NUCLEAR REGULATORY COMMISSION

IN THE MATTER OF:

PUBLIC SERVICE COMPANY OF
OKLAHOMA, et al.

(Black Fox Station, Units 1 and 2)

Docket Nos. 50-556
50-557

Place - Tulsa, Oklahoma

Date - Wednesday, February 21, 1979

Pages 7797 - 7993

7903080513

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

In the matter of:	
PUBLIC SERVICE COMPANY OF OKLAHOMA ASSOCIATED ELECTRIC COOPERATIVE, INC.,	
-and-	Docket Nos. 50-556
WESTERN FARMERS ELECTRIC COOPERATIVE	50-557
[Black Fox Station, Units 1 and 2]	

United States Courthouse
Courtroom No. 3
333 W. 4th Street
Tulsa, Oklahoma

Wednesday, February 21, 1979

Hearing in the above-entitled matter was reconvened, pursuant to adjournment, at 9:00 a.m.

BEFORE:

SHELDON J. WOLFE, ESQ., Chairman,
Atomic Safety & Licensing Board.

DR. PAUL W. PURDOM, Member.

FREDERICK J. SHON, Member.

APPEARANCES:

JOSEPH GALLO, ESQ., Isham, Lincoln & Beale,
1050 17th Street Northwest, Washington, D.C. 20036
-and-
GLENN NELSON, ESQ., Isham, Lincoln & Beale,
4200 First National Bank Building, Chicago, Illinois,

Counsel for Applicants.

[Appearances, continued:]

JOE FARRIS, ESQ.,
Green, Feldman, Hall & Woodard
816 Enterprise Building
Tulsa, Oklahoma.

Counsel for the Intervenors.

DOW DAVIS, ESQ., COLLEEN WOODHEAD, ESQ., and WILLIAM PATON, ESQ.
Office of the Executive Legal Director, United States Nuclear Regulatory Commission, Bethesda, Maryland.

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I N D E X

P R O C E E D I N G S

Whereupon,

ROBERT E. STIPPICH

resumed the stand as a witness on behalf of the Applicants and, having been previously duly sworn, was examined and testified further as follows:

CHAIRMAN WOLFE: The hearing is resumed.

Before we proceed with the cross-examination of Mr. Stippich, the Board has a ruling to make.

On February 19th, 1979, at Tr. pages 7515, Mr. Gallo objected to the admission of Staff Exhibit 9, marked for identification, which was and is the affidavit of Mr. Karlowicz. The objection was overruled. Unlike the Staff, Applicant had not objected on the grounds of irrelevancy when on October 11th, 1978, Mr. Woodard, at Tr. page 4666, asked Mr. Karlowicz:

"Do you know of any utility that is getting a 15 percent return on common equity?"

Mr. Gallo only reserved the right to object dependent on whether or not the affidavit which the Board had ruled should be furnished, reflected "straightforward information."

The objection voiced by Mr. Gallo of the irrelevancy is too late and is overruled.

However, upon reviewing the transcript pages 4631 through 4671, and especially the Karlowicz testimony on

October 11th, 1978, at pages 4657 through 4671, we must reverse the ruling that we made at Tr. page 4667, when we overruled Staff's objections to Mr. Woodard's question as posed to Mr. Karlowicz.

The question as put was well outside the scope of Board Question 18-1, and is thus irrelevant, so we sustain Staff's objection at Tr. page 4666, and we withdraw our direction to Staff at Tr. pages 6668 and 6669 to submit Mr. Karlowicz's affidavit and withdraw our ruling that upon reading the affidavit, both Messrs. Woodard and Gallo would have the right to request that Mr. Karlowicz be returned for cross-examination.

We always try to make well-grounded and reasoned rulings. When we don't, we will reverse, and we do so in this case because in this instance we see no connection between PSO's rate of return on common equity and the Board's question which merely and narrowly queried whether PSO provided different data on covered ratios for bonded debt to NRC and OCC and, if so, what is the reason for the difference.

Excuse me. The transcript pages that I read as being 6668 and 6669, correct the transcript pages in our ruling, I cited transcript pages 6668 and 6669. It should be transcript pages 4668 and 4669.

All right, Mr. Farris, you may proceed with your cross-examination of Mr. Stippich.

CROSS-EXAMINATION [Continued]

BY MR. FARRIS:

Q Mr. Stippich, were you able to find any information or any data concerning the expected distribution of missiles within a 25 degree arc out from a turbine?

A No, sir, I could find no specific reference. On reflection, I believe that that assumption can be justified by considering the way that the low pressure turbine is constructed. In this case, it consists of seven low pressure stages, starting from the innermost stage outward to the -- out to the last stage, which is the largest of the low pressure stages.

It involves the 43-inch blade and the largest turbine disk.

Now, the disks for each stage consist of a rather massive disk attached to the rotor, and on the periphery of the disk are attached the turbine blades.

This is typical for each of the stages that they do vary in size, increasing from the first stage out to the last stage so the first stage is the smallest, and the last stage is the largest.

In between each of the stages is a diaphragm that consists of a diaphragm web that is near the rotor and a diaphragm ring that is at the outer part, and is near the wrapper of the low pressure casing.

In between the two diaphragm pieces are veins that the function of which is to redirect the flow of the steam into the next successive stage.

The last stage does not have a web ring nor does it have a diaphragm web or a diaphragm ring on the out-board side. It has one only on the in-board side.

Furthermore, the wrapper of the low pressure turbine which surrounds this whole entire assembly does not extend completely over the final stage.

As a consequence, when a fragment, if the last stage disk should fail, when the fragment starts away from the shaft, it would have a preference for the plane normal to the original plane of the disk, but upon striking the web which is now only on one side, it would be deflected, and then upon striking the diaphragm ring, it would be deflected still further to the outside, and then finally, since a wrapper does not cover the last stage disk entirely, it would be deflected further to the out-board end, which would tend to give the bias of the distribution toward the outside in, and I think on that basis that the uniform distribution of the directional probability for the last stage blade is a reasonable assumption for the distribution.

[Pause.]

end 1

Q Mr. Stippich, if you expect that any turbine missile generated would be deflected two or three times, wouldn't you expect that the distribution may be -- tend to be concentrated toward the outside angles?

MR. NELSON: Objection. I don't believe the witness testified that it would be deflected "two or three times." I believe that is an erroneous interpretation that Mr. Farris has added to the testimony.

MR. FARRIS: I thought he said it would be deflected as much as three times.

CHAIRMAN WOLFE: Address that question first, then, to the witness, Mr. Farris.

BY MR. FARRIS:

Q Mr. Stippich, did you state that the missile was likely to be deflected as much, or as many as three times?

A That wasn't the point of the statement. The missile is going to interact at -- in a random fashion. It could interact as much as three times, but not necessarily. It is a random thing. It simply tends to cause the missile to favor an outward direction. That was the main point.

Q You stated, did you not, that you would expect a bias toward the outside angles?

A I said, "in that direction," I believe; not that it would be at the outside end.

Q And this is based on your intuitive judgment?

A. Yes.

Q. About what would happen when a missile is generated?

A. It is based upon an intuitive judgment that supports -- that is supported by the Westinghouse studies and by the assumptions that have been made in other licensing proceedings where a uniform distribution has been assumed.

Q. Again, though, you have no data -- no empirical data that would show what the distribution in fact may be?

A. No, sir. No, I don't, specifically.

Q. It is true, is it not, Mr. Stippich, that the initial inertia of the missile would tend to be at a 90-degree angle from a longitudinal axis of the turbine?

A. That is the plane of the disk, yes.

Q. Is it your testimony that you expect that any deflections or interactions would overcome that inertia to such an extent you would expect uniform distribution?

A. I believe that is the way I testified, yes.

Q. Mr. Stippich, by "uniform distribution" do you mean that you would expect as many turbine missiles to travel on exactly an angle of 25 degrees as at 0 degrees?

A. By "uniform distribution," I mean that the directional probability over the surface of the inverted cone half of the cone extending through 180-degree arc around the axis of the turbine, I would expect that the probability of

any direction for that missile would be equal.

Q In other words, it is just as likely that a turbine missile could hit the containment from another unit as it would be to hit any other structure within that 25-degree arc of the same size?

A I didn't say that, no. Because the directional probability is not a linear function of the strike probability. And I believe you were referring to the strike probability, were you not?

Q Mr. Stippich, if you have uniform distribution of those missiles within a strike zone, then if part of the containment is within that strike zone the probability of striking the containment would be directly proportional to the size of the containment to the area of the strike zone?

A If I understand what you are saying, for a probability of a one-square-foot -- of striking a one-square foot area in the region of the containment, the probability of striking the containment would then be the area of the containment times that one-square-foot probability, yes, that would be correct, times the susceptible area of the containment.

Q Mr. Stippich, since the containment of a particular unit at Black Fox Station can only be -- or appears, assuming the 25-degree angle of constraint is valid, using that assumption as valid, then the containment of a particular

unit could only be struck by low trajectory missile from the other turbine; correct?

A. No. It could also be struck by a high trajectory missile from the other unit.

Q. I mean, from a low trajectory missile could only be struck by a missile generated by the adjacent unit's turbine?

A. Yes, sir.

Q. But both containments could be struck by a high trajectory missile, possibly?

A. Yes, sir.

Q. In your testimony on page 2, Mr. Stippich, the bottom of the page, you define a "high trajectory missile as "one which is ejected nearly vertically upward and falls almost straight downward landing in the plant area."

A. Yes, sir.

Q. Do you consider 25 degrees off of a straight vertical line "nearly vertically upward"?

A. No, sir. If it had that initial elevation, it would pass a -- a high trajectory missile would pass over the containment and land a considerable distance away.

Q. So is your definition wrong here, then? That it is one that is "ejected nearly vertically upward"?

A. No, sir. It has to be ejected nearly vertically upward in order to fall in the site region. That was the

point. In order to fall on the containment.

Q So you don't mean this statement to be defining a high trajectory missile?

A No, sir.

Q This is the only kind that has the probability of falling on the plant?

A That is correct.

Q What sort of angle, or what would be the maximum angle that a vertical missile could travel before it would have a chance of falling in the plant area?

A I don't know. It would depend upon the velocity.

Q Assuming the maximum velocity -- which I believe you have assumed is 500 feet per second in your testimony --

A Yes, sir.

Q -- can you tell me what angle, what would be the maximum angle or the -- from what degree to what degree would there be a probability or likelihood of the turbine missile falling within the plant area?

A No, I couldn't. That particular range od of degrees doesn't enter into my calculations, so I did not calculate it.

Q It is true that if it left at greater than some certain angle, there would be no probability of it falling in the plant area, but it would be expected to clear the plant area?

A Yes, sir.

Q It would be something between zero degrees and X degrees for those missiles that would be generated that would be likely to strike either containment?

A Yes. Whatever X might be, that again is going to depend upon the velocity of the missile, and that velocity can range from zero to 500 feet per second as a maximum.

Q Mr. Stippich, if you will refer to the drawing that you have attached to your testimony, it shows the relationship of the two units to the turbines and the 25 degree angle.

A Yes, sir.

Q What, Mr. Stippich, would be the angle, if you can tell from your drawing, or if you know from other sources, would be the maximum angle that would clear the containment structure itself?

A You cannot determine that from this drawing. This drawing is indicated -- is intended to indicate the low trajectory missile strike zone. We have been discussing high trajectory missiles.

Q Let's go back to low trajectory for a minute.

A All right.

Q If we were to draw a line from the turbine tangential to the circular containment, do you know what the angle would be between zero degrees and that tangential line?

A Projected on the vertical plane?

Q On the horizontal plane.

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MR. NELSON: I am going to object. I don't believe the question made any sense. He referred to the turbine, that is tangential to the containment, and then he referred to the tangential line, and I believe the whole question was just confused.

MR. FARRIS: I think I talked about a line from adjacent or from the adjacent turbine unit. I didn't mean from the adjacent unit, the other unit's turbine, drawing a line from that point tangential to the circle, within the containment, and I asked him to tell, if he could, the degrees between that zero degree line and that line or an approximation.

CHAIRMAN WOLFE: Do you understand the question?

THE WITNESS: Yes, sir.

CHAIRMAN WOLFE: Objection overruled.

THE WITNESS: No, sir, I cannot tell you what that angle is. It did not enter into my probability calculations.

BY MR. FARRIS:

Q Looking at your drawing, would you say that it would be as an approximation that that angle would be no greater than 20 degrees?

A Roughly, that would seem to approximate that angle.

Q In other words, to strike the containment, a missile would have to travel at an angle of between approximately 20 and 25 degrees?

A Yes, sir.

Q Roughly?

A Roughly.

Q I assume your probability calculations then for striking the containment would assume that ratio of using uniform distribution, then, of approximately using 20 to 25 degrees, one to five -- one out of five would be in that area?

A Actually I used the solid angle subtended by the wall of the containment.

Q What I am asking, Mr. Stippich, is assuming that 20 degrees is the maximum angle out from the turbine which would -- which a missile would begin to impinge upon the angle of the area in which a containment would be found, then using that figure, we could say that one out of five, assuming uniform distribution, one out of five turbine missiles could be expected to travel, whether or not it strikes the containment, would travel within that five degree area?

MR. NELSON: Objection, Mr. Chairman. I find it highly prejudicial that Mr. Farris repeatedly mischaracterizes the testimony of this witness.

Now the concept of uniform distribution was given in relationship to the high trajectory missile and not the low trajectory missile. I think it is a misapplication and a misinterpretation of the testimony already given, and it is prejudicial to this witness.

MR. SHON: Mr. Stippich, did you assume a uniform distribution with respect to this 25 degree angle in the case of the low trajectory missile?

THE WITNESS: Yes, I did.

CHAIRMAN WOLFE: Do you withdraw your objection, Mr. Nelson?

MR. NELSON: Yes.

BY MR. FARRIS:

Q Do you understand the question, Mr. Stippich?

MR. SHON: I think we hung up a bit on something here. You seem to be thinking in terms of two different ways of looking at the probabilities, Mr. Farris, than Mr. Stippich seems to be. The uniform distribution in Mr. Stippich's view is over a solid angle. That is not over an angle definable in degrees, but in steridians or some such thing. It takes account of the fact that only a portion of this 25 degree angle with respect to the plane of the disk is intercepted, but also only a portion of the elevation angle which is an angle in a different direction, is also intercepted by this.

That is the sort of thing you meant, isn't it, Mr. Stippich?

THE WITNESS: Yes.

MR. SHON: It is on that that your probability is based in the uniform distribution per steridians,

but he would never really arrive at the number that you are trying to generate, 1/5 of the total.

MR. FARRIS: I didn't mean to say that one out of five would strike. I meant that one out of five would be at least within the five degree angle and have the probability of the solid angle plane, and then we have to factor into the vertical plane.

MR. SHON: Yes.

MR. FARRIS: I understand that. I may not be clear about it, but I understand what you are saying.

MR. SHON: I see. The question is certainly still valid and you want to approach it both ways.

CHAIRMAN WOLFE: Do you understand the question?

THE WITNESS: May I have the question repeated, please?

[The reporter read the pending question, as requested.]

THE WITNESS: Yes. If you just considered a unit elevation, that would be true. I don't know how that would be helpful in arriving at the strike probability of a low trajectory missile on the containment. At least that is not the way that I had calculated it.

BY MR. FARRIS:

Q All right, sir, but if our first step is getting it to one out of five, and then the next step would be to factor

in the area from the horizontal plane up to the top of the containment, taking into account the area of that vent, correct it would be some range of those two figures?

A I believe so.

Q By the same token, then, in the high trajectory lob, we could expect 1/5 of the missiles to travel within an area from a vertical line of zero to 5 degrees, could we not?

A Yes. If that five degrees covered the entire range from zero to 180 degrees around the axis of the turbine, and we are talking about five degrees outward from the plane of the disk, yes, sir, that would be correct.

Q From the plane of the disk outward, assuming an outward turbine disk?

A Yes.

Q That it has the same constraints as 25 degrees?

A Yes.

Q In a high trajectory missile?

A Yes, it has.

Q And then we could assume from zero to five degrees, we would expect to see 1/5 of the total missiles generated?

A Yes.

Q Assuming uniform distribution?

A Over the entire 180 degree arc, yes, sir.

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Q. And if we assume that, in order to be able to strike any of the plant area, a missile would have to be generated within 0 to 5 degrees, or would have to travel on the path of 0 to 5 degrees, then we would have, for a high trajectory lob, both plant areas or both units, therefore both containments, subject to a strike within that area, or from a missile generated within that angle?

A. I think that many of the missiles that -- again, looking at the entire 180-degree arc, many of the missiles within that arc would either be low trajectory missiles, or missiles -- high trajectory missiles that would be projected far beyond the immediate site region.

Q. That is true. But within some angle off of the vertical, there would also be an angle off of the 180 degrees right or left, some angle between 0 and 180 degrees -- I'm sorry, between 90, I guess, and 0?

A. All right. An angle near the vertical would -- and 5 degrees out from the plane of the disk, would have a probability of landing in the immediate site area, and could land on either containment, yes, sir.

Q. I guess my point is, Mr. Stippich, with a high trajectory lob in two potential areas effected, and assuming your uniform distribution is correct, I find it hard to understand why the probabilities of a containment structure being struck by a turbine missile -- why those probabilities

are the same. Can you explain that difference? Or, explain the similarity?

A. I don't understand the question.

Q. All right, let me try to make it better.

A high trajectory lob can hit either containment, potentially?

A. Yes.

Q. A low trajectory missile, assuming the 25-degree constraint is valid, can only hit one containment?

A. Yes.

Q. And for that matter, a low trajectory could only hit the other containment -- the other unit's containment from a center point, the outside; whereas, a high trajectory would have the ability to hit the containment at any point, would it not?

A. I believe so, if I understand.

Q. So I don't understand, and I would like for you to explain to me, for a high trajectory missile there are two possible sources for a missile being generated, and there are two possible targets, and both targets have a larger area exposed to the missiles.

A. You say "two possible sources." On a per-turbine, per-year basis, no, there is only one source. It is true that you could hit two containments, but to determine the probability there, simply multiply the probability by two

and that will give you the probability for two containments.

Assuming that the probability -- the area of probability is the same for each of the containments, it may not be; but for a wide range of that missile speed of 0 to 500 feet per second, there is a range of probability for both containments for a high trajectory missile strike on both containments which would be virtually the same.

Q Are you saying that, with two units the probabilities are doubled?

A For high trajectory missile strike, if you double the area, yes, you double the probability of a strike.

Q Mr. Stippich, since you have two potential sources for a missile being generated, you would double not only the end two targets for the missile to strike, you would double not only P_1 but P_2 as well?

A Not at all. I said that there would not be two sources. There would be only one source for a turbine failure and we are looking at turbine failures per year. That is the P_1.

Q But with two turbines, the probability of a containment at Black Fox Station being struck, or rather the probability of a missile being generated by Black Fox turbine would be twice that probability, wouldn't it, in a given year?

MR. SHON: I think the difficulty arises in that

Mr Farris wants to calculate the total probability on a containment strike for Black Fox Station, which includes two containments, and you want to calculate it for "a containment" which includes only one containment.

He has an additional factor of 2. It is true that there are twice as many turbines that can fail yielding a single containment strike, but he wants to double it again for the second containment.

Isn't this the big difference?

MR. FARRIS: I think so.

MR. SHON: So it is simply a matter of, if you want to talk about probabilities per reactor or per station. And I think, since the terms we have usually used have been "per reactor" and the staff usually evaluates in terms of per-reactor-year, not per-station-year, since there might be many reactors at a station, it is probably well to keep with the calculation that Mr. Stippich has been doing which includes only one containment but two sources.

Also, Mr. Chairman, I was under the impression that Mr. Stippich described it in terms of one source, rather than one containment. Perhaps it would be well to clarify the terms.

THE WITNESS: I was describing it in terms of one source and two containments. But it is the same.

MR. SHON: But each containment can suffer missiles

from two different sources if they are high trajectory missiles, can it not?

THE WITNESS: Yes, sir; that is correct.

MR. SHON: That is probably the best way to look at it, since the probability of a containment or reactor having an accident per year is dependent on the fact that it is sitting near another turbine, also.

THE WITNESS: Your point is well taken.

MR. SHON: That is one way to look at it: one containment for two sources for high trajectory, and one containment for only one source for low trajectory. Does that make sense?

THE WITNESS: Yes, it does.

MR. SHON: Has that straightened anything out? Or made it more complex?

MR. FARRIS: That is what I was getting at.

BY MR. FARRIS:

Q Then your analysis is really most valid for a single-unit nuclear power plant with one turbine configuration and one containment.

A I think that Mr. Shon's way of looking at it would certainly be rational -- although I don't think that the results would change. I think that the probabilities would be identical. It is a question of whether you multiply the area of the containment by 2, or simply double the probability

of a failure per year to account for two sources. And I would agree that, yes, that is a very reasonable way to look at it, and a helpful way to look at it, but it does not change the result of the analysis.

Q Are you saying, Mr. Stoppich, that the possibility of a turbine missile strike on containment at the Black Fox Station -- a two-unit station -- would be the same as for a one-unit station?

A No, sir, I didn't say that.

Q Would it be greater at the Black Fox Station?

A It would be greater for a two-unit station than for a one-unit station, yes, by a factor of 2.

end #4

Q Mr. Stippich, a high trajectory missile would also have less or fewer barriers to go through to exit the turbine building and to enter the containment?

A Yes, sir, it would. The barriers along the sides of the turbine rim are not high enough to intercept a high trajectory missile, and we have not taken credit for any of the turbine building roof structure in impeding the missile. That is a conservatism that is built into the calculation, although it would indeed have to punch through the turbine room roof.

Q Mr. Stippich, you indicated earlier that you relied to some extent on your judgment that turbine missiles would be generated in uniform distribution over their angle of constraint, that you relied on Westinghouse's turbine analysis; correct?

A That analysis was the one that described the 25 degree restraints, the Westinghouse analysis, and that has been considered to be applicable to all nuclear units in a number of licensing applications.

Q Mr. Stippich, don't GE turbines have heavier wheels and buckets than Westinghouse turbines?

A There are differences, but it wouldn't necessarily affect the distribution of the missiles or of the fragments of the wheel in the event of a turbine failure.

Q Mr. Stippich, how many low pressure sections will

the Black Fox turbines have, each turbine building?

A There would be three low pressure sections, low pressure hoods.

Q Is each low pressure section considered a turbine for purposes of statistical probabilities?

A No. The statistics are based upon units which include the entire turbine generator unit.

Q The turbines have different -- they are larger, have different -- some have more turbine low pressure sections than others?

A On Black Fox, no. The two units are identical.

Q In the general turbine population?

A Oh, yes. There is a difference.

Q Would you say that the more turbine sections there are, low pressure sections, that the greater probability there is for turbine missiles being generated?

A The statistics do not indicate that, no.

MR. FARRIS: We have no further questions, Mr. Chairman. We pass the witness.

CHAIRMAN WOLFE: Mr. Nelson, redirect?

REDIRECT EXAMINATION

BY MR. NELSON:

Q Mr. Stippich, in questioning yesterday, Mr. Farris made reference to the second article published by Mr. Bush. Do you recall that?

A Yes, sir.

Q Have you had an opportunity to review the second article?

A Yes, sir, I have.

Q In the second article, did Mr. Bush make further findings with respect to the key 1 value that he had predicted in his first article?

A He says, and I quote from the last paragraph of the article:

"The preceding values using more sophisticated techniques compare favorably to the volume predicted for 1977 in the earlier report; namely a failure rate ZT of about 7×10^{-5} turbine year."

I would judge this to mean that he was satisfied with the value that he had given in his previous paper, and would not change that value, that it still represented a reasonable estimate of turbine failure rates to use in turbine missile analysis.

If he had not meant that, I am sure that he would have said what value should have been used in the analysis, other than the one presented in the first paper which has been used in many, many licensing applications.

Q Mr. Stippich, referring to the paragraph immediately preceding what you read from, did Mr. Bush provide numbers for the P_1 value?

A Yes, based upon the method that he used, he concludes that the range of probabilities would be 3.3×10^{-5} to 3.1×10^{-4} per turbine year for a turbine population corrected to be relevant to nuclear reactors, and his original value in the first paper falls within that range, which is undoubtedly the basis for the statement in the succeeding paragraph.

I see no reason to change the value for turbine missile turbine failure rate.

Q Mr. Stippich, would it be your interpretation that from a mathematical and statistical point of view, that it would be appropriate to select one of the values representing the extreme of this range that Mr. Bush has given?

MR. FARRIS: I object to the form of that question, Mr. Chairman. That is a leading question.

CHAIRMAN WOLFE: Objection sustained.

BY MR. NELSON:

Q Mr. Stippich, you indicated in your previous answer the numbers that Mr. Bush had provided in the article. Would it be appropriate to select any one of these values?

A He made no -- stated no preference for one value over another. He stated it as a range. Again, the values given here are two significant figures. Perhaps he intended to leave that for the reader to round off.

I think the point here, though, is that in my

judgment, reading the article, that he was satisfied with the number that he had come up with in the preceding study, and he gives no preference for either one of those numbers, limiting the range.

Q And does the range thing represent a range of probability?

A It represents, or it could represent the extremes of failure probabilities and, indeed, he used the Weibull method to determine this, and the Weibull method is an extreme value method.

So, again, the most likely estimate to be used in the turbine missile analysis would fall within that range, but it isn't likely that it would fall at those extremes.

Q Now in the analysis you performed, which you had described in your testimony, what value did you attribute to the P_1 factor?

A The turbine failure rate, the overall turbine rate 10^{-4} per year.

Q Is that value within the range that Mr. Bush gave in the second article?

A Yes, it is.

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Q Based upon your review of Mr. Bush's second article, are you satisfied that the value you selected is still a valid assumption?

A Yes, sir.

Q Would you explain that, please?

A I guess I would have to explain that on the basis that the population of the actual nuclear units that he uses is rather small. And, that in all probability the precision that is given in the article is not real; that perhaps one should round off the numbers to a lower significant figure.

So doing that, the numbers would be essentially the same in the second article as in the first article.

Q And if you were to round off the values given by Mr. Bush, as you just described, what would the rounding off result in?

A A probability of about 10^{-4}.

Q Is that what you used?

A Yes, sir.

Q Mr. Stippich, in questioning this morning Mr. Farris asked you, with respect to the barriers which would have to be perforated by a high trajectory missile, as compared to a low trajectory missile.

Can you quantify for us the thickness of the barriers, taking first the low trajectory missile?

A Yes. After a hypothetical missile punched through the turbine casing, it would have to perforate a 3-1/2 foot thick radiological shield along the side of the turbine room, and then it would have to perforate a 2-foot-thick shield building wall, and then just stop short of the -- perforating a 1-1/2-inch-thick mild steel containment vessel.

Q And when you say "stop short," you mean that if it did perforate the containment building, you would then have a damaging strike?

A That would be considered an unacceptable strike, yes.

Q In the case of the high trajectory missile, can you quantify for us the thickness of the barriers that would have to be penetrated?

A Again, after leaving the turbine casing, the missile would have to perforate the 2-foot-thick roof of the shield building, and the 1-1/2-inch-thick -- stop just short of perforating the 1-1/2-inch-thick mild steel containment vessel.

Q And again, if it actually did perforate the latter, it would then be a damaging strike?

A Yes, sir.

Q Mr. Stippich, I believe Mr. Farris also asked you what was the maximum angle of the high trajectory missile that would strike the containment. And in answer, you responded that you had not calculated that. Is that correct?

A. Yes, sir.

Q. Why didn't you calculate that?

A. Because it didn't enter into my calculations in calculating the strike probability.

Q. Are you assuming that all missiles within the 25-degree-angle distribution would strike containment?

A. No, sir.

Q. What are you assuming, then?

A. The assumption depends upon whether you are considering high trajectory missiles or low trajectory missiles.

In the case of low trajectory missiles, it was based upon the ratio of the solid angle subtended by the protective structure to the total solid angle of the possible missile directions.

In the case of the high trajectory missiles, the probability would be a function of velocity, and with -- and the direction, as well.

So the two are entirely different concepts. One is based upon the trajectory of a -- from a classical ballistic standpoint; the missile is projected into the air and comes down.

Now the original angle and the velocity determines the point that that will fall in. And if you take the boundaries of a unit, solid angle that is near the vertical, and

determine where the missile would strike in the plant site region at each of the four extremities of that solid angle, assuming a roughly square area, then that would define the strike area for the fraction that the unit's solid angle bears to the total solid angle.

And that would, by dividing that by the total area, then you could come up with the square-foot strike probability for that particular missile in the plant site.

Q Yesterday, Mr. Farris asked you a question. I am referring now to page 7772 of the transcript. I will read it verbatim: "Q And would you assume, therefore, that the lack of any missile being generated at a nuclear power plant thus far is insignificant statistically in light of the number of turbines that are being used in connection with nuclear power plants?"

Your answer, Mr. Stippich, was: "A. That would be one presumption, but not necessarily the only one, that could be made on the basis of that data."

Do you recall that question and answer?

A Yes, sir.

Q At this time, Mr. Stippich, would you indicate what other presumptions could be made?

A That the entire population of all turbines would be representative of the nuclear population as well, even though the nuclear population represented only a small percent of the

total population.

And I think that this has been verified by Bush's second paper where indeed he did try to quantify, or characterize those failures that would be applicable to nuclear turbines, and indeed the probability was the same for nuclear turbines as for the entire turbine population.

Q In questioning this morning, Mr. Farris asked you about the 25-degree angle of distribution in the context of its having been developed in a study by Westinghouse, as I recall. Do you recall that?

A Yes, sir.

Q Are you aware, Mr. Stippich, of whether the staff has accepted this 25-degree distribution as applicable to nuclear power plants?

A Yes, sir, they have. It is part of the staff position as indicated in Regulatory Guide 1.115 on low trajectory turbine missile protection.

Q In questioning yesterday, Mr. Farris asked about -- if I have the terminology correct -- the radiolytic decomposition of water in the turbine area. Do you recall that line of questioning?

A Yes.

Q Correct me if I am using the terms incorrectly. I think you mentioned that there would be a short-lived radioisotope of N-17. Is that right?

A N-16, it should be.

Q I see.

And the question he raised was whether this would pose any problems for maintenance in the turbine area.

And, as I recall, you answered that: "It might make maintenance more difficult."

Is that right?

A Yes, sir.

Q As a result of the difficulty for the maintenance that you testified about, would it be your opinion that there would be a higher incidence of missile turbine failures?

A Not necessarily.

I think that steps would be taken to overcome that difficulty. The isotope in question is short-lived, and it decays rapidly. That helps to take care of some of the difficulty, and it is just a question of using maintenance methods that are designed to overcome the difficulty.

end #6

Q Mr. Stippich, in response to a question, I believe, asked by Mr. Shon yesterday as to the values you found in your analysis, and which you are describing in your testimony for the factor of P_2, I believe it was your testimony that both in the case of the high trajectory missile and the low trajectory missile, you found a value for P_2 of 10^{-3} or less; is that right?

A Yes.

Q Let's take the high trajectory missile first.

Can you tell me what specific value you found for the P_2 factor?

A That would be 6.0×10^{-4} per containment with two missile sources, in the context that Mr. Shon gave the probabilities.

Q Were you finished?

You are saying 6.0×10^{-4} and one can view this either as a single reactor with two sources, or one source and two containments as a target.

A Yes, sir.

Q And this represents the P_2 value for the high trajectory?

A Yes, sir.

Q Could you explain, please, how you derived that figure?

A The first step in the analysis was to determine

the range of velocities that would cause damage to the containment, and that would be the perforation of the containment.

This is taken as the basis for defining damage, and this was arrived at by using the multiple missile barrier concept in regulatory guide 1.15.

I believe that is Recht & Ipson, I-p-s-o-n, their concept.

Q That is what revision of the reg guide?

A Revision 1. The latest revision.

Q So you had this factor representing the velocity that could cause damage?

What was the next step then in the analysis?

A The next step was to determine the unit area strike probability in the immediate vicinity of the plant, or the velocity that corresponded to the minimum damaging velocity.

Q Could you give me the values for these factors as we are going along?

A The minimum damaging speed or, I should say, the minimum speed required to penetrate the roof of the shield building and stop just short of penetrating the containment vessel head is 234 feet per second.

Q And the value for the unit area strike probability?

A The one corresponding to that velocity is

6.40×10^{-8} per square foot.

MR. SHON: Mr. Stippich, would you say a word or two more about how that particular calculation is carried out, how you get from the velocity to the probability?

It seems a very complex thing to me.

MR. FARRIS: Mr. Chairman, I wish the witness would identify what he is referring to as part of the answer to that question.

CHAIRMAN WOLFE: Mr. Stippich, what are you referring to?

THE WITNESS: I am referring to my working sheets.

MR. NELSON: Mr. Chairman, I am prepared to provide copies of the work sheets he is referring to.

[Counsel distributing documents.]

MR. NELSON: I would like the record to reflect that counsel for Applicants has provided copies of the work sheets to which the witness is referring in giving his calculations.

THE WITNESS: This set of work sheets does not indicate the method used to calculate the unit area of probability. That is the one that I attempted to describe earlier in my testimony that is based upon the missile velocity and the classical ballistic formula, so if we start with a unit solid angle and take the ratio of that unit angle to the total solid angle, calculate the area that a

missile within that unit angle would circumscribe on the ground in the landing zone, then that is the unit area probability.

MR. SHON: You are taking the unit probability as dependent upon the ratio between the area of strike and the total area of the target zone?

The probability has to be dimensionless to begin with. You don't have the sheet wherein you did this particular calculation, or did you look it up, or what?

It seems to be a very complex calculation involving a lot of assumptions.

THE WITNESS: I really don't think it is, sir. If I could explain it, it is really a generic thing, and isn't that peculiar to my missile analysis. It has been used in many analyses before and --

MR. SHON: Very well. Go ahead.

THE WITNESS: The difficulty I am having in communicating that is, I think, the problem in communicating my description.

I would like to -- what I have done was to compute the actual landing zone area for an angle at the origin that is right at the vertical, that if a missile were projected in a five degree by five degree solid angle adjacent to the vertical, the area of the landing zone would be .0279 times the V squared over G quantity squared based upon the classical

ballistic formula.

This defines now an area, and then if I evaluate that equation using V as an independent variable, I come up with a unit area strike probability of $192/V^2$, and this is based upon the fact that a five degree by five degree angle, solid angle, is 1/180 of the total solid angle.

MR. SHON: Fundamentally, then, you took a five degree by five degree pencil at this velocity you had determined, determined the area of the circle thus generated by the impacts with those parameters of discharge. That is velocity and angle with respect to the ground? A trajectory like a gun trajectory?

THE WITNESS: Yes, sir. Essentially.

MR. SHON: And then to get the probability, you introduced a fraction that represented the fraction which that five degree by five degree pencil is of the total solid angle of total projectedness as around the turbine blade; is that right, sir?

THE WITNESS: Yes.

CHAIRMAN WOLFE: Excuse me a minute, please.

Off the record.

[Discussion off the record.]

CHAIRMAN WOLFE: Back on the record.

BY MR. NELSON:

Q Had you completed your explanation of how you derived

the unit area strike probability, Mr. Stippich?

A Yes, sir, I had.

Q What, then, was the next step in your calculation?

A Again, referring to my worksheets for the specific analysis, I used the general equation that had been derived from the classical ballistic formula with V as the independent variable.

That would be 192 divided by the 4th power of V, and I came up with a unit area probability of 6.4×10^{-8}. I had calculated the effective area of the containment head to be 9000 feet, 9000 square feet; multiplying this by the unit area probability gives me a P_2 of 5.8×10^{-4} for one containment, and one source.

Now for both containments, the quantity would be 2 times that, or 1.16×10^{-3}. That is for the minimum speed of the damaging missile, 234 feet per second; but that is not the only speed that the missile can have.

The range of speeds is from 0 to 503 feet per second, or nominally 500 feet per second.

Q Reflecting on the steps that you have just described, now, Mr. Stippich, I believe you said you had applied the general ballistic formula? Is that right?

A Yes. That was to derive a general equation for relating unit area probability to velocity.

Q Okay.

And from what source did you get this general ballistic formula?

A It is in any engineering mechanics textbook.

The next step was to define the strike probability at the upper bound velocity of 503 feet per second. That unit area of probability is done the same way as the previous one, except using 503 feet per second is 3×10^{-9} per square foot.

Now it is, of course, higher because the velocity is higher, and the probability decreases as the 4th power of the velocity.

Q Could you explain, then, why a separate analysis was performed at this higher velocity value?

A Because the missile doesn't necessarily have to have a velocity of 234 feet per second, or 503 feet per second. It is going to have a velocity that lies somewhere within the range of 0 to 503 feet per second.

Q Does the latter value, then, represent the upper bound?

A Yes, it does.

Q Could you explain why?

A It is based upon the residual velocity of the missile after it punches through the turbine casing. A certain portion of the initial kinetic energy of the missile will be dissipated in punching through the casing, and the velocity then is calculated -- the limiting velocity is then calculated then on the basis of the upper bound of the residual kinetic energy after the missile punches through --

MR. SHON: Mr. Stippich, that bothers me a little bit, your arithmetatical treatment of these two velocities. I think it is true that the lower velocity is the lower bound for penetration and the upper velocity is the upper bound for total velocity, because that is as fast as the wheel spins, so to speak.

You have taken an average of a sample linear average of the two different velocities of the two different probabilities per unit area corresponding to these velocities.

More properly, should one not regard these as limits of integration, and integrate the distribution of particle velocities from the lower bound to the upper bound, summing them all, rather than simply taking an average?

In other words, I say that the total probability of a missile strike per unit area is the sum of all probabilities of a missile strike per unit area, the integral from 234 feet per second and its value, to 500-and-whatever-it-was, 503 feet per second.

Is the averaging process you have used the same as a straight integration?

THE WITNESS: It implies a uniform distribution of velocity over the range, which I think is reasonable because the damage probabilities that are based after the missile leaves the turbine are based upon its ability to penetrate concrete and to penetrate steel, and basically these are

linear functions.

MR. SHON: It makes, fundamentally, the assumption that there are -- putting it in a crude way -- the same number of missiles at every velocity, or the same probability of a missile having any velocity. Is that right?

THE WITNESS: Yes.

MR. SHON: Thank you. I think I understand, now.

BY MR. NELSON:

Q Had you completed describing the steps in your calculation, Mr. Stippich?

A The next step is the averaging step that Mr. Shon was referring to.

And then the final step is to calculate the final P_2 probability, which is 6×10^{-4} for two containments, and one source; or, for two sources and one containment.

MR. SHON: I find only one thing that I might disagree with. Your second P -- that is, the upper bound velocity -- you didn't double that one to account for two sources. You did double the other one. I think they should both be treated arithmetically in the same fashion, shouldn't they?

THE WITNESS: Yes, sir.

MR. SHON: That would slightly raise your probability. I think it would raise it by about .15, or something times 10^{-9}, not much. It would be a little bit

larger. Is that right?

BY MR. NELSON:

Q Are you able to determine whether it would change the numbers, as Mr. Shon suggested?

A No, I don't see where, in what step --

MR. SHON: The top of your second page, you have calculated a figure called P_a as 192 over 503. That is 3×10^{-9}. A few lines down, you use $.3 \times 10^{-8}$ which is the same number.

I think this, however, is the number which in its nature should really be doubled, should it not? You had doubled before to get your 6.4.

THE WITNESS: The 6.4 that was used in relation there was not doubled.

MR. SHON: I see. No, that's right. Okay, you're correct.

THE WITNESS: And that completes the description of how P_2 was arrived at for high trajectory missiles.

MR. SHON: Where does that factor of 2 enter into the rest of the calculation?

THE WITNESS: The P_2 value rounded off, the one that appears at the center of the page, is 3.0×10^{-4}. Doubling that would be 6.0×10^{-4}. That is where the factor of 2 enters in.

MR. SHON: Would that change your ultimate value?

THE WITNESS: No, sir.

MR. SHON: You have $P_1 \times P_2$, 5×10^{-5} and 3×10^{-4}, would it not?

THE WITNESS: Yes, that value would change.

MR. SHON: Your final answer would actually be closer to 3×10^{-8}, then --

THE WITNESS: Yes, sir.

MR. SHON: Thank you.

I am sorry to have interrupted so much, but it was confusing until we saw these figures.

I think now it is cleared up a great deal on what Mr. Stippich did.

MR. NELSON: No problem.

Mr. Chairman, it occurs to me that it might be more efficient here to offer the witness for cross-examination on the scope of the testimony he has just given, before I proceed to the recapitulation of the calculation for the low trajectory missile.

end #8

CHAIRMAN WOLFE: Is there cross-examination, Mr. Farris?

MR. FARRIS: Mr. Chairman, I think we would like to reserve the right to the cross-examination on this when we conduct the rest of our cross-examination.

CHAIRMAN WOLFE: Staff?

MR. DAVIS: No cross from the Staff, Mr. Chairman.

CHAIRMAN WOLFE: We will proceed.

Mr. Farris has reserved the right to cross.

Dr. Purdom has a question.

DR. PURDOM: I am a little confused there. I believe you indicated you take the $3x10^{-4}$ and you double that and you would have the probability of the missile generated by one turbine striking the two containments. Is that what you are saying?

THE WITNESS: Yes, sir. Or, conversely, two sources striking one containment.

DR. PURDOM: I guess the question that seems to be a little evasive here is what would the probability then be of two sources and two containments, probability of a missile being generated and hitting either of the two containments?

THE WITNESS: If one were to consider two sources and the probability of strike on two containments, it would be double what is here.

DR. PURDOM: Thank you.

BY MR. NELSON:

Q Does that complete your description of your calculation for the high trajectory missile P_2 value?

A Yes, it does.

Q Then with respect to the P_2 value you found for the low trajectory missile, could you state for us what that value was?

A For the probability of a strike P_2 on the aggregate safety-related structures of one turbine from a low trajectory missile from the adjacent unit, it would be 8.9×10^{-4}.

Q 8.9×10^{-4}?

A Yes, sir.

Q And, again, this is representing one source and striking one containment; is that correct?

A Yes. That is the only -- well, it is all of the safety-related structures, including the containment, that are included within the low trajectory strike zone. That 25 degree bound that is shown in Exhibit 1 of my testimony.

Q And could you explain, please, how you arrived at this figure?

A Yes. I first calculated the -- well, the purpose of the first part of the calculation again is to determine the velocity of the missile that would be required to damage the containment on the same basis as the high trajectory missiles, except using a line-of-sight missile. The Rackt and

Ipsen formula again was -- formula was conservatively used to characterize multiple barriers.

I found that the low trajectory missile speed to perforate the turbine building shield wall, the shield building wall and stop just short of perforating the containment vessel wall to be 431 feet per second.

Now, if we look at Exhibit 1, we find that neither the wall alongside the turbine building or the containment building presents a face normal to the direction of the low trajectory missile. It varies. And I have looked at the extremes, I have looked at the normal case, and then I have looked at the case, the maximum case, where the vessel would penetrate at a 45 degree angle.

The assumption is that if the angle exceeds 45, exceeds the angle of impact, exceeds 45 degrees, the missile will curve from the wall and now I calculate another minimum velocity required for damage, and that velocity for a low trajectory missile to perforate the turbine building, the shield building wall, the turbine shield wall, the shielding wall, and stop short of perforating the containment vessel wall corresponds to 529 feet per second.

This exceeds the maximum low trajectory missile speed of 503 feet per second so that the range of missile speeds needed to damage the containment is greater than 452 feet per second, and the probability that the missile will have

let's see, the average speed necessary to inflict the damage is 480 feet per second, and the probability that the missile will have this velocity is .0457 for the average thickness of the barriers.

Q Again, Mr. Stippich, are you assuming here that there is a random distribution within the velocity range?

A It is a uniform distribution over the velocity range.

Q Uniform distribution?

MR. SHON: Mr. Stippich, just one very small detail.

At the middle of the page, you have used this formula for the V sub Cl, and the factor you have used is 1 over the cosign of 25 degrees, you say.

I thought you were considering penetrations always at 45 degree angles. Has this something to do with the 25 degrees as the maximum, or what?

Above it, I noticed you have used 1.414 in the formula a few lines above and that is 1 over the cosign of 45 degrees, not 25 degrees.

THE WITNESS: Yes, sir.

Well, the maximum angle this is in reference to the biological shield wall along the turbine building, and the maximum angle of incidence there is 25 degrees, not 45. It is 45 on the shield building wall.

MR. SHON: Thank you.

THE WITNESS: The next step was to determine the probability of a strike using the principles of the solid angle subtended by the safety-related structures in this instance.

We will be talking about the containment vessel, and the total solid exit angle is 1.33 steradians. The strike probability is then the ratio of the solid angle subtended by the target to the total solid angle of exit of the missile at the missile source, and the determination of the angle subtended is shown in the diagram at the bottom of the page where it shows the elevation of the containment and the source being 550 feet from the centerline of the containment, and then on the succeeding page where a plan view is shown, in the solid angle would then be the approximate 80 feet height times the 38 foot width divided by the average distance of 550 feet.

BY MR. NELSON:

Q Mr. Stippich, what would be the product of that calculation? Do you have it?

A That answer would be found two pages later for the reactor building with the width of 38 feet and a height of 80 feet and a distance R of 550 feet. The strike probability is then .00756, or 76.

Q With this calculation, then, what was the next step following this?

A The next step was to examine the other Category 1 structures, the other safety-related protective structures that are relied on to protect essential structure systems and components.

Q So are you then determining the strike probability for each one of these structures?

A No. They are determined in aggregate, in accordance with the requirements of Regulatory Guide 1.115, Revision 1.

e9

A. (Continuing) The strike probabilities for the category 1 structures other than the shield building and the containment were calculated in the same fashion, and those probabilities are shown -- the calculations for those probabilities are shown on the following page, along with the one for the reactor building.

Q. Mr. Stippich, taking these one by one, the next structure is what?

A. The auxiliary building.

Q. And what was the value you derived for the auxiliary building?

A. .00346.

Q. And this is the strike probability for that building?

A. Yes, it is.

Q. What was the next structure, then, that you considered?

A. The next structure is the control building. The strike probability is .00331.

Q. And what was the next structure?

A. The low bay of the control building, which is .00445.

Q. Are there other structures? Or is that all?

A. That is all that are within the 35-degree low trajectory strike zone.

Q. Now how did you combine these values, then?

A Well, the next step was to determine the probability of damage which is dependent upon the probability of the missile penetrating the walls. And that probability for the reactor building is .0457. That is summarized on the next page, and --

Q Can you explain how that value is derived?

A Yes. That is based upon the probability of the missile having a velocity necessary to penetrate the -- all of the barriers and stop just short of perforating the containment vessel.

In this case, if it does -- well, this is the basis for the damaging probability for the reactor building. Now for the other remaining safety-related buildings, the difference is slightly -- the method is slightly different.

We combine the probability of perforating the barriers with the probability of striking a safety-related structure housed within the structure of these safety-related structures. They do not occupy the entire area of the safety-related buildings in which they are housed. So the probability of striking one, even though the missile should penetrate, is not a certainty.

So based on estimates made from the plant arrangements, the total -- the combined probability of penetrating the wall and striking a safety-related system is estimated to be .06 for the other safety-related buildings besides the

reactor building.

And then, these are combined with the probability of a strike on the building --

Q. Did I understand you to say that the value for the damage probability for the auxiliary building, and for the control building, would be the same?

A. No, sir.

The probability of penetrating the wall and striking a safety-related system inside is estimated to be the same. But you have to combine that with the strike probability on the building itself, which is a function of the area.

Q. Could you explain why they would be the same?

A. It is judged based upon the area that the safety-related equipment bears to the total area of the building. If the missile should penetrate, there is still a probability that it would not strike an essential structural system or component simply because they do not occupy the entire area of the building.

MR. SHON: Mr. Stippich, there is one thing that is confusing about these two calculations -- or that I find very confusing.

The bottom line on both the sets of calculations headed "reactor building," and on that headed "auxiliary building," both bottom lines talk of probability P_2, and

each represents the first as a product of two numbers, and then an "equals" sign, and then .00346. The two pairs of numbers that are multiplied to get this, in each case, are not the same pair of numbers.

I find that confusing. It may be your notation, but do you see that these are not the same pairs of numbers that you have multiplied to get the same result? They both can't really be right.

THE WITNESS: One of the two obviously is incorrect.

MR. SHON: Yes.

BY MR. NELSON:

Q Are you able to determine which one would be incorrect, Mr. Stippich?

A Just judging from the order of magnitudes, I think the one respecting the reactor building would have to be correct, and the other one was not used in connection with the auxiliary building.

MR. SHON: My pocket calculator says the reactor building one is right.

THE WITNESS: Yes.

BY MR. NELSON:

Q I'm sorry? Were you saying the value for the auxiliary building was not used in the calculation?

A No, it was not. The unit area strike probability--

or the strike probability was .00149 was used in the calculation. That is the probability of a strike on the building.

Q I believe you had described all of the steps until you had derived the damage probability for each of these different buildings. Had you completed that description of your calculations?

A I beg your pardon?

Q Reassessing where you were in describing your calculations, I thought you had completed the description of how you got the damage probability for each of these different buildings.

A Yes.

And the next step --

Q Yes, go ahead.

A -- is to calculate the overall P_2 and summarize them. And this was done in the right-hand column on the final page. And the total P_2 for the aggregate of the reactor building and the other safety-related structures is 8.9×10^{-4}.

Q Can you explain how the different values are combined in order to derive that value?

A The damage probability, or -- which -- the damage probability PVS, which is the probability of the missile penetrating the wall and striking the safety-related structures, multiplied by the probability of striking the building. And

those are --

Q Do I understand you to say that you begin with the reactor building, and for that you multiply the probability of the damage to that building times the probability of a strike on the building?

A Yes, sir; that is correct.

Q What product do you get when you perform that multiplication?

A .00035.

Q Now what is the next step?

A To do the same thing for the remaining buildings, and the aggregate combined strike and damage probability is .0054, and the sum is .0089, which is 8.9×10^{-4}.

Q So that when you combine -- when you performed this multiplication of the damage probability times the strike probability for the auxiliary building, what result do you get?

A Well, since the damage probability was the same, I just sumed all of the auxiliary and the control building. I didn't calculate those separately. The effect is the same.

Q So you performed a single multiplication for the--

A I summed up the strike probabilities for each of the other buildings and multiplied it by .060, which was the common damage probability of PVS.

Q That again resulted in what?

A .00054.

Q And you then took that value, and what was the next step?

A Added it to the probability of P_2 for the reactor building to get the total probability .00069, which is 8.9×10^{-4}.

and #10

MR. NELSON: Could I have a moment, Mr. Chairman?

CHAIRMAN WOLFE: Perhaps this would be a good time to have a recess, a 10-minute recess, until 11:00 o'clock.

[Recess.]

CHAIRMAN WOLFE: Back on the record.

BY MR. NELSON:

Q Mr. Stippich, referring again to the second article by Mr. Bush, do you have that?

A Just a minute.

All right.

Q I believe you stated you had an opportunity now to review that article?

A Yes, sir, I have.

Q In your review of the article, did you agree with the conclusions reached by the author?

A I saw nothing in the article that would cause me to disagree; but on the other hand, I didn't make a very detailed analysis of all of his methods.

Generally I agreed with it, yes.

MR. NELSON: At this time, Mr. Chairman, I am handing the court reporter three copies of the article, and first I will have the witness identify the article.

BY MR.NELSON:

Q Is this the article you are referring to, Mr. Stippich?

[Handing document to the witness.]

A Yes, it is.

MR. NELSON: I would ask the reporter to mark this as Applicants' Exhibit No. 37.

[The document referred to was marked Applicants' Exhibit No. 37 for identification.]

MR. NELSON: Applicants would move the admission of the document that has been marked as Exhibit 37 as part of their case-in-chief.

CHAIRMAN WOLFE: Any objection?

MR. FARRIS: No objection from Intervenors.

MR. DAVIS: No objection from the Staff.

CHAIRMAN WOLFE: Applicants' Exhibit 37 is admitted into evidence.

[The document previously marked Applicants' Exhibit No. 37 for identification, was received in evidence.]

BY MR. NELSON:

Q Mr. Stippich, in the second Bush article, where the author refers to the fact Z(T), does that describe the same factor as he referred to in the first article as Δ?

A Yes, it does.

Q Is there any difference at all?

A Apparently there is none.

Q For the factor P_1 in the first article, what was the value that Mr. Bush found?

A For P_1 he found 7×10^{-5}.

Q And rounded off, what would be the value of that?

A 10^{-4}.

Q Now, Mr. Stippich, what would be the uncertainty factor that would be attached to that value, in your opinion?

A From the way it was rounded off, it would imply that he felt that the figure was good, the number was good to one significant figure.

Q But does it represent an estimate or median or how would one apply this value?

A If we looked at his original article, he took the value of 7×10^{-5} that he had calculated from his statistical analysis and rounded off and said this is the number that we would recommend for evaluating turbine failures. This is the turbine failure rate to be used in evaluating the turbine missile risk.

I don't know that those were his exact words, but this is his meaning, I believe.

Q Do you know the number of actual turbine missile failures that he used as his basic data in the first article?

A I can't tell you right off the top of my head what that number is. It covered 70,000 turbine years of experience,

a considerably smaller number of turbines, of course.

Q But as to the number of actual turbine failures using that as a data point, do you recall how many failures he was considering?

A It was on the order of 22 or 23, I believe.

Q And the same question with respect to the second article, do you know how many turbine failures again resulting in missiles that he considered as a data base there?

A The question you asked previously, you didn't restrict it to resulting in missiles. You said turbine failures, and not all of those failures that he considered in his study, original study, did result in missiles. Not all of the turbines that failed in his second study resulted in missiles.

Q Going back to the first study, are you able to determine how many of the turbine failures which resulted in missiles, how many of those he considered?

A I would judge roughly 2/3, about 16 failures out of the 24.

MR. SHON: Mr. Stippich, you sort of confused me again. If he had 16 missile type failures out of 70,000 turbine years of operation, I don't think he would have gotten $.7 \times 10^{-4}$, would he? He might round it off.

THE WITNESS: I don't know what the details of his statistical analyses were, Mr. Shon.

MR. SHON: I see.

BY MR. NELSON:

Q Did I understand you to say that it is your understanding that Mr. Bush considered approximately 16 turbine missile failures in preparing his first article?

A That appears to be the case from the list that he gives of the machines in the first article.

Q And are you able to determine how many he considered when he prepared his second article?

A Again, I haven't actually counted them. I would have to make an estimate of that. I would judge possibly 24 involving missiles, resulting in missiles.

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CHAIRMAN WOLFE: And you took that number, Mr. Stippich, from some table in the second article? Is that correct?

THE WITNESS: Yes, sir. That is looking at Table 6 and Table 7 from the first article.

CHAIRMAN WOLFE: From the first article?

THE WITNESS: I'm sorry, from the second article.

BY MR. NELSON:

Q Since the number of turbine missile failures in the second article was greater than that in the first article, does this give you any indication of the uncertainty factor which would surround the conclusions that Mr. Bush drew in those respective articles?

A You would expect that a larger population would result in less uncertainty.

Q In the second Bush article, did Mr. Bush consider only turbine missile failures at nuclear power plants? Or did he include certain other power plants of a conventional variety?

A He included conventional units, as well as nuclear units.

Q And what was the basis for him to make that inclusion?

A What inclusion is that?

Q To include the incidents from conventional power

plants?

A That they would represent the relatively -- be fairly representative of the failure rate that is also applicable to nuclear turbines.

Q Do you agree with Mr. Bush's assessment on that point?

A I think that the second article substantiates it, yes, because the second article includes a greater number of nuclear units. It also includes, counting as nuclear units, the units that had failures which -- of a nature that could also occur in the nuclear unit population which would indicate to me that it was a reasonable assumption in the first instance, in the first article, where there were very few nuclear units to contribute to the overall population.

So I would say: Yes, I would say that it was a reasonable assumption.

Q So you personally have no problem with the concept of including experience gained at certain conventional power plants in the data base for assessing turbine missile failures at nuclear power plants?

A No, I don't. I think there is enough similarity between conventional units and nuclear units that you can say that, if you included the population of the conventional units, you would come up with a conservative number, and one that would be representative of the nuclear population.

Q In your review of the historical data on turbine missile failures, were you able to discern any greater probability for conventional power plants to have turbine missile failures, as opposed to nuclear plants, or vice versa?

A No. I think that the two probabilities of those two populations was approximately the same.

Q Do you know whether the NRC staff in their analysis of turbine missile failures has included the data base from conventional power plants?

A Only indirectly. And that would be by virtue of the reference to the Bush study in Regulatory Guide 1.115.

Q Are you referring to Revision 1?

A Revision 1, yes.

Q Now did I understand you to say that Revision 1 of Reg Guide 1.115 takes into consideration and adopts the analysis in the second Bush article?

A No. The Regulatory Guide was issued prior to publication of the second Bush article. It only refers -- it only references the first article.

Q So it adopts essentially the analysis from the first article?

A I don't know that you can characterize it as adopting it. I think that there is an inference that they accepted, in that they cite the same or similar probability in the discussion.

Q And did the first Bush article also combine data from turbine missile failures at conventional power plants as well as those at nuclear power plants?

A Yes, they did.

MR. NELSON: No further questions at this time.

CHAIRMAN WOLFE: Staff, do you have any cross?

MR. DAVIS: Yes.

RECROSS-EXAMINATION

BY MR. DAVIS:

Q Mr. Stippich, I am looking at yesterday's transcript, and in response to a question from Mr. Farris as to what the two probability ranges identified by Dr. Bush were, this is transcript 7782, the recorded answer is, "3 x 10^{-5} and 2 x 10^{-4}."

Is that 2 x 10^{-4} actually 3 x 10^{-4}?

A May I see the transcript, please? I would like to put that in context.

(Handing document to witness.)

(Pause.)

Q We discussed the same number again today, and you stated "3 x 10^{-4}" today as being the number that came out of the Bush article.

A I don't recall saying 3 x 10^{-4} as the number that came out of the Bush article. I said 7 x 10^{-5}, I believe. Evidently, this is referring to the second article.

Q That's correct. And the second article you were asked about the range of P_2, and it went from 3×10^{-5}, and the lower range was something less than that, and it involved 10^{-4}. Do you know what the --

A This is incorrect. I believe it is 3.3×10^{-4}. Let me refer to the article.

Q Okay.

end #12

A The range of values that Dr.Bush gives in the last, the next to the last paragraph, is 3.3×10^{-5} to 3.1×10^{-4} per turbine year for a turbine population connected to be relevant to nuclear reactors.

Q In your testimony, you give the figure of the risk from a high trajectory missile causing damage to a safety-related structure, and equipment, as being 10 -- less than 10^{-7}, and you give the same figure for low trajectory missile.

When you say less than 10^{-7}, does that mean that you consider that a conservative rather than a realistic number?

A Yes, sir. That is a conservative number. It is taken from standard review plan 2.2.3 on accident analysis.

Q Would you be able to enumerate the conservatisms describing them briefly in your calculations that would make a realistic number less than 10^{-7}? Would you be able to detail for the Board where the conservatisms are in your calculations?

A The conservatisms in the calculations are primarily in the selection of the missile and in the manner in which the probabilities were calculated.

I cannot say exactly what magnitude of conservatism might be, but I don't recall any assumptions that were made that would have a less than -- that would be unconservative, so we have a conservative acceptance criteria and a conservative

evaluation of the missile probabilities.

MR. DAVIS: Staff has no further questions.

CHAIRMAN WOLFE: Mr. Farris?

MR. FARRIS: Thank you.

BY MR. FARRIS:

Q Mr. Stippich, it is true that we have a lack of empirical data in this area upon which to base our conclusions, isn't it?

A I don't know that you can characterize it by lack. There is -- there is certainly empirical data.

Q Let's put it this way:

The probabilities are based upon analytical methods, rather than a solid base of empirical data, are they not?

A Oh, I think it is a combination of empirical data and analysis.

Q Would you say that there is reliance upon analysis to a large extent,more than so in most engineering judgments?

A More so than most? That is difficult to define. Judgmentally I would say you can't define the numbers and test them. It doesn't have the same type of safety factor that you would have if you designed a structure. The acceptance criteria, though, represents a very very low risk, and I am sure that many structures would be designed with a much higher risk of failure than is represented by that

acceptance criteria.

Q Let me put it to you this way:

Is there a lack of statistical, valid statistical data upon which these probabilities are based?

A I am not in a position to judge that. I am relying on Dr. Bush's assesement of the reliability of the data base that he used to come up with his recommendation for the failure rate.

Q And Dr. Bush gave a range of probabilities for nuclear reactors,didn't he?

A He did in the second article, yes.

Q In the second article, that range was from 3.1×10^{-4} to 3.3×10^{-5}?

A For nuclear reactors, yes.

Q And yet, in your testimony, you picked the figure of 10^{-4}.

A Yes, sir, I did.

Q Mr. Stippich, isn't it good engineering practice to use the most conservative figure available when you have an inadequate statistical base?

A What do you mean by an inadequate statistical base?

Q That is a pretty broad range of probabilities, is it not?

A Dr. Bush didn't say that his statistical base was inadequate. I would have no reason to say that it was, and

therefore, one should adopt the most conservative figure. It doesn't follow.

Q Would you say that the variation between 3.3×10^{-5} or roughly three out of 100,000, as opposed to 3.1×10^{-4} or three out of 10,000,is a broad statistical range?

A Not in the context in which it is used in Bush's second article.

Q Wouldn't you say those figures represent a great deal of uncertainty in the probability analysis in this area?

A Again, it has to be related to what one would consider a sound estimate, and I think that Dr. Bush made that judgment, and I think that he reaffirmed that judgment in the second article.

I am sure if he had felt that his first position was inadequate, he would have changed his position.

Q Mr. Stippich, didn't, in fact, Dr. Bush come up with a different value for nuclear turbines as opposed to the general turbine population?

MR. NELSON: Mr. Chairman, I didn't understand the question. I don't know if the witness did. I believe the question needs clarification as to value for what Mr. Farris is asking about.

MR. FARRIS: P_1.

THE WITNESS: The value in the last paragraph in summarizing, he doesn't say. He gives --

BY MR. FARRIS:

Q In the next to the last paragraph under the summary, doesn't he in fact indicate that for nuclear turbines, the probability is approximately in the range, for that matter is approximately twice as high as for the general turbine population?

A I think that is correct, yes. Looking at the ratio of the numbers.

Q And on page 696, of Dr. Bush's article, doesn't he in fact state that it is his opinion that GE and Westinghouse's predictions and models were overly optimistic?

A Yes, he does.

Q Doesn't he, on that same page, indicate that turbines associated with older fossil units differ markedly from nuclear units with regard to material property stresses, rotor design, and control stresses?

A Where are you?

Q 696, the last paragraph on the left column.

A Last paragraph. Okay.

I think that is referring to the General Electric report, not to any conclusion of Bush's.

CHAIRMAN WOLFE: Mr. Nelson, do you have a spare copy of the second article?

MR. FARRIS: I have some extra articles.

[Documents distributed to Board.]

MR. FARRIS: I am referring to page 696.

BY MR. FARRIS:

Q Mr. Stippich, didn't you testify that you thought the experience with conventional turbines was relevant to nuclear turbines?

A I believe I did.

Q Do you know if GE agrees with that opinion?

A No, they don't. If you take the statement that you were just referring to in the Bush report, it is clear that they didn't.

Q And Mr. Stippich, did you in fact round off the probabilities for the total turbine population as reported by Dr. Bush -- that is, 7×10^{-5} -- which you rounded off to 10^{-4}?

A No. I think if you round it off to -- in the same way that he rounded off his numbers in the original report, if you round it off -- these numbers on the nuclear turbine population, you can justify a number on the order of 10^{-4}.

Q Mr. Stippich, yesterday I asked you if you were aware of any turbine failures at nuclear power plants that had generated missiles. In your review of Dr. Bush's article, did you notice any chart or tables that indicated that there had been missiles generated in connection with a nuclear turbine?

A Yes, sir.

Q And was that indicated on Table 6, at page 690 of the article?

A That is one place it was represented, yes.

Q Would you suspect, Mr. Stippich, that the higher rate for -- the higher probability for failure of nuclear turbines is based upon the relationship of that one failure to the total number of turbines being used with nuclear reactors?

A I don't think that that is the approach that Dr. Bush used in developing his statistics.

Q Have you made any comparison between the number of turbine hours associated with nuclear reactors and their failure rate to determine whether or not there may be some basis statistically for a higher rate for nuclear reactors?

A No, sir.

Q Mr. Stippich, on the second page of your calculations -- your worksheet that counsel provided us -- for high trajectory missiles --

A Yes, sir?

Q You indicated that for the two containments, the probabilities P_1 was 6×10^{-4}.

A Yes, sir.

Q And that is the probability of either containment being struck by a missile from a turbine?

A. That's correct.

Q. And for Black Fox Station, that probability would be twice that, as you indicated in response to a question from Dr. Purdom?

A. No. If you assume two failures, two turbine failures in a year, then it would be doubled.

Q. But if you have two turbines, then the probabilities for Black Fox Station -- not for a particular unit, but for Black Fox Station with the two-unit configuration, would then be 12×10^{-4}? Or 1.2×10^{-3}?

A. No, sir. It would be, for two units to cause damage to one reactor, or for one unit to cause damage to both reactors. We are looking -- the point that Mr. Shon made here was that it would be better, or more logical to look at two sources and, in effect, double the rate per year, and look at that as causing a missile for a containment -- look at the risk to a containment.

CHAIRMAN WOLFE: Off the record.

(Discussion off the record.)

BY MR. FARRIS:

Q. Mr. Stippich, aren't you looking at this as either two sources for a missile and one containment, or one source for a missile and two containments?

A. Yes, I am.

Q. For a high trajectory missile, isn't it true you