ORIGINAL

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

In the matter of:

PACIFIC GAS & ELECTRIC COMPANY

(Diablo Canyon Nuclear Power Plant)

Docket No. 50-275 OL
50-323 OL

Location: Avila Beach, Calif.

Pages: D-2300 - D-2386

Date: Tuesday, November 15, 1983

TR01 add LPDR
0/1
return original
to Chris Cater
EW-529

TAYLOE ASSOCIATES
Court Reporters
1625 I Street, N.W. Suite 1004
Washington, D.C. 20006
(202) 293-3950

MELTZER
MM/ki

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING APPEAL BOARD

In the Matter of:	:	
PACIFIC GAS & ELECTRIC COMPANY	:	Docket Nos. 50-275 OL 50-323 OL
(Diablo Canyon Nuclear Power Plant)	:	

Bay View Room
San Luis Bay Inn
Avila Road at Avila Beach
Avila Beach, California
Tuesday, 15 November 1983

The hearing in the above-entitled matter was convened, pursuant to notice, at 9:00 a.m.

BEFORE:

THOMAS S. MOORE,
Chairman, Atomic Safety & Licensing Appeal Board

JOHN H. BUCK,
Member, Atomic Safety & Licensing Appeal Board

W. REED JOHNSON,
Member, Atomic Safety & Licensing Appeal Board

xxxx 1b

APPEARANCES:

On Behalf of the Applicant, Pacific Gas & Electric Company:

BRUCE NORTON, ESQ.
Norton, Burke, Berry & French, P.C.
2002 East Osborn
P.O. Box 10569
Phoenix, Arizona 85064

RICHARD F. LOCKE, ESQ.
PHILIP A. CRANE, JR., ESQ.
Law Department
Pacific Gas & Electric Company
77 Beale Street
San Francisco, California 94106

On Behalf of the Governor of the State of California:

MICHAEL STRUMWASSER, ESQ.
Special Counsel to the Attorney General
PETER KAUFMAN, ESQ.
SUSAN DURBIN, ESQ.
Deputy Attorneys General
State of California, Department of Justice
3580 Wilshire Boulevard
Los Angeles, California 90010

On Behalf of the Joint Intervenors, San Luis Obispo Mothers for Peace:

JOEL REYNOLDS, ESQ.
ERIC HAVIAN, ESQ.
Center for Law in the Public Interest
10951 West Pico Boulevard
Los Angeles, California 90064

On Behalf of the Regulatory Staff:

LAWRENCE J. CHANDLER, ESQ.
HENRY J. MC GURREN, ESQ.
Office of the Executive Legal Director
United States Nuclear Regulatory Commission
Washington, D.C.

Representing the IDVP:

MAURICE AXELRAD, ESQ.
Lowenstein, Newman, Reis & Axelrad, P.C.
1025 Connecticut Avenue, N.W., Suite 1214
Washington, D.C. 20036

mml

I N D E X

11b1

P R O C E E D I N G S

JUDGE MOORE: Come to order, please.

Mr. Chandler, you are holding a handful of papers and I assume you have something, this morning, for us.

MR. CHANDLER: Yes, sir. I have already provided, to the Board and parties, copies of a Board Notification to the Atomic Safety and Licensing Appeal Board, Diablo Canyon 1 and 2, the subject of which is construction QA concerns reported to the NRC Staff by Henry Myers. It's Board Notification 83-180.

Dr. Myers is an assistant, I believe, to Congressman Udall on the Subcommittee on Energy Environment.

That's the only preliminary matter I have, Mr. Chairman.

JUDGE MOORE: Any other preliminary matters, this morning?

MR. STRUMWASSER: Yes. Mr. Chairman, before we call our final witness, we have reviewed the transcript of yesterday's proceeding and Mr. Hubbard has identified an error in his testimony and we would like to call him for the purpose of correcting one error in his testimony.

JUDGE MOORE: Have you discussed this with the other parties?

MR. STRUMWASSER: No. I just indicated it was an error and it was in the course of his Voir Dire questioning by

Mr. Norton. I just advised the parties as we were coming in because we literally just looked at the transcript when we got here this morning.

JUDGE MOORE: Why don't you let me know what the area is, before we proceed.

MR. STRUMWASSER: The specific area -- I can give you the citation if you'd like. It's on page 2193. The question and answer at lines 5 through 7. Mr. Hubbard misheard the question and as a result, the answer is an error. We think that the question is irrelevant but it is now an incorrect statement. He would like his testimony to be correct.

JUDGE MOORE: Staff and Applicant, do you have any objection?

MR. CHANDLER: I have no objection.

MR. NORTON: No.

JUDGE MOORE: Joint Intervenors?

MR. HAVIAN: No objection.

JUDGE MOORE: All right. Continue, call him.

Whereupon,

RICHARD B. HUBBARD

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

JUDGE MOORE: Proceed, Mr. Strumwasser.

11b3

FURTHER DIRECT EXAMINATION

BY MR. STRUMWASSER:

Q Mr. Hubbard, you have before you a copy of the transcript, open to page 2193. Is there an error in your testimony on that page?

A Yes.

Q Would you describe to the Board the nature of the error, and correct it?

A Yes.

Q The question at lines 5 and 6, "Did you not in any way discuss your testimony here, this morning, with Mr. Havian?" My answer, "That's correct" is in error. I thought the question had to do with the testimony you were going to give this afternoon and I did have a general discussion with Mr. Havian about my testimony in the morning. More or less, he told me well, he thought it was going well and things of this sort. We did not discuss specifics but there was discussion about how it was going and hang in there, that sort of thing.

MR. STRUMWASSER: That's all we have, Mr. Chairman.

JUDGE MOORE: Mr. Norton, do you wish to have any cross?

MR. NORTON: No.

MR. CHANDLER: No, Mr. Chairman.

MR. HAVIAN: No.

11b4

JUDGE MOORE: All right. The witness is excused.

(Witness excused.)

MR. NORTON: Your Honor, we have one preliminary matter. I was going to bring it up without this, but it deals in the same subject matter.

As the Board knows, we have the burden of proof in this case, and I think the order of cross examination yesterday was not proper. Obviously the Joint Intervenors have the same contentions as the Governor, and to allow them to cross examine the Governor's witness after our cross examination -- we don't have a chance to cross examination on the information they solicit.

I'm not suggesting another round of cross examination but I am suggesting a change in the order. If the Governor and Joint Intervenors put up a witness, then they should cross examine first, before me, so that I have the opportunity to do something with any information elicited on that cross examination.

As it was yesterday, Mr. Havian's cross examination of Mr. Hubbard was very short and frankly, it didn't prejudice me. But it could.

JUDGE MOORE: The Board is aware of that prospect.

Yes, Mr. Strumwasser. Do you have any comment?

MR. STRUMWASSER: Just that I think the condition that Mr. Norton alludes to is very much the same as the

condition created by the Staff's position in this litigation. That is, that the Applicant puts on testimony first. We cross and then the Staff comes in last and their position happens to be largely the same as that of the Applicant. So I think that the order in which the Board is following conforms to the way in which the rest of the hearing is being conducted.

MR. REYNOLDS: Mr. Chairman, I would add to that. This is the order we've always used. I don't think it's anything extraordinary.

MR. NORTON: That's incorrect. It is not the order we have always used. This is the first time we've done it this way.

JUDGE MOORE: Mr. Chandler?

MR. CHANDLER: I would tend to agree with Mr. Norton. I think, as a matter of practice in this proceeding, it has been the other way with the Joint Intervenors following the Governor.

MR. REYNOLDS: That's simply inconsistent with my recollection.

MR. NORTON: Your Honor, the difference between the Applicant and the Staff, however, is that the Applicant has the burden of proof, not the Staff.

JUDGE MOORE: I recognize that, Mr. Norton.

Why don't we take a brief three minutes, while

11b6

the Board can put their heads together, and then we will proceed with Mr. Strumwasser's last witness.

(Recess.)

end t1

KI:ki 2:1

JUDGE MOORE: Come to order, please.

Do any of the parties have the seismic hearing transcript here, by any chance?

MR. NORTON: You're talking about the reopened '79 seismic hearings?

JUDGE MOORE: I'm sorry.

JUDGE BUCK: No, we're talking about --

JUDGE MOORE: The hearing before the Appeal Board.

I seriously doubt it, but we can check.

JUDGE MOORE: We will take a 15-minute recess while the Board checks that transcript. We'd like to check the record.

MR. STRUMWASSER: Mr. Chairman, I don't want to prolong this or make this any tougher for anybody, but from out point of view, we do not view the precedent of relationship between Governor Brown or any of the parties here as the same as the relationship between Governor Deukmejian and any of the parties here.

I do not know -- I am the least responsible for knowing what went on at that last hearing, but our view is that the Governor is an independent party and bears no affiliation, relationship, alignment with the other parties.

MR. CHANDLER: Mr. Chairman, if I could just add one point of comment. I certainly have no problems with what Mr. Strumwasser just indicated. However, as pointed out

KI:ki 2:2

earlier, it is rather significant that what we are litigating are the joint contentions of the Joint Intervenors and the Governor with respect to affiliation or affinity between them.

MR. STRUMWASSER: It should be clear that that was at the instruction of the Board.

MR. CHANDLER: Oh, I understand that, but nevertheless they are the joint issues of the State and the Joint Intervenors, and for that reason, I think it more appropriate that the presentation proceed as Mr. Norton suggested earlier.

JUDGE MOORE: We would like to check the record of the proceeding to check on the recollections of all counsel.

MR. NORTON: I'm having problems recollecting the CQA hearing, which was not that long ago. And if I could think for a moment, I think we could all remember what the procedure was in that one.

JUDGE MOORE: Mr. Norton, we've already searched our memories, and that's why we're going to --

(Laughter.)

MR. NORTON: We have that transcript, though.

JUDGE MOORE: We'll take a 15-minute recess and then reconvene after we've had an opportunity to look at the record.

(Recess.)

JUDGE MOORE: Come to order, please.

KI:ki 2:3

We have checked the record and best as we can determine, this has been a continual problem in all the Diablo Canyon hearings, and it appears that from best we could determine at this point, there was no consistency in approach or the application of the order.

Mr. Strumwasser just informed me that before we make a ruling, that counsel worked out a compromise.

MR. STRUMWASSER: Yes. The compromise was intended to enable the Board not to have to do any further research. I don't know if the compromise is still good, and I have not polled the parties to find out. Do we want to proceed on that assumption, gentlemen?

JUDGE MOORE: You can't have it both ways.

(Laughter.)

Let's hear the compromise.

MR. NORTON: Can we hear the vote first?

(Laughter.)

JUDGE MOORE: Mr. Strumwasser.

MR. STRUMWASSER: We had proposed to split the difference. There are two remaining witnesses, and we had agreed that for Dr. Apostolakis, that Joint Intervenors would cross before PG&E, and for Dr. Samaniego, that PG&E would cross before the Governor. Is that correct?

MR. NORTON: Yes. I have no problem with that.

JUDGE MOORE: Well, that's a Solomon-like approach

KI:ki 2:4

to the problem. If the parties are agreed to that, we will not interpose an objection ourselves to cutting the baby in that fashion.

We will proceed on that basis.

Continue, Mr. Strumwasser.

MR. CHANDLER: The Staff, of course, would follow the Applicant in that present order.

JUDGE MOORE: I believe that that was understood in what Mr. Strumwasser said.

MR. NORTON: Could you now tell us how you would have ruled?

(Laughter.)

JUDGE JOHNSON: We don't have a three-headed coin.

MR. STRUMWASSER: Mr. Chairman, the State calls George Apostolakis.

May we have your name for the record, please?

MR. APOSTOLAKIS: George Apostolakis.

MR. STRUMWASSER: And Professor Apostolakis, where are you employed?

MR. APOSTOLAKIS: The University of California at Los Angeles.

Whereupon,

DR. GEORGE APOSTOLAKIS

was called as a witness and, after being first duly sworn, was examined and testfied as follows:

KI:ki 2:5

MR. STRUMWASSER: Mr. Chairman, the traditional corrections to the prepared testimony, we have but a single correction.

Page 7, line 8, and I note that the typing is slightly below the line, so it's line 8-1/4. The fourth word is "that." It should be "than," so that the line now reads: "higher failure rates than the experts had predicted."

DIRECT EXAMINATION

XXXX BY MR. STRUMWASSER:

Q Professor Apostolakis, with that correction, is your testimony true and correct to the best of your knowledge and belief?

A It is.

MR. STRUMWASSER: May the testimony of Dr. Apostolakis be admitted?

JUDGE MOORE: So ordered.

MR. STRUMWASSER: And the Affidavit of Qualifications?

JUDGE MOORE: That accompanies it -- shall be bound in the record as if read.

(The Testimony of Dr. George Apostolakis, with

XXXX Lay in his Affidavit of Professional Qualifications is as follows.)

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING APPEAL BOARD

In the Matter of	)	
PACIFIC GAS AND ELECTRIC COMPANY	)	Docket Nos. 50-275 O.L. 50-323 O.L.
(Diablo Canyon Nuclear Project, Units 1 and 2)	)	

DIRECT TESTIMONY OF GEORGE APOSTOLAKIS

Q. Please state your name.

A. George Apostolakis.

Q. What is your business address?

A. 5532 Boelter Hall, University of California, Los Angeles, California 90024.

Q. What is the purpose of your testimony in this proceeding?

A. I have been asked to render my professional opinion on the applicability of probability theory, decision theory, and statistics to the verification of the design of a nuclear power plant and to evaluate the adequacy of the Independent Design Verification Program (IDVP) to insure the adequacy of the design of Diablo Canyon Nuclear Power Plant, Units 1 and 2. Specifically, my testimony pertains to contentions 1 and 7.

I.

QUALIFICATIONS

Q. What is your present position?

A. I am a Professor in the School of Engineering and Applied Science at the University of California, Los Angeles, where I

have taught since July 1974. I am a member of the faculty of the Mechanical, Aeronautical, and Nuclear Engineering Department.

Q. Please summarize your education.

A. I hold a Ph.D. in Engineering Science and Applied Mathematics and an M.S. in Engineering Science, both from the California Institute of Technology. I also hold a diploma in Electrical Engineering from the National Technical University, Athens, Greece.

Q. Are you a member of any professional organizations?

A. I am a member of the American Nuclear Society and the Society of Risk Analysis. I am a past recipient of the Mark Mills Award from the American Nuclear Society.

Q. Please summarize your work experience in the fields of risk assessment and nuclear engineering.

A. For the past ten years, I have been continuously engaged in research in risk assessment, including the conduct of probabilistic risk analyses for nuclear power plants; probability theory, decision theory, and statistics; reliability analyses; and nuclear engineering.

Since 1977, I have served as a consultant to Pickard, Lowe and Garrick, Inc., where I participated in probabilistic risk analyses of the Oyster Creek, Zion, and Indian Point nuclear generating stations; I also served for Pickard, Lowe and Garrick on the technical review board for the Seabrook Probabilistic Safety Study. For the past three years, I have also served as a consultant to the Bechtel Power Corporation

on probabilistic risk assessment. In the past I have served as a member of the Peer Review Panel for the Load Combination Program of the Lawrence Livermore National Laboratory, as a consultant to the Seismic Safety Margins Research Program of Lawrence Livermore National Laboratory, as a consultant on risk methodology for geologic disposal of radioactive waste for the Sandia National Laboratories, and as a member of a research review group for the Probabilistic Analysis Staff of the U.S. Nuclear Regulatory Commission.

My research work at UCLA has been both theoretical and applied. I have conducted research on the foundations and methods of probabilistic risk analysis, on data analysis, on fire risk analysis, and the general area of risk-benefit. I have developed and taught two courses on probabilistic risk analysis. I have also taught courses in nuclear engineering as well as basic engineering courses.

Q. Do you regularly publish in the professional literature?

A. Yes. I have edited one book and contributed to another on risk analysis. I have published numerous articles on probabilistic risk assessment, nuclear engineering, and related matters. I also serve as a reviewer for Nuclear Safety, Nuclear Science and Engineering, Nuclear Technology, IEEE Transactions on Reliability, AIChE Journal, Risk Analysis, and Reliability Engineering. The list of my publications has been submitted separately in my affidavit of qualifications.

/

II.

PROBABILITIES AND STATISTICS

Q. What do you mean by statistical inference?

A. Statistical inference is the process by which evidence is incorporated in our body of knowledge. This body of knowledge is, in general, expressed by probabilistic statements.

Q. How is evidence incorporated in our body of knowledge?

A. I view this question in the context of the Bayesian (or Subjectivistic) Theory of Probability. According to this theory, we always have some degree of knowledge of any uncertain event of interest. Bayesian Theory asserts that our degree of knowledge can be expressed in terms of probabilities. As information becomes available, we modify our state of knowledge; that is, we revise our probabilities. This modification is done in a consistent manner, using Bayes' Theorem.

Q. What do you mean by "evidence"?

A. "Evidence" can be any kind of information. This includes what is commonly referred to as "statistical evidence" as well as such qualitative information as opinions of people, scholarly literature, the results of experiments, etc.

Q. What does the term "statistical evidence" mean?

A. For present purposes, I use the term "statistical evidence" to refer to information concerning the frequency with which a given attribute is observed in a specified population. This would include how many redheads we find in a given group of

people, the number of times a coin turns up heads in a sequence of tosses, the proportion of American families within a given income bracket, and so on.

Q. What is the relationship between frequencies and probabilities?

A. Frequencies are observable quantities in a given sample or population. Often we express a frequency as a proportion of a sample or a population. Probabilities, on the other hand, are not observable. They are numerical measures of degrees of belief. In other words, frequencies are objective facts and probabilities are subjective beliefs.

Q. What is the distinction between probability theory and statistics?

A. Statistics is part of probability theory. Probability theory is a set of rules that, if obeyed, guarantee coherence. Statistics is that part of probability theory that deals with the coherent use of evidence.

Q. What do you mean by "coherent"?

A. Human beings dealing intuitively with uncertainty have been found to make inconsistent and unreliable use of the information at their disposal. Probability theory, or, more generally, decision theory, requires them to make their reasoning process, their assumptions, and their use of information consistent with certain principles of rational behavior. This makes the decision process explicit and visible.

/

Q. What is the virtue of making the process explicit and visible?

A. Probabilities are inherently subjective, as are decisions made under uncertainty, leading to differences of opinion among people. By making the process explicit and visible, we allow people holding different opinions, and third parties observing the differences, to approach resolution of the differences on a reasoned basis.

Q. What is the nature of the differences in opinion among people?

A. People differ in their assessments of probabilities. They also differ in their assessments of the costs and benefits of different consequences of decisions.

Q. What are the reasons for different probability assessments?

A. Different decision makers may have different states of knowledge. In addition, there is evidence that human beings have great difficulty expressing their knowledge in terms of probabilities.

There is a substantial body of evidence indicating that people perform poorly in assessing probabilities, that is, in dealing coherently with a body of incomplete evidence. For example, Slovic, Fischhoff, and Lichtenstein, in their article "Facts and Fears: Understanding Perceived Risk" (published in Societal Risk Assessment, R.C. Schwing and W.A. Albers, Jr., Editors, Plenum Press, 1980), state, on the basis of their own experiments and research and those of others, that people tend to deny uncertainty, misjudge risks, and express unwarranted confidence in their judgments. The

same authors show that expert assessments are also susceptible to biases, particularly underestimation of risks.

Kaplan, Garrick, Duphily, and I found similar evidence of expert underestimation of failure rates in a study we did of the performance of several components of a nuclear plant. We found, somewhat to our surprise, that the statistical evidence of failures at that plant indicated substantially higher failure rates ~~that~~ than the experts had predicted. (Apostolakis, Kaplan, Garrick and Duphily, "Data Specialization for Plant Specific Risk Studies, Nuclear Engineering and Design, 56:321-329 (1980).)

For rare events the difficulties people have assessing probabilities can lead to dramatically different opinions. Of course, this is one area where statistical evidence can be most useful. Bayes' Theorem tells us that when statistical evidence is strong, the prior beliefs (i.e., beliefs prior to obtaining the statistical evidence) become unimportant and the probability assessments are controlled by this evidence, that is, they are independent of the assessor. All this, of course, assumes that different assessors interpret the evidence in the same way, something that is not always true.

III.

DESIGN ERRORS

Q. Has there been any formal research done on the frequency and significance of design errors in nuclear power plants?

A. Yes. Three studies are particularly pertinent here:

/

(1) J. R. Taylor, "A Study of Failure Causes Based on U.S. Power Reactor Abnormal Occurrence Reports," in Reliability of Nuclear Power Plants (Proceedings of a Symposium, Innsbruck, April 14-18, 1975), pp. 119-130, Unipub, Inc., N.Y., 1975. Taylor studied Abnormal Occurrence Reports (now known as Licensee Event Reports (LERs)) submitted to the Atomic Energy Commission and found that a large proportion of the failures in U.S. plants involved design, installation, and operation errors, with an unexpectedly large proportion of the incidents involving multiple failures. Of 490 failures, he classified 36 percent as being due to design errors. The largest single cause of design errors was found to be unforeseen conditions.

(2) T. M. Hsieh and D. Okrent, "On Design Errors and System Degradation in Seismic Safety," in Transactions of the 4th International Conference on Structural Mechanics in Reactor Technology, San Francisco, Calif., August 15-19, 1977, T. A. Jaeger and B. A. Boley (Eds.), Vol. K, Paper K9/4, Commission of European Communities, Luxembourg, 1977. Hsieh and Okrent investigated the possible number and influence of seismic-related design errors by examining the historical record of such errors for a specific reactor. Their estimates of the core melt frequency were substantially higher than those of the Reactor Safety Study (WASH-1400), which had not taken into account the possibility of design errors.

(3) P. Moieni, G. Apostolakis, and G. E. Cummings, "On Random and Systematic Failures," Reliability Engineering, 2:199-219 (1981). We analyzed the LERs for two power reactors plus 100 design errors compiled by Oak Ridge National Laboratory. We found that 18 percent of all licensee events at one of the two reactors and 13 percent at the other were due to design errors. We found that the most common design error was the failure to foresee environmental conditions. That design error alone accounted for nearly as many LERs as all operational procedure errors.

It is important to keep in mind that these results are based on each group of researchers' definitions of the term "design error" and on their interpretation of the events reported. Despite these reservations, there is a great deal of useful information in these studies. For example, they show that design errors are a more frequent cause of failures in nuclear power plants than has been widely assumed.

Q. What are the typical causes of design errors in nuclear power plants?

A. The cited studies indicate that major causes appear to be unforeseen environmental conditions, specification errors, and wrong analyses.

Q. Do these studies show that design errors are inevitable or widespread in commercial reactors?

A. Not necessarily. Each of these studies has examined previously identified operational failures and classified

them in various ways. There is no evidence from which one could conclude how representative the plants experiencing these events are of all commercial U.S. reactors. I know of no study of how frequent design errors are in general and of what their impact on the margin of safety is.

So while these studies show that design errors are a more significant factor in plant failures than was previously thought, they do not tell us how frequent and how important to safety such errors are.

Q. Is there any basis for evaluating the safety significance of the design errors described in the literature?

A. One must be very careful about the meaning of the term "safety significance." If by that we mean actually causing injuries to the public, then none of the errors were safety significant. But if we are speaking about an error having the potential for such harm under possible conditions that were not actually experienced before the error was detected, then it is more difficult to dismiss any error as not being safety significant.

I think that the most meaningful way to investigate these issues is based on the reduction in the presumed margin of safety. The only way I know to practically evaluate the safety significance of an error in these terms is to conduct a probabilistic risk assessment. This enables one to test the sensitivity of a given facility to designated system and component failures. In my experience, PRAs sometimes reveal failure paths not perceived by knowledgeable engineers

involved in the design of the plant. Furthermore, the potential of multiple failures of redundant components due to design errors cannot be fully assessed without a PRA.

Q. In the probabilistic risk assessments with which you are familiar, how have design errors been treated?

A. Design errors have been treated only indirectly. By this I mean that, while something is usually done, the analysis is not as rigorous as other parts of PRAs are. For example, Appendix X to the Reactor Safety Study (WASH-1400, NUREG 75/014, October 1975) is entitled "Design Adequacy." The study team felt that they needed additional assurance that certain components would function as intended under severe conditions. Part of the reason for this was that the failure-rate distributions did not reflect experience with such environments. The design adequacy assessment was performed by the Franklin Institute Research Laboratories, which checked a sample of components, systems and structures. They found only minor problems, e.g., errors in assumptions used to calculate stresses and inadequate tests. The consequence of these errors was assessed to be a reduction in the safety margin.

In more recent PRAs, like those for the Zion and Indian Point nuclear power plants, the issue of design errors was in the minds of the analysts when they quantified their judgment, so that very low values for failure rates were avoided. Design errors were part of the "other" category of failure causes, which means, causes not explicitly

quantified. The notion of the "other" category has been proposed by Kaplan and Garrick (see Risk Analysis, vol. 1, p. 11, 1981), who were among the principal investigators performing these PRAs.

IV.

VERIFICATION OF DESIGN

USING PROBABILITY THEORY

Q. Do you know of any case where the adequacy of a nuclear power plant's design was demonstrated using sampling?

A. No. There have been the studies of design errors I described above. But to the best of my knowledge, no nuclear power plant has ever been licensed using a sampling verification program as a substitute for a quality assurance program that was found to be inadequate.

Q. What is the significance of the decision to verify the design by sampling?

A. Ordinarily, licensing decisions are framed in deterministic terms, i.e., does the plant design comply with the NRC criteria? A relatively straightforward answer to this question could be obtained by checking the entire design and fixing any errors found. If one decides to verify the design by sampling less than 100 percent of the design, then one transfers the problem into the realm of probabilities, i.e., one is assessing the probability of an affirmative answer to the original question regarding compliance with the NRC criteria. In other words, one is no longer asking the deterministic question, "Does the design meet the licensing

criteria?" Instead, one is asking, "What is the probability that the design meets the licensing criteria?" Or, more precisely, one is asking, "What is the probability that there are no deviations from the criteria in the existing design?"

The nature of the problem has now been considerably changed. One is now explicitly accepting the possibility of a deviation from the licensing criteria remaining undetected.

Q. Can statistical techniques make a contribution to a program to verify the design of a nuclear power plant?

A. Yes, given my earlier discussion of statistics as part of probability theory. Once the decision has been made to characterize the problem in probabilistic terms, statistical techniques enable us to make full use of the information that we have available and furnishes the discipline and guidance that insures we are using the data properly.

Q. How do statistical techniques do so?

A. These methods can provide guidance to the decision maker concerning both the qualitative aspects of the problem (e.g., what kinds of errors have been made, what can be done about them, etc.) and the quantitative aspects (e.g., how likely errors of a certain type are, how many errors remain undetected, etc.)

In this way, probability theory and statistics further the goal of making the analysis and evaluation explicit and visible.

Q. Is it possible to estimate the frequency of design errors in a nuclear power plant using statistical techniques?

A. Yes. Again, one has to be very careful with one's terminology. Because there is no general definition of "design errors," a definition would have to be established at the outset of the study. The definition would have to correspond to the purpose of the study and be precise enough to permit consistent classification of observations. These requirements are not substantially different from the requirements for any engineering study, whether or not statistics are used.

Assuming, however, that we are working with well-defined events, like selecting the wrong design pressure, we could, then, consider the universe of such selections and apply random sampling to estimate the frequency of such errors.

Q. What is a "random sample"?

A. A random sample of a population is one in which each element of the population has an equal chance of being drawn for the sample.

Q. What is "judgmental sampling"?

A. This is not a term I had encountered before my involvement in this case. I gather from the IDVP materials I have read that the IDVP uses this term to refer to the process of selecting elements from the population by using engineering judgment.

Q. Are both kinds of sampling used in statistical analysis?

A. There are places for the use of informed judgment, including engineering expertise, in a statistical study. For example, judgment is used to formulate hypotheses. However, once a

/

population is identified for study, samples are drawn from the population randomly.

Q. Why?

A. In statistical terms, any sample that is not drawn randomly is suspect of biases. Once one departs from random selection, the danger exists that the selection mechanism contains a bias, presumably unintended, that will lead to an unrepresentative sample and results that cannot validly be generalized to the population from which the sample was drawn.

Q. Can you state a pertinent example?

A. There are many well known examples of biased samples rendering invalid results. One of the best known is the Presidential preference poll taken by the Literary Digest before the 1936 election. Over two million respondents to the poll showed a preference for Landon over Roosevelt by a 57% to 43% margin. In the election, President Roosevelt got 62% of the vote.

Any time one departs from random sampling one hazards similar errors. For example, it has been stated that the IDVP sampled the Diablo Canyon design work emphasizing complex designs on the assumption that those were the designs where errors were most likely to be found. However, it is entirely possible that the managers who oversaw the design work recognized the complex problems and assigned them to the most competent engineers and designers. If so, sampling in this way could underrepresent the work of those people most likely to make errors.

Q. Are you saying that what the IDVP calls judgmental sampling has no place in a design verification program?

A. No. If one has information leading one to suspect the location or type of errors, that information should be exploited. But I do not believe that a sample drawn non-randomly can validly be used to generalize about the frequency of errors in the unsampled portion of the population.

V.

EVALUATION OF THE IDVP

Q. What have you reviewed concerning the Diablo Canyon Independent Design Verification Program?

A. Parts of the Phase II Program Management Plan, the IDVP Final Report, NUREG-0675 (Safety Evaluation Report, Supplement 18), the IDVP Program Management Plan for Phase II, Interim Technical Reports 1, 8, 34, and 35, and certain depositions and interrogatory answers.

Q. What is your understanding of how the IDVP sought to verify the adequacy of the non-seismic design?

A. Three systems were selected (the auxiliary feedwater system, the control room ventilation and pressurization system and the safety-related portions of the 4160-V electrical distribution system). I am told that the IDVP verified completely the design of these systems in Unit 1. The IDVP examined the design of these systems and identified errors. It grouped these errors into classes according to whether or

/

not the errors caused criteria or operating limits to be exceeded.

The IDVP then sought to group some of these errors into "generic concerns." Five generic concerns were raised and all systems where these could apply were verified. No other samples were taken.

On the basis of this examination, the IDVP drew conclusions about the adequacy of the overall design of Unit 1, including the systems not sampled.

Q. In your opinion, did the IDVP proceed in an appropriate way?

A. It is not clear to me why they chose to sample and use probabilistic arguments rather than a full deterministic review. Given, however, that they decided to sample, the available statistical methods, particularly random sampling, that would justify extrapolation of their findings to parts of the plant not sampled, have not been used.

Q. In your opinion, was the IDVP's judgment concerning the five generic concerns sound?

A. I do not have enough information to judge. I do recognize that issues like this involve extensive use of judgment. Therefore, different analysts may classify errors in many different ways. Nevertheless, I find the presentation of the IDVP's classification unconvincing.

For example, the selection of system design pressure, temperature, and differential pressure across valves is identified as a generic concern. I can see a more general

concern being the selection of system design parameters, which would also include other variables, such as stress, enthalpy, humidity, etc. Since the literature I cited above suggests that incorrect selection of design parameters in general is a common source of errors, I find no adequate justification for limiting this generic concern to incorrect selection of pressures, temperatures, and differential pressures across valves.

As a second example, it is stated on page 6.3.4-2 of the IDVP Final Report that three EOIs (8001, 963 and 1069) involve the misapplication of computer programs. Because there was no commonality between the programs involved in EOI 8001 and the other pair, and because the types of errors were different, a generic concern was not identified. It may be reasonable, however, to identify "misapplication of computer codes" as a generic concern.

Q. What is the significance of the fact that the IDVP found what it called "random errors," that is, errors that were not covered by the five generic concerns?

A. If the three sampled systems were really representative of the unsampled systems, this implies that there are similar errors remaining to be found in the unsampled parts of the plant. On the other hand, if the three systems are unrepresentative, we have almost no information about the unsampled elements of the design and no basis for confidence in the adequacy of the design.

Q. Is the safety significance of the errors uncovered relevant?

A. It depends on what the issue is. If the issue is whether the plant's design meets licensing requirements, safety significance of the design errors is not relevant.

If the issue is the safety of the plant, then safety significance of errors is obviously relevant, but, as I stated earlier, the only way I know to perform such an evaluation is in the context of a PRA.

Q. In your opinion, does the IDVP's work provide a basis for estimating the number of as yet undetected design errors?

A. No. The failure to use random sampling techniques makes a reliable extrapolation impossible and creates the suspicion that there may be errors whose types are not known yet. Furthermore, the same lack of random sampling does not allow the estimation of error frequencies or absolute numbers. The design of the IDVP was not amenable to providing a basis for estimating frequencies.

Q. Does the IDVP provide a basis for concluding that the rate of undetected errors is acceptable?

A. No. To decide that a given rate of errors is acceptable, one must know two things: what the rate of errors remaining in the plant is and what rate is acceptable. For the reasons I have just given, one cannot get from the IDVP's work an estimate of the rate of remaining errors at Diablo Canyon. And nowhere have I seen anyone attempt to set and justify an acceptable rate. The decision that I identified earlier, namely, to recast the problem in probabilistic terms has created the need to have a criterion for acceptability. The

issue of an acceptable rate of design errors has not been studied and resolved.

Q. Could one not attempt to set a rate that provides reasonable assurance of safety?

A. The term "reasonable assurance" is not defined. This term is usually used in NRC regulatory matters to refer to the level of assurance sought in setting the design criteria. Thus, we say that the criteria, if met, will provide a reasonable assurance of safety. It would be a significant departure to talk about a reasonable assurance that the criteria are even met. Then one is talking about a reasonable assurance of meeting license criteria that, if met, would provide a reasonable assurance that the plant is safe. This is a novel notion, the implications of which are not obvious.

Q. What can be said about the adequacy of Diablo Canyon Unit 2 from the verification program for Unit 1?

A. I have already said that the findings of the IDVP in Unit 1 cannot be generalized to the portions of Unit 1 not examined. That is obviously true of Unit 2, for which the IDVP does not have a sample at all.

Q. Do we know whether the rates and distribution of errors in the two units are the same?

A. No. We know of certain similarities and certain differences between the two units. To be able to say anything about the error rates in the two units, random samples would be needed from both units.

/

Q. What can now be done to achieve confidence in the design of Diablo Canyon?

A. As a first step, the decision to cast the problem in probabilistic terms should be fully understood. Given the decision to verify by sampling, the objectives of the study and the decision criteria should be explicitly stated, and the populations should be defined. Random samples should be drawn to determine the nature and frequency of the errors. This would permit one to draw valid conclusions about the design as a whole.

VI.

CONCLUSION

Q. How would you summarize your evaluation of the IDVP's work?

A. In general, it appears that a great deal of good engineering work has been done. In my opinion, the greatest weakness of the IDVP effort has been its failure to recognize the implications of the decision to cast the verification program in probabilistic terms and its failure to use the principles and methods appropriate to a probabilistic analysis. These shortcomings are particularly manifested in the lack of explicit and visible decision rules and the failure to use random samples.

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING APPEAL BOARD

In the Matter of PACIFIC GAS AND ELECTRIC COMPANY (Diablo Canyon Nuclear Project, Units 1 and 2)	)	Docket Nos. 50-275 O.L. 50-323 O.L.

STATE OF CALIFORNIA)
) ss.
COUNTY OF LOS ANGELES)

AFFIDAVIT OF GEORGE APOSTOLAKIS

George Apostolakis, being first duly sworn, attests:

1. I am Professor of Engineering and Applied Science at the University of California, Los Angeles, where I have taught since July 1974. I am currently a member of the faculty of the Mechanical, Aeronautical, and Nuclear Engineering Department in the School of Engineering ad Applied Science.

2. I hold a Ph.D. in Engineering Science and Applied Mathematics and an M.S. in Engineering Science, both from the California Institute of Technology. I also hold a diploma in Electrical Engineering from the National Technical University, Athens, Greece.

3. I am a member of the American Nuclear Society and the Society of Risk Analysis. I am a past recipient of the Mark Mills Award from the American Nuclear Society. I serve as a reviewer to AIChE Journal, Nuclear Safety, Nuclear Science and

Engineering, Nuclear Technology, IEEE Transactions on Reliability, Reliability Engineering, and Risk Analysis.

4. For the past ten years, I have been continuously engaged in research in risk assessment, including the conduct of probabilistic risk analyses for nuclear power plants; probability theory, decision theory, and statistics; reliability analyses; and nuclear engineering.

5. Since 1977, I have served as a consultant to Pickard, Lowe and Garrick, Inc., where I participated in probabilistic risk analyses of the Oyster Creek, Zion, Indian Point, Browns Ferry, and Midland Nuclear Generating Stations; I also served for Pickard, Lowe and Garrick on the technical review board for the Seabrook Probabilistic Safety Study. For the past three years, I have also served as a consultant to the Bechtel Power Corporation on probabilistic risk assessment. In the past I have served as a member of the Peer Review Panel for the Load Combination Program of the Lawrence Livermore National Laboratory, as a consultant to the Seismic Safety Margins Research Program of Lawrence Livermore National Laboratory, as a consultant on risk methodology for geologic disposal of radioactive waste for the Sandia National Laboratories, and as a member of the research review group for the Probabilistic Analysis Staff of the U.S. Nuclear Regulatory Commission.

6. I have chaired conferences and participated in seminars on probabilistic risk analyses for nuclear power plants, reliability studies, and risk assessment.

7. I was an editor of G. Apostolakis, S. Garribba and G. Volta, Editors, Synthesis and Analysis Methods for Safety and Reliability Studies, Plenum Press, 1980, and I wrote the chapter on "Bayesian Methods in Risk Assessment" in Advances in Nuclear Science and Technology, J. Lewins and M. Becker, Editors, vol. 13, Plenum Press, 1981.

8. I have authored and co-authored the following articles:

Madrid, A., Apostolakis, G., and Conn, R. W., "On the Development of Accident Sequences Involving Tokamak Impurity Control System," Nuclear Technology/Fusion, 4:1135-1140, September 1983.

Mosleh, A., and Apostolakis, G., "A Method for Estimating Fragility Curves Using Expert Opinions," Paper M3/4, 7th International Conference on Structural Mechanics in Reactor Technology, Chicago, Illinois, August 22-26, 1983.

Apostolakis, G., "Time-Dependent Accident Sequences," presented at the U.S.-German Joint Seminar on Structural Risk Analysis, Columbia University, New York, May 18-20, 1983.

Apostolakis, G., "Data Analysis in Risk Assessments," Nuclear Engineering and Design, 71:375-381, August 1982.

Apostolakis, G., Kazarians, M., and Bley, D. C., "Methodology for Assessing the Risk from Cable Fires," Nuclear Safety, 23:391-407, July-August 1982.

Apostolakis, G., "Bayesian vs. Classical Methods in Probabilistic Risk Analysis," presented at the Symposium on

Quantification of Risks: Reducing the Uncertainties, Annual Meeting, Pacific Division, American Association for the Advancement of Science, Section P, Industrial Science, Santa Barbara, California, June 21-22, 1982.

Mosleh, A., and Apostolakis, G., "Models for the Use of Expert Opinions," presented at the workshop on low-probability/high consequence risk analysis, Society for Risk Anaysis, Arlington, Virginia, June 15-17, 1982.

Kazarians, M., and Apostolakis, G., "Modeling Rare Events: The Frequencies of Fires in Nuclear Power Plants," presented at the workshop on low-probability/high consequence risk analysis, Society for Risk Analysis, Arlington, Virginia, June 15-17, 1982.

Siu, N. O., Apostolakis, G., "Probabilistic Models for Cable Tray Fires," Reliability Engineering, 3:213-227, May 1982.

Mosleh, A., Apostolakis, G., "Some Properties of Distributions Useful in the Study of Rare Events," IEEE Transactions on Reliability, R-31:87-94, April 1982.

Moieni, P., Apostolakis, G., Cummings, G. E., "On Random and Systematic Failures," Reliability Engineering, 2:199-219, July 1981.

Apostolakis, G., and Kaplan, S., "Pitfalls in Risk Calculations," Reliability Engineering, 2:135-145, April-June 1981.

Kaplan, S., Garrick, B. J., and Apostolakis, G., "Advances in Quantitative Risk Assessment; The Maturing of a

Discipline," IEEE Transactions on Nuclear Science, NS-28:944-946, February 1981.

Wu-Chien, J. S., and Apostolakis, G., "On Risk Aversion in Risk Acceptance Criteria," Reliability Engineering, 2:45-52, January-March 1981.

Chu, T. L., and Apostolakis, G., "Methods for Probabilistic Analysis of Noncoherent Fault Trees," IEEE Transactions on Reliability, R-29:354-360, December 1980.

Apostolakis, G., and Chu, T.L., "The Unavailability of Systems Under Periodic Test and Maintenance," Nuclear Technology, 50:5-15, Mid-August, 1980.

Apostolakis, G., and Kazarians, M., "The Frequency of Fires in Light Water Reactor Compartments," ANS/ENS Topical Meeting on Thermal Reactor Safety, Knoxville, Tennessee, April 7-11, 1980.

Apostolakis, G., Kaplan, S., Garrick, B. J., and Duphily, J. R., Data Specialization for Plant Specific Risk Studies," Nuclear Engineering and Design, 56:321-329, 1980.

Apostolakis, G., Kaplan, S., Garrick, B. J., and Dickter, W., "Assessment of the Frequency of Failure to Scram in Light Water Reactors," Nuclear Safety, 20:690-705, November-December 1979.

Lee, T. Y., Okrent, D., and Apostolakis, G., "A Comparison of Background Seismic Risks and the Incremental Seismic Risk Due to Nuclear Power Plants," Nuclear Engineering and Design, 53:141-154, June 1979.

Apostolakis, G., and Mosleh, A., "Expert Opinion and Statistical Evidence: An Application to Reactor Core Melt Frequency," Nuclear Science and Engineering, 70:135-149, May 1979.

Salem, S.L., Wu, J. S., and Apostolakis, G., "Decision Table Development and Application to the Construction of Fault Trees," Nuclear Technology, 42:51-64, January 1979.

Chu, J., and Apostolakis, G., "On the Probability of Loss of dc Power Following ac Failure in a Nuclear Power Plant," Nuclear Technology, 40:149-158, September 1978.

Lee, Y. T., Okrent, D., and Apostolakis, G., "An Evaluation of the Incremental Seismic Risk Due to the Presence of Nuclear Power Plants," American Nuclear Society Topical Meeting on Probabilistic Analysis of Nuclear Reactor Safety, Newport Beach, California, May 8-10, 1978.

Apostolakis, George, and Mosleh, Ali, "A Study on the Quantification of Judgment," American Nuclear Society Topical Meeting on Probabilistic Analysis of Nuclear Reactor Safety, Newport Beach, California, May 8-10, 1978.

Apostolakis, George, "Probability and Risk Assessment: The Subjectivistic Viewpoint and Some Suggestions," Nuclear Safety, 19:305-315, May-June 1978.

Kazarians, M., and Apostolakis, G., "On the Fire Hazard in Nuclear Power Plants," Nuclear Engineering and Design, 47:157-158, May 1978.

Salem, S. L., Apostolakis, G.. E., and Okrent, D., "A

New Methodology for the Computer-Aided Construction of Fault Trees," Annals of Nuclear Energy, 4:417-433, 1977.

Apostolakis, G. E., and Bansal, P. P., "Effect of Human Error on the Availability of Periodically Inspected Redundant Systems," IEEE Transactions on Reliability, R-267: 220-225, August 1977.

Wu, J. S., Salem, S. L., and Apostolakis, G. E., "The Use of Decision Tables in the Systematic Construction of Fault Trees," International Conference on Nuclear Systems, Reliability Engineering and Risk Assessment, Gatlinburg, Tennessee, June 20-24, 1977.

Apostolakis, George, and Lee, Yum Tong, "Methods for the Estimation of Confidence Bounds for the Top-Event Unavailability of Fault Trees, Nuclear Engineering and Design, 41:411-419, May 1977.

Apostolakis, George E., "The Effect of a Certain Class of Potential Common Mode Failures on the Reliability of Redundant Systems," Nuclear Engineering and Design, 36:123-133, January 1976.

Hsieh, T., Okrent, D., and Apostolakis, G. E., "On the Average Probability Distribution of Peak Ground Acceleration in the U.S. Continent Due to Strong Earthquakes," Annals of Nuclear Energy, 2:615-624, December 1975.

* * * * * *

Apostolakis, George E., "An Analytical Estimate of the Error in Conventional Point Kinetics Reactivity Due to Spatial Effects," Nuclear Science and Engineering, 53:141-152, February 1974.

George Apostolakis

GEORGE APOSTOLAKIS

Subscribed and sworn to before me
this 14th day of October, 1983.

Judith M. Ranger

Notary Public in and for Said
County and State

JUDITH M. RANGER
NOTARY PUBLIC - CALIFORNIA
COUNTY OF LOS ANGELES
My Commission Expires July 10, 1985

KI:ki 2:6

REBUTTAL EXAMINATION

BY MR. STRUMWASSER:

Q Professor Apostolakis, have you reviewed the prefiled direct testimony of PG&E's Panel 6, written by Dr. Kaplan?

A I have.

Q Are there any areas in which you agree with the testimony of Dr. Kaplan?

A Yes.

Q Would you describe that for the Board, please?

A I agree with the general framework that Dr. Kaplan has developed. I think it sheds a lot of light into the issue of the design errors and how to handle them in a probabilistic framework. And it's a very useful first step towards a quantitative analysis.

Q What in particular are you talking about when you speak of the "analytic framework"?

A Like his definitions of design elements, the general use of Bayes' theorum. I found the diagrams that are in the testimony very useful.

Q Let me direct your attention, if I may, to Part 7 of the testimony, in particular to Section 7.2.

Do you have a copy of the prefiled direct testimony there?

A Yes, I do.

Q In Section 7.2, Dr. Kaplan applies Bayes' theorem

KI:ki 2:7

to what he --

A What page is that, please? Oh, okay,I found it.

Q Do you agree with the way Dr. Kaplan applies and documents the use of Bayes' theorem?

A Again, I agree that you can use Bayes' theorem in such a context, and I like the fact that the use of the theorem here, as usual, makes the whole quantification process visible and explicit.

However, I have some reservations about other aspects of the analysis.

Q Would you identify the nature of the reservations?

A I think there are a few omissions in this analysis. As I say in my testimony, there is a considerable body of evidence that suggests that people in general have difficulties expressing their beliefs and state of knowledge in terms of probabilities. And there is also the issue of unintended biases, and I --

Q That was "unintended biases"?

A Right.

And I did not see any discussion of that fact in Part or Section 7.2 of the testimony.

Furthermore, when you use Bayes' theorem to incorporate the opinions of experts into your own body of knowledge and beliefs, you have to assess the credibility of the numbers that the experts are giving you,and there is no

KI:ki 2:8

discussion of that here either. And that discussion, I believe, would have helped the Board.

JUDGE JOHNSON: May I ask a question? Are you dealing primarily now with the "prior" that Dr. Kaplan uses of .001 as the likelihood of finding significant error?

THE WITNESS: It's both the prior and the likelihood, but primarily the prior, yes, because the likelihood also is an expert's opinion.

BY MR. STRUMWASSER:

Q That's the likelihood of detection?

A Right. The .15, I believe.

JUDGE JOHNSON: Oh, okay. Sure.

I had primary reference to the prior, .001.

THE WITNESS: Primarily, I'm referring to that, yes.

JUDGE JOHNSON: Okay, carry on.

BY MR. STRUMWASSER:

Q Well, Dr. Apostolakis, is the -- I believe you were discussing your reservations about Dr. Kaplan's using documentation of the Bayes' theorem.

A There's one more, I believe.

Q Go ahead.

A One additional piece of information, I think, that would have been helpful in this chapter would have been a sensitivity analysis to see how the prior distribution, the

KI:ki 2:9

.999 of zero errors, how the prior distribution affects the posterior distribution, and how different the prior distribution would have impacted on the posterior distribution.

Q Is there any relationship between the factors you discuss -- the weakness of people assessing probabilities, and the possibility of unintended bias -- and the prior that DCP has given?

A What is the question again?

Q In your view, is there any relationship between these factors -- the infirmities of human assessment of probabilities -- and the prior that Dr. Kaplan uses?

A I believe there is because, first of all, in general, part of your state of knowledge is that indeed people have difficulties expressing their beliefs in terms of numbers. You ought to see some kind of a discussion of that in any assessment of prior distributions or subjective distributions. But I believe, especially in this case, that would have been much more appropriate because of what I would call a strong prior that has been proposed.

Q You described the DCP's prior as "strong." Is that the term you used?

A That's the term I'm using. It expresses strong beliefs, I would say.

Q Do you recall Dr. Kaplan's testimony on cross examination regarding the information that went into the DCP

KI:ki 2:10

prior?

A Vaguely, yes.

Q Well, do you recall the testimony that the DCP was including both the knowledge, information available as of November of '81, and other information that was obtained subsequently?

A Yes, I do.

Q Does that kind of information validly go into a prior?

A In principle, yes. Even though the name "prior" suggests that there is some chronological order, there is nothing in Bayes' theorem that says that you have to follow a chronological order.

On the other hand, if you have certain information available to you, and then you decide that you will exclude part of that information and develop a prior distribution based on the rest of the information that's available to you, then again you have all these problems that I mentioned earlier that have to do with the ability of people to express their opinions in terms of numbers. It is a very difficult thing to do, in other words.

Q Well, is the filtering of the subsequently-obtained evidence a difficult process, independently a bias?

A The filtering of a -- in the other words, the removal of the information you have in formulating your prior,

KI:ki 2:11

is that a difficult process for people?

A I think it is, yes.

Q In Section 7.1, Dr. Kaplan creates a scale for what he calls "significance of errors."

Do you have an opinion on that scale?

A Well, I believe that it would be difficult to use the scale because the definition is not very clear of the three regions, and I also have problems with the notion of addressing the issue of significance of errors in a context outside the probabilistic risk analysis.

Q Do you recall my asking Dr. Kaplan to recalculate his posterior based on different prior distribution and likelihood?

A I do.

Q Do you know where the numbers I gave him came from?

A I gave them to you.

Q What do those numbers represent? We're talking now about the .4.3.3 prior in particular. What does that represent?

A Well, the idea was to do two things with that. As I said earlier, it's always useful to a decision-maker to know how sensitive the posterior distribution is to the prior distribution. And since that was not done in Section 7.2 of the testimony, I felt that maybe we ought to do that calculation to see what results one gets.

KI:ki 2:12

On the other hand, you don't want to just do numerical exericses and just use priors that are completely meaningless. And I thought that that particular prior of .4.3.3 is a prior that a reasonable person could have at the end of 1981.

Q There was also testimony about what was called "synergistic effects of errors." Do you recall that?

A I do.

Q And Dr. Buck expressed an interest in such examples of synergism. Do you have any information to enlighten us on this question?

A Yes. I believe that during the cross examination, the word "synergistic" was interpreted to mean non-linear effects of different things. And that's not exactly what I had in mind when originally I raised the issue.

As Dr. Kaplan said, that is not a word that is used in a PRA context. But what bothered me, though, was the fact that in the testimony of Part 6, the issue seemed to be how many errors there were, and then how many safety-significant errors there were. And I have a problem with that, with the safety significance of the errors.

And I don't think that -- well, I believe that you ought to look at these errors again in a PRA context, where the possibility of two or three errors coexisting would be analyzed. And it is possible, it seems to me, if you look

KI:ki 2:13

at them in isolation, to dismiss a particular kind of error as being insignificant, whereas in fact that error could, in combination with something else, lead to something serious.

A quick example: In one of the PRAs that I worked on, we found that a fire in a particular room, in combination with the unavailability of a turbine-driven pump, which unavailability had nothing to do with the fire, that combination would lead to core damage.

So I can see now someone doing this kind of analysis and, say, looking at fires and dismissing that fire as being unimportant because that particular fire, by itself, cannot lead to core damage.

So the whole issue was raised in the context of the PRA and how significant these errors are or could be.

JUDGE JOHNSON: May I?

I for one was having trouble with the use of the word "synergism," and it seems to me that from what you just said, synergism is an improper word.

You're looking at combination or chains of failures as opposed to synergistic effects of combined failures.

THE WITNESS: That is correct.

JUDGE JOHNSON: Okay. You agree, then, that the word "synergism" is not entirely correct.

THE WITNESS: It was not a proper use.

JUDGE JOHNSON: Or not what you had in mind, anyway.

KI:ki 2:18

THE WITNESS: That's right. Yes.

JUDGE JOHNSON: Since I've got your attention and have interrupted, you mentioned the lack of a sensitivity analysis with respect to Dr. Kaplan's testimony at 7.2.

Since the arithmetic display there is relatively simple, and the role played by the prior is relatively simple analytically, is the fact that there was not a sensitivity study done of particular importance?

I mean I have done a sensitivity study in the sense of determining what variation in the prior would do to the ultimate result. And I think anyone with analytical ability would be able to do that.

Is that not -- I mean am I missing something?

THE WITNESS: I don't believe you're missing anything.

JUDGE JOHNSON: I mean the strength of the prior in the final -- in terms of its effect on the final result is fairly obvious; is it not?

THE WITNESS: Well, it depends on how well you understand Bayes' theorem. But I agree with you --

JUDGE JOHNSON: I don't understand it at all.

(Laughter.)

THE WITNESS: I agree with you. Yes, it's fairly obvious.

End 2

MR. STRUMWASSER: I have no further questions.

31b1

JUDGE MOORE: If I remember the compromise struck, Joint Intervenors are now to cross examine.

CROSS EXAMINATION

BY MR. REYNOLDS:

Q Dr. Apostolakis, at page 2 of your testimony, you describe some of the experience that you have had in the nuclear industry. You indicate, at line 21, that you have served as a consultant to Pickard, Lowe and Garrick, Incorporated. Could you tell us what that organization is?

A It is a consulting firm located at Irvine, California.

Q Do you know for whom your work was done, with respect to the Oyster Creek facility?

A Yes. It was a utility that owns the plant, Jersey Central Power and Light, I believe.

Q What about the Zion facility?

A It was the utility that owned the facilities.

Q And the Indian Point facility?

A The same.

Q Would you consider yourself to be pro-nuclear, or anti-nuclear, or either?

A How do you define pro --

Q Do you favor nuclear power?

A Not uncritically. I think it's a useful resource that cannot be excluded. That doesn't mean that anything that

31b2

has to do with nuclear I would favor uncritically.

Q And the converse, do you oppose nuclear power?

A A similar answer. I do not oppose it without thinking, I guess.

Q Have you ever worked for an Intervenor in a nuclear power plant licensing proceeding before?

A No.

MR. REYNOLDS: No further questions.

JUDGE MOORE: Mr. Norton?

CROSS EXAMINATION

BY MR. NORTON:

Q Dr. Apostolakis, the number .4.3.3 -- where did that number come from?

A From me.

Q But how did you derive it?

A By just reflecting on the situation and trying to see whether a distribution like that could be reasonably given by a person at the end of '81.

Q Does your testimony accurately reflect the materials you have reviewed in this case?

A To the best of my ability, yes.

Q I think you're going to have to move the microphone. You're looking at me.

And so you picked the number based on the information you have. You obviously didn't pick it on information somebody

else had.

A On the information that I had.

Q Do you believe that Dr. Kaplan is a reasonable person?

A Yes.

Q I believe you said that you needed reasonable people to come up with priors and I think that was part of the terminology in response to Mr. Strumwasser's questions, wasn't it?

A That's part of what you need, yes.

Q Do you have any reason to believe that Mr. Anderson and the people, the engineers who are familiar with the various disciplines involved, were unreasonable? Do you have any reason to believe that?

A No.

MR. REYNOLDS: Objection. No foundation that he even knows Mr. Anderson or Mr. Moore.

MR. NORTON: My question was do you have any reason to believe they were unreasonable?

JUDGE MOORE: Unreasonable?

MR. NORTON: I believe you answered no?

THE WITNESS: I answered no.

BY MR. NORTON:

Q Dr. Apostolakis, I would like to explore with you a moment now, the question of judgement sampling versus random

sampling and I am going to try and set up a hypothetical, if you will, that is an analogy. It's not about Diablo Canyon.

I want you to assume that you are the decision-maker, if you will. You are the person who has to make the decision in this hypothetical. I want you to assume that you are going to -- your goal is to find out if there is a significant supply, as opposed to an insignificant supply. You're not interested in finding an oil reserve of 1000 gallons, or even maybe 10,000 gallons, but a significant supply of oil.

You are told -- whatever your source is, whatever it was an oil company or whatever -- whoever is in charge of you has told you that North Carolina is where you are to find out if there are any significant deposits of oil or an area say, the size of North Carolina.

Are you with me so far, as to the hypothetical?

A I am.

MR. STRUMWASSER: I'm not. Was he being told that North Carolina had oil or was likely to have oil? Or is that --

MR. NORTON: That's the area in which he was to find out whether there are significant deposits of oil.

BY MR. NORTON:

Q Now you also have available to you a team of geologists who have spent their professional careers working for various oil companies, looking for oil, advising oil companies. And it's their specialty to understand where oil

can be found.

My question to you is would you rely upon those professional people, as to where to look for significant deposits of oil, or would you lay out a grid both on the surface and vertically. And let's say you would label the surface grid with letters and number the vertical grid so that you could -- my kids have a game. You find each side's submarines and you call out a number and a letter and that's where you put the little buttons. You understand the kind of grid I have.

Would you randomly select letters and numbers to go explore for oil -- i.e. various surface locations at various depths -- or would you rely upon the judgment of this team of experts that you have hired from the various oil companies, to advise you as to where you would best look for significant deposits of oil?

MR. STRUMWASSER: I object to the two ambiguities in the question. First of all, that the witness does not have any information about the reliability of this panel of experts and secondly, the implication that the choice is either of those two options and no other.

JUDGE MOORE: I'm sorry, you're last --

MR. STRUMWASSER: That he must either randomly sample or go where the geologists tell him. That those are the only two options available to him.

MR. NORTON: Those objections can certainly be taken care of on redirect, Your Honor.

JUDGE MOORE: I think the witness has enough information to answer the hypothetical. Overruled.

BY MR. NORTON:

Q Which of those two would you do?

A Well, given what you said, I would rely on the experts.

Q Now I want you to further assume that the experts do a couple of things. One, they go down through the entire vertical, where they look where they think there may be oil. They don't stop at 500 feet or 5,000 feet but they go as far as they can go.

MR. STRUMWASSER: The China Syndrome?

BY MR. NORTON:

Q In a number of spots --

JUDGE MOORE: Excuse me. Counsel we will have no more of that, from any counsel. Go ahead, Mr. Norton.

BY MR. NORTON:

Q That these people pick the locations and they drill all the way down. But in addition to that, as they drill down, they -- on occasion -- hit a strata which -- to the geologist -- is promising, that that type of geologic strata increases greatly the probability of there being oil, okay? And that whenever they do that, they then horizontally

31b7

follow that strata through the whole region, the whole North Carolina if you will. Each time they find that strata, they go all across the whole surface -- that they can somehow follow that strata, obviously.

All right. Are you with me, so far?

A It's very familiar, yes.

Q All right. When they get all done, they have found no significant deposits of oil. They have looked in those places where they believe it would be found, completely vertically. In addition, when they found these promising leads, if you will, they have looked horizontally throughout the entire population and they have found no oil.

Would you say that they could make reasonable inferences about the lack of oil in the unsampled population?

A They could.

Q All right. Now the final part of the analogy, or the hypothetical, I want to give you is that, in going vertically and horizontally they have, in effect, looked at 75 to 80 percent of the population. Would you feel, given that additional information, that you now have a value as to what percentage they looked at, that they would have a great deal of confidence about the remaining 20 to 25 percent that they didn't look at? That it didn't contain any significant deposits of oil because now they have looked at 75 to 80 percent of all the squares, both horizontal and vertical.

31b8

A Yes. They would have a degree of confidence that there is no oil, yes.

Q Do you think they would have reasonable assurance that there is no oil?

A Yes.

Q Do you think they would have reasonable assurance that there is no oil in that unexplored 20 percent, 25 percent, no significant deposits?

A Well, in that situation, of course, it's somebody's money that is involved.

Q I haven't put money into this at all. Do you think they would have reasonable assurance that that 20, 25 percent they have not sampled, did not have significant deposits?

MR. STRUMWASSER: The term "reasonable assurance" is undefined, ambiguous.

JUDGE MOORE: I think it can be understood for whatever it means, in common parlance.

THE WITNESS: Yes. They could have reasonable assurance, I guess.

end t3

41b1

JUDGE JOHNSON: Are you through with that analogy, Mr. Norton?

MR. NORTON: I may come back to it, but I'm through with it at this moment, sir.

JUDGE JOHNSON: May I ask the witness a couple of questions, with respect to it?

MR. NORTON: Please feel free, sure.

JUDGE JOHNSON: It is clear to me -- I assume it is clear to you, the analogy that is being made between the IDVP or the Verification Program at Diablo Canyon, through the oil exploration.

THE WITNESS: Yes.

JUDGE JOHNSON: In your mind, is there a difficulty in this analogy, because with respect to the oil exploration team finding oil is their desired goal, and in the Verification Program finding a significant error is an undesired goal? Do you think that aspect of the search, without attempting to impune the searchers in either case, would have any bearing on the validity of the analogy?

MR. NORTON: Excuse me, Your Honor, I want to make a record on that question. Obviously, it's going to be asked and answered, but I would object for insufficient foundation that it was the goal not to find significant errors. I don't know if there's any of that in the record --

JUDGE MOORE: This is Dr. Johnson's hypothetical,

41b2

Mr. Norton.

MR. NORTON: I understand that. I just wanted to make the record.

JUDGE JOHNSON: If I used the word goal, I misspoke. The desired thing, in one hand -- on the one hand, was to find oil. An undesireable event, on the other hand, would be to find a significant error. Does that situation, in your opinion, have any effect on the analogy?

THE WITNESS: I think so. I think it does have an effect, yes.

JUDGE JOHNSON: In what way?

THE WITNESS: I believe that -- although, I must say I have not really thought about this problem of oil exploration very much, but I think it is a much more complex problem to try to find the errors in a design of a nuclear power plant than finding oil.

JUDGE JOHNSON: All right. Let me ask another question, then. And again, I am questioning the validity of the analogy. In the design of the nuclear plant there is, to some degree, a thread of continuity that runs throughout the design. In other words, with respect to oil, whether oil exists at location elevation minus grid position xy is more or less independent, totally, of whether there is oil somewhere else, at least from the standpoint of sampling I think.

In the Design Verification Program, the original

design which might be subject to error was made by a group of people. And ingeneral, the same overall group of people did the whole design. So if you sample, as the Verification Program did, from a considerable percentage of the whole -- Mr. Norton used 75 to 80 -- does the fact that the work was done by one group of people change your opinion as to the relative degree of assurance you have that there will be an error -- as opposed to the degree of assurance you have that there will be oil. If you sample 75 to 80 percent of the state of North Carolina and its underlying strata. That was a very complicated question. Do you understand what I'm asking?

THE WITNESS: I think I do, but I think one of the problems is that it was not one group of people who designed the whole plant. And that could be a cause for concern, reducing the assurance that one would have. I don't know what the analogy would be now, in the oil exploration problem, but I think the fact that there were different groups of designers involved is definitely a difference. And that would --

JUDGE JOHNSON: Now if every single element in the plant was designed by a different group, that would make the analogy to the oil exploration almost precise, wouldn't it?

THE WITNESS: I don't know why I can't say yes, but I don't feel like saying yes.

41b4

JUDGE JOHNSON: Okay, fine. That's a perfectly fair answer and I will terminate my line of questioning there.

JUDGE MOORE: Mr. Norton, proceed.

BY MR. NORTON:

Q Dr. Apostolakis, in your testimony, have you not concluded that in a design verification program there would be considerable difficulty in designing and estimating an error rate and further difficulties in using an error rate for decision making?

MR. STRUMWASSER: Compound.

MR. NORTON: I agree, it is.

JUDGE MOORE: Split it.

MR. NORTON: Sure.

BY MR. NORTON:

Q Dr. Apostolakis, in your testimony, have you not concluded that in a design verification program there is considerable difficulty in designing and estimating an error rate?

A Yes.

Q Haven't you also -- the same thing -- as an error rate, that there would be further difficulties in using the error rate for decision making?

A Yes.

Q Would you then agree that the question of interest, for this Board, in connection with the non-seismic review is

not "what is the error rate" but is there a significant safety error which remains undetected?

A I have a problem with that. I keep going back to the contentions and I don't think that's the issue here, whether there is safety significant error. I thought the issue was whether the plant complied with the license criteria.

Q You do not believe the issue before this Board is whether or not there is a significant safety error out there?

A In a broader sense it may be, but I don't think that that's their issue, no.

Q On page 13 -- 14, the question is on the bottom of page 13 and the answer is on the top of page 14.

A Of what?

Q Your testimony, I'm sorry. Did you not state that "it is possible" to estimate the frequency of design errors in a nuclear plant?

A Yes.

Q All right. In describing how to do this, you give an example, on page 14, of selecting the wrong design question, correct?

A Yes.

Q Then you say you would "consider the universe of such selections and apply random sampling", correct?

MR. STRUMWASSER: I think that mischaracterizes his testimony. He doesn't say he would. Everything there is

put in the hypothetical.

MR. NORTON: Your Honor, the words say "we could then consider the universe of such selections". I mean, if his testimony is all hypothetical and they want to stipulate to that, I won't cross examine anymore.

JUDGE MOORE: You won't get that stipulation, Mr. Norton. I think the question was proper. Go ahead.

BY MR. NORTON:

Q Do you want me to repeat it for you?

A Yes, please.

Q You say that you could "consider the universe of such selections and apply random sampling." Do you not?

A Yes.

Q For that phrase, "consider the universe of such selections" am I right in understanding that the population you have in mind is the set of "selections" made during design?

A Yes.

Q Is this set of selections about the same idea of what Dr. Kaplan called "the set of design decisions" in his testimony?

A I remember there was a distinction between design decisions and design elements. You are making that distinction now?

Q I'm asking you if your selections, you said you can consider the universe of the selections. Are those

selections the design decisions that Dr. Kaplan was talking about?

A I believe they are, yes.

Q All right then, in Dr. Kaplan's testimony, this would be the set of balls in the Ball and Urn language, wouldn't it?

A It would, yes.

Q All right. And then the frequency you are talking about here would be the fraction of selections or design decisions that are in error, correct?

A Correct.

Q Have you made any attempt to delineate this set of design decisions? That is, to define the balls for Diablo Canyon?

A No.

Q Any other nuclear power plant -- all the design decisions?

A No.

Q Do you have any evidence that this has ever been done, that anyone has ever sat down and made a list for any nuclear power plant in the world, of all of the design decisions?

A No.

MR. STRUMWASSER: Excuse me. At some point here, in this line of questions, we went from designating -- enumerating all of the selections of design pressure to designating

all of the design decisions and I'm not sure at what point the witness's questions -- the witness's answers switched from design -- selections of pressure to selections of just all design decisions. I'm not sure when Mr. Norton started asking that question.

JUDGE MOORE: Mr. Strumwasser, as I followed the line of questioning I think you missed the hookup with Dr. Kaplan's use of the terms with which Dr. Apostolakis has agreed.

MR. STRUMWASSER: I understand that and I didn't object. And perhaps I should have. But the problem has now gotten incorporated in some subsequent answers. The question was whether selection of design pressure is a design decision like Kaplan uses. And the answer is yes. But that did not necessarily mean that all of the design decisions constituted selections of design pressure.

JUDGE MOORE: I don't think the question carries any such implication. Go ahead, Mr. Norton.

MR. NORTON: Thank you.

BY MR. NORTON:

Q My last question -- and I'm not sure whether your answer got recorded -- was do you know whether this has ever been done, a listing of all of the design decisions -- in any nuclear power plant anyplace in the world? And I believe your answer was no?

41b9

Is that correct?

A That is correct.

Q What evidence do you have that that is a feasible or workable thing to do, to sit down and actuall, literally do that?

MR. STRUMWASSER: List all design pressures or all design decisions?

JUDGE MOORE: Design decisions is what was clear from his question.

JUDGE JOHNSON: May I interrupt here, Mr. Strumwasser? In reading the paragraph that Mr. Norton is using, he is using -- he is saying that we are working with well defined events, like selecting the wrong pressure, and we could then consider the universe of such selections. So it doesn't appear, to me, that Dr. Apostolakis -- in that particular portion of testimony -- was specifying that selecting of pressure was any more than giving an example of the various well defined events that he was talking about.

MR. STRUMWASSER: But I don't think the testimony is that all design decisions are equally well defined.

JUDGE MOORE: Continue, Mr. Norton.

end t4

MR. NORTON: I'm not sure what my last question was.

JUDGE MOORE: The question was why it hasn't been done essentially.

MR. NORTON: Okay, it was a feasible, workable question.

BY MR. NORTON:

Q Do you believe, or do you have evidence -- what evidence do you have that this is a feasible, workable thing to do, to literally list every single design decision in a nuclear power plant?

A Well, as I said, I don't think anybody has done this and I believe I do acknowledge in my testimony that that would not be a very straightforward or easy thing to do. However, from my general knowledge of modeling things, especially in the PRA context, I don't think that that would be possible. And in fact, that belief I think was strengthened after I saw Dr. Kaplan's testimony.

Q Have you considered that the design decision -- you're talking about hundreds, of not a thousand or more, engineers working on a project, in this case for 15 years -- how many design decisions there would be? Do you have any ideas of the even orders of magnitude of how many decisions that would be?

A There would be quite a few.

Q Do you have any idea of how many years it would take to do that, by how many people?

A Well, I think I know where you are going, but on the other hand, I do have Kaplan's testimony which I think shows you can do that, or something like that, in a reasonable amount of time.

Q Didn't Dr. Kaplan say take these numbers and this process with a very large grain of salt?

A I believe he did.

Q Okay. Have you discussed this with the various discipline engineers that you would need to rely on to do such a listing of design decisions? Projects such as mechanical, electrical, piping, on and on and on?

A I have not.

Q Have you ever heard of the old saying, nothing is impossible for the man who doesn't have to do it himself?

(Laughter.)

A I have not.

Q Now you have.

A Now I have.

Q Let's just assume then -- I want to carry this further. Just assume it's possible to delineate these design selections or decisions. Then you have to define design error, don't you? That's the next step.

A Yes.

51b3

Q You say, in your testimony at page 14 line 2, do you not, that there is no general definition of design error?

A Yes, sir.

Q Have you ever attempted to make such a definition?

A I have attempted, yes.

Q In what situation? What context?

A I had a research project once where one of my graduate students was working on this issue and we thought about the problem a little bit.

Q Has your definition been accepted as workable and useable by those who would need to use it?

A I didn't say I had a definition.

Q Who are you assuming would be the ones to come up with this definition?

A Knowledgeable people, in general.

Q People like the people who did the IDVP in this case?

A They would certainly have a strong input, yes.

Q Have you discussed -- not those specific people, but with those types of people, the feasibility or realism of coming up with this term, with this definition?

A Definition of a design error?

Q Yes.

A I don't recall specific discussion, no.

Q All right. Then let's assume that we have gotten over this hurdle now. You have defined a population of design

51b4

decisions which are the balls, the Ball and Urn problem, correct?

A Yes.

Q And you defined error, which we call black, for black balls, okay?

A Okay.

Q So there would now exist a frequency in the population and you would then attempt to apply classical sampling techniques to estimate this frequency, correct?

A Do I ever say that you would apply classical sampling techniques?

Q Would you apply random sampling?

MR. STRUMWASSER: To do what?

BY MR. NORTON:

Q To arrive at that decision frequency rate.

A The frequency rate of these errors in that well-defined sampling, yes I would.

Q Okay. Well, then that is classical sampling technique.

(Off the record)

MR. NORTON: I have to revisit where I am.

JUDGE MOORE: It is nice to know it's not only my lapses occurrin

MR. NORTON: Unfortunately, the longer this case goes on, the older I get, the more frequent the lapses.

JUDGE MOORE: I suffer from the same infirmity.

THE WITNESS: I don't think the principles of random sampling are limited to classical statistics.

51b5

BY MR. NORTON:

Q I didn't say they were, but they are classical statistics, are they not?

A They're also Bayesian. Yes, you are right.

Q All right. The first thing you need to do then, is select design decisions at random to look at. Isn't that true?

A Yes.

Q How do you do that, roll the dice?

A That's one way to do that, yes, or use a more sophisticated thing like --

Q A table of random numbers?

A Right.

Q So then I take it you would make -- you would have this list, which I presume hopefully would be on a computer so that nobody would have to hire a truck to carry it around and you would give each one a number, correct -- or a letter or whatever? Some identification, each design decision?

A Yes.

Q Then you would take a table of random numbers and select the numbers to check the corresponding decision, right?

A Yes.

Q Then you would decide if it was an error or not, correct?

A Yes.

51b6

Q Do you believe the exercise we just went through is what the Independent Design Verification Program should have done in this case?

A Only what we just discussed? No. I do not believe so.

Q Do you think -- I have to explore that answer. Do you think they should have done what we just discussed, plus something else?

A Yes.

Q Do you think they should have gone through this exercise that has never been done, listing every single design decision ever made at Diablo Canyon? Do you think they should have done that?

A I can't say right now that yes, they should have done it and if they don't do it, you know, the world collapses around them. But it sounds like something that maybe ought to have been done, yes, at this point. I would have to do more thinking, but yes.

Q If you did that, would you have 100 percent assurance that there were no significant design errors?

MR. STRUMWASSER: There's missing foundation here. He hasn't told us how many black balls he got.

BY MR. NORTON:

Q Let's assume you've got the same number of black balls that the IDVP has gotten out of the way it has done it.

51b7

Okay? And they are of the magnitude that the IDVP has found and that you can extrapolate that number to the other 75 -- excuse me, the other 25 percent unsampled. But that's what you end up with that sampling process.

MR. STRUMWASSER: Objection. That assumes facts contrary to the evidence. The IDVP did not sample 75 percent of the balls.

JUDGE MOORE: Mr. Norton, do you mean to assume -- it's an assumption that they did 75 percent?

MR. NORTON: That the plant was reviewed, 75 to 80 percent in the non-seismic, whether it was the IDVP or the ITP. And that the number of errors is constant throughout, that the IDVP discovered throughout the 100 percent.

JUDGE MOORE: With that understanding, please answer the question.

JUDGE JOHNSON: No. Are you saying that 75 percent of the balls in the urn were sampled? The urn being the list of design decisions?

MR. NORTON: No, no. I'll start all over because obviously there's some confusion.

BY MR. NORTON:

Q I want you to assume that you randomly sampled -- pursuant to the thing we just went through -- I have all these things and you end up with an error rate the same as an extrapolated IDVP error rate. Is that question clear

to the Board, now?

JUDGE MOORE: What is the question, now?

MR. NORTON: That hypothetical. Is that clear? I want to ask the question.

MR. JOHNSON: It's not clear to me because you have not specified what fraction of the total you have sampled.

MR. NORTON: Neither did the witness. He just said he would random sample and I'm asking now, when he has finished that process and he comes up with the same error rate, all right?

MR. STRUMWASSER: I'm sorry. Is this the 1.3 percent error rate reported in Dr. Kaplan's testimony?

MR. NORTON: Whatever the error rate is that Dr. Kaplan is familiar with. I don't want to put a quantity on it. Whatever it is.

BY MR. NORTON:

Q We start over again, Dr. Apostolakis. You have done your random sample after having this exercise we have just gone through and you come up with an error rate -- the same as the one the IDVP came up with, okay?

A Okay.

Q Would you have greater confidence in that value than you would in the value that the IDVP came up with?

A Yes, I would.

51b9

Q You would have greater confidence?

A Right.

Q Now in that exercise, we just went through, would you have looked at any total system?

A In that exercise, no.

Q But you'd still have greater confidence?

A At that rate, yes.

Q Would you have looked at each and every disciple, necessarily? Would you have looked at all of the -- I mean, each of the disciplines?

A No, I wouldn't have.

Q You would still have greater confidence?

A Yes.

Q Would you have necessarily ever looked at the engineering process, the process of the outfit that designed the facility? Because you haven't looked at each disciple, or hadn't looked at the total system?

A Again, in the context of the example, no I would not have.

Q But you would still have greater confidence?

A Yes.

Q Would you have looked at how one system relates or interacts with another system?

A In that example, no.

Q And you'd still have greater confidence?

A Yes.

End t5

ki 6:1

JUDGE MOORE: May I interrupt, Mr. Norton, the witness and inquire why you would have greater confidence?

THE WITNESS: Well, I kept saying "in that example."

JUDGE MOORE: In the context of that example.

THE WITNESS: In the context of that example, namely, defining a population of, say, selecting pressures and

S2 BU

then being interested in deriving an error rate. This is a very well-defined problem.

It is what Dr. Kaplan calls a "ball and urn" problem. And it's a well-known problem in statistics. You want to find the error rate with a certain degree of confidence. You use statistical techniques of random sampling, and you do that.

JUDGE BUCK: But I think the example is different, is it not here, because Mr. Norton was taking the sample out of the total design decisions being made, and this is the total reactor, the total set of systems.

What you are considering here is only one system.

THE WITNESS: That's exactly what I was doing.

JUDGE BUCK: That's not the problem, because then you would not have exampled most other systems.

THE WITNESS: I was considering the universe of pressure selections when I gave my answer. That's what I had in my mind.

JUDGE BUCK: I think you better go back and redo it, Mr. Norton.

ki 6:2

JUDGE MOORE: You were speaking of just one component system of the universe, of the larger universe of all the systems, than the nuclear reactor when you were answering.

THE WITNESS: That is correct.

JUDGE MOORE: I think is probably a good time to take a brief recess, and then we will, in 10 minutes, reconvene for you to continue your cross examination, Mr. Norton.

(Recess.)

JUDGE MOORE: Come to order, please.

Mr. Reynolds, I would appreciate it if you would keep a closer eye on the clock.

Mr. Norton, continue with your cross examination.

BY MR. NORTON:

Q I'm not sure exactly where that last exchange with the Board left us, Dr. Apostolakis. But you don't think when I was talking about the signed decisions during the last half hour and asking you about how many man-years it would take and had it ever been done, and so on and so forth, I was just talking about the decisions for pressures, did you?

A No. Those original questions, I don't think you were talking just about pressures.

Q Where is it you thought I switched to pressures?

A When you asked me about the rate.

Q The error rate?

ki 6:3

A And whether I would have higher confidence in that number that I would have derived, using random sampling. I thought you were talking about the well-defined problem.

Q We were talking about the design decisions -- we were talking about the universe of design decisions, the total world of the design decisions.

Remember, we said it would be truckloads. Hopefully, it would be on a computer, because it would be so long that they would carry around those design decisions?

JUDGE MOORE: Mr. Norton, it's your record, but I would suggest you back up and do it again, and get on with it.

BY MR. NORTON:

Q I hope to avoid that.

Is that where you thought I was talking about design pressures, where I said we have assigned them random numbers from a random number table? You thought that was pressures, as opposed to the universe of design selections or design decisions?

A Yes. I thought it was pressures.

Q All right.

If it were the universe of design decisions, would your answers be different? Would they be different than they were?

A So that would be now the universe of all conceivable

ki 6:4

decisions, design decisions?

Q Yes.

A And we randomly sampled?

Q Right.

You have assigned a number to each of the design decisions made over a 15-year period, and then you use a table of random numbers and pull a sample, and the ultimate question was, you came up with an error rate, right?

A Right.

Q Would you have more confidence in that error rate than you would in the independent design verification program's error rate that Dr. Kaplan came up with?

And I believe I asked you to assume that the two numbers came out the same, 1.3 percent, or whatever they were.

A I'm trying to recall what Dr. Kaplan did with the design elements That's where I think he defines the 1.3 percent.

Q Yes. He made some rudimentary number of design elements as opposed to every single design decision, which would obviously be in the millions.

MR. STRUMWASSER: Now, does the hypothetical use design elements or design decisions?

MR. NORTON: Design decisions; every design decision made from the beginning of the project until November 1981.

MR. STRUMWASSER: And that's the thing that's got

ki 6:5

the 1.3 percent error rate?

MR. NORTON: Sure. As a result of your random sampling.

BY MR. NORTON:

Q I'm asking if you have more confidence in that number than you would in the number derived from the IDVP, when you consider that in your random sampling, you never look at a total system, you never look at one system and how it interacts with the other, and so on and so forth, because you're just looking at discrete, very discrete pieces.

MR. STRUMWASSER: That's an assumption?

MR. NORTON: That's right. That's what the random is.

MR. STRUMWASSER: You're assuming that the random sample does not include interaction, right?

MR. NORTON: Excuse me. Who's the witness?

JUDGE MOORE: I've been wondering that, between the both of you. I think, as it stands, the witness can answer it, if you gentlemen will give the witness that opportunity.

THE WITNESS: Well, I think a lot of it depends on the way you define the population, what we call the decision elements. It seems to me there are two issues here. One is how you define the population; and, second, given the population, and you want to derive an error rate,

how do you do it?

For the second part, it seems to me that you have to do it using random sampling, and I would also use judgment, what the IDVP calls judgment sampling, because I think that's useful, too.

I still have difficulty seeing how we would define the decision elements, and I'm not saying that's the only way of doing it. But yes, in terms of numbers, I would have higher confidence in sampling that came out of random sampling.

BY MR. NORTON:

Q All right. You've got that number now. Let's say it's 1.3 percent or whatever it is.

A Okay.

Q If you were up there as a member of this Appeal Board making a decision, what would you do with that number?

A I wouldn't know.

Q What would you compare it to?

A There is nothing to compare it against.

Q Assume that instead of going to the design decisions, each and every discrete design decision that was made ,that you somehow made a much more -- somehow were able to make a much more concise, in terms of numbers anyway, strata of systems and you came up with a number like 10 or 20 or 30, however you wanted to define systems. And you randomly sampled those systems, and instead of the auxiliary feedwater

ki 6:7

system and the containment HVAC and the 4 KV systems, which were the three chosen by the IDVP, that instead you randomly came up with the auxiliary feedwater system. We'll say you got that one the same. But then you also came up with a containment hydrogen venting system and another very minor electrical system, and when you went through that review process and you came out with a 1.3 percent non-significant error rate, would you feel more confident in starting the plant up at that point in time because the systems had been chosen randomly, rather than where we are today?

A I think we are mixing here the issues of design errors and the importance of systems. When it comes to design, whether it is a safety-significant system or not, it seems to me, should not be part of the decision. If we are looking at safety-significant systems, which again is a kind of a fuzzy notion in my mind, then I think the question would be much more meaningful.

But the issue of random sampling, it seems to me, is something you should do because of all the reasons I have in my testimony. It protects you against your own biases.

Q Let's talk about bias for a minute. I think Dr. Johnson asked you, in the followup to the oil analogy, he asked I think two questions, one of which seemed to favor the oil and one which seemed to favor Diablo Canyon.

The one that seemed to favor the oil had to do with --

ki 6:8

I think he initially used goal and changed that where he said people looking at Diablo Canyon would be hopeful of not finding significant errors. Would that somehow change your degree of confidence?

Do you recall that question from Dr. Johnson?

A No, I do not.

Q I believe Dr. Johnson asked you -- I think he tried to explain that in an oil field, when you go down and don't find oil here, it doesn't tell you anything about finding oil 20 miles away. Do you recall?

And then he said, if on the other hand, where you're looking at the process and the same people did the design, and you get a feel for the work they did, that does give you some confidence about another system that they designed, or gives you some knowledge about that.

Do you recall that part of it?

A I recall that,yes.

Q That's the other half of it. Do you recall the first half of it, where he asked you about the bias? I don't think he used the term "bias," but was implicating bias on the part of the looker-- when you're looking for oil, there is no bias; you want to find oil --but implied there might be a bias when you're looking for significant errors, you might not want to find the significant errors.

Do you recall that?

ki 6:9

A No, I do not.

Q Well, then let me ask you this. If, in fact, the people looking for the errors stood to gain by finding errors, financially, because if they found significant errors they would have to do more looking and get paid more money, would that influence your feeling about bias of those lookers?

A Yes, it would.

Q Which way would it influence it?

A Which are the two ways they would tend to find errors?

Q Right. If they stood to gain by finding errors, if they were hired to go and look, and part of their program said if you find errors you will look further, would you think they are more likely to find errors than if they were paid not to find errors?

A I think they would be biased, yes, that way. They could be. That's the right word. They "could" be biased.

End 6

T7 mm1

Q Dr. Apostolakis, I am not sure I interpret your testimony correctly, so let me ask you if you are saying in your testimony that the only way to perform an evaluation of safety significance of a design error is by doing a PRA?

A Well a PRA, of course, is not -- it is another one of the not-very-well-defined terms. I do not mean that you would have to do a 7-, 8000 page document each time, to produce a document like that to assess it. But, you can also do PRAs on a smaller scale.

But that is the kind of framework that I like to see, and that is the kind of framework that gives you a quantitative answer to questions like, "What is the margin of safety?" and "How much has it been reduced?" and so on.

That is what I mean. I don't mean that you have to produce something like a Zion PRA all the time.

Q Are you really talking about a mini-PRA?

A It could be, as the case may be.

Q But how many mini-PRAs like that have you done on design errors?

A Me, personally, I don't think I've done any.

Q What are we talking about in terms of volume? You said 6-, 7-, 8000 pages, something to that effect for a PRA. How big is a mini-PRA? Are we talking about 1000 pages, 100 pages, 10 pages?

A Again, the number of pages really is very secondary

mm2

here. What I am talking about is a framework that would allow you to come up with quantitative answers to questions like "What is the margin of safety?" and "How much has it been reduced by this particular error?" and so on.

If it takes half a page to do it, that's fine. If it takes 100 pages to do it, that's fine, too.

Q Would you refer to page 17 of your testimony, please, the bottom of the page where you answer a question regarding the IDVP's judgement concerning the five generic concerns.

A Yes.

Q In essence you are saying that you find the IDVP's classification unconvincing because you could find a "more general concern" isn't that correct?

A Yes.

Q Let's suppose the specific item found was an error in a pipe stress calculation in a particular small bore pipe in the auxiliary building. One could then "generalize" from this specific item to generic concerns in various ways, couldn't one?

A I believe so, yes.

Q For example, one could advance as generic concerns, pipe stress calculations and all small bore piping in the auxiliary building, correct?

A Yes.

mm3

Q Or, pipe stress calculations and all small bore piping in any building, correct?

A Yes.

Q Or pipe stress calculations in any pipe, small or large, correct?

A Yes.

Q Or stress calculations of any type anywhere?

A That's correct.

Q Or calculations of any type anywhere, correct?

A That is correct, too.

Q Where do you draw the line?

A I don't know. That is a very difficult problem, I must say.

Q So you think they were inadequate because you could be more general?

A I don't think I said inadequate.

Q Unconvincing?

A Yes.

Q Put what good is it to be more general? Why is it unconvincing just because you could be more general? I was more general there. Would that make somebody stopping pipe -- stress calculations at all small bore piping inadequate? or unconvincing because they stopped there?

A I would say that they could be unconvincing because they didn't give me all the information, maybe, that

mm4

led them to the particular decision they made. I believe I have an example here.

Q What do you mean they didn't giveyou all the information?

A In what I read.

Q Did you ask for it?

A No, I did not.

Q Do you believe that you are as competent as the Independent Design Verification Program to make those judgments as to where to stop?

A Probably not.

MR. NORTON: Your Honor, I am hesitating because I am, believe it or not, getting rid of a lot of questions, and I apologize for it.

BY MR. NORTON:

Q Let's examine -- you just mentioned those areas of generic concernwhich you identified in your testimony on pages 17 and 18. You state there that the selection of system design pressure and differential pressure across valves has been identified by the IDVP as a generic concern, correct?

A Yes.

Q Are you aware that these items arose from design judgment and code interpretation involving the selection of modes of operation for which a particular system,

mm5

the auxiliary feedwater system, was designed?

A I don't quite follow the question.

Q I read it, and I will try to read it more slowly.

A Okay.

Q The concerns that you have identified, are you aware that those items arose from design judgment and code interpretation involving the selection of modes of operation for which one particular system, the auxiliary feedwater system, was designed.

Are you aware of that fact?

A I don't believe I am.

Q Could you have your counsel supply you with a copy of the Phase II Final Report ITP, please?

(Document handed to witness)

A I have it in front of me.

Q If you would turn to page 3-9.

A Okay.

Q Would you please read to yourself -- well, let me ask you, have you read this before, because this is the three EOIs, 8009, 8010 and 8062. I assume you have not read it because in response to my question you said you weren't aware of it.

Is that a correct assumption?

A I think it is, yes.

mm6

Q You have not read it. Will you take the time to read Section 3.3.4 -- let me strike that.

Page 3-9, 3-10 to the top of 3-11.

(Pause)

Have you read enough to answer my question now?

A The question being whether I was aware that these --

Q Are you now aware of that?

JUDGE MOORE: Repeat the question, Mr. Norton.

BY MR. NORTON:

Q Are you now aware that those EOIs arose from design judgment and code interpretation involving the selection of modes of operation for which one system, the auxiliary feedwater system was designed?

A Yes.

Q All right.

Now, according to the principles set out in your testimony, do you think random samples should have been taken from all other safety related systems where the potential for incorrect system design, pressures, temperatures and differential pressures across valves exist?

A If you are deriving a rate of wrong selection of these parameters, yes you should do it.

Q If your goal is to derive a rate?

A Yes.

Q That's what you should do?

71b1

A Right.

Q How about if your goal is to find out -- strike that.

Are you aware that the Internal Technical Program conducted a 100 percent review by examing all elements of all safety related systems, to assure that temperatures and pressures had been correctly determined?

A Yes, yes. For their generic concerns, yes, that's what they did.

Q Then you have testified that this generic concern that the IDVP should have led to random sample for other system designs, stresses, such as stress, enthalpy, and humidity, correct? And I refer you to pages --

A Yes.

Q Let's examine those parameters. What do you mean by enthalpy?

A Well, that's a well defined notion in thermal dynamics.

Q Could you answer my question.

A What I mean by enthalpy?

Q Yes.

A I believe internal energy plus PV, as I recall.

Q Could you explain it to Judge Moore and myself, who don't understand what you have just said?

JUDGE MOORE: Just Mr. Norton.

(Laughter.)

71b2

MR. NORTON: You don't want to know, huh?

THE WITNESS: It's internal energy plus the product of the pressure and volume of a particular substance.

BY MR. NORTON:

Q How would a mischaracterization of enthalpy lead to a failure to meet criteria or have safety significance?

MR. REYNOLDS: Compound.

MR. NORTON: That's compound, I agree.

BY MR. NORTON:

Q How would a mischaracterization of enthalpy lead to a failure to meet safety criteria?

A Again, I have to answer that in a hypothetical. If the license criteria specify -- and I think this is an example here, it says such as -- and you do not use the right value, then you have violated the criteria.

Q Do you know whether or not there is a criteria for enthalpy?

A No, I cannot give you an example right now, but I don't know that there isn't, either.

Q How would a mischaracterization of enthalpy have safety significance?

A I don't know.

Q Are you aware that by verifying all aspects of all safety related systems for temperature and pressure, the Internal Technical Programs would necessarily have obtained the

71b3

enthalpy as well?

A Would you please repeat the question?

Q Are you aware that by verifying all aspects of all safety related systems for temperature and pressure, the Internal Technical Program would necessarily have obtained the enthalpy as well?

A Oh, I see. It is possible, yes.

Q What do you mean by stress as a system design parameter?

A Force divided by area.

Q What are you referring to, piping?

A It could be, although that probably is part of the seismic review.

Q Well what are you referring to in your testimony?

A I didn't really have specific examples to give you. I just say that it seems to me that pressures, temperatures, and differential pressures across valves is not the only -- are not the only parameters that are dealt with by the license criteria.

Q Right. And you list stress. Are you referring to stress in piping?

A I could, yes.

Q I'm not asking what you could. I'm asking what you are referring to in your testimony. Those were your words, Dr. Apostolakis.

71b4

A Yes, piping or supports.

Q All right. Are you aware that the Internal Technical Program conducted 100 percent review of all large bore piping, for all safety related systems designed by PG&E or its service-related contractors, including stress analysis?

end t7

81b1

A I guess I'm not aware of that. But I'm not surprised they did that.

Q Finally, you mentioned humidity. How could a mischaracterization of humidity -- I won't make it compound this time -- lead to a failure to meet criteria?

A Again, if the criteria deal with humidity, they would give you a number I suppose which, if not applied properly, then would lead to a violation of a criteria.

Q As in the case of enthalpy, you don't know whether there is such criteria or not, correct?

A I do not.

Q How could a mischaracterization of humidity lead to -- excuse me. How could a mischaracterization of humidity have safety significance?

A I cannot give you an example of that.

Q Are you aware that humidity was reviewed, on a 100 percent basis, by the ITP on all safety related systems?

A No. I am not. I was not.

Q You next talk about computer programs, is that correct?

A Yes.

Q Misapplication of computer programs?

A Yes.

Q Are you aware that the ITP did 100 percent review of application of computer programs?

81b2

A No.

Q Dr. Apostolakis, we briefly discussed earlier the subject of difficulty of defining and calculating error rate for design. Again, assuming this could be done, you discuss on page 19 on line 17 and following, the problem of setting a "acceptable" error rate.

A Yes.

Q Have you or anyone else ever proposed a "acceptable" error rate?

A No.

Q On page 19 lines 26 through 27, you refer to the decision to "recast the problem in probabilistic terms." By this do you mean the decision of the IDVP to study a sample rather than to review 100 percent of the design?

A Yes.

Q You say, then, that this decision has made it necessary to establish an acceptable error rate, correct?

A Yes.

Q Is it your view, then, that if we have not defined and calculated lamda in a meaningful and feasible way, and if we have not set an acceptable value for it, then we have no choice but to do 100 percent design review?

A Well, the issue is compliance with the license criteria. Yes. You have no choice.

Q What makes you think 100 percent review would give

you zero defects?

A You mean after you have correct things?

Q Yes. Let's say you do 100 percent review. We've got 100 percent review of the seismic and we've apparently got a 75 to 80 percent review of the non-seismic. And if we did the rest of it, what guarantee would you have that you met your licensing criteria? Would you have a guarantee?

MR. STRUMWASSER: I don't know at what point Mr. Norton considers these hypothetical, but when he keeps throwing in the 75, 80 percent, I object with the grounds that the question assumes facts not in evidence.

MR. NORTON: I thought I remembered Mr. Anderson testifying between the IDVP and the ITP, between 75 and 80 percent of non-seismic was reviewed and I believe it's in the transcript. And I will be happy to -- after the break -- give you a specific page and line cite.

MR. STRUMWASSER: I agree he testified to that effect. He also testified the number was soft and the depth of the review was less than the IDVP. So the question is also misleading, when phrased that way.

MR. NORTON: Excuse me, Your Honor. That's different than there being no evidence.

JUDGE MOORE: It certainly is. Overruled. Continue. But you better ask it again, for the witness.

MR. NORTON: I'll start over. I'll rephrase it.

81b4

new bu

BY MR. NORTON:

Q Assuming that you had 100 percent review, what confidence do you have -- what confidence level do you have that you still don't have some criteria someplace that you have missed?

A I don't think that you can say that you haven't missed anything if you do 100 percent review. But what you can say is that by doing some, you have complied, or you have done the best you could. You have followed accepted procedures to comply with the license criteria, like any other plant in the country that has been licensed.

So if there are any errors, presumably would not be any different from errors in other plants. But the main issue of sampling 75 percent or 40 percent, and then drawing conclusions from that would not be there anymore.

Q Dr. Apostolakis, if the IDVP reviewed 100 percent would you not agree that there is a very strong likelihood that, given the definition of -- you know -- Errors A, B, and C or just Errors A and B, would you not agree that there would be very high likelihood that someplace out there there would be an Error A or B -- as there would be in any other plant?

A I like the part as there would be in any other plant. I dont' know if it's a very high likelihood, but it wouldn't bother me to agree with that.

Q Fine. But that overstress of one support cut of

tens of thousands, you would agree, would be highly likely, isn't it, in any plant, anyplace, of all of the licensing material, all of the literally hundreds of thousands of potential for missing a licensing criteria by some amount?

A Given all that, yes.

Q So you could do 200 percent, right? You could do it again, and you would still have a probability, wouldn't you?

A That is correct?

Q So don't you have to, at some point in time, come up with reasonable assurance? No matter what approach you use?

You're shaking your head?

A Yes.

Q Dr. Apostolakis, is there any difference, in your mind, between reasonable assurance and adequate confidence? Do those two terms mean anything different to you?

A Well, I am familiar with the term reasonable assurance. Adequate confidence I'm not sure I'm familiar with.

Q The words, do they mean anything different to you? Adequate confidence, reasonable assurance? They mean the same to me, as a person who has some passing familiarity with the english language. I don't see any difference, do you?

A In that sense, I don't see any difference either.

Q Adequate confidence and reasonable assurance would be the same thing?

A Yes, it would be the same.

MR. NORTON: I have nothing further.

JUDGE MOORE: Does the Staff have any cross examination of this witness?

MR. MC GURREN: We just have a couple of questions, Your Honor.

JUDGE MOORE: Proceed.

CROSS EXAMINATION

BY MR. MC GURREN:

Q Dr. Apostolakis, my name is J. McGurren. I'm with the Nuclear Regulatory Commission. Mr. Norton asked you a couple of questions about the use of a PRA and I believe that one of the questions he asked you was a PRA -- or did you testify that the PRA could be used to determine the safety significance of a design error? Do you recall that question?

A Yes.

Q I believe you said it could be.

A Yes.

Q When you answered that, were you thinking in terms of a particular design error or the universe of design errors that might be existent at a nuclear power plant?

A No. That was a general statement. I didn't have

81b7

any particular error in my mind.

Q Then I think you indicated that it would be -- really, what would be necessary would be just a small or mini PRA. Is that correct?

A Again, I would not want to prejudge, but it seems to me that most of the time, really, you would not need a major probabilistic study. I think the reason why I got into it is because PRA has tended to mean, now, these huge documents that have been produced in the last three or four years. The huge documents, we're talking about thousands of pages I just wanted to make it clear that I did not mean that you have to do that all the time.

Q But the number of pages, is that exclusive of the amount of work -- well, the amount of work that would be involved determining all the universe of design errors that would be existent in a nuclear power plant. Potential design errors that may be existent at a nuclear plant -- consideration rather, of design decisions that may be existent in a nuclear plant?

A I'm afraid I lost the question?

Q Well, I believe in the questioning by Mr. Norton, in developing the Ball and Urn approach, that there would come a point in that analysis where you would be looking at the universe of design decisions. Is that correct?

A Yes.

81b8

Q Wouldn't, in doing a PRA analysis to determine the significance of potential design errors, wouldn't that same step be necessary? That is, a looking at each design decision. Isn't that correct?

A Again, maybe I'm tired, but I'm not following exactly. I think what you are saying -- maybe you are not -- is that if you want to look at the universe of all these decisions you would need one of those big documents.

Q That's not what I'm saying at all. I'm saying that in order for you to use the tool of a PRA for a plant and you wanted to use it and add, in that PRA, the significance of potential design errors, wouldn't you have to look at each design decision?

A Yes. Yes.

Q Wouldn't there be quite a number of those decisions?

A There would be, yes.

Q And in addition, wouldn't you have to determine -- make a determination of the frequency of design of error for each one of those decisions?

A I don't know that you would have to, but I think that brings me back to my problem with casting this whole issue in probabilistic terms. Somewhere there, I guess you would have to derive a rate and again, what to do with that rate, I don't know.

Q Are you saying that you don't know what you would

81b9

do with that rate in PRA?

A I do not. No, I don't think anybody does.

MR. MC GURREN: I have no further questions, Your Honor.

EXAMINATION BY THE BOARD

BY JUDGE JOHNSON:

Q Dr. Apostolakis, in your testimony at page 8, there and on page 9 you cite the results of several studies. And one of the results of those studies, which you point out, is that a considerable fraction of the Licensee event reports which are filed are reports which are generated as a result of design errors. Is that a proper characterization of your testimony?

A Yes.

Q Does this finding have any -- presumably these reactors, in which these data were obtained, had properly functioning Quality Assurance programs?

A I believe so, yes.

end t8

ki 9:1

Q In your view, is a properly functioning quality assurance program a highly reliable method of assuring that there will be no design errors? And, obviously, what you have included in your testimony makes me ask that question.

A It would not seem to be a very highly reliable method, given the surprise, I think, of people who look at the area, after they find out that a lot of these errors could be attributed to design or construction.

Q I believe Dr. Kaplan in his testimony stated that in the reliability data that are used in probabilistic risk analyses, the problem of design error is included in unreliability rate. Is that your opinion?

A Yes. But I would like to comment on that.

Q Sure. I think he did, too. I generalized his testimony.

A Okay.

When we collect data from LERs, typically, to derive the failure rates that we use in PRAs, we just look at failures, or a lot of these failures. As even a lot of the experts agree to, a lot of these failures are due to design errors. And sure, they are used in the calculation of the failure rates.

However, there is a major omission there, it seems to me, because the fear really is that of common cause failures. And the way we handle these design errors in the

ki 9:2

failure rates completely ignores that fact. We just look at the pump, for instance, and say there is a failure there. Nobody really looks at the cause, and that is part of the data base now. Whether that error had a generic potential or whether there was another pump that failed because of that error typically is now analyzed unless there is something spectacular that happens, that you can go to Nuclear News and read about.

Then, of course, you can't avoid it. So there isn't care, and I think that's really the major issue there, plus of course there may be design errors that you never see because they haven't had an opportunity to surface.

Q Well, given what you have just said, and what I understand the ITP did when they found an error in the system, they looked laterally at other components or -- for that same type of error, that thing that Mr. Norton went through on temperatures and pressure -- would that have any bearing, in your mind, on the likelihood of common cause errors in Diablo Canyon?

In other words, the fact that if they found an error in one component, related to one particular parameter, they, as I understand it, looked laterally at that parameter in other components?

A They did that for the five generic concerns.

Q Yes.

ki 9:3

A Yes. That's the reason I believe they did that, because of the potential for a common cause failure.

Q And this would have an effect on that potential?

A Yes, definitely.

Q My questions are somewhat disjointed, but in the calculations that Mr. Norton led you through of error rate, based on random samples of design elements -- do you recall that?

A Yes.

Q I thought you said your degree of confidence was independent of the fraction of the population which had been sampled. If I misunderstood, I would like to be informed of that.

A If I said that, I was wrong. No, that is not correct.

Q If we assume that population consists of 10,000 members --

A Okay.

Q If you sample 10 and find one error, your degree of confidence in the error rate that you project is considerably lower than if you sample 1,000 and find 100, is it not?

A I believe so.

MR. STRUMWASSER: Did you mean it that way?

BY JUDGE JOHNSON:

Q I thought they did. My first example was you

ki 9:4

sampled 10 and found one, which gives you an error rate of 10 percent.

A Right.

Q My second example is, you sampled 1,000 and you found 100 errors, which also gives you an error rate of 10 percent. I assume your degree of confidence is greater in the second case?

A Yes.

Q Approximately 10 times greater?

A Oh, I don't know what measure we're using.

Q All right, forget that.

We get over my head in statistics very quickly.

JUDGE JOHNSON: I have no more questions.

(Board conferring.)

JUDGE MOORE: Do you have any redirect, Mr. Strumwasser?

MR. STRUMWASSER: Yes.

JUDGE MOORE: Continue.

REDIRECT EXAMINATION

XXXX BY MR. STRUMWASSER:

Q Professor Apostolakis, I'd like to take you back to North Carolina for a moment. You recall Mr. Norton's example concerning oil drilling in North Carolina?

A Yes.

Q First of all, he had a panel of geologists that

ki 9:5

were giving you an expert -- that were giving you opinions about where to drill. Do you recall that?

A Yes.

Q Would you want to know anything about those geologists before assessing whether to follow their advice?

A Yes.

Q What would you want to know?

A Well, like in any situation where you are using expert opinion, you want to know how good the experts are. In this particular case, for instance, you would like to know whether these people have had success in the past identifying areas where oil was found, indeed found. I don't know whether it applies to oil exploration, but I would also like to know whether there are different schools of thought, whatever that means. Are there groups of peoplethat think in one way and groups of people that think in another way?

And there are conflicting points of view, and as a decision-maker, do I have all that.

Q Is it clear to you that engineering judgment at finding errors in design is of the same quality, same reliability as geologists' judgment in finding oil?

A Oh, I don't know. The same reliability? Now, they are both expert opinions, and I have stated several times what the problems are with expert opinion. I don't know if it's of the same reliability.

ki 9:6

Q So the fact that they are both expert opinions does not necessarily mean they are of equal reliability. Is that what you're saying?

A I don't think so, no.

Q I would like you to assume in Mr. Norton's example that the grid that he drew produced 3,968 little cells, and that following the panel of geologists, you dug 911 holes, and that you found oil deposits in 9 of the 911 holes.

Would you then feel comfortable in concluding that there was no oil in North Carolina?

A I have found oil?

Q In 9 of the 911.

A No.

MR. STRUMWASSER: No further questions.

JUDGE MOORE: Any recross?

MR. REYNOLDS: I just have one question, Mr. Chairman.

RECROSS EXAMINATION

XXXX

BY MR. REYNOLDS:

Q There was some discussion on the question of bias --

MR. NORTON: Excuse me, Your Honor. I'm going to object. This has to be directly related to the redirect and the redirect only.

JUDGE MOORE: Is your recross on the redirect?

MR. REYNOLDS: No. It relates to a Board question.

ki 9:7

JUDGE MOORE: Well, in light of the fact that we asked it, go ahead.

BY MR. REYNOLDS:

Q There was some discussion of bias and whether or not a reviewer might be biased for one reason or another. And my question simply is this: If the reviewer knew that if he found too many errors he might not be hired by another utility to do a similar review, do you think this might bias his conclusions?

MR. NORTON: Object. Improper hypothetical. No evidence in the record whatsoever to support that.

JUDGE MOORE: Mr. Reynolds, I believe that was Mr. Norton's line of questioning, not one that came from the Board in any event.

MR. REYNOLDS: I thought it started from the Board.

JUDGE MOORE: I don't believe it did.

Mr. Norton, do you have any -- I'm sorry. Does the Staff have any recross?

MR. MC GURREN: We have no questions, Your Honor.

JUDGE MOORE: Dr. Johnson has a final question.

JUDGE JOHNSON: Dr. Apostolakis, you are familiar with the diagrams in Dr. Kaplan's testimony which purport to indicate the amount of sampling that was done by the IDVP and the ITP.

THE WITNESS: I recall that.

ki 9:8

JUDGE JOHNSON: The horizontal systems that were looked at -- I mean the vertical systems in entirety and the horizontal rows?

THE WITNESS: Right.

JUDGE JOHNSON: If we make the assumption that 50 percent of the design elements that comprised the totality of design decisions, design elements that were included in the total design of the plant, are represented by one of those diagrams -- in other words, the IDVP and the ITP looked at 50 percent of the design work in their systematic approach or in the approach they took, and then you went and did a random sampling of that same population, how many of the elements which you sampled, in general terms, would be identical to those sampled by the verification program in the way that they went about it?

THE WITNESS: I think you can come up with probabilities in one particular sample. Let's say I decide to sample 20 elements, okay? The question is, how many of these would be the same. In the long run, of course, if you do that many times, 10 of them would be half of them, because they have sampled half of the population, but in one particular sample --

JUDGE JOHNSON: No, I meant if you did it over and over again.

THE WITNESS: Then it would be about the same.

JUDGE JOHNSON: About 50 percent?

THE WITNESS: Yes.

JUDGE JOHNSON: Okay, fine.

JUDGE MOORE: The witness is excused. We thank you for your testimony and your attendance.

(Witness excused.)

Since no other witnesses are here ready to be called today, we will recess until 9:00 a.m. tomorrow morning. At that time, the Joint Intervenors will be prepared to call their witness, to be followed by at least one, hopefully two, Staff panels.

And let me check with the Staff. That will be Panel No. 2 and Panel 1, in that order.

MR. MC GURREN: That's correct, Your Honor.

JUDGE MOORE: Thank you. We now will recess until tomorrow morning.

(Whereupon, at 12:25 p.m. the hearing was recessed, to resume at 9:00 a.m., the following morning, Wednesday, 16 November 1983.)

CERTIFICATE OF PROCEEDINGS

This is to certify that the attached proceedings before the

NRC COMMISSION

In the matter of: PACIFIC GAS & ELECTRIC COMPANY
(Diablo Canyon Nuclear Power Plant)

Date of Proceeding: Tuesday, 15 November 1983

Place of Proceeding: Avila Beach, California

were held as herein appears, and that this is the original transcript for the file of the Commission.

Mimie Meltzer
Official Reporter - Typed

Mimie Meltzer
Official Reporter - Signature