGHAVAN: Right. I was. But what I was going to say was typically when you're in the field we are familiar with work done by others in your profession. And I'm not aware of any publications of Dr. Keeler regarding the work at Steubenville. And so my knowledge goes to what he discussed in his testimony.

MR. AYRES: Okay.

THE COURT REPORTER: Excuse me. It's better if you don't use the microphone.

MS. TIPSORD: But you need to speak up then.

MR. AYRES: So he testified that he measured actual deposition in Steubenville, correct?

MR. VIJAYARAGHAVAN: Yes.

MR. AYRES: And then he said he used sophisticated empirical techniques to establish footprints identifying different

kind of sources, such as coal-fired power plants, didn't he?

MR. BONEBRAKE: I'd --

MR. VIJAYARAGHAVAN: But he also --

MS. TIPSORD: Mr. Bonebrake, I'm going to allow this line of questioning. I think he's getting to a point and we're going to give him a little bit of leeway. All he's asking is if the witness recalls what was testified to and he's already said he was present for the testimony. And I assume we're getting to that point here?

MR. AYRES: We are.

MS. TIPSORD: Thank you. You can answer the question.

MR. VIJAYARAGHAVAN: Yes. Dr. Keeler testified that he looked at chemical footprints of coal-fired power plants. But he also stated that he would not be able to differentiate between different types of coal-fired -- the same type of coal-fired power plants which varied by location. And I believe he also stated in that a serious limitation was the fact that they could go

back only three days in the meteorology. So these were some of the things I recall about Dr. Keeler's testimony.

MR. AYRES: And you find his source apportionment technique consistent with good scientific practice in the field?

MR. VIJAYARAGHAVAN: One of the limitations of his source apportionment technique was that it not account for sources whose emissions were transported more than three days away, which is very typical for mercury. So that would be a serious limitation of the model.

MR. AYRES: But with that limitation, you would regard it as good scientific practice the way he went about it?

MR. VIJAYARAGHAVAN: Keeping that limitation in mind and also limitations such as the inability to distinguish between sources emitting similar types of mercury, it's hard to quantify it as best scientific practice. That is a subjective term.

MR. AYRES: All right. But these methods all have their limitations and your

modeling method does, too, correct?

MR. VIJAYARAGHAVAN: Yes. That is correct.

MR. AYRES: Okay. And you agree with Dr. Keeler's conclusion that reductions in emissions of mercury will result in reductions in the deposition of mercury.

MR. VIJAYARAGHAVAN: Well, that would depend on the type of mercury that is controlled and the type of source.

MR. AYRES: But doesn't your testimony say that if emissions are reduced, deposition will be reduced? I thought that's what those charts showed.

MR. VIJAYARAGHAVAN: Right. I just said the level of reductions in deposition would depend on the type of source.

MR. AYRES: I'm just speaking of direction, not level, at this point.

MR. VIJAYARAGHAVAN: So to answer, yes, typically, reductions in emissions seem to indicate that there would be some reductions in mercury deposition.

MR. AYRES: Okay. Now, Dr. Keeler's

method has certain advantages over air quality modeling for understanding deposition, doesn't it.

MR. VIJAYARAGHAVAN: Yes. As you just pointed out, both models have their advantages and limitations. A serious limitation of Dr. Keeler's method is it cannot be used for predictive modeling.

MR. AYRES: But there's no need to make an assumption about the initial conditions or the boundary conditions in his method, is there?

MR. VIJAYARAGHAVAN: Yes.

MR. AYRES: And there's no need to estimate emissions from power plants either, is there?

MR. VIJAYARAGHAVAN: I'm not aware of such.

MR. AYRES: And it's also not necessary to make assumptions about the atmospheric chemistry of mercury plumes from power plants, is it?

MR. VIJAYARAGHAVAN: Well, there is an inherent assumption in the mercury chemistry

when you look at mercury that comes from afar and get transformed and deposited at, say, Steubenville. There is an inherent assumption. Dr. Keeler, for example, referred to his review of the literature in coming up with his best understanding of what the mercury chemistry was.

MR. AYRES: But in order to measure the mercury deposited as he did, you don't need to know that?

MR. VIJAYARAGHAVAN: To make a measurement of mercury deposition, no, you do not.

MR. AYRES: And in order to do the analysis of the source type that he did, you don't need to know that either, do you?

MR. VIJAYARAGHAVAN: Well, again, the chemistry of mercury is inherently present in assumptions in his model. So, for example, Dr. Keeler mentioned how when he did a source apportionment, mercury that's coming from afar would probably get oxidized and washed down before it hits Steubenville. So there is an inherent assumption of the mercury

consumption so one cannot really separate mercury chemistry from any type of modeling that you do.

MR. AYRES: Also, there's no need to postulate dividing up the atmosphere in the grid squares or developing layers or anything of those things either, is there?

MR. VIJAYARAGHAVAN: That is correct.

MR. AYRES: So would it be correct to say that a major difference between atmospheric modeling that you present and the method presented by Dr. Keeler in his testimony is that his conclusions are based on real observations, while the output of the TEAM's model depends heavily on a series of assumptions?

MR. VIJAYARAGHAVAN: Well, Dr. Keeler's modeling is based partly on observations, but it's partly based on several assumptions that may be erroneous. For example, the assumption that sources -- there is no long-range transport of mercury, whereas it has been demonstrated by, say, a Professor Dan Jaffe at the University of

Washington that their mercury does get transported over long distances.

MR. AYRES: That's elemental mercury, isn't it?

MR. VIJAYARAGHAVAN: That is correct.

MR. AYRES: And if that were washed out of the stratosphere and deposited, that wouldn't be reactive, would it?

MR. VIJAYARAGHAVAN: To get washed out, it would have to be reactive.

MR. AYRES: Okay. That's the end of my questions.

MS. BASSI: Could I follow-up, please?

MS. TIPSORD: Sure.

MS. BASSI: I forgot what I was going to say. Never mind.

MS. TIPSORD: Mr. Harley?

MR. HARLEY: I'd first like to ask you a couple questions to make sure that the record is very clear on a couple points that were made during the break.

MR. VIJAYARAGHAVAN: Please.

MR. HARLEY: The first question is, is it your testimony that virtually all of

Illinois will experience lower mercury depositions under the Illinois rule than under CAMR/CAIR 2010?

(Witness peruses documents.)

MR. HARLEY: Without reference to a table or a chart. I think that you're well-acquainted with your testimony. I think you're well-acquainted with the presentation you gave. Is it your testimony that virtually all of Illinois will experience lower mercury deposition under the Illinois rule than under CAMR/CAIR 2010?

MR. VIJAYARAGHAVAN: We look at regions where there is less than a -- or there's greater than a .5 micrograms change or greater than a 1 percent change. So when you look at the regions represented in the find range, the answer may be no. But, otherwise, its seems to be yes. So that would be my answer. So it's both yes and no, depending on the range of deposition you look at.

So by and large, in most of

Illinois, one could say yes. But it's hard to tell without actually looking at the data for every grid cell. And that is not something I can do at this point.

MR. HARLEY: Is it your testimony that mercury deposition on average across the state will decrease between 4 and 5 percent more under the Illinois rule than under CAIR/CAMR 2010?

MR. VIJAYARAGHAVAN: Yeah. The modeling results, the simulated mercury deposition results, indicate that you would get an additional roughly 4 percent reductions in deposition on average in the Illinois rule when compared to the 2010 CAMR rule.

MR. HARLEY: Thank you. A few other questions.

As part of your testimony, have you quantified mercury emissions from an individual coal-fired power plant in Illinois?

MR. VIJAYARAGHAVAN: The emissions were provided by CRA International and were

directly inputted to the model.

MR. HARLEY: Does your testimony include any information about mercury emissions from any individual coal-fired power plant in Illinois? Not in terms of its input data, but in terms of your testimony?

MR. VIJAYARAGHAVAN: My written testimony does not.

MR. HARLEY: Does your testimony include any information quantifying mercury emissions from any subgroup of coal-fired power plants in Illinois? And by way of explanation what I mean by a subgroup, to illustrate, in the Chicago air quality region we have five coal-fired power plants operated by Midwest Generation, Waukegan, Fisk, Crawford, Joliet and Romeoville. By a subgroup, I mean a smaller group of coal-fired power plants. Do you quantify mercury emissions from any subgroup of coal-fired power plants in Illinois in your testimony?

MR. VIJAYARAGHAVAN: No.

MR. HARLEY: As part of your

testimony, do you characterize the deposition of mercury from any individual coal-fired power plant or subgroup of coal-fired power plants in Illinois?

MR. VIJAYARAGHAVAN: Only to the extent what we discussed in my presentation when we looked the at the specific cells that Madam Hearing Officer was interested in.

MR. HARLEY: But you do not trace individual grid cell deposition patterns to any individual source, do you?

MR. VIJAYARAGHAVAN: No, I do not.

MR. HARLEY: Or any subgroup of sources, do you?

MR. VIJAYARAGHAVAN: No, I do not.

MR. HARLEY: Are you familiar with the term hot spot?

MR. VIJAYARAGHAVAN: Yeah. There has been some discussion of that phrase, yes.

MR. HARLEY: Generally, what does that term mean to you?

MR. VIJAYARAGHAVAN: The term hot spot has never been clearly discussed or explained. There have been instances where

people referred to red areas on a color map as hot spots. There have been instances when -- I believe it was the U.S. EPA that related hot spots to a certain methylmercury level. So there is really no clear understanding or definition of what a hot spot is.

MR. HARLEY: Would you agree that generally a hot spot means a geographic area disproportionately impacted by deposition of a pollutant like mercury?

MR. VIJAYARAGHAVAN: I don't mean to digress here, but if you go back to why do we call it a hot spot, my understanding is -- and I may be wrong here -- is, again, the word hot is associated with high levels because the color red, fire, flame, and so on, anything that's brighter or more heavily impacted than other spots. So in that sense, a hot spot -- it's hard to give an exact answer to your question. But if your question was is a high area of deposition -- could it be classified as a high area of deposition? Yes. But what is a hot spot?

No. I mean, we don't really --

MR. HARLEY: Could a high area of deposition, as you've just described it or defined it, be smaller than an area which is 20 kilometers square?

MR. VIJAYARAGHAVAN: I think we went over this earlier today with Mr. Ayres' questions. So do you want to go over it again.

MS. TIPSORD: I don't remember that.

MR. AYRES: I don't think that question was asked.

MS. TIPSORD: Yeah. I don't remember that.

MR. VIJAYARAGHAVAN: Okay. So the issue here is the higher area of deposition could -- it is possible that a higher area of deposition could be in a certain location in a 20 kilometer grid cell, yes.

MR. HARLEY: In light of the fact that you have not quantified emissions, modeled dispersion patterns or determined mercury deposition related to any Illinois coal plant or subgroup of plants, how can you discount

the potential for hot spots in areas smaller than 20 kilometers?

MR. VIJAYARAGHAVAN: That's a mischaracterization of my testimony.

MR. HARLEY: I'll strike the question.

MS. TIPSORD: Okay. Dr. Girard?

MR. GIRARD: I have a quick question then. Mr. Vijayaraghavan, looking back at Exhibit 127, which is part of the diagrams from your PowerPoint -- I'm looking on Page 18 here, figure nine, which is the percent change in total deposition of mercury between Illinois rule scenario and 2010 CAIR/CAMR. Looking at that diagram there, doesn't that diagram show that under the Illinois rule, most of Illinois would have a reduction in mercury deposition when compared to the 2010 CAIR/CAMR?

MR. VIJAYARAGHAVAN: That is correct.

MR. GIRARD: Thank you.

MS. TIPSORD: Ms. Bassi?

MS. BASSI: I had just a couple of follow-ups to Mr. Ayres' line of questioning a few minutes ago.

Krish, is there a difference in purpose or result between deposition modeling and deposition measurements, such as Dr. Keeler was performing?

MR. VIJAYARAGHAVAN: Yes. Deposition modeling, the purpose is predictive modeling. We are trying to predict or estimate to the extent that is possible scientifically what the impact on deposition would be caused by controlled technologies whereas a deposition measurement is a snapshot in time, if you will.

MS. BASSI: Would it be fair to say that these two approaches are two ways that examining mercury deposition compliment each other?

MR. VIJAYARAGHAVAN: Yeah. That is correct.

MS. BASSI: Thank you.

MS. TIPSORD: Are we ready for question number six then?

MR. VIJAYARAGHAVAN: Question six: On Page 16 of his testimony, Mr. Vijayaraghavan notes that because incinerators emit a higher

fraction of Hg2+ and have shorter stacks than coal-fired power plants, that it is inappropriate to extrapolate the results of an incinerator program to the potential effects of a coal-fired power plant emission reduction program.

Question A: Is it likely that most of the Hg2+ emitted from a coal-fired power plant unit deposits within 150 kilometers of the emission point? If there are water bodies in the path of that plume, would you expect deposition to those water bodies?

Answer to A: The deposition of Hg2 would depend on the height of the stack and the meteorology. Also, there is some evidence that some fraction of Hg2 may get transformed to Hg0. In coal-fired power plant plumes as discussed in the peer-reviewed literature. The reference was one I had given before, Edgerton, E-D-G-E-R-T-O-N, Edgerton, et al., 2006. Thus, one cannot conclude whether it is likely or unlikely that most of the Hg2 emitted from a

coal-fired deposits within 150 kilometers of the emission point. Based on our work published in the Journal of Air & Waste Management Association, Seigneur, et al., 2006(b), less than 7 percent of emissions from a power plant are estimated to deposit within 50 kilometers. This is so because the plume is typically released at an altitude higher than 100 meters, thereby delaying the dry deposition; also, wet deposition occurs only in the presence of precipitation.

And the answer to the second subquestion: Yes. If water bodies are in the path of the plume, there would be some dry deposition to those water bodies. Wet deposition would depend on the occurrence of precipitation when the plume crosses the water body.

MR. AYRES: Can I follow up on that?

MS. TIPSORD: Sure.

MR. AYRES: Is it not true also that in the literature that there are indications that there are reactions transforming the elemental mercury to the reactive form of

mercury as well in the plume in the atmosphere? The reaction goes in both directions?

MR. VIJAYARAGHAVAN: Yeah. And the reactions transforming elemental mercury to gaseous mercury are by ozone, OH and bromine. And these oxidants are in limited quantities in the power plant plume, especially in the earlier stages of the plume. And so, yes, the reaction does happen, but to a very limited extent.

MR. AYRES: But as the plume travels further away, there are oxidizing agents in air --

MR. VIJAYARAGHAVAN: Right. But also --

MR. AYRES: -- that would have that effect?

MR. VIJAYARAGHAVAN: That is correct. But also as the plume travels further away, the plume is more diluted so the mercury concentrations are also lower correspondingly.

MR. AYRES: You said that you could

not conclude that most of the Hg2 from a power plant plume would be -- most of the dry deposition would occur within 150 kilometers. If there were a storm that occurred at a given point while the plume was traveling along, wouldn't that bring most of the reactive mercury to the ground there?

MR. VIJAYARAGHAVAN: It would wash out a lot of the mercury.

MR. AYRES: Okay. Thank you.

MS. TIPSORD: Question B.

MR. VIJAYARAGHAVAN: Question B: Would you expect there to be a point of maximum deposition of Hg in the plume of power plant emissions.

Answer: Yes, there would be a point of maximum deposition in the plume of power plant emissions. Note that the maximum point of deposition varies with time as the meteorology affects the plume rise and direction.

Question C: If a deposition model predicts a point of maximum mercury deposition from incinerator emissions in a

water body that is close to the source and predicts a point of maximum mercury deposition from a coal-fired power plant that is relatively close to the source, would there be any difference in the significance of that information, other than the impact point from the power plant is probably further from the source? What I'm trying to get at here is that Hg2+ from incinerators is not different from Hg2+ from coal-fired power plants. The difference is the proportion in the emission and the distance it will be transported due to difference release parameters. Once it comes down, if it comes down in an impaired water body, it makes no difference where it came from. If you reduce the mercury emissions by 90 percent, whether it's an incinerator or a coal-fired power plant, wouldn't you expect a 90 percent reduction in deposition at the point of maximum impact?

Answer: Yes. There is a difference in the significance of the information because, one, the plume is more

diluted when further away from the source and, two, there is some evidence that some Hg2 may be reduced to Hg0 in coal-fired power plant plumes. Reductions in deposition do not vary linearly with reductions in mercury emissions because of the contribution of other sources and the global atmospheric mercury pool so, no, I would not expect a 90 percent reduction in deposition at the point of maximum impact but a lower percentage because the source being controlled contributes only a fraction of the total mercury deposition.

MR. AYRES: May I ask a follow-up question?

MS. TIPSORD: Yes.

MR. AYRES: I ask you to imagine maybe it's a changeable source. I'm not sure quite how to describe it but a power plant with a let's say 300 meter tall stack or a 500 meter, if you wish, tall stack, and an incinerator with a 150 meter tall stack.

MR. VIJAYARAGHAVAN: It's likely shorter than that.

MR. AYRES: A shorter stack?

MR. VIJAYARAGHAVAN: Yeah.

MR. AYRES: And you imagine them right next to each other, let's say. Each is emitting a plume with mercury in it, but one much higher than the other. Downwind a few hundred meters, let's say, there's a thunderstorm, would you expect the reactive gaseous mercury in both plumes to be washed to the ground to a large extent?

MR. VIJAYARAGHAVAN: Right. Some of the reactive gaseous mercury there is some evidence that it gets converted to elemental mercury in the coal-fired power plant plume. But that which does not get released, yes, you would expect that to get washed down.

MR. AYRES: So the stack height really wouldn't make much difference in that circumstance I described, would it?

MR. VIJAYARAGHAVAN: That is correct.

MR. AYRES: Okay.

MS. BASSI: I have a follow-up on that.

MS. TIPSORD: Ms. Bassi?

MS. BASSI: Would the velocity of the emissions going up the stack make a difference?

MR. VIJAYARAGHAVAN: Yeah. If the velocity is higher, the plume rises higher and so the plume gets transported further aloft so that would make a difference. So that would lead to lower deposition.

MS. BASSI: Which of those two types of stacks would you expect to have lower velocity?

MR. VIJAYARAGHAVAN: I'm not sure about that.

MS. BASSI: Okay. If the shorter stack -- he said 150 meters for an incinerator stack and you said shorter. What would you expect?

MR. VIJAYARAGHAVAN: I would say less than 100.

MS. BASSI: Less than 100?

MR. VIJAYARAGHAVAN: Yeah.

MS. BASSI: And was there someplace in your testimony where you were saying 100 meters was some kind of a magic line?

That stacks that are taller than 100 meters tend to emit mercury that travels further away than a stack that is shorter than 100 meters?

MR. VIJAYARAGHAVAN: Well, there is -- I don't think there is a magic number but typically the ones that are higher would get transferred aloft and get transported over longer distances.

MS. BASSI: And so given those two stacks side-by-side and the types of sources that are behind those stacks, would you expect the emissions from the incinerator to travel as far as the emissions from a power plant?

MR. VIJAYARAGHAVAN: No, I would not.

MS. BASSI: Thank you.

MR. AYRES: Except in the case where there's a rainstorm downwind, correct? That's what you testified earlier.

MR. VIJAYARAGHAVAN: Yeah. At any given point in space and time whether it is 100 meters away or 10 kilometers away, if

there was rain it would wash out the reactive gaseous mercury. But we have to keep in mind that the mercury concentrations are diluted the further away you are from the stack, which is typically the case with a taller stack.

MR. AYRES: Okay. Madam Hearing Officer, because this is related to the incinerator issue, it may be a good time to raise some -- to ask some questions about his comments on the Florida study and the usefulness of that study as a -- to inform the Board's decision.

MS. TIPSORD: Go ahead.

MR. AYRES: In the case of the Florida study, the source of the emissions which were affecting the Everglades area was incinerators, was it not?

MR. VIJAYARAGHAVAN: Part of the sources were incinerator emissions. But a paper by
Dr. Guentzel, G-U-E-N-T-Z-E-L, points out that a monitoring site right there in the Everglades showed no decrease or very little

decrease in mercury wet deposition in spite of the large reductions in incinerator emissions, thereby postulating that sources that were further away and possibly global accounted for some of the deposition in Florida in the Everglades.

MR. AYRES: Well, you're getting toward the question I wanted to ask. You mentioned the -- I think it's the Dvonch study --

MR. VIJAYARAGHAVAN: Yes, sir.

MR. AYRES: -- which indicated that 71 percent of the measured deposition was the result of emissions from local sources; is that correct?

MR. VIJAYARAGHAVAN: Yes.

MR. AYRES: Do you know how that study was done? Was that based on actual monitoring sites?

MR. VIJAYARAGHAVAN: Well, I believe, first, there were monitoring sites and also they estimated what the background was by looking at monitoring data in a rural site to get a sense of what is the local contribution

versus a contribution that's more remote.

MR. AYRES: Were there about 17 monitoring sites in that area?

MR. VIJAYARAGHAVAN: I do not recall the exact number.

MR. AYRES: Okay. Now, in that study they attempted to explain the pattern of deposition on a fairly short time basis, did they not? Meaning short time intervals.

MR. VIJAYARAGHAVAN: Yeah. That is correct.

MR. AYRES: And on relatively small spatial areas, as well, correct?

MR. VIJAYARAGHAVAN: Over small areas, correct.

MR. AYRES: Yeah. And they found different patterns under different airflow conditions?

MR. VIJAYARAGHAVAN: Yes.

MR. AYRES: Could your model have explained the pattern of deposition that we're seeing in that study with 20 kilometer grid cells?

MR. VIJAYARAGHAVAN: Well, our model

does show reasonably good prediction that the southern Florida Everglades sites I believe is within about 20 percent, so --

MR. AYRES: Is that --

MR. VIJAYARAGHAVAN: I'm talking about a comparison of model wet deposition with the monitored wet deposition.

MR. AYRES: And this is on, what, a long term average and --

MR. VIJAYARAGHAVAN: Yes.

MR. AYRES: -- larger spatial basis.

MR. VIJAYARAGHAVAN: Yes, sir.

MR. AYRES: So isn't it true that a model of this sort you're talking about would not be appropriate to use if you were talking about a four to five kilometer distance scale like some of these measurements?

MR. VIJAYARAGHAVAN: As addressed in the first question in my testimony, a plume model is most appropriate to assess Hg deposition close to an emission source.

MR. AYRES: Of the other studies that you sited, the studies that you site indicate that the deposition from localized sources

may have been less. Are any of those from your shop?

MR. VIJAYARAGHAVAN: Seigneur, et al., 2004.

MR. AYRES: Just the one.

MR. VIJAYARAGHAVAN: Yes, sir.

MR. AYRES: Okay. And as to the -- did you say Guentzel?

MR. VIJAYARAGHAVAN: Yes.

MR. AYRES: The Guenztel study, how was that study done?

MR. VIJAYARAGHAVAN: This is part of the FAMS study, F-A-M-S, where they measured deposition in precipitation at several sites in southern Florida and tried to estimate the contributions again to deposition from those measurements.

MR. AYRES: And were those based on monthly deposition samples?

MR. VIJAYARAGHAVAN: I do not recall if they were based on a particular event base on different modeling.

MR. AYRES: You don't remember?

MR. VIJAYARAGHAVAN: Yeah. I could

look it up.

(Brief pause.)

MR. VIJAYARAGHAVAN: So it's monthly integrated precipitation and weekly integrated particulate samples.

MR. AYRES: So in that instance what they did, if I may put it crudely, is they put a bucket out to collect rain samples for a month and then analyzed that bucket?

MR. VIJAYARAGHAVAN: That would be one way of crudely putting it.

MR. AYRES: It captures of essence, though, doesn't it? Doesn't it rain every other day in the Florida in the Everglades area?

MR. VIJAYARAGHAVAN: Pardon me?

MR. AYRES: Doesn't it rain about every other day in the Florida Everglades?

MR. VIJAYARAGHAVAN: It is a very wet place.

MR. AYRES: So it would be very difficult to analyze the direction from which the mercury in the bucket came based on monthly samples, wouldn't it?

MR. VIJAYARAGHAVAN: But keep in mind that there, -- for example, there is one location in Florida which showed no change in the deposition over the time period they looked at. So, in essence, what you're trying to look at is the changes in deposition that are happening over a period of time because methylation -- the final impacts of the mercury that is falling to the earth is not seen over a period of hour or days but over a much longer period of time.

MR. AYRES: The Seigneur study, the one from your shop.

MR. VIJAYARAGHAVAN: Yes, sir.

MR. AYRES: Is that a modeling study?

MR. VIJAYARAGHAVAN: Yes, sir.

MR. AYRES: And then the Selin study. I don't know how you say that.

MR. VIJAYARAGHAVAN: Yes. That's out of Harvard University. Yes, Selin, S-E-L-I-N.

MR. AYRES: Yes. I didn't see that reference. Maybe I missed it in your list. There is a document that you referred to?

MR. VIJAYARAGHAVAN: Right. That is in -- so that's in my reference list. That's the third from the end.

MR. AYRES: Okay.

MR. VIJAYARAGHAVAN: So, yes, it is in my reference list.

MR. AYRES: And is that study a modeling study?

MR. VIJAYARAGHAVAN: Yes, sir, that's a modeling study out of Harvard.

MR. AYRES: So the Dvonch study is the only one that used a method which is appropriate to smaller grid squares or smaller areas of deposition and took monitored samples on a regular and frequent basis; is that correct?

MR. VIJAYARAGHAVAN: No, it would not be correct to say that was the most appropriate method because the method they used to determine the local versus regional contribution is flawed in the sense that they look at deposition at a remote site and quantified that as the background, if you will. So, no, I would not -- the answer

would be no.

MR. AYRES: But that's the only one that's based on regular --

MR. VIJAYARAGHAVAN: No. The study by Guentzel is also based on measurements.

MR. AYRES: On monthly measurements. Not on short term measurements.

MR. VIJAYARAGHAVAN: Yes. And, again, we are looking at effects that are happening over a period of time and not over a period of hours or days.

MR. AYRES: On the conclusions of that study, of the Florida study that you discuss, we know that the source of the emissions -- well, maybe you won't agree with this. I don't know. But certainly the state of Florida believed that the source of emissions which were affecting the Everglades that they measured were primarily local; is that correct?

MR. VIJAYARAGHAVAN: Well, I do not believe -- I do not know what the state of Florida believes or not. But there is evidence that, for example, you have these

intense thunderstorms that you just talked about, again, wash out the global pool of mercury and there are sites in southern Florida which had -- a site, for example, which had no decrease in deposition with the changes in incinerator emissions. So it would be not an easily-justifiable conclusion.

MR. AYRES: We don't have a lot of natural experiments, so to speak, that allow us to look at the effects of large reductions in mercury emissions, do we? Wouldn't this be about the only one where there were large reductions in mercury emissions and we had the ability and did, in fact, carry out studies of mercury in the tissue of animals and birds?

MR. VIJAYARAGHAVAN: I'm not aware of any study or a natural event which involved a large reduction in mercury.

MR. AYRES: But in Florida there was a large reduction in localized emissions over a short period of time, wasn't there?

MR. VIJAYARAGHAVAN: There was a

reduction -- a significant reduction in incinerator emissions, yes.

MR. AYRES: About 93 percent during the early '90s perhaps?

MR. VIJAYARAGHAVAN: Yeah. About 90 percent over a period of several years.

MR. AYRES: And the investigators in Florida who were taking samples of fish and bird feathers -- fish flesh and bird feathers concluded that there were large reductions in the mercury in that tissue that occurred afterward, but within a fairly short period of time afterward of these large emission reductions, did they not?

MR. BONEBRAKE: I'm going to object to that question to the extent that Mr. Ayres is asking the witness to opine about what some individual or individuals may have concluded. If your question is relating to a particular section or a part of a report, you may ask him about that report. That seems to me to be an appropriate question. But as framed, you seem to be asking him to speculate about what people may have thought about results in

Florida.

MR. AYRES: I'm sorry if I gave that impression. I'm referring to a report which was issued by the Florida Department of Environmental Protection, which I'm sure the witness knows.

MS. TIPSORD: Excuse me, Mr. Ayres. Is that in the record here?

MR. AYRES: It is not in the record, I don't think. But we can certainly make it available.

MR. BONEBRAKE: There was a --

MR. AYRES: The witness is aware of that, isn't he?

MR. BONEBRAKE: I think there was a Florida report that was put in the record, if I recall correctly, from the first set of hearings in Springfield. I don't happen to know what the number is.

MR. AYRES: It would be that one, yes.

MR. VIJAYARAGHAVAN: There may have been an exhibit. I don't recall the exhibit number.

MR. AYRES: I don't either. But if that was put in evidence, it would be that report that I'm speaking of.

MS. TIPSORD: All right. Let me check because I'm not comfortable with you asking him questions about a report that's not a part of the record. I have Exhibit 20, Integrating Atmospheric Mercury Deposition With Aquatic Cycling in South Florida; An Approach For Conducting a Total Maximum Daily Load Analysis For an Atmospherically Derived Pollutant from the Florida Department of Environmental Protection, October 2002.

MR. AYRES: That's correct. That's the testimony I'm speaking of.

MS. TIPSORD: Thank you.

MR. AYRES: Now may I go ahead and ask my question?

That report reports a large reduction in the measured mercury content of fish and bird specimens over a fairly short period after these emission reductions were made, does it not?

MR. BONEBRAKE: I'm going to object to

the characterization of the report. It speaks for itself and I believe there was testimony that was provided at the first hearing in Springfield about the fact that there were some increases and decreases. So I think that the question inaccurately characterizes the report as described in testimony provided in the June hearings.

MR. AYRES: I believe the report shows that there were about 80 percent reductions in the measured mercury concentration of fish and bird samples in large parts of the Everglades.

MR. BONEBRAKE: But I guess my problem here is -- I'll finish my objection -- is we're talking about a report and the report is not before any of us. We all have recollections about what the report said that we have from two months ago when we read it and there was testimony about it. And I think it's unfair for Mr. Ayres to be characterizing the report as it was described in testimony two months ago without presenting a copy of the report to the

witness.

MS. TIPSORD: I think that's legitimate because I can't --

MR. AYRES: I'll withdraw the question.

MS. TIPSORD: I mean, if you want to ask him if he recalls the report and a specific question about the report, if he can answer that. But I think to characterize that the report says this, is that correct, I think is unfair without presenting it.

MR. AYRES: All right. Let me do it the other way.

MS. TIPSORD: Okay.

MR. AYRES: Do you recall this report, the Florida report in question?

MR. VIJAYARAGHAVAN: Yes, I do.

MR. AYRES: And does that report, in your view, report reductions of 80 percent or more in the concentrations of mercury found in the flesh of fish and the feathers of birds in the Everglades?

MR. VIJAYARAGHAVAN: I do not recall the specific numbers.

MR. AYRES: Okay.

MS. TIPSORD: Question number seven.

MR. VIJAYARAGHAVAN: Question seven: You are employed as a paid consultant, are you not? Who is funding the modeling study you described in your testimony.

Answer: Yes, I am employed as a paid consultant. The Illinois Utilities funded our modeling study. Note, however, that AER's work is a scientific modeling study that draws upon our research published over the years in the peer-reviewed literature. Also, AER's compensation does not depend on the results of the study.

Question eight: On Page 3 of your testimony, you state that U.S. coal-fired power plants contribute less than 1 percent to the worldwide emissions of mercury. What do coal-fired power plant contribute to just the total emissions of mercury in the U.S.? Are coal-fired power plants the largest category of mercury emissions in the U.S.?

Coal-fired power plants are estimated to contribute 44 percent to the

anthropogenic emissions of mercury in the U.S. The percentage would be lower if one includes natural emissions of mercury in the U.S.

Answer to the second subquestion: Yes, coal-fired power plants are the largest identified category of mercury emissions in the U.S. I included the fact that U.S. coal-fired power plants contribute less than 1 percent to the worldwide emissions of mercury in my testimony because mercury can be transported and deposited globally, for example, to the U.S. from other continents such as Asia. Measurements that demonstrate the transport of mercury from Asia to the U.S. have been, for example, published about Professor Dan Jaffe, J-A-F-F-E, at the University of Washington.

Question nine: On Page 6 of your testimony, you mention the Mercury Deposition Network. Could you please describe the Mercury Deposition Network? How many monitors in the U.S.? How many monitors in Illinois? Are the monitors located in urban

areas or rural areas? Who operates the network? Does it measure both wet and dry deposition? Is the network designed to measure regional deposition or deposition from specific sources? Are there any monitoring data in Illinois that can be used to evaluate local-scale deposition?

Answer: The Mercury Deposition Network is a national measurement network of mercury concentrations in precipitation and wet deposition and is part of the National Acid Deposition Program or NADP. There are about 80 monitoring sites in the U.S. and I believe seven in Canada and two in Mexico.

There is one monitor in Illinois at Bondville in Champaign County. The monitors are typically located in rural areas. There are a few urban monitors such as in Indiana, New Jersey, Wisconsin, et cetera. The MDN monitors are operated by the Illinois State Water Survey. And they do a rather good job, if I may add. They currently measure wet deposition and concentrations in precipitation and not dry

deposition. The main reason for this is that dry deposition measurement methods have more uncertainty than wet deposition methods because dry deposition measurements are based on indirect measurements of speciated mercury, while the latter, that is wet deposition measurements, are based on actual collected samples of rainfall. However, the MDN is currently working on a proposal for a dry deposition network. Initially, 12 stations in the U.S. would measure speciated mercury concentrations and then estimate the Hg dry deposition rates. The MDN network is typically designed to measure regional deposition.

Yes, there are data in Illinois that can be used to evaluate local-scale deposition. Wet deposition simulated by TEAM is slightly, i.e., about 15 percent, higher than the wet deposition measured at IIT Chicago by Landis, Vette, V-E-T-T-E, and Keller during the Lake Michigan Mass Balance Study.

Question ten: On Page 7, you

mentioned that the model you used has a grid resolution of 20 kilometers. Please describe the effects of grid resolution on model performance. What factors influence your selection of the model's resolution? Is 20 kilometers adequate for regional modeling? Is 20 kilometers adequate for local-scale modeling? What would the model show with respect to mercury deposition near power plants if finer grid resolution were used?

Answer: Model performance could improve or degrade with a finer grid resolution. In theory, model performance should improve with a finer spatial specification resolution or grid spacing. However, there may be some compensating effects. For example, the overestimation of vertical diffusion, that was discussed earlier, in a grid model may be compensated by horizontal dilution at a 20 kilometer resolution but not as much at a finer resolution. We had to consider this factor as well as the computer CPU time required when selecting the model's resolution. A

finer grid spacing, of course, would entail more CPU time. The 20 kilometer grid offers a good balance and is adequate for regional modeling in the central and eastern United States.

As discussed above, or earlier in this testimony, a plume model is more appropriate for local-scale modeling than a grid-based model. Using a grid model, though, regardless of its spatial resolution, leads to artificially increased mercury deposition at the model's spatial resolution immediately downwind of large point sources such as power plants.

This work has also been published in the peer-reviewed literature. The reference would be Seigneur, et al., 2006(b). There are two main reasons why a grid model tends to artificially increase mercury deposition downwind of elevated point sources such as power plants and thus the estimates of deposition may be over-estimates; one, incorrect enhanced vertical dispersion to the ground and, second, some evidence of

reduction of Hg2 to Hg0 power plant plumes.

MR. AYRES: You testified a moment ago that, in theory, a smaller grid resolution should give greater accuracy, correct?

MR. VIJAYARAGHAVAN: Yes.

MR. AYRES: But that it might be counterbalanced by vertical diffusion issues?

MR. VIJAYARAGHAVAN: Yes.

MR. AYRES: Could those be compensated for by changing the emissioning height or the size of the vertical grids that you put into your model?

MR. VIJAYARAGHAVAN: Yeah. We've actually done -- changed the vertical spacing in another model called CMAQ-MADRID, which is again done by our company or it's another model that's been published in the literature. And there we see that even with a change in the spacing, you still see the artificial vertical dispersion.

MS. TIPSORD: Question number eleven.

MR. VIJAYARAGHAVAN: Question number eleven: On Page 9 you describe the modeling scenarios you ran. Is there a reason you did

not run a 2020 scenario with CAIR/CAMR and with Illinois' proposed 90 percent control? In your summary of the results on Page 11, you stated that the 2020 CAIR/CAMR scenario provides lower mercury deposition than the 2010 scenario with CAIR/CAMR and with 900 percent mercury control in Illinois. Wouldn't you also expect lower mercury deposition in 2020 with CAIR/CAMR and with 90 percent mercury control in Illinois than with just CAIR/CAMR in 2020?

Answer: We selected our modeling scenarios based on the rules proposed by U.S. EPA and Illinois EPA. The 2020 CAMR scenario was based on the rule proposed by the U.S. EPA and the 2010 scenarios were selected based on the rules proposed by the Illinois EPA. Note that fewer differences are expected to be seen between the 2020 CAMR and the 2020 CAMR with Illinois controls rather than between the 2010 CAMR and the 2010 CAMR with Illinois controls and, hence, we did not model the 2020 CAMR scenario with 90 percent Illinois controls.

MS. TIPSORD: Mr. Harley?

MR. HARLEY: You had more. I'm sorry.

MR. VIJAYARAGHAVAN: I was just going to complete, but please go ahead.

MR. HARLEY: I would like to call your attention to Page 14 from your presentation earlier in the afternoon.

MS. TIPSORD: Exhibit 127.

MR. VIJAYARAGHAVAN: Yes.

MR. HARLEY: In this table you contrast the reductions which would be expected under the 2010 CAIR/CAMR rule with the reductions which would be expected if CAIR/CAMR were in effect as well as the Illinois controls; is that correct?

MR. VIJAYARAGHAVAN: Yes.

MR. HARLEY: And you actually provide an estimate through your model of the total reduction in mercury that would be deposited between those two programs; is that correct?

MR. VIJAYARAGHAVAN: Yes.

MR. HARLEY: And the total reduction that you estimate that would be deposited in Illinois would be 321 fewer pounds of

mercury; is that correct?

MR. VIJAYARAGHAVAN: Yes.

MR. HARLEY: So your model predicts there will be 321 fewer pounds of mercury deposited in Illinois under the Illinois rule than under CAIR/CAMR 2010 alone; is that correct?

MR. VIJAYARAGHAVAN: Yes.

MR. HARLEY: I want to test your willingness to take a look beyond 2010 in light of your expertise as to how that trend might play out then in 2011. What would you expect to see in 2011 in terms of reduction of mercury deposited in Illinois under the -- if we were talking about CAMR/CAIR in 2011 versus the Illinois program?

(Whereupon, a discussion was had off the record.)

MR. VIJAYARAGHAVAN: I was hesitating because the modeling study is derived from emissions that were developed by CRA and one would really need to conduct the analysis to answer that question.

MR. HARLEY: You've testified that in

2010 there would be an additional 321 pounds and you testified that in 2020 the difference would be much smaller between the two programs; is that correct?

MR. VIJAYARAGHAVAN: Yes.

MR. HARLEY: That suggests that between 2011 and 2020 we would see decreases in mercury deposited in Illinois every year, but at a smaller amount; is that correct?

MR. VIJAYARAGHAVAN: That makes sense.

MS. BASSI: I'm going to object. The reason why I'm objecting to this, Mr. Harley, is because the emissions inputs were provided to him by CRA International, which he's testified to and I think that you're asking him to provide you with numbers between 2010 and 2020 that are -- I mean, those questions should have been more appropriately addressed to Dr. Smith.

MR. HARLEY: I'm not asking --

MR. AYRES: These numbers were not available at the time that Dr. Smith was available, as I recall.

MR. HARLEY: Ms. Bassi, I'm not asking

for him to provide any numbers. I'm asking for him to provide an opinion about a general trend.

MR. VIJAYARAGHAVAN: Right. I can answer that. I mean, it is difficult to estimate a trend. It could be flat and then drop significantly. It is difficult to quantify or to expect or to estimate a certain trend without actually doing the analysis.

MR. HARLEY: It's possible, though, isn't it, that the benefits to be achieved through the Illinois rule would continue on in 2011 in terms of reduced mercury deposition in Illinois?

MR. VIJAYARAGHAVAN: Again, that would depend on what the CAIR/CAMR scenario emissions are from 2011.

MR. HARLEY: You have no opinion on that?

MR. VIJAYARAGHAVAN: Yeah. My opinion is that if the CAIR/CAMR scenario emissions were comparable to the Illinois rule scenario emissions in 2011, then the reductions, or

the benefits as you called them, would not be as significant. On the other hand, if the CAIR/CAMR emissions were not as -- if the emission were lower in the CAIR/CAMR -- let me rephrase.

If the CAIR/CAMR emissions in 2011 were comparable to the Illinois rule emissions in 2011, then the reductions would not be as much as what we see here. And on the other hand, if they're not comparable, then the reductions may continue to occur.

MR. HARLEY: Thank you.

MR. AYRES: May I ask one follow-up question?

MS. TIPSORD: Please do.

MR. AYRES: Since we're talking about these reduction figures on Page 14 of his slide slow, when I asked you earlier whether you could calculate confidence intervals for these point estimates, you said that you couldn't do it right here, you'd have to go home and calculate it. Could you calculate the 90 percent confidence levels for the benefit of the Board and the Illinois EPA?

MR. BONEBRAKE: Are you meaning after this hearing?

MR. AYRES: After this hearing, yes.

MR. VIJAYARAGHAVAN: This is the kind of analysis that -- let me think about this for a second.

MR. AYRES: Well, you did provide us with a statistical characterization of the data that explained 50 percent of the variance and I'm simply asking for you to provide us also with an additional statistical characterization that relates to the likelihood that the numbers that you give us will be within 90 percent confidence.

MR. BONEBRAKE: I think he's also explained, Mr. Ayres, a number of other pieces of information that provides some confidence regarding his predictions. So I guess part of what we're wrestling with here is your question I think is assuming reliance upon a single statistical test when his testimony deals with a number of other corroborating factors.

So I think when you talk about

statistical analysis, I think you're perhaps ignoring some of the other testimony that the witness has already put into the record regarding corroborative points and analyses that he's done.

MR. AYRES: Well, I'm only asking for a statistical expression. The 90 percent confidence level is a statistical term --

MR. BONEBRAKE: I guess if we don't know whether this kind of statistical analyses can be done or has been done in this kind of setting before, I guess that's a question we can take a look at and then respond to. I guess I'm getting some reticence from you and so that's a question we're going to have to take a closer look at.

MR. AYRES: Okay. Thank you.

MS. TIPSORD: Excuse me. I'm still really hung up on this difference between 2010 and 2020. It's my understanding, and I believe the Agency would agree with this, that we're sort of on a belt curve that we're going to get 90 percent in 2010 and everybody else will get there in 2020.

MR. JOHNSON: Seventy percent, right?
MS. TIPSORD: Seventy percent. I'm sorry. I stand corrected. But Illinois is doing it faster. That's what this proposal will do is get us lower emissions faster, I think. After 14 days-plus, 20 days now of hearings, I think I've got that much of an understanding. So, in effect, in 2010 there is 361 --
MR. HARLEY: Three-hundred-twenty-one pounds.
MS. TIPSORD: -- 321 pounds less deposition of mercury?
MR. JOHNSON: Do it as a percentage, too, like you did before.
MS. TIPSORD: And 4 percent additional?
MR. JOHNSON: Right.
MS. TIPSORD: So from the years 2010 to 2020 when we level out and the Illinois rule gives about the same amount of total amount of deposition as the CAIR/CAMR 2020 and the same percentages as CAIR/CAMR, during that 10-year period presumably we will have

at least have had the benefit of the difference -- as CAIR/CAMR comes down, it will level off throughout the next 10 years, correct?

MR. VIJAYARAGHAVAN: That is correct.

MS. TIPSORD: So for approximately 10 years, there will be that much less mercury going into the waters and into the environment in Illinois, correct?

MR. VIJAYARAGHAVAN: Well, yeah. We should note that the -- I'm not familiar with the details but you do see emission reductions happening significantly in 2015. So the general trend you're reporting is correct but it's not necessarily a gradual trend.

MS. TIPSORD: So let's assume that the Florida report did say that there was an 80 percent reduction in methylmercury in fish tissue in that seven-year period, that would mean then that if that were to carry -- and I know there are thousands of reasons why it might not carry through to Illinois but let's assume that it does, and I know this is a

huge assumption for a scientist and an engineer -- then that would mean that Illinois could conceivably see a reduction in methylmercury in fish earlier than if we wait until the reduction of CAIR/CAMR in 2020?

MR. VIJAYARAGHAVAN: Yes. But only to the extent that power plants contribute to that level of methylmercury.

MS. TIPSORD: Okay. Thank you. Mr. Harley?

MR. HARLEY: One follow-up question. Isn't it true that one of the consequences of CAMR/CAIR in 2020 is that Illinois will also experience fewer pounds of mercury deposition because of reductions in other states?

MR. VIJAYARAGHAVAN: That is correct.

MR. HARLEY: Thank you.

MS. TIPSORD: I think maybe I've got it now.

MR. VIJAYARAGHAVAN: I want to finish up the answer to question 11. Additional modeling would be required to predict whether mercury deposition in 2020 with CAIR/CAMR and 90 percent Illinois mercury control would be

lower than with just CAIR/CAMR in 2020. Chemistry transport models such as TEAM offer this predictive modeling capability unlike receptor models.

MR. AYRES: Madam Hearing Officer, could we say by now perhaps this question has been asked and answered? It's been asked in various pieces, I think.

MS. TIPSORD: Yeah. I think so. Unless you want to add something additional?

MR. VIJAYARAGHAVAN: Question 12: What is the importance of precipitation in deposition? Is it important to ensure that precipitation is handled properly in the model, both amounts and locations.

MR. AYRES: I think I'd say the same of this one.

MS. BASSI: Do you agree?

MR. VIJAYARAGHAVAN: Yeah.

MS. TIPSORD: Question 13.

MR. VIJAYARAGHAVAN: Question 13: On Page 15, you noted that large convective storms may extend to the upper troposphere.

What is the typical height of these storms in the Midwest? Are large convective storms important for mercury deposition? How are they handled in grid-based modeling? What is the height of the top of the model's highest grid layer? Is it high enough to model large convective storms? If not, wouldn't the performance of the model be compromised with respect to wet deposition from these events?

Large convective storms are important for mercury deposition sometimes because they tend to wash out the global pool of atmospheric mercury. They typically go up to the tropopause in the Midwest, so you're looking at roughly 12 to 13 kilometers, but sometimes these penetrate the stratosphere. These are typically handled in grid-based modeling only if the input meteorology accounts for them. The height of our model's highest grid layer is six kilometers. This is not high enough to model large convective storms.

So the model does not take into account the deposition of mercury from the

upper atmosphere and the model may, therefore, underestimate the contribution of global sources of mercury and conversely may over predict the U.S. power plant contributions to deposition.

MR. AYRES: I have no further questions.

MR. GIRARD: I have a question. Mr. Vijayaraghavan, do you know of any models that would have predicted the reduction in mercury in the fish or bird tissues in south Florida when the incinerator mercury condition regulations were changed down there?

MR. VIJAYARAGHAVAN: I know they used a mercury cycling model, but that is outside the area of my expertise.

MR. GIRARD: So you don't know if anyone tried to go back after we had this data in hand and tried to see if there were any models that would have predicted this or tried to alter any models to show any relationship between atmospheric mercury and mercury levels in, say, you know, predator

fish or predator fish and birds?

MR. VIJAYARAGHAVAN: From what I recall, the mercury modeling study of the report released by the Florida DEP does address that but, again -- and they do discuss some methylation and mercury cycling in the lake, some modeling of that. But, again, I'm not familiar with the details.

MR. GIRARD: Thank you.

MS. TIPSORD: I note that Prairie State Generating also filed some questions, so if we could go through those.

MR. VIJAYARAGHAVAN: Question one: Did the TEAM results presented in your testimony contain any conversion of ionic mercury to elemental mercury in the plume.

Question A: Are you aware that measurements by Eric Edgerton, E-D-G-E-R-T-O-N, at Atmospheric Research & Analysis, Incorporated, indicate this conversion occurs?

Question B: How would your results have been affected if the mercury conversion were added?

Answer: No. The TEAM results do not account for any conversion of ionic mercury to elemental mercury in the power plant plume.

Answer to A: Yes, I am aware of measurements made by Eric Edgerton at Atmospheric Research & Analysis that indicate that some ionic mercury may be converted to elemental mercury in plumes from coal-fired power plants. This work was published in the peer-reviewed literature, Edgerton, et al., 2006.

The authors measured air concentrations of Hg0, Hg2 and Hgp at three sites in southeastern U.S. They were then able to associate these Hg measurements with plumes from six different coal-fired power plants. And results for such -- for 21 such plume events showed that total Hg was conserved, but the Hg0 fraction increased from 42 percent at the source to 84 percent in the plume. And one of the possible reasons suggested by the authors is that some Hg2 is reduced to Hg0 during transport in the

plume.

We should note that the authors also suggest three other possible reasons; loss due to dry deposition, errors in emission estimates and measurement errors. However, they explain that each of these three reasons is unlikely or unlikely to be the sole explanation.

Answer to B: If this conversion of ionic to elemental mercury were added in our model, we would predict lower contributions of Illinois coal-fired power plants to local and regional mercury deposition because elemental mercury has a much lower deposition rate than ionic mercury. The exact decrease in the contributions would depend on the chemical conversion rate used in the model.

MS. TIPSORD: Question two.

MR. VIJAYARAGHAVAN: Question two: Have you reviewed the testimony of Dr. Keeler and the limited information that is available on his receptor modeling at Steubenville?

Question A: Are Dr. Keeler's

results different and unexpected from the earlier modeling results of AER or EPA? That would be U.S. EPA.

Question B: Can a receptor model be used to make predictions about the future effects of a regulatory program?

MS. BASSI: Have these been answered already?

MS. TIPSORD: I don't think they have.

MS. BASSI: Okay.

MR. VIJAYARAGHAVAN: Yes, I have reviewed the testimony of Dr. Keeler.

Answer 2a: Dr. Keeler in his testimony reports that according to a receptor modeling analysis, coal-fired power plants within about 1000 kilometers are estimated to contribute about 70 percent of mercury by deposition in Steubenville in 2004 with an uncertainty of about 15 percent. TEAM predicts that U.S. coal-fired power plants contribute 62 percent of mercury deposition in the grid cell where Steubenville is located. And this value is within the range proposed by Dr. Keeler via

receptor modeling. And, therefore, the two results are somewhat consistent thereby providing some confirmation that these results are comparable.

One must note, however, that TEAM and the receptor modeling techniques have uncertainties and they are both likely to overestimate mercury deposition due to the reasons cited earlier. U.S. EPA, using CMAQ, predicted that U.S. coal-fired power plants contributed 43 percent to mercury wet deposition in the grid cell where Steubenville is located. However, EPA also reports that a neighboring cell has a contribution of 71 percent, thus agreeing with Keeler's results.

Answer 2b: No. A receptor model cannot be used to make predictions about the future effects of a regulatory program. This fact has also been confirmed by Dr. Keeler in his testimony.

MS. TIPSORD: Question three.

MR. VIJAYARAGHAVAN: Question three: Have you reviewed Exhibit 65, Preliminary

Modeling Results for June 2002.

MS. BASSI: Madam Hearing Officer, I have additional copies of Exhibit 65, if you'd like them.

MS. TIPSORD: I don't think I have one with me.

(Document tendered to the Board.)

MR. VIJAYARAGHAVAN: Question three: Have you reviewed Exhibit 65, Preliminary Modeling Results for June 2002? If yes, what is your interpretation of the data.

Yes, I reviewed Exhibit 65 which presents results of Illinois EPA's mercury modeling study for the Illinois rule. The exhibit consists of a few maps of the U.S. showing deposition in a base case scenario and changes in deposition due to the Illinois rule.

The deposition reductions obtained in Illinois EPA's modeling study seem to be lower than those simulated by AER using TEAM. For example, the maximum reduction anywhere in the state in summer is about 10 percent

and this is a maximum across the state. The averages tend to be much lower. Note, however, that we cannot quantify this more accurately because of the poor resolution of the maps and the lack of accompanying text so it's hard to quantify exactly what is happening.

MS. TIPSORD: Thank you very much, Mr. Vijayaraghavan. It's been a pleasure.

MR. VIJAYARAGHAVAN: Thank you.

MR. AYRES: Thank you, Mr. Vijayaraghavan.

MR. VIJAYARAGHAVAN: Thank you, Mr. Ayres.

MS. TIPSORD: It's about quarter to 5:00. Let's go off the record for just a second.

(Whereupon, after a short break was had, the following proceedings were held accordingly.)

MS. TIPSORD: Given the lateness of the hour and that Mr. Peter Chapman is available only tomorrow morning, rather that

proceed with Ms. Charnley we will start with Mr. Chapman in the morning and then with Ms. Charnley tomorrow afternoon. I thank you for your patience.

And then after that, if we can get to Mr. McRanie tomorrow afternoon, we will attempt to do that. Otherwise we will do on Wednesday the Dominion Kincaid testifiers, which are C.J. Saladino, Andy Yaros and finish with Mr. McRanie. Thank you very much. We're recessed.

(Which were all the proceedings had in the above-entitled cause on this date.)

STATE OF ILLINOIS)
) SS.
COUNTY OF WILL)

I, Tamara Manganiello, RPR, do hereby certify that I reported in shorthand the proceedings held in the foregoing cause, and that the foregoing is a true, complete and correct transcript of the proceedings as appears from my stenographic notes so taken and transcribed under my personal direction.

_____
TAMARA MANGANIELLO, RPR
License No. 084-004560

SUBSCRIBED AND SWORN TO
before me this ____ day
of _____, A.D., 2006.

_____
Notary Public