ORIGINAL

DOCKETED
USNRC

UNITED STATES OF AMERICA

'84 SEP 11 A10:00

NUCLEAR REGULATORY COMMISSION

OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

In the Matter of:

DOCKET NUMBER
PROD. & UTIL. FAC. 50-247 SP
50-286 SP

SERVED SEP 11 1984

DISCUSSION OF INDIAN POINT
PROBABILISTIC RISK ASSESSMENT

OPEN MEETING

Location: Washington, D.C. Pages: 1 - 102

Date: Wednesday, September 5, 1984

FREE STATE REPORTING INC.
Court Reporting • Depositions
D.C. Area 261-1902 • Balt. & Annap. 269-6236

DS02

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

DISCUSSION OF INDIAN POINT

PROBABILISTIC RISK ASSESSMENT

OPEN MEETING

Nuclear Regulatory Commission
1717 H Street, N.W.
Room 1130
Washington, D.C.

September 5, 1984

The Commission met, pursuant to notice, at 10:00 a.m.

COMMISSIONERS PRESENT:

NUNZIO PALLADINO, Chairman of the Commission
THOMAS ROBERTS, Commissioner
JAMES ASSELSTINE, Commissioner
FREDERICK BERNTHAL, Commissioner
LANDO W. ZECH, JR., Commissioner

STAFF AND PRESENTERS SEATED AT COMMISSION TABLE:

S. Chilk, Secretary
M. Malsch, General Counsel
J. Moore
F. Rowsome
H. Denton
T. Speis

DISCLAIMER

This is an unofficial transcript of a meeting of the United States Nuclear Regulatory Commission held on September 5, 1984, in the Commission office at 1717 H. Street, N.W., Washington, D.C. The meeting was open to public attendance and observation. This transcript has not been reviewed, corrected, or edited, and it may contain inaccuracies.

The transcript is intended solely for general informational purposes. As provided by 10 CFR 9.103, it is not part of the formal or informal record of decision of the matters discussed. Expressions of opinion in this transcript do not necessarily reflect the final determinations or beliefs. No pleading or other paper may be filed with the Commission in any proceeding as the result of or addressed to any statement or argument contained herein, except as the Commission may authorize.

PROCEEDINGS

CHAIRMAN PALLADINO: Good morning, ladies and gentlemen. The Commission is meeting this morning to hear a discussion by the staff on the Indian Point probabilistic risk assessment.

The Commission's desire to have this briefing resulted from the last meeting that we held to discuss the Indian Point special proceeding.

At that time, the staff volunteered to walk through the Indian Point PRA to help the commissioners better understand the techniques used in the study and the uncertainty in the results.

Before we begin, I believe we should address the question of whether or not we should solicit comments on today's transcript from the other parties in the Indian Point special proceeding.

At our last meeting, the general counsel's office indicated the Commission would need to decide the question, but I do not believe that we ever reached a decision.

In light of the slide package indicating the scope of this vast presentation, I wonder if we could get general counsel's advice on this matter.

MR. PLAINE: Yes, Mr. Chairman. I think, since it does relate to the special proceeding that you ought to ask the parties for their comments, probably serving a copy of today's transcript of that.

CHAIRMAN PALLADINO: Do you see any problems with doing that? Well, let me ask. Do the commissioners agree to serve the transcript on the parties?

MR. PLAINE: Requesting that they use the transcript.

CHAIRMAN PALLADINO: I would agree.

COMMISSIONER ZECH: Yes, I agree.

CHAIRMAN PALLADINO: Okay. I knew we'd have three that would.

COMMISSIONER ROBERTS: Fine.

CHAIRMAN PALLADINO: Okay. All right. Then with that, let me turn the meeting over to Harold Denton.

COMMISSIONER ROBERTS: Mr. Chairman, do you have any idea this meeting is going to last?

CHAIRMAN PALLADINO: Well, by looking at the slides, I would guess if we're going to cover all of this and understand it, it would be about four hours.

(Laughter.)

COMMISSIONER ROBERTS: Okay. Well, I'm leaving at noon, and that does not display any lack of interest in the subject matter, but I have a previous commitment.

CHAIRMAN PALLADINO: Well, I suspect that by noon we will have been presented as much as we could possibly absorb for two hours.

COMMISSIONER ROBERTS: I suspect that's the case.

CHAIRMAN PALLADINO: Okay. Well, why don't we let the staff proceed.

MR. DENTON: We have a planned one-hour presentation, Commissioner, and we were going to step over a number of the slides.

This was an unprecedented effort, I think, on the part of the staff, and I welcome the opportunity today to characterize the record of this proceeding so far as how the staff's participation in the proceeding went.

I have with me at the table Ms. Janice Moore, who was the attorney who tried the case on behalf of the staff.

I put on the table to Janice's left the record, five boxes, but this is just the record of the wrist portion of the proceeding, not the entire record.

I'll shortly ask Janice to characterize the legal setting in which this record was made.

Frank Rowsome, on my left, was our principal staff witness in the proceeding. We had literally dozens of staff witnesses in this, and Frank will characterize for you the opinions and judgments we reached in the proceeding and the basis for those judgments. He will be our principal speaker today.

On my right is Themis Speis, who will participate in some of the discussion about the containment analyses that we did.

I think the staff made a substantial advance over WASH 1400 in the area of containment analyses both with regard to understanding the capability of the containment and also the loads to which it might be experienced.

We asked a number of consultants who were in town or near Washington today to be present today in case you had some detailed questions.

So in the audience today is Ray Cobb, from Sandia, John Reid, from Jack Benjamin Associates, which assist us in the seismic review, and Trevor Pratt, from Brookhaven.

So they're here in addition to the staff witnesses who might be able to answer detailed questions.

I'd like to start by giving a brief background on how we got here and that's slide number one.

This proceeding was initiated by petition the Commission received from UCS on September 17, 1979, requesting that among other things that Unit 1 operating license be revoked and that the license of Unit 2 and 3 be suspended, and they cited the bases for their request.

I responded to that petition in February of 1980 and in responding, issued a number of requirements to both Indian Point and Zion.

I treated both Indian Point and Zion the same with regard to the orders that I issued. These were intended to assure me that the safety of these plants was adequate.

They were mainly items that dealt with personnel training, drills, adequacy of those kinds of things, at those plants.

Those orders, incidentally, are still in effect today. I've not modified them, even though both applicants have asked about it, pending the ultimate outcome and the Commission's decision in this case.

At the same time, we initiated the study of possible mitigation features that might be appropriate for these two plants, in view of their high population density.

The question at the time, since we didn't have a detailed study of their plants, was do they represent a disproportionate share of the risk to the U.S. public or not.

So we looked at such things as filtered vented containments, core catchers, a number of other systems that we thought might be very cost-effective in reducing risk. During the summer of that year, the Commission requested a task force report on the adequacy of interim operation.

This was done by Bob Bernaro, who was in research at the time, which was done by people different than the NRR staff.

Based on that report and other things, the Commission issued an order in 1981, calling for the proceeding.

The staff continued its study of possible acts and mitigation strategies. We published NUREG 0850.

The next year, the Indian--in my order, I had required that Indian Point and Zion study accident mitigation.

I didn't really request a PRA. But the way they attacked the issue was to do a detailed PRA. That came in in March of '82.

I had the front end, so-called, of that review reviewed by Sandia. That's the accident initiators. The staff and Brookhaven reviewed the containment performance and the consequences of accidents, and that was done during '81 and '82.

We identified what we felt were the dominant accident contributors to risk and came to agreement with the licensee on what should be done about the dominant vulnerabilities in the fall of '82. I stayed away from the hearing itself, but just to cover the events that led up to the proceeding, I'd like to now turn to Janice Moore and have her just summarize for you the legal situation surrounding this proceeding. Janice?

MS. MOORE: Thank you. As Mr. Denton has noted, in January of 1981, the Commission issued its order setting forth the seven questions they wished addressed in this special proceeding and setting forth the procedures which were to be followed in the conduct of that proceeding.

Slide number two represents a brief chronology of the entire hearing process.

The Commission's order of January '81 was clarified in September of 1981, and a licensing board was appointed to conduct the proceeding.

During the fall and winter of 1981 and 1982, petitions for leave to intervene, requests for participation as interested states and proposed contentions were filed by a number of organizations, local agencies, and municipalities.

Pre-hearing conferences were held during that time period to discuss the standing of the petitioners and to discuss the admissibility of their proposed contentions. In April of 1982, the licensing board admitted 17 parties in addition to the staff and the two licensees.

And they admitted certain of the proposed contentions. The hearings actually began in June of 1982 with regard to Commission questions 3 and 4, which related to emergency planning at Indian Point.

The hearings were suspended in July of 1982 in order for the board to take account of further Commission guidance on the nature of the issues to be litigated in the proceeding.

The licensing board was reconstituted in September of 1982 and the board finalized contentions on Commission questions 1, 2, 5, and 6 in November of 1982.

These questions concerned the risks posed by Indian Point, the question of comparative risk, the question of the cost of shutdown of the Indian Point facilities and the question of the effect on risk of the director's order issued in 1980.

The hearings recommenced in January of 1983, primarily to take testimony on Commission questions 1 and 2.

The contentions relating to Commission questions 3 and 4 were finalized in February of 1983. And testimony on these contentions was heard thereafter.

The record closed in the proceeding on April 29, 1983, after some 55 days of hearings and after compiling of a hearing transcript, not including that the testimony and exhibits filed by the parties of over 15,000 pages.

The testimony was taken of approximately 221 witnesses. In July of 1983, the parties filed extensive proposed findings of fact and recommendations with the licensing board.

It was based on the record that I've just described that the licensing board made these findings in October of 1983.

The parties were given an opportunity to comment on these findings and did so in submission to the Commission in February of 1984.

That is a brief summary of the events which took place in this very long, complex, and I would say very highly tested procedure.

I would turn this over now to Frank Rowsome, to discuss the staff's testimony or the staff's analysis concerning Commission questions 1, 2, and 5.

CHAIRMAN PALLADINO: Thank you.

MR. ROWSOME: Thank you, Janice. In the interest of time, I'll skip over the narrative on the outline of the material here, fleshing out the important points there as the individual points come up in the body of the material.

I'd like to turn first to slide 4.1, the distinguishing features of Indian Point. As a matter of design, quite apart from the site characteristics, there are many ways in which Indian Point differs from other pressurized boiler reactor plants, even those with similar system design in the broadest outline, the particular reactor and the like.

Among the more unusually favorable features, the plant has an unusually good set of backup electrical power supplies to the off-site power into the main unit generators with which to energize the principal motors and valves and the like within the plant.

It is common to find two diesel generators per unit at most plants, many have one per plant with one swung among multiple units at plants.

In this case we have three diesel generators for each of the two units together with three full capacity gas turbine generators at the site which can serve as a backup to off-site power.

This results in substantially less vulnerability to station blackout at this plant than at most plants and station blackout is perhaps notable as the singlemost universally found dominant accident sequence in PRAs.

Its importance is also supported by a precursor study which found more precursors of station blackout than at any of the other potentially severe accident scenarios.

Another distinguishing feature is its design with respect to interfacing system LOCA. This is a vulnerability shared by all pressurized water reactors.

The problem has to do with the failure of the pressure boundary segregating the reactor coolant system from low pressure systems outside of containment.

If this pressure boundary fails, it constitutes a loss of coolant accident. But more seriously, it constitutes a breach of containment and still further it precludes the emergency core cooling system from functioning and recirculation so it guarantees core melt and uncontained core melt if this failure were to mature.

As a result, it is of extreme severity, although it's thought to be of very low likelihood that any pressurized water reactor...

COMMISSIONER ASSELSTINE: Frank, is that Event V?

MR. ROWSOME: That's Event V. What distinguishes Indian Point from most plants is that most plants have between three and six pipes through which this failure can take place, one or two on the section side of the residual heat removal system and two to four on the ECCS injection lines.

Now at Indian Point most of the low pressure equipment that might fail is actually in containment so that a pressure boundary failure would not constitute all these common cause failures I've described if they were to take place on the injection side.

There's only one pipe, a single RHR section line, with this vulnerability at Indian Point so as a matter of design, it's simply immune at most of the sites where fellow pressurized water reactors are generally vulnerable.

It results in substantially lower vulnerability for each of the Indian Point units than is typical of almost any other pressurized water reactor.

System reliability studies routinely show wide variations in system reliability from plant to plant. Design variations frequently produce differences as much as a factor of 100 or so in the probability of failure on demand of engineered safety features.

For the most part, Indian Point turned out to have a fairly high reliability in each of the important engineered safety features.

There aren't any sore-thumb vulnerabilities found for this plant of the kind that pop up every now and then in PRAs with respect to system reliability that have been found in other plants.

CHAIRMAN PALLADINO: Frank, could you give us an example of a safety system design which is more reliable than in other plants? Just....

COMMISSIONER ASSELSTINE: What are some of the sore thumbs that pop out at others?

MR. ROWSOME: Well, a sore thumb we found in the PRA of Sequoia that was discussed in the licensing process and rectified was a design that enabled ECCS to be defeated in the recirculation mode because the water being circulated could accumulate in the refueling canal and not make its way back to the sump to close the loop to be recycled.

The vulnerability had to do with the maintenance error that could allow those sump drain valves to be left closed, and one would have no way of knowing it after one had gone back to power.

I think that's been fixed, but it degraded the reliability of the system.

MR. DENTON: The point we were trying to make here that we'll get to at the end of the presentation is that we think the public risk is determined as much by the plant design as by the population around the plant, and last time there was a lot of discussion of the population side.

We wanted to show you have to look at both the plant and the population, and that's what we think we did during this proceeding.

MR. ROWSOME: Yes. When we get to the back end of the presentation, you'll see material that suggests that the plant range of variation in the frequency of severe releases of radiation is probably larger, at least as large and maybe larger than the differences that could be attributed to a population site demography.

Among the containment features Indian Point shares with a number of other PWIs with large dry containments, a large free volume and a high failure pressure.

It's one of the better in those respects, but not outstanding.

There is, however, one containment attribute that is outstanding and very rare. The base mat under the reactor in the floor of the containment is made with basaltic concrete rather than the far more common limestone-based concrete.

The difference has to do with the amount of gas generated if the concrete were to be attacked by molten fuel.

Limestone concrete is very gassy, and basaltic concrete is not. That has the effect for a broad class of accident sequences in which one postulates that a base mat is attacked, that Indian Point could bottle up those accidents whereas plants with limestone-based concrete, because of the extra pressure produced, would be unable to bottle them up.

COMMISSIONER ASSELSTINE: Does that assume, Frank, that the molten fuel just drops down as a blob, as opposed to being ejected under pressure from the vessel?

MR. DENTON: We intend to cover that in detail, and I sent the Commission last week a recent report from Sandia dealing with steam explosion.

Dr. Speis will go through the various containment failure modes that were studied.

COMMISSIONER ASSELSTINE: Okay, and assumptions that were made in the PRA for this plant and how those are now subject to some question based upon the Sandia work.

MR. DENTON: Yes. And we've discussed that report with Sandia, and as I mentioned, Mr. Cobb is here from Sandia.

COMMISSIONER ASSELSTINE: Okay.

MR. ROWSOME: Now to turn to the unusually...there should be an "n" in "unusual."

COMMISSIONER ASSELSTINE: Are you going to get back to Event V at some point in the presentation, or is now the right time to ask questions about Event V?

MR. ROWSOME: Go ahead and ask them.

COMMISSIONER ASSELSTINE: Okay. You mentioned that that was a low probability but a high consequence event.

MR. ROWSOME: That's right.

COMMISSIONER ASSELSTINE: Is that because you only have this one pipe and just a few valves on that pipe and they were deemed to be of high reliability?

MR. ROWSOME: Well, that's a good summary of the comparative evidence of how this plant compares with other plants.

It's thought to be very unlikely at any plant.

COMMISSIONER ASSELSTINE: Yeah.

MR. ROWSOME: Because the kind of valve failures down the pipe failures, pressure boundary valves, have in fact never happened, even one such failure, much less several failures of two valves in sequence, within nuclear power operating experience.

And in fact, people have looked beyond nuclear experience to fossil plant and chemical plant experience and find such failures to be extraordinarily rare.

And for this scenario for that to take place, it would take two of them in coincidence.

COMMISSIONER ASSELSTINE: What probability did you assign to the possibility of someone opening the two valves?

MR. ROWSOME: They in fact can't be opened while the plant is in service for a variety of reasons. One is that they're inaccessible to manual operation.

At least one of them, maybe both, is in containment, and in fairly high radiation area to which access is available.

They are normally kept deep energized. The breakers are locked out. There's an interlock, if they are energized, there is an electronic interlock to preclude a closure signal when the reactor is at pressure.

And finally, there is some question of whether the valve motor operator has enough torque to lift them when there's a big differential pressure across them.

They're not intended to be opened under that circumstance. And it's thought unlikely, although by no means impossible that the valve could be opened by its motor actuator, even if all these things were overridden.

MR. DENTON: This has been a source of study since WASH 1400 was issued and identified this sequence. No one has come up with a way to put a low pressure system and high pressure system together that will guarantee they don't act in the Event V mode.

Interestingly enough, the Millstone 3 safe PRA, which we ordered to be done because that's also a high population site, the first result from there showed that Event V was a 98%, represented 98% of the total risk of that plant.

And that prompted me to focus on that at Millstone, and that area is being relooked at.

But Event V is still a troublesome issue for all plants, and it's not been solved, to my knowledge, satisfactorily completely anywhere.

COMMISSIONER ASSELSTINE: Yeah.

MR. DENTON: People have gone to more valves and still be more inspections, putting detectors between the valves to detect leakage.

And it gets a lot of attention. I notice Frank will mention it later, I guess, but it's shown here at about 5×10^{-7}.

COMMISSIONER ASSELSTINE: Yeah.

MR. DENTON: As a probability of initiating a core melt sequence at Indian Point.

COMMISSIONER ASSELSTINE: But at least for the design of Indian Point, you're saying it's practically impossible for someone to open those valves while the plant's operating.

MR. ROWSOME: That's my understanding, yes.

COMMISSIONER ASSELSTINE: So really you're left just with the probability of failures of the valves.

MR. ROWSOME: That's right.

COMMISSIONER ASSELSTINE: Okay.

MR. ROWSOME: Now, among the unusually unfavorable features initially found in the licensee's PRA was a seismic vulnerability of the Unit 2 control building.

The control building is a frame and siding structure which is nestled into an L of other structures at the site.

And the seismic analysis suggested that under earthquake loads, these buildings might move apart and then crash together again and that that could cause structural failure of the ceiling of the control building over the control room and cause the ceiling to fall in on the control room.

Second, again because of the frame and siding structure of the control building, and also the Unit 2 diesel generator building, it was thought to be vulnerable to very high winds, particularly those associated with hurricanes in this manner.

In addition, for both units, not just Unit 2 but Unit 3 as well, there is a single tunnel between the control building and what's called at this station the primary auxiliary building, and the containment, through which most control and instrumentation and power cables lead.

So it's a pinch point, if you will, where fire or the like could sever communications between the control building and power supplies, between the control building and the rest of the plant.

That had been known for some time, incidentally. It didn't take a PRA to tell us that there was this one tunnel.

As a result of the concerns with fire protection, alternate cables had been provided for what were thought to be those safety features you would need to have survive such a fire.

The systems analysis associated with the PRA showed that there were some other subtle scenarios that you needed to protect against, in addition to those that had been understood previously.

And that led to the new discovery that this vulnerability harbored something important to the safety profile of the plant.

Turning next to the systems analysis, the systems analysis is the first of three principal phases of a risk assessment.

This part of an analysis entails cataloguing the variety of accident scenarios to which a plant might be subject.

In broad outline, this is done by classing initiating events and cataloguing accidents according to whether the basic safety functions or the principal safety systems successfully perform their function or not.

Since they're only a handful of these functions and a handful of these systems, it's not difficult, at least in a formal sense, to develop a complete logical model that has every permutation combination of safety systems functioning in safety systems failing, so that at this level of classifying accident sequences, there's no trouble with completeness.

This catalog is done with event trees. Having amassed this catalog, which is essentially a deterministic logical map of the variety of accidents, one uses system reliability models to trace the functional failure of systems to the variety of root causes, to the variety of component failures, common cause failures, human errors and the like that could give rise to system failure.

This is in part, again, a deterministic logical map that assembles the failure modes, catalogs of the failure modes of system.

And it's also a tool that enables the probabilities of these constituent fault events to be added or multiplied as appropriate into estimates of accident sequence likelihood and likelihood estimates for the ensembles of the accident sequences.

COMMISSIONER BERNTHAL: Frank, just to give me a calibration here of the significance that attaches to...I'm going back to previous two or three pages here.

You've used a nice turn of phrase here, where you talk about "unusually favorable features" and then "usually unfavorable features."

MR. ROWSOME: Typo. Unusually.

CHAIRMAN PALLADINO: He put that.

COMMISSIONER BERNTHAL: Oh, it's unusually favorable. All right.

CHAIRMAN PALLADINO: He called that to our attention.

COMMISSIONER BERNTHAL: Well, in any case, what I was seeking, and if you're not prepared to do that now, then we should later have Bob, perhaps, or the people who are going to speak specific about PRA, address the issue, but I would like to get some sense for these two classes of features, what quantitative PRA significance and weight you attach to the various ...

MR. ROWSOME: That will emerge later on in the presentation.

COMMISSIONER BERNTHAL: Okay. All right.

MR. ROWSOME: Now, I think I'll skip over the details of systems analysis and turn to uncertainties, in which I know you're interested.

These are uncertainties surrounding the systems analysis, that is, the estimation of the likelihood of the accident sequences, slide 5.4 in your package.

Some of the uncertainties originate in the fault likelihood data. The initiating event frequencies are not known precisely.

The component failure probabilities are not known precisely and the like. The hazard curves describing severity versus return frequency for earthquakes or fires or floods and the like, all have uncertainties attached to them, particularly when you get to the very rare and more severe events.

Such sources of uncertainty can be described by probability distributions and this was done by the licensees in their PRA.

Other uncertainties originate from modeling and let me briefly sketch the examples in the table. Reactor coolant pump seal LOCA. There is reason to believe that when the cooling water to the seals, the seal water injection fails, the seals will heat up and they mail fail.

We didn't know what probability to assign to that; we didn't have enough experience to be able to precisely say, "Less than such a fraction of time this happens, the seal will fail."

In this instance, we took a pessimistic position as did the licensee in their PRA and assumed it always failed.

We assumed a probability of one. That's probably pessimistic. It's probably only once in ten times or once in 100 times. We don't know. We don't have enough experimental evidence to make that judgment.

But here we made a pessimistic assumption. That's one of many modeling approximations that got embedded into the analysis.

COMMISSIONER ASSELSTINE: Isn't that issue about to become an unresolved safety issue?

MR. ROWSOME: It already is, I believe, or certainly...

MR. DENTON: We intend to propose it to the Commission formally. We've gotten the agreement of the ACRS on the topic.

MR. ROWSOME: Second fan coolers. The fan coolers are heat exchangers together with filters in the containment which serve the function of removing heat from the containment atmosphere and collecting filterable particulate contaminants in the containment atmosphere.

There is some question of whether they might be filed by the particulates that would be in the containment atmosphere after a core melt accident.

The experimental evidence is ambiguous. Our best judgment is that they will work, they'll certainly work for a while and they'll probably work for a long time, but we weren't absolutely certain of it.

In this case, we did our modeling with the assumption that they work, and then did a sensitivity study on it and came back later and altered the analysis to show how it would change if they never worked, just assumed they always failed.

The result was that most measures of risk got worse by about a factor of 2 or 3, not a gigantic effect. So we weren't particularly sensitive to the act of faith we made in doing our principal calculations with the assumption that the fan coolers provided that the fans run and the cooling water is there, all the auxiliary, all the support systems were working, would continue to operate in the hostile environment.

Feed and bleed cooling, we assumed work. There's fairly good evidence that it can work if it's started promptly, and we used suitable pessimism about the reliability with which the operators would start it promptly to allow for the fact that we become less confident that it would successfully cool the core if the operators waited a long time before trying to start it.

Completeness questions are another source of uncertainty. The licensee, though they did a pioneering job in many respects, fully state of the art in many respects in advancing the state of the art in PRA and many other respects, did not fully achieve state of the art level in their study of accidents initiated by failures of auxiliary systems like DC power, service water, component cooling water, instrument air, and the like. It was a weak spot in their own PRA.

We made some effort to look for unpleasant surprises in these weak spots. We asked our contractors at Sandia to do so, and we and the staff did some as well.

And we found one, a vulnerability to break in the component cooling water piping, which would have the effect of cutting off cooling to these reactor coolant pump seals that I mentioned above and perhaps give rise to a small loss of coolant accident.

This same cooling water system also cools the high pressure safety injection, the very ECCS system you want to have functioning to respond to that loss of coolant accident were it to occur.

So we added this sequence into our estimations of risk, although that was missing in the licensee's study, and later on in the tables of the numerical results, you can see its significance.

We added in our own study a model of steam generator tube rupture with a stuck-open safety valve that had not been in the licensee's study.

Neither we nor the licensees' model attempted to model deliberate acts of sabotage as contributors to the risk.

Likewise, modeling design errors, apart from the way they may show up in the database, in historical data on equipment unreliability...

CHAIRMAN PALLADINO: But you did not include sabotage.

MR. ROWSOME: We did not include sabotage.

CHAIRMAN PALLADINO: What about design errors?

MR. ROWSOME: To the extent they're reflected in the database, they are included. To the extent they show up in the modeling of system design, they are included.

But to the extent that they might compromise equipment reliability in ways that are now shown by the system layout or piping and instrumentation diagrams or the record of equipment reliability in surveillance tests and routine challenges, those are missing.

For example, what might be missing is something of the following kind. If there were a design error in the civil structures that would cause them to be more vulnerable to earthquakes than the design intent, and that were not recorded in an obvious way in the design documentation that the people estimating fragilities were using, they would not have been aware of that kind of a design error and so would not have reflected it in their analysis.

Likewise, there are many forms of human error that we can model fairly well, but among the ones we cannot model well are the operators communally all locking on to an erroneous hypothesis of what's happening in the plant and not systematically using the wrong procedures.

And conversely, we do not model the creativity that operators display in inventing imaginative fixes of the kind that saved Brown's Ferry during the fire.

COMMISSIONER ASSELSTINE: I was just going to say we've had examples of both of those.

MR. ROWSOME: Exactly.

COMMISSIONER ASSELSTINE: And I guess it's hard to decide how much credit or debit to assign to...

MR. ROWSOME: We've got, as you say, one data point on each side, one instance where history proved PRAs to be optimistic in this respect and one where it's pessimistic in this respect.

COMMISSIONER ASSELSTINE: How do you assign an uncertainty, how much uncertainty can you assign to that, or do you assign to that?

In your estimate, for example, in this proceeding, how much of the uncertainty margin that you gave as your best judgment in the hearing was assigned to that element?

MR. ROWSOME: There is some testimony in the record on this subject. It's far more influential on those accident sequences that we expect to be well contained than those which already have enough common mode failure attributes to breach containment as well as a core melt.

In a scenario where you have enough failures postulated or a strong enough failure mechanism already identified to deprive you of core cooling and containment.

It tends to be a mute point because you're already in it too deep so that kind of a sequence is particularly sensitive to this problem in PRA modeling.

Therefore, on the bottom line risk, which is sensitive to the big contributors, it doesn't have a great deal of influence, we don't think.

I'll be describing to you some bounding arguments that will indicate that the risk cannot be very large in absolute societal terms, despite these uncertainties.

COMMISSIONER ASSELSTINE: Although wouldn't you say that at TMI that was a very big contributor?

MR. ROWSOME: Yes.

COMMISSIONER ASSELSTINE: To the bottom line risk of that ...

MR. ROWSOME: The principal mechanism.

COMMISSIONER ASSELSTINE: Yeah.

MR. ROWSOME: Yes.

COMMISSIONER BERNTHAL: But I'm surprised in a way that you can't...this probably reflects my ignorance of PRA and its possibilities, but it surprised me in a sense that you can't select a base line worst possible case assuming there's not malice on the part of the operator for...there are so many things he can do and you select the worst possible case, if he did everything wrong.

It would seem to me that that has a certain calculable risk outcome.

On the other hand, it would be very difficult, I should think, to imagine all of the constructive things that an operator might choose to do.

So I can understand the uncertainty there, but there should be a bounding case, it seems to me, assuming no malice on the part of an operator, to the worst things that he can do.

MR. ROWSOME: Even with malice, you can bound it in terms of the phenomenology where you have difficulty assigning a likelihood.

So you can identify phenomenologically what would happen if he turned off all the active engineered safety features.

COMMISSIONER BERNTHAL: That in itself is almost the useful exercise in calculation.

MR. ROWSOME: There are damage stakes. There are scenarios that would have those attributes. I mean, phenomenological attributes we'll talk about in time. So let's pick that up again later on. Let's turn now to slide 5.5.

COMMISSIONER ASSELSTINE: Before you leave that one, you mentioned design errors.

CHAIRMAN PALLADINO: Yes.

COMMISSIONER ASSELSTINE: Were not considered accepted as you had described them. Let me ask about, for example, compliance with our regulations.

Normally when PRA is done, say, for example, on Appendix R, do you go back and walk through the fire protection areas and base your PRA estimates on the plant as it exists, or do you simply assume that the plant has fully effective fire protection measures in compliance with Appendix R?

MR. ROWSOME: No, almost never. There is one important exception I'll mention, but almost never in PRAs do we take as an act of faith compliance means we're out of the woods.

We go to the basic system diagrams as built, if we can get them, and the best available data on how the plant is actually built, and use that to create the models of system realiability, and fault propagation and the like rather than ...

COMMISSIONER ASSELSTINE: In this case, was the plant used as the base line, the as-built plant?

MR. ROWSOME: What was done in this instance was that we developed our model from a critical analysis of the licensee's model up through this catalog of core melt scenarios and the estimation of their likelihood.

The rest of the PRA was an independent staff effort that did not draw upon the licensee's effort. But in this instance, we took their PRA, we checked it for internal logic and checked the dominant sequences and as I mentioned, added a few sequences where we had discovered their analysis to be weak.

And so we depended on them to translate the plant documentation into the first cut of system models and so forth, with the exception of the dominant sequences they found or we found, where we'd go back and verify that, yes, in fact that modeling does reflect the plant, we did not second-guess their modeling where it did not rise to the surface as potentially important.

My understanding is that they used as-built documentation of the greatest currency they could find, the most recently updated.

MR. DENTON: Fires are very difficult to model.

COMMISSIONER ASSELSTINE: Yes.

MR. DENTON: And you might want to comment, Frank, on how successful we've been here and other places to try to model for either plants that do fully meet Appendix R or don't fully meet Appendix R.

What we have found in general is that as our regulations are met in different ways by different designers, and you may recall the famous study of auxiliary feedwater where the reliability differed by a factor of 100 or so, even though they all met our basic deterministic standards.

COMMISSIONER ASSELSTINE: How many accident sequences did the licensee's PRA consider, and did you review all of those or a portion of those?

MR. ROWSOME: In a sense, we reviewed all of them. I don't know the number offhand, and because the way they're catalogued is a little of the way biologists classify life forms.

There are several levels of detail, and you get a different number, depending on which level of detail you go to.

There are two kingdoms of life forms and several phyla and many more classes and orders, and so forth, so that it is something in the eye of the beholder.

What we did do is we checked each of the event trees, the big catalogs, departed from them in places where we thought the modeling of auxiliary system accidents was inadequate and we checked each system reliability model, though not in every last detail.

So at least in a cursory sense, we looked at all of the failure modes of all of the systems in a detailed, thorough cross-check sense, the more prominent ones we checked quite thoroughly.

COMMISSIONER ASSELSTINE: Was that sort of a joint effort by you and your contractor?

MR. ROWSOME: It was more nearly redundant than joint. The contractors did it independently of the staff.

COMMISSIONER ASSELSTINE: And then you did it.

MR. ROWSOME: And the staff looked intensely at the dominant contributors but didn't try to be so comprehensive in our review.

COMMISSIONER ASSELSTINE: Do any PRAs consider sabotage?

MR. ROWSOME: No PRA has ever modeled sabotage.

COMMISSIONER ZECH: Could I refer back to the operator diagnosis or misdiagnosis reference and have you been able to determine any measure at all of improved performance or lesser performance when the shift was made from event-oriented type analysis to the symptom-oriented analysis?

I have noticed this at the plants I've visited and discussed it with the operators. Have you had any measure of that in this subject that we're talking about at all?

MR. DENTON: That's too recent to have gotten reflected in this study. I sure hope it occurs, but we don't have any data yet to show it.

COMMISSIONER ZECH: Uh-huh.

MR. DENTON: And perhaps a year from now when we look back, they haven't been in place that long, long enough to influence...

COMMISSIONER ZECH: I think it might be a worthwhile initiative to look into it in some manner that...because it seems to me that it has been an order of magnitude improvement over the system that was used previously in analyzing events and trying to come up, on the part of the operator, to diagnose completely what happened immediately, the newer system, the system you have in place now, the symptom-oriented type analysis seems to me a real big step in the right direction and could have some impact on the risk analysis assessment.

MR. DENTON: Well, we'll be sure we look at that.

COMMISSIONER ZECH: I'd be interested in hearing about that.

CHAIRMAN PALLADINO: I think the creativity of the operators is a factor that's significant, plus even in all the events that have taken place, even TMI 2 accident, eventually the operators did something to curtail the continued event.

COMMISSIONER ASSELSTINE: Uh-huh.

CHAIRMAN PALLADINO: Especially they took action at Brown's Ferry. Creativity, I don't know, I'm not trying to push that there should be a plus, but I think it tends to be more a plus than it does a minus.

COMMISSIONER ASSELSTINE: I think it can be both.

CHAIRMAN PALLADINO: Well...

COMMISSIONER ASSELSTINE: It can be a big plus or it can be a big minus.

CHAIRMAN PALLADINO: Well, but you get feedback from what you do, and the operators do react accordingly.

I think if you were making a probabilistic risk assessment of airplane malfunctions and you ignored what the pilot did, we'd find a far greater risk than actually I believe is the case.

COMMISSIONER ZECH: However, the newer system of symptom-oriented procedural analysis of problems really does get right to their problem, and I don't have to diagnose the complete...

CHAIRMAN PALLADINO: Yes, I agree with you.

COMMISSIONER ZECH: ...problem. As a result of that, I think that it probably is...they're doing something to correct the symptoms and that's quite a change from trying to analyze exactly what happened and take imaginative action which may or may not be good, but the newer system, it seems to me, eliminates some of the doubt as part of the operator's concern and he is attacking and correcting something that's gone wrong.

And to me, the logic proc...s that he goes through and has gone through with the written procedures that he's using now have to add some kind of a safet, factor to the whole diagnosis process.

To me, it's something I think is rather significant and in a way it takes a little bit away from the operator, the imaginative analysis and so forth.

But I do think it gets directly to solving the problem the DCs before.

MR. ROWSOME: Let's, in the interest of time, jump over the numbers. We'll return to numbers when we have the containment analysis and the consequence analysis.

CHAIRMAN PALLADINO: I just wanted to ask you a question, if you're going to skip 5.5, you say after fixes, what particular fixes are there?

MR. ROWSOME: We...

CHAIRMAN PALLADINO: Or can you refer me to the right slides, so that I don't have to...

MR. ROWSOME: Yes. There are slides further on that describe the fact that we found four sore-thumb vulnerabilities in the station or the two unit station, three at unit 2 and one at unit 3.

MR. DENTON: That's slide 9.3, Mr. Chairman.

MR. ROWSOME: Which in aggragate we're responsible for about 90% of the risk, as we found it before any alterations inspired by the PRA were made in the plant.

NRR verified, using conventional engineering analyses, that these vulnerabilities were real. They verified that they were significant, though, of course, conventional engineering analyses don't give you probabilities.

And verified that the fixes that the licensees volunteered to institute did in fact eliminate the vulnerability altogether or very substantially reduce it.

CHAIRMAN PALLADINO: When you give a number on this table, is that the number of core melt as a result of that particular sequence?

MR. ROWSOME: That's right. Back on 5.5, these are core melt frequencies per reactor year for Unit 2.

CHAIRMAN PALLADINO: Okay.

MR. ROWSOME: Now I think the presentation will go more quickly and more lucidly if we turn to 6-1, and I talk about the containment analysis.

Containment analysis actually entails something far broader than is depicted on this slide. It's the process of developing an evaluation model that takes you from the fact of core melt, models the phenomenon of core heat-up, core damage, core uncovery, core damage, core meltdown, vessel failure, challenge to the containment, if in fact the containment has not been bypassed, and out to the analysis of the release to the biosphere, the estimation of the timing and of the chemical composition and energy and radioactivity associated with the release.

MR. DENTON: I'd like to make the point here, Frank, this is an area which we didn't use any of the new source term, and I felt there was a footnote in the OPE report source term and it might have been written to imply we use the new source term. We didn't; we used the WASH 1400 type source term.

This is an area where I think the staff and its consultants made substantial progress in estimating what is the risk to the public, given that a core melt, severe fuel melting is occurring inside the reactor vessel.

And I'd like to spend a little bit of time on this to go through because it's a different perspective on containment failure than we had from WASH 1400.

MR. ROWSOME: The work that was the basis for our testimony and our risk models was initiated back in 1980 with the intent not of ever doing a risk assessment per se, but finding the engineering basis for studying options for mitigating core melt accidents at this station.

And the staff studied for a period of three or four years, three years from 1980 on, the potential design and effectiveness of hypothetical alterations to the containment in order to better the plant's ability to bottle up or minimize the off-site radiological effects of core melt accidents.

And it is that body of work which is principally aimed at mitigation that provided the technical foundation for our analysis of how containments would respond to the challenge of core melt accidents.

For those scenarios in which containment cooling is provided by the sprays, there are a number of possible containment failure modes that could occur.

When the molten core slumps into water in the bottom of the reactor vessel, a steam explosion is quite likely.

The best evidence we ave suggests that that same explosion will have nowhere near the energy needed to burst the reactor vessel or throw a missile through a containment.

On the other hand, we do assign a finite probability. Our best evidence in this work suggested it was one chance in 10,000 that the steam explosion would produce a missile from the reactor vessel that would knock a hole in the containment.

As you know, there's been a recent board notification on the basis of some Sandia work saying they can't rigorously prove that that conditional probability is not one.

The best evidence is that it is still small and as we get further on in the work, I will show you the effect of assuming higher probabilities of steam explosion than is shown on this table.

CHAIRMAN PALLADINO: Is that a bar over the 10^{-4}, or is that an extraneous mark?

MR. ROWSOME: I think it's extraneous.

MR. DENTON: This is the probability of containment failure by that mechanism, given the core melt. Maybe it would be worthwhile if Themis would stop here and discuss what's going on in looking at the possibility of steam explosions and how it differs from WASH 1400.

COMMISSIONER ASSELSTINE: Let me ask one quick question first. Did you consider the possibility of a steam explosion in the vessel at all?

MR. ROWSOME: No, this is what this number comes from.

COMMISSIONER ASSELSTINE: All right.

MR. SPEIS: The 10^{-4} conditional probability given of core melt is the one that could take place within the vessel.

In fact, it's the only place that you could have severe consequences. It has to take place in the confined environment, because what you need is you need to generate a missile which could then penetrate containment.

So what is basically postulated is the molten core slumps into the bottom of the vessel where there was some water left, and there is an interaction takes place between the hot core and the cold fluid.

The heat transfer process that takes place is very fast, and that's where the word steam explosion comes from.

It's a fast production of steam. Then if you have a confined environment like in the vessel, you can accelerate, it's like a bobbit, from the high pressure steam and that possibly could fail the head itself by failing the bolts or possibly some other things inside the vessel like the control rods.

And then you have to impart enough energy to them to finally throttle to the containment and bridge the containment and that basically is this particular mode of failure.

All these mechanisms would look very carefully...let me go back and say that this issue has been studied very extensively over the last ten years, both for LWRs and well as (inaudible).

If you recall, WASH 1400 looked at this whole process and decided that there was a large uncertainty range varying somewhere between 10^{-1} and 10^{-3}, and they assigned the mean value of 10^{-2}.

Since that time, additional work has been done but the process and the mechanisms and the whole scenario that takes you from the steam explosion all the way to the containment failure, and in our testimony to Indian Point board, we assigned a volume of 10^{-4}.

As Mr. Denton said, Sandia has looked at the information again and they did an uncertainty study and they decided that the uncertainties are large enough and it's pretty hard to pin them down.

In fact, the author of the report said that the uncertainty can vary anywhere from between zero and one.

COMMISSIONER ASSELSTINE: Yeah.

MR. SPEIS: We have looked at this again, the information that the author of the report has provided, and we have no basis for changing our testimony or our conclusions.

In addition to that, though, we have initiated a meeting. We have sent in a report to a number of experts in the United States both at the universities and the laboratories involving this area, and we have asked them to review this, this new evidence, the way the analysis was done.

By the way, it's important to read this report, because the author himself split the uncertainty into three ranges, low, or middle, and high.

And you have to go into the high ranges to come up with probabilities of one. The middle range gives you a number of 10^{-4}, even though the author warns us not to assume the middle range is equivalent to a best estimate analysis.

MR. DENTON: May I interject? We talked to Dr. Snyder, who runs our research program at Sandia, about that report, because I was under the impression that this issue had been put to bed several years ago.

A number of consultants that we use in this area, who are very prestigious in the area of steam explosion, had told us their opinion.

It was a small contributor and unlikely to occur. Dr. Snyder told us that his own opinion of this is that its most likely value is 10^{-4}, but the intent of the report was that if you have the experiments been done with sufficient numbers of core meltdowns of full-scale material, to show...

COMMISSIONER ASSELSTINE: Or larger scale material, anyway.

MR. DENTON: That the authors say no, they can't demonstrate without full-scale tests what will happen. What it takes, it takes the coherent failure of practically the entire volume of the core all at one time and everybody who looks at this in detail that we've hired as consultants come up with a value of 10^{-4}, but we are convening this meeting again in October of all the experts in the U.S. on the topic to relook at it.

So it was a little surprise to us, and we're still trying to understand exactly what the authors had in mind, but I thought you might want to know that Dr. Snyder, who directs the program, didn't think 10^{-4} was an unreasonable value to use.

COMMISSIONER ASSELSTINE: Is the only risk from this the possibility that you would generate a large missile from the vessel, either the head or something else from it, and then throw that into the containment?

What about the possibility that this explosion would send a large pressure spike, say, through the primary system and rupture weakened steam generator tubes?

Is that a possibility?

MR. SPEIS: You're in a situation where very soon you will be failing the vessel anyhow, but there is...have we looked at the possibility of...that would be in a coolant that was vivant and would bypass the containment.

COMMISSIONER ASSELSTINE: Right.

MR. SPEIS: But from this area that we looked, if you don't fail the containment from a steam explosion, eventually you will fail the containment from the...you know, you still have decay heat.

The molten core has decay heat and that heat has to be translated into something, and if it interacts with water, the steam itself eventually will pressurize the containment.

If there is no water in the cavity as you mentioned earlier, the molten core will interact with concrete and eventually this containment would fail even though it's a much slower process.

MR. DENTON: Maybe you'd like a briefing on this just by itself. It's a terribly complicated subject and we put it here to show it's not a large contributor in our testimony, in the record on Indian Point.

That is really what we wanted to call to your attention.

COMMISSIONER ASSELSTINE: Yes. It is interesting. I was at Sandia just a few weeks ago and I saw their movies of the steam explosions, and they get a pretty big bang out of a small amount of material.

MR. SPEIS: Nobody argues that materials don't explode, okay?

COMMISSIONER ASSELSTINE: Yeah.

MR. SPEIS: I think there is agreement in the technical community that productivic materials do indeed explode, okay.

COMMISSIONER BERNTHAL: The point, though, is, the explosion depends on a wide differential in temperature, by and large, or rather a very rapid interaction, I would presume.

So when you speak of molten core slumping into the water, it has to be a pretty fast slump.

MR. DENTON: It has to be a coherent slump.

COMMISSIONER BERNTHAL: Coherent.

MR. DENTON: And not a dribble.

COMMISSIONER BERNTHAL: You don't dribble in and get an explosion. And to make an instinctive judgment, one would expect not to have a lump catastrohpic sudden core melt, but rather that you would melt the core slowly and dribble in, in fact.

MR. SPEIS: Yes, it has to achieve some pre-mixing type of configuration.

COMMISSIONER BERNTHAL: Right.

MR. SPEIS: For the process to propagate.

MR. DENTON: Since we might want to come back and brief you on just steam explosions because I think that one does deserve a lot of attention, but should we walk through the other containment failure modes which appear more likely?

MR. ROWSOME: Yes, I think so. The next possibility is a possible failure to isolate the containment.

It could be a penetration left open or a failure of the isolation system or the like. System analysis suggests that's one chance in 1,000.

Bulk historical data on industry average suggests that having a large penetration open has roughly that likelihood as well.

CHAIRMAN PALLADINO: How about the probability of bursting some of the seals of the penetrations? Is that considered in your no containment failure?

MR. ROWSOME: No. What we consider in this branch is that from the outset there's a hole in the containment big enough to preclude pressurization of the plant.

That's what is being modeled here. Later in other decision branches, we have the possibility of gross failure as a result of the prevailing conditions.

CHAIRMAN PALLADINO: Look down where at the bottom you have no containment failure, and it says 80% of the time with core melt, if I understand your numbers right, that there would be no containment failure. Does that take into account the seals as well?

MR. ROWSOME: Well, the way we model no failure is actually with a leak rate that's about ten times higher than the design leak rate.

So what we mean when we say no failure is no gross failure. Elevated leak rates are included and are in fact modeled in the consequence analysis for that outcome, that 80% outcome of no containment failure, does assume a 1% volume per cent per day leakage throughout the course of the accident.

So modestly elevated leak rates are carried all the way along here throughout in every scenario. The hydrogen burn scenario postulates that the pressure spike will do sufficient damage to depressurize the containment.

Now that could be cooking seals and producing substantially elevated leak rate much above 1% per day that would enable rapid depressurization as well as a sudden bursting of the vessel itself.

From a consequence point of view, it doesn't matter a whole lot which, so long as you get the curies out very promptly.

MR. DENTON: I think the key here is it shows how important containment cooling is. In other words, for that big containment, as strong as it is, there's a fair chance that it won't fail catastrophically if the cooling provided by the sprays is available.

And maybe we should move to the next case, without containment cooling.

MR. ROWSOME: Yeah, I'll move to that. Let me alert you to some evidence we'll see later on when we see consequence results, and that is that the hydrogen burn scenario, that has the 3% here, is fairly benign in radiological effect.

The effect of the spray scrubbing the containment atmosphere before that failure takes place takes the edge off that release, so that's not a particularly nasty release. The base mat penetration is very well filtered and also is even more benign in its off-site radiological effects.

The modest leakage attached to no containment failure does not alter the picture very much from a TMI-like scenario, negligible radiation, radiological effects, both property damage or health effects off-site.

So that all three of these bottom three outcomes here are comparatively benign.

MR. DENTON: WASH 1400 had the containment failing at about two hours, didn't it, Themis?

MR. SPEIS: 99.

MR. DENTON: 99% of the time it failed at about two hours. That shows that with sprays, it more than likely survived.

MR. ROWSOME: Now, in the event that there is no containment cooling, the pressures rise and stay quite high in the containment atmosphere, though they don't seem to rise dramatically, particularly if the water that's been boiled out of the reactor in the course of exposing the core and melting down stays suspended as steam in the containment atmosphere, and the analysis suggests that almost all of it will, so there's a dry sump, the pressure sits up there and hovers near what we believe to be the failure pressure.

Again, steam explosion, one chance in 10,000; again failure to isolate, one chance in 1,000. Hydrogen burn, the statistics are a little different here because the much higher moisture concentrations in the containment atmosphere tend to at least partially inert the containment.

Hydrogen is much less likely to burn, and that's reflected in the fraction of the scenarios that go to hydrogen-induced failure.

Long-term over pressure is likely, if there's water in the sump, overall we judge that would occur about 40% of the time.

If there's not water in the sump, the pressure will sit under the failure pressure for quite a long time and base mat melt-through or the reaching of an equilibrium state with no containment failure are the likely outcomes, base mat melt-through to the more likely of the two.

CHAIRMAN PALLADINO: Frank, I didn't understand your comment about hydrogen burn. With the sprays, you'd have water, wouldn't you?

MR. ROWSOME: The sprays tend to condense steam in the containment atmosphere.

CHAIRMAN PALLADINO: I see.

MR. ROWSOME: There would be the spray droplets there, but one would have fairly low temperature, low humidity conditions, well, a high relative humidity but not a high absolute amount of moisture in the cooled atmosphere.

So the hydrogen is more combustible if the sprays are on than if the sprays are off and you have saturated high temperature conditions where there are many tons of steam in the atmosphere.

So that if the heat...

CHAIRMAN PALLADINO: Okay, if you explain it that way, I can understand your numbers.

MR. ROWSOME: Yeah.

CHAIRMAN PALLADINO: All right.

MR. ROWSOME: Okay. Good. So 40% of the time in this scenario we have a fairly nasty radiological outcome, the long-term overpressurization, although they're rather long characteristic times to get to that stage.

It's about 11 hours after the core melt, about 13 hours after the onset of the accident, to get to the long-term overpressurization for the wet cavity scenarios.

The base mat penetration takes at least three days, so you've got good containment for a very long time in the lower two possible outcomes, roughly 60%, 59% of the time in this analysis.

That's an extraordinary finding. Never before has any PRA or any staff study suggested that you can go without containment cooling and still have even a prayer of a chance of bottling it up.

This is an extraordinarily good performance. This is the best we've ever seen. Now that it is this good is attributable at least among large dry containment plants, to that very rare basalt concrete, that we're not getting a lot of noncondensable gases coming out of the concrete in that scenario where the base mat is being attacked.

CHAIRMAN PALLADINO: You're talking about the implication, but this does say that 53% of the time under this condition you would have base mat penetration.

MR. ROWSOME: Right. Well, that's a very benign outcome. It's desirable in this case. So we...

MR. DENTON: The timing is very important because you get the cake and you get the other things that take place.

And this kind of finding also influences the value that we place on filter containment venting, for example.

If you thought containment was going to fail due to overpressurization almost every time there was a core melt, then it would be very desirable to have something to hold up, delay the gases getting out, such as the Swedish filtered containment venting concept.

MR. ROWSOME: The only thing the vent filter would be good for in this analysis is the 40% of these scenarios that go to long-term overpressurization.

They would be effectively mitigated by the filtration function. However, note that in the...well, I'll talk to this again.

CHAIRMAN PALLADINO: What do you mean by long...

MR. ROWSOME: Consequences on the table.

CHAIRMAN PALLADINO: What do you mean by long-term overpressurization? Do you mean overpressurized for a long period of time, or...

MR. ROWSOME: This is what I described as 11 hours after core melt, 13 hours after the onset of the accident.

MR. SPEIS: At that point in time, the containment failure pressure will be reached, and the containment failure pressure is the best estimate analysis.

It is not a design basis. It is something like maybe 2 or 2.2 times the design pressure. So it's like for this plant, it's something like 120 to 130 psia, 120 to 130 psia.

COMMISSIONER BERNTHAL: Unfortunately the element that's missing here is the time factor, and you have base mat penetration 50% of the time under these circumstances, but you've now mentioned that that takes three days, whereas long-term overpressurization is a matter of ten-odd hours.

I guess that leaves me with the question of for all of these cases, the filtered vent is primarily useful for long-term overpressurization.

But when you take into account the repetity of the various events, does that cause that accident scenario to maintain great significance, or face into less significance?

MR. ROWSOME: Let's wait 'til we get to consequences and we'll put that material on the table.

MR. DENTON: But just to try to answer it briefly, if you have a sudden containment failure due to an earthquake type phenomenon, then the filter containment vents don't help you.

COMMISSIONER BERNTHAL: Sure.

MR. DENTON: If you never lose containment grossly, then filtered containment vents don't help you. So they are most helpful in which containment would pressurize right up and fail suddenly, and we don't find that to be the case in this containment.

So I think the consequence one is the one that wraps it together.

So maybe you should move ahead.

MR. ROWSOME: Yes. Next slide describes briefly how consequence analyses are done. There's a little block diagram that describes it.

I think it's pretty self-explanatory, and I'll leave it to you to read it at your leisure. Briefly, one models the dispersion of an atmospheric release calculates contamination off-site matches that with the population and an evacuation model calculates dosimetry, health effects, and property damage...

CHAIRMAN PALLADINO: You say you use the revised evacuation model. How does that compare with what OPE had assumed and stated in its 8/29 memo?

MR. ROWSOME: We have not been provided with the OPE material, except their most recent memo. Let's see. I have.

Oh, yes. Oh, yes, that's the one we do have. Right.

CHAIRMAN PALLADINO: Well, if you don't have an answer, we can ...

MR. ROWSOME: I don't remember what they've described here, but I've got a backup slide on the way we did evacuation modeling, if you're interested in that.

CHAIRMAN PALLADINO: Let me not destroy continuity.

MR. DENTON: The staff can look at that and answer it before we reach the topic.

CHAIRMAN PALLADINO: Okay.

MR. ROWSOME: Let's flip ahead to 7-4, the description of what the release categories mean, to get you introduced to the lingo here, so you can understand the table I'll produce next.

7-4 identifies with a letter designation of release categories what they physically mean in terms of the kind of scenario.

Release category A models a plant with no containment at all and core melt following right on the heels of full power generation.

Physically we mean that to model a scenario in which an earthquake has caused the containment to fail. It's by far the worst.

It's the same answer you'd get if you assumed the reactor were out in the air and there weren't any containment building there at all, and it incurred a core melt immediately following normal power generation.

CHAIRMAN PALLADINO: Well, I didn't get those to be equivalent, an earthquake causing containment collapse depending on what you mean by containment collapse. You could get difference source...

MR. ROWSOME: You're quite right that it's perhaps an unduly pessimistic view of what actual containment failure due to an earthquake might be.

Mechanistically we don't expect the containment to fall down altogether. What was mechanistically modeled was earth slumping into the side of containment, perhaps collapsing one side of the containment, possibly producing a large hole but not necessarily producing a large hole.

Both the licensees and we, in the interest of economy and not wanting to justify how big the hole was and all that, simply took a pessimistic model that the containment was never there at all at any time in the scenario.

MR. DENTON: It's obviously in excess of the SSE. These are models for doing the dose calculations. Then you have to multiply these events by what you think the probability of that event of that type of release occurring is.

MR. ROWSOME: Release category B is a fair approximation of what one would expect for those steam explosion failure modes we were speaking of and also for Event V, the interfacing system LOCA. This is containment bypass following a...or resulting in a fairly early core melt that just bypasses containment altogether.

Release category C is that 11 hour to 13 hour long-term overpressurization of containment for the case in which no containment heat removal has taken place, that 40% chance of overpressure failure in those scenarios.

D through F are hydrogen burns under different scenarios, some early, some late, some with spray, some with fan coolers, and so forth.

G is the penetration left open throughout the incident, a hole big enough so the containment cannot pressurize.

H, base mat penetration, the melt-through of the base mat. I, no containment failure except for that elevated leak rate I mentioned before.

Now the two prior slides starting with 7.2 shows the conditional consequences, that is, what you expect to find in the way of off-site radiological consequences if one of those releases, which are arrayed across the top in different columns, were to take place.

There are no probabilities in here except for the fact that we've averaged the radiological consequences over the variety of possible weather conditions.

So there's some randomization with respect to the weather in here, which is probabilistic.

There's no accident likelihood information in here, and the only reflection of our containment analysis is really the association between the release categories and the description of what's happened.

So you have here distilled in average values what the consequence analysis tells you releases of a spectrum of severity can give you in terms of off-site effects.

MR. DENTON: And this takes into account, Commissioner Bernthal, your question about the time at which the containment fails.

COMMISSIONER BERNTHAL: Right.

MR. DENTON: So that's a factor in here, as the radiological side, but nothing about probability.

MR. ROWSOME: Right. For the time being...

CHAIRMAN PALLADINO: Could you just pick one of these numbers and tell us what it means?

MR. ROWSOME: Right. Let's take the top row of numbers. It's under early fatalities with supportive medical treatment, the top row is the evacuation model of emergency response.

The first entry for Unit 2 under release category A is 2.30 (3). That (3) is the exponent, how many places you should move the decimal point.

So it says if we were to have an early core melt in a plant with no containment at all, our model of the earthquake collapse of containment, at Unit 2, one would expect on the average over weather conditions 2,300 early fatalities from that event.

Moving over to release category C, it says zero early fatalities because it's an accident that laid over pressurization takes 13 hours to develop.

The evacuation will have been successful. You have a large amount of warning time on this scenario, so you get zero early fatalities.

Early fatalities from that scenario do not extend outside the plume explosure EPZ. And likewise for the hydrogen explosions and the other scenarios, you either have zero or a very, very tiny chance of getting any early fatalities at all.

These accidents just don't kill, at least in terms of early fatalities.

CHAIRMAN PALLADINO: What do you mean by evac relocation as compared to early and late?

MR. ROWSOME: Okay. That's an interesting subject. Let me come back to that after I've made a few points here.

CHAIRMAN PALLADINO: Okay.

MR. ROWSOME: I don't want to ...

CHAIRMAN PALLADINO: No, I just want to understand.

MR. ROWSOME: ...carry along too many logical themes. I promise I will get back to that in a minute or two.

That in itself is an interesting study.

COMMISSIONER ASSELSTINE: Although under release category C, if I can go back to that other point...

MR. ROWSOME: Yes.

COMMISSIONER ASSELSTINE: Although you'd have no early categories, you'd have 3,700 delayed cancer fatalities and another 960 delayed thyroid cancer fatalities.

MR. ROWSOME: That's correct. That's correct.

COMMISSIONER BERNTHAL: In fact, that category 3 is significant across the board, because I presume that what it shows, in effect, is that most of these events are sudden and catastrophic that you're assuming some sort of long-term release, I think, right?

And that therefore there is a widespread long-term lower level of exposure as opposed to the first two category A and B, which dominate...well, A and B dominate early fatalities, and A, B, and C dominate early injuries.

COMMISSIONER ASSELSTINE: Yeah.

COMMISSIONER BERNTHAL: It's just...

MR. ROWSOME: Many of them are modeled, for example, the hydrogen burn ones are modeled as puff releases.

COMMISSIONER BERNTHAL: Right.

MR. ROWSOME: But nonetheless, some mitigating effect is intervened to take the edge off the release. So you are right in saying that release category C in fact harbors almost all the risk.

When you fold in the probabilities, you find that release category C of the non-trivial, of the ones that have non-trivial consequences, has by far the most probability.

And so virtually all of the radiological risk except for early fatalities, which are particularly sensitive to the A and B release categories, can be attributed to that laid over pressure failure.

There's some interesting things you can infer from this table if you would like to suspend judgment on accident likelihoods based on the PRA or even suspend judgment on containment performance based on the PRA and look only at these conditional consequences.

You can develop some interesting bounding arguments. For example, we have at home and abroad well over 1,000 years of reactor experience on plants comparable to our own light water reactors and in that time, we've had one core damage scenario at Three Mile Island and no full core meltdowns.

So it's hard to imagine that the industry average frequency could be appreciably higher than once in 1,000 years.

If we take that as applicable to this plant as a bound, a rough bound, and say it could be arbitrarily severe, let's say that it's interfacing system LOCA.

Let's say that it's release category B and multiply that by a condition.

CHAIRMAN PALLADINO: V as in Victor? Or B?

MR. ROWSOME: Release category B from interfacing system LOCA. The conditional consequences there are about 1,000 early fatalities.

1,000 early fatalities once in 1,000 years is about one casualty per unit year. So that even if you use these bounding arguments, you can't get societal risks over about one casualty per unit year.

You get up to about five or ten if you do the same thing with cancer fatalities. You can't get a big societal risk here no matter how severe you assume, all the way over to no containment at all, release category A.

Unless you're positing accidents that occur with the frequency of once in ten years or once a year or more.

That's the only way you can get from this consequence analysis of big societal risk, if by big you mean ten or 100 casualties per plant year, which is the level at which I personally would start thinking seriously about shutting down a unit, and that would be the level at which I personally would start worrying about the equity issues in comparative risk.

Does this plant pose a disproportionate share of the risk is an important question if you're dealing with ten casualties or 100 casualties, but becomes a mute question if you're dealing with less than once casualty per unit year.

It's like worrying about the equity of the tax code. If one of us owes ten cents in income taxes and another of us owes $100 in income taxes, the equity problem is intense, but nobody cares very much because it's so small in absolute terms that the equity problem doesn't really arise.

CHAIRMAN PALLADINO: The fact that it doesn't happen often is an important consideration.

MR. DENTON: The point we wanted to make is we tried to put in the record both views, what the consequences would be under various scenarios, forgetting about probability of the event occurring, and then we multiplied those by what was our best estimate of the probability of that event actually occurring. And that's the statement.

MR. ROWSOME: Slide 7.5, please. 7.5 in your package gives the expected risks when our best estimates of likelihood and their containment analysis and their consequence analysis are combined into one risk calculation.

First line, early fatalities under the assumption of supportive medical treatment which incidentally has the effect of elevating the dose levels at which early fatalities become probable.

One finds a little over between one and two chances per 100 per unit year of an early fatality, .015 early fatalities per unit year.

CHAIRMAN PALLADINO: Where are you reading?

MR. ROWSOME: Top line, right-hand column, total.

CHAIRMAN PALLADINO: Okay, thank you.

MR. ROWSOME: So we're way under that bounding calculation I described. This would suggest even over a 40-year lifetime of the plant no more than one expected early fatality.

Third line down gives early fatalities under the assumption that no one receives supportive medical treatment.

Then it's .036, about three times as high, still a very small number. Early injuries, about .1 per unit year.

This is describing Unit 2 and it's describing after fix circumstances, that is, after the improvements inspired by the PRA had been made.

There are several rows here for cancer fatalities. The total cancer fatalities could be obtained by adding numbers from row six and row eight.

Altogether it's about 0.2 cancer fatalities per unit year, one every five years on the average smoothed out.

The population dose is on average about 2,600 person ram per unit year. The smoothed averaged value of the costs of cleaning up off-site contamination and loss of services of land contaminated, about $280,000 per unit year, and so forth.

MR. DENTON: We wanted to make the point, we didn't stop here and say these are acceptable or automatic for society.

The real intent was to then look and see what else could be done to further reduce these, and this is what we get into next.

COMMISSIONER BERNTHAL: I think it's of interest, especially in view of some recent discussions we've had in another context at this table, that for those catastrophic events where you have early effects, early fatalities, large exposure to population, even here in the state of New York it is earthquakes and hurricanes that dominate things to an order of magnitude greater than all other events. That's very significant.

MR. ROWSOME: Well, it's significant and it's also a little unusual. It's an artifact of two things. First, this plant is unusual in the quality of its prevention features for the on-site contributors, the LOCAs, the trangents and the like.

That it was so good is an artifact of some of those unique design features I mentioned at the outset. We've never found in a PRA as intensive as this one was a plant so free of sore-thumb vulnerabilities among the internal events.

So partly the importance of external events has to do with the fact it's so good on internal events. Second of all, the dramatic influence of the external events is in part an artifact of the before-fix picture.

It's gotten reduced by the fixes that lopped off the four prominent vulnerabilities. This table you're seeing is after-fix, however, but understand that it was about a decade higher before.

COMMISSIONER BERNTHAL: Well, that's still very interesting that in the state of New York earthquakes and hurricanes are by an order of magnitude for those early catastrophic events still the dominant feature.

I'm curious, however, about your comment that the first column, all of the other accident scenarios are so good.

What does that mean, for this plant are so good, and therefore the dominance of earthquake and hurricane events appears here where I gather it would not appear for other plants, necessarily.

What does "so good" mean? What would those numbers in the first column be if you could hazard a guess for other plants?

MR. ROWSOME: Well, the frequencies of severe releases for other plants have been one or two decades higher for the internal events than we found at this plant, in worst case, three decades higher.

COMMISSIONER BERNTHAL: So in effect, for other plants, earthquakes and hurricanes would be sort of in the category of many other events, whereas here ...

MR. ROWSOME. Yes. Let me give you two other reasons why the earthquakes and the hurricanes stand out in this table.

One has to do with a unique treatment given the emergency response for those non-nuclear regional disasters.

We presumed that an earthquake or a hurricane of sufficient intensity to cause an accident at the plant, and the thresholds for causing an accident, are very high, would constitute total devastation of the whole region around the plant, from non-nuclear causes.

One of the attributes of that devastation which we did not otherwise account for would be ground transportation wouldn't work.

Most normal modes of communication wouldn't work. A lot of houses would have collapsed or been structurally damaged.

There is no assurance that people who normally would be indoors will be indoors in the scenario. So not only did we turn off evacuation but we also turned off expeditious relocation of people from mat hot spots of radiation, which in our intermediate emergency response model, you asked about the emergency response model.

Let me now describe it and give you a backup slide that gives you a visual picture of it. That's backup slide 5.

CHAIRMAN PALLADINO: Are you going to try to explain early the evac?

MR. ROWSOME: Yes, sir.

CHAIRMAN PALLADINO: Okay.

MR. ROWSOME: Backup slide 5 shows you ...

CHAIRMAN PALLADINO: Is that in here?

MR. ROWSOME: It's a graphical picture. It's not in your package, but it'll appear on the screen, I trust.

CHAIRMAN PALLADINO: Do you have a hard copy I could see?

MR. ROWSOME: I have one. I could get you others.

CHAIRMAN PALLADINO: Okay. That's okay. Just so I can follow parts.

MR. DENTON: We'll make copies.

CHAIRMAN PALLADINO: I'll return it to you and then you can give us copies.

MR. ROWSOME: Now, under the so-called evac reloc model, we assumed evacuation inside the plume exposure EPZ but something different outside.

Outside we assumed relocation from hot spots some 12 hours after plume passage. That's why the evac and the reloc, evac ten miles, relocation outside.

That is the emergency response we employed for those scenarios we didn't expect to find correlated with something that interfered with or disturbed off-site emergency response.

As a counterpoint to that, we tried the early relocation model, which is the middle picture in that slide, where we assumed no anticipatory evacuation at all.

People go about their daily lives, unperturbed, ignorant of the fact that an accident is in progress, enjoying whatever shelter and shielding factors are typical of every day life, but not assuming people were any better shielded than they would be at home or at work, or going about their normal life.

We assumed that eight hours after plume passage, which were many scenarios, many more hours from that after the origin of the accident, the mapping of hot spots would be done and there would be selective movement of people out of highly contaminated areas, Eight hours after plume passage inside ten mile and 12 hours after plume passage beyond ten miles.

CHAIRMAN PALLADINO: And what do you call that one?

MR. ROWSOME: That is the early relocation model.

CHAIRMAN PALLADINO: I didn't get the early part. I thought it was...

MR. ROWSOME: That's to be compared with the really pessimistic case I'm about to describe, which we used for these non-nuclear...

CHAIRMAN PALLADINO: Are you doing earlier evacuation than you did in the first case?

MR. ROWSOME: No. The relocation times are the same where relocation applies. It's just early as contrasted with the third scenario where we suppose that the non-nuclear devastation in the region was such that neither anticipatory evacuation nor relatively prompt relocation after lume passage would be technically feasible, would be practical.

Furthermore, just to be on the conservative side, in considering the amount of damage the earthquake could have done to buildings or structures, or hurricanes for that matter, we did not assume any shelter and shielding factors.

We assumed everybody was outdoors for 24 hours, nailed down to where they'd been when the accident happened.

Needless to say, it's an extremely pessimistic model of emergency response, but one which we felt perhaps warranted to get an outer bound of what might happen for earthquake-induced or hurricane-induced accidents.

So where you find three different emergency response models described, these are the three.

There's another interesting backup slide 5.1 which compares the results in which everything is held constant except that emergency response.

Top of the table, early fatalities with supportive medical treatment, that's the familiar number I read you from the other table, .015, with evacuation relocation model.

With early relocation model, it's still .015; it's changed by one part in 1,000. It doesn't seem to make any difference whether you have evacuation so long as the alternative is fairly expeditious relocation from highly contaminated ground.

Likewise, or for the late relocation model where you assume everybody's nailed down outdoors for 24 hours, things get worse but only by about a factor of two, less than a factor of two in early fatalities.

If you make a comparison for early injuries, the differences are smaller, for total cancer fatalities, the differences are smaller still. Person ram, only slightly affected.

Most of the consequences look the same, no matter what model we used from this rather optimistic evacuation model in one extreme, and the radically pessimistic late relocation model at the other.

So there are interesting implications for the effectiveness of evacuation as an emergency response tactic.

You can trace some of that to what their effects are on the individual release categories, the early ones, the late ones, the benign ones, the severe ones, by going back to that table of conditional consequences, which had these numbers for each release category done separately, not the expected, but the conditional.

And you find that there is no release category, be it a severe one happening early or a benign one happening late, and which evacuation as distinct from fairly prompt eight-hour to 12-hour relocation from hot spots buys you much in the way of consequence reduction.

MR. DENTON: Let me ask, Frank. You have to leave in ten minutes, Commissioner. Would you like us maybe to skip, maybe, to the conclusions and then come back later?

CHAIRMAN PALLADINO: Can we get copies of 5.1 and the other ones?

MR. DENTON: Yes, sir. If you'd like, then, we'll skip to...

CHAIRMAN PALLADINO: Yeah, go ahead.

MR. DENTON: Slide number 12 and then come back.

There are a number of points we could make, but...

CHAIRMAN PALLADINO: I think this backup file of slide 5.1 is good, is worthy of further study by us and maybe...

MR. ROWSOME: We'll send you 5 and 5.1.

CHAIRMAN PALLADINO: Okay.

MR. ROWSOME: Turning to 12.1 of the principal package, the 12 series of slides seems to summarize the weight of the evidence deduced by the staff on the question of whether Indian Point should be shut down or other action taken.

There are earlier slides that are more pointedly focused on the mitigation question on other compensatory actions such as the safety assurance program.

But you can read those at your leisure.

COMMISSIONER ROBERTS: I have some questions on that fact, but this is not the appropriate time. I have a lot of questions about the safety assurance program.

MR. ROWSOME: Right. Perhaps we'll need to come back. The intra-plant comparative risk picture, I think, is one of the more reliable uses of PRA, the identification of which among the myriad of hypothetical accident scenarios to which the plants might be subject, which are the more important vulnerabilities, is, I think, quite a reliable use of the PRA in that conventional engineering analyses can validate whether these have been correctly identified or not, at least in qualitative terms, whether the vulnerabilities are real and significant.

We did find the four sore thumbs mentioned before. The licensees did in fact volunteer fixes either through design or procedural changes which resulted in a tenfold reduction in the staff estimates of the likelihood of severe releases of radiation.

Next, absolute risk estimates. Basis for consideration goes to Commission question 1, which called for such an assessment and the prevailing backfit guidelines called for regulatory analysis.

CHAIRMAN PALLADINO: What slide are you on?

MR. ROWSOME: On 12.3 now.

CHAIRMAN PALLADINO: Okay.

MR. ROWSOME: And the backfit guidelines called for cost benefit tests, which go to absolute risk as well. They call for comparing the value accorded absolute risk reduction to the costs entailed in the action.

The results suggested, as we just described, that the absolute radiological risk is quite small, much less, in fact, than one casualty per unit year, although, as I indicated, bounded by something of the order of one a year from arguments outside the PRA.

Shutdown appears to cost more than it's worth by a factor by about 41 to 1, to 100 to 1, depending on how you monetize the value and whose estimate of the cost of shutdown and so forth you use.

The staff in its responce to Commission question 6 came up with an estimate of somewhere between $4 billion and $5 billion as the cost of replacement power if the unit should be shut down.

Very much less value could be assigned to eliminating the risk for the rest of the life of the unit.

The mitigation conceptions, both those that were subject to contention and those that had been developed in the staff task action plan and were described in our testimony cost more than they were worth, though some lay in the gray area.

The prevention improvements volunteered by the licensees were worth roughly a quarter of a billion dollars in averted risk, a whopping big value.

Their cost, though we did not actually get the licensees to publish an accurate estimate of what it cost, was of the order of $1 million or thereabouts, for about 100 to 1 value to cost ratio.

In fact, if you count in the whole cost of the hearing and the inquiry and the PRAs and everything in the balance, the value accorded, the fixes we found was about ten times the cost of the entire enterprise.

So this is one instance in which litigation proved to be a cost-effective enterprise.

COMMISSIONER BERNTHAL: Would you say that again, please?

(Laughter.)

COMMISSIONER ASSELSTINE: Interesting point.

COMMISSIONER BERNTHAL: It does raise the question, however, that you, I presume, will address at some point here, of whether there are any other fixes that you have considered that might fall also into the category of being cost-effective.

MR. DENTON: We skipped to chapter 12, Commissioner, in view of Commissioner Roberts' departure.

COMMISSIONER BERNTHAL: I see, and that is the stuff we skipped.

MR. DENTON: We can come back and pick those up at a later time this afternoon.

COMMISSIONER BERNTHAL: All right.

MR. ROWSOME: Our intent was to harvest the more significant potential through the safety assurance program. To go on to comparison with non-nuclear background risk, such a comparison was called for by contention 1.1 which asserted that the risk was high as far as New York City.

And we took high to be a comparative measure and so did a comparison with non-nulcear background risk of accidental death and cancer fatality, averaged out to 50 miles for both early fatality and for cancers.

The results were that the early fatality projections for Indian Point, both units taken together amount to 2.5 parts per million of the background risk of accidental death and the latent cancer 11 parts per million of the background non-nuclear cancer mortality risk from all causes.

The latter of these two tests coincidentally matches one called for in the Commission safety goals, which also says a background test of 50 mile average.

So coincidentally the contention elicited the same kind of tests that's in the Commission safety goals for cancer, though without reference to the particular threshold tests suggested in the Commission safety goals.

For curiosity, though, we acknowledged that the Commission has indicated that the safety goals are not to be used for decision-making during the evaluation period. We did produce testimony on what the safety goal comparison was.

CHAIRMAN PALLADINO: There was one slide where it seemed to use the wrong word. You said "prescribed" where I thought you meant...

MR. ROWSOME: Proscribed.

CHAIRMAN PALLADINO: Oh, proscribed.

MR. ROWSOME: I think you'll find that typo got fixed in the latest package.

CHAIRMAN PALLADINO: Okay.

MR. ROWSOME: I certainly meant it to be fixed. Proscribed is certainly the right word, no doubt about that.

As I say, something like the mortality risk outlined for cancers was elicited by the contention. And the result is much smaller than the one part in 1,000 or 1,000 parts per million. We've got 11 parts per million instead, so we're about two decades below the safety goal test for cancer mortality risk.

Two decades is enough that it's extremely unlikely that errors in the PRA would lead to a higher number.

For early fatalities, the safety goal calls for a test against background out to one mile rather than 50 miles.

Therefore, you're not diluting the test population of so many people far away, having low individual risk and it's a much more stringent test.

We found for the before-fix case, that is, before the sore-thumb vulnerabilities had been rectified, that the results straddled the safety goal.

That is in the near field, within a mile or so, that the mortality....that the early fatality risk was in fact about one part in 1,000 in the background, which is the test in the safety goal.

After the fix, our best estimate suggested it was about one-third, one-quarter of one part in 1,000 of the background accidental death risk.

But the uncertainties, of course, are large compared with that kind of difference. So we don't really know with a high level of confidence what the comparison says on the near field early fatality mortality risk guideline.

On the inter-plant comparative risk, which the Commission in its charge to the board indicated would be the primary basis for the Commission's decision, the evidence is less clear than the other cases.

In individual risk, which is called out as one of the two principal Commission concerns, the case is fairly clear, and that is that the individual risks are well within the range of risk posed by other plants.

And we found that site demography has no influence on individual risk.

As to societal risk, societal risk, of course, sums the individual risks over the population at risk and so is roughly proportional to population density.

For the widely studied internally-initiated accidents, better than average design fully compensates for the higher than average population.

So we get a good picture for the internally-initiated events.

There is really little basis for comparison on the external events because comparable PRAs at the time the testimony was taken had been done on only one other plant, Zion, and a very roughly approximate comparable attempt to look at external events had been done on Big Rock Point comparisons were in testimony and in attached slides.

One can say a number of things that illuminate this societal comparison.

COMMISSIONER BERNTHAL: Let me stop you for just a moment. I'm a little surprised that you reached the conclusion that demography has no effect on individual risk because to me, that implies that there is no consequence to the individual of having a high population density.

That's saying the same thing another way, and yet your risk scenarios are dominated by earthquake and hurricane type events which somehow one might expect would because of the sheer volume of people, should evacuation routes, for example, be severely damaged, the sheer volume of people, then, might, one would think, raise the risk for the individual as well as for the societal...

MR. ROWSOME: That's one of the reasons we did those sensitivity studies by comparing those three models.

CHAIRMAN PALLADINO: Were you here when we...you might have been out.

COMMISSIONER BERNTHAL: Yes, I was.

MR. ROWSOME: Since evacuation model produces the same risk estimates as the relocation model, the speed of evacuation is no longer a sensitive parameter.

COMMISSIONER BERNTHAL: But you're still assuming that even relocation can be ...

MR. ROWSOME: We were pessimistic.

COMMISSIONER BERNTHAL: ...very quickly even with...as quickly with a large number as...

MR. ROWSOME: Not for the earthquakes and the hurricanes. The earthquakes and the hurricanes, we used the light relocatio model, the very pessimistic picture that people are nailed down outdoors for a full day after the release.

COMMISSIONER BERNTHAL: Well, okay, I accept your analysis. It seems a little unlikely in a way that...

MR. ROWSOME: That particular pessimism masks any feedback of population on individual risk or evacuation times or whatever.

But the sensitivity study that says if you come along eight hours later and move people off the hot spots, albeit with a helicopter or whatever, it's a very different logistics of relocation.

Then you need only clear the hot spots and you can do that by moving people transverse to the path of the plume very short distances.

So that the logistics of relocation are very different from evacuation.

COMMISSIONER BERNTHAL: But you see, my point is that if you have 100,000 to move instead of ten, somehow that makes a difference.

MR. ROWSOME: Yes, we were quite prepared to find a difference, but this insensitivity to whether evacuation takes place at all convinced us that it wasn't an important parameter.

COMMISSIONER BERNTHAL: Okay. Go ahead.

MR. ROWSOME: Now, what we can say, despite the absence of comparative external event PRAs, absence of external event PRAs that could serve as a basis for comparison, we can say this: other plants share with Indian Point equally adverse demography, and there is nothing distinct about the Indian Point site demography that makes it quantitatively or even appreciably quantitatively different than, say, the Zion or Limerick or a number of other sites.

COMMISSIONER BERNTHAL: Well, I think you should say two other plants. I mean, Zion and Limerick, or those three, really, are in almost in a separate class.

MR. ROWSOME: Well...

MR. DENTON: You might go to slide 7.6, but we looked at demography a lot of different ways, and we ended up ordering more studies of that done at Big Rock Point, at Zion, Limerick, and, I believe, Millstone was the other of the plants.

es.

MR. DENTON: This slide is only out to ten miles, and we get a look at the different miles and the weather factors.

COMMISSIONER BERNTHAL: Yeah.

MR. DENTON: So they were the plants that we have singled out in the past as being under the Commission policy regarding high population sites requiring a detailed look at mitigation features.

MR. ROWSOME: There are two reasons for noting that plant demography particularly is measured by total population out to 10 or 30 or 50 miles, is not by itself an accurate predictor of risk or the consequences should a severe release take place.

First of all, weather is very critical in the magnitude of consequences. A severe release at a site, a very remote site, were it to happen under conditions of very unfavorable weather, could have much worse consequences than the very large release at the Indian Point site if it took place during times of average weather.

So it's only in the statistical averaging over weather that that effect wipes out. In fact, the effect of climate on risk turns out to be pretty comparable.

Sites don't differ all that much by virtue of differences in the weather profile. But inversion conditions, very stable, very low wind speeds, very little dilution of the plume produces severe consequences whereas normal turbulence, normal wind speeds, rapidly dilutes and disperses the plume and produces very modest consequences altogether.

Second, given the weather and given the site, it's the population that happens to be in the footprint of the plume that's obviously affected and you can find sites that don't loom large in total population to ten miles or 30 miles or 50 miles that happen to have a little city ten miles away, so if you pick that wind direction, you can get something as bad or worse than Indian Point.

So although you obviously have a correlation with the integrated population in the statistical sense, you've got a relationship to it.

Population densities of the kind that are displayed in these tables are not by themselves predictors of how bad an accident would be if they are to occur.

You can get bad consequences at remote sites and benign consequences at high population density sites.

COMMISSIONER ASSELSTINE: Although you did say that generally the sites tend to average out on the weather.

MR. ROWSOME: They average out in such a way that a desert site will have the same percentage of...

COMMISSIONER ASSELSTINE: Yeah.

MR. ROWSOME: ...highly adverse weather conditions and highly favorable weather conditions as would, say, the Indian Point site, so that in making inter-site comparisons, the weather does not highly complicate the demographic analysis.

The other thing is something that I mentioned earlier on, and that is the plant differences in the likelihood of severe releases are at least as big a source of variance if not more than site demography, so that even when you average over weather and average over wind directions and the like, it could well be that the most hazardous plant in the country happens to be one with a particularly high frequency of severe releases, a fairly typical site. We can't exclude that possibility.

So that as an indicator it's good, but as a way of ranking plants by the magnitude of their societal risk, it is not a good predictor.

MR. DENTON: Mr. Chairman, we've taken up our allotted two hours and left some things uncovered. We're at your pleasure as to how you proceed.

CHAIRMAN PALLADINO: Well, let me first thank you for a very excellent presentation. I found it very illuminating on a very complex subject.

But now where the Commission wants to go next is a question I have to address to the Commission. Do we want to have another session where we delve more into this?

Should we go back to the basic documents that were were addressing what to do on the Indian Point special proceeding? Or do something else?

COMMISSIONER BERNTHAL: I would just say there's at least one issue that I think we ought to discuss further that I gather I don't think possibly could have been covered during my short absence, and I think was not covered at all, and that is the issue of whether there may be other cost-effective mitigation or prevention features that one might recommend for this or for other sites.

At least I would like to see some further discussion of that, and I'm not sure that we've entirely aired the question of what the issue is here, of whether we should primarily be focusing on consequences as I think perhaps Jim was suggesting at the last meeting or whether we should focus on some composite in the nature of what the staff has presented toward the end of this morning's session.

I think that we do need to spend a little bit more time on this, I guess.

CHAIRMAN PALLADINO: Well, in what way?

CHAIRMAN PALLADINO: Well, I would like to hear a discussion of those points for sure.

CHAIRMAN PALLADINO: Of what, the cost-effective mitigation?

COMMISSIONER BERNTHAL: What other features there might be. Because, for example, we have discussed at least the issue of filtered vents in respect to Indian Point and there has been a comment or two already on that today, pointing out that there was apparently only one scenario that was high probability that the filtered vent would be very effective in mitigating.

So I would like to hear more about filtered vent, for example, versus other possible cost-effective, maybe more cost-effective mitigating steps that could be taken.

I just want to also compliment staff, and you, Frank, especially, on an extraordinarily good presentation, and also on the sometimes cold-sounding and unpleasant-sounding objectivity that attaches to that kind of presentation, but I think that's the kind of thing that one has to hear and then we can make the balancing judgments here.

Thank you.

MR. DENTON: We tried to not appear as an advocate for our views, but just give our same views we gave the hearing board to you.

COMMISSIONER ZECH: May I also say that I would like to compliment Ms. Moore and her colleagues on the licensing board who obviously have done a very thorough and painstaking and I believe an extensive hearing process. I think that certainly deserves our respect, and I congratulate you, Ms. Moore, and your colleagues.

MS. MOORE: Thank you.

COMMISSIONER ZECH: I also would like to express my appreciation to you, Dr. Denton, Dr. Rowsome, and Dr. Speis.

I think this has been a very helpful and enlighting presentation. I think you have, in my judgment, presented it very fairly.

And I think you have certainly shown a depth of effort and understanding that makes this very, very important issue something that we can all focus on an awful lot better.

It certainly does, in my view, in ultimate require a judgmental decision which is not perhaps as easily attained for any of us, because we're dealing in uncertainties.

On the other hand, I think you have shown a very logical sequence of thought that certainly has been very helpful to me.

One thing that I've learned from this, my review and your presentation, about the PRA process itself, it seems to me that the process you go through to come up with a determination, that process itself has got to add safety to our nuclear plants because in going through that logic, it's clear to me that you do uncover areas where we can make improvements and in setting your own analysis and your own estimates on these possibilities whether we can argue that number you eventually place on them, I'm sure, and you've argued amongst yourselves, I'm also sure.

But the process of going through that and very thoughtfully and logically putting together your tree simply has to help us point out areas of improvement in the safety of our plants. And of course, that's what we're all about.

So I, too, congratulate you on a very, very thoughtful and excellent presentation on a very important but difficult subject to come to grips with.

COMMISSIONER ASSELSTINE: Joe, it occurs to me that Tom had some questions on the safety assurance program. I'd like to chew a bit on what the staff has said today, particularly on the use of PRAs and come up with some additional questions in that area.

I think it might be helpful to have a follow-on meeting to this one, where we have the staff there. We can cover other areas in the presentation that they didn't get a chance to make today, perhaps with our questions, and then cover some of the material that they did cover with any additional questions that we have. And it also strikes me that it might be useful to invite to that meeting a couple of the other major participants in the proceeding who were involved on the PRA issue, including the licensees and some of the other participants to hear briefly from them on the kinds of information that the staff has presented to us and that we've been talking about today.

So I think you could have one meeting and hear from the staff again, which gives us an opportunity to raise some of the questions that I think all of us have, and then hear from the other participants briefly as well.

CHAIRMAN PALLADINO: I don't know if I can cover it all in one meeting, but let me suggest that each of you put down the topics you'd like to see covered at the next meeting.

I think the questions on safety assurance and questions on other means for mitigation of consequences are important.

So at agenda planning we can schedule a meeting.

COMMISSIONER ASSELSTINE: Okay.

CHAIRMAN PALLADINO: And my effort, my desire in getting you to jot down what you'd like to have covered is to give guidance to the staff so that when we have the meeting, we can answer the questions.

COMMISSIONER ASSELSTINE: Fine.

CHAIRMAN PALLADINO: Yes.

COMMISSIONER ZECH: I do have questions on the safety assurance program, and I would appreciate getting more information on that.

CHAIRMAN PALLADINO: How about a short note ...

COMMISSIONER ASSELSTINE: Fine. I do think it's...

CHAIRMAN PALLADINO: And other commissioners to indicate what you'd like to cover.

COMMISSIONER ASSELSTINE: I do think it's worth noting that while the staff's presentation has been very useful to us, they were one party in the proceeding.

CHAIRMAN PALLADINO: Sure.

COMMISSIONER ASSELSTINE: Others obviously have different views on the subject and if we're not going to hear from them in a subsequent meeting, at least I think we ought to provide an opportunity for them to submit comments on what the staff has told us today so that we can look at the full range of views and information that was presented.

CHAIRMAN PALLADINO: Well, what I was trying to say is, I don't want to shortchange anyone.

COMMISSIONER ASSELSTINE: Yeah.

CHAIRMAN PALLADINO: I think I would propose that we send this...we've agreed to send the transcript of today's meeting to the parties for comment.

I would propose that we have another meeting with the staff and then focus on a meeting in which we have the other parties make presentations.

COMMISSIONER ASSELSTINE: Right.

CHAIRMAN PALLADINO: What I'm afraid of is we would spend an hour and a half with the staff and then try to...

COMMISSIONER ASSELSTINE: Yeah.

CHAIRMAN PALLADINO: ...compress everybody in the last 15 or 20 minutes.

COMMISSIONER BERNTHAL: Could we even...I think what you're suggesting is that we get comments immediately on today's meeting from the other parties, and I think we ought to do that.

Frankly, one of the things that I think might prove most useful for me, at least, would be to have those comments and some summary done of those comments and perhaps even then have those who might take issue with some of the staff's analysis appear at the same table, and let's hear what they have to say to each other.

CHAIRMAN PALLADINO: I am suggesting that for a subsequent meeting.

MR. DENTON: Commissioner, I just want to make the point that's what we did in the proceeding.

CHAIRMAN PALLADINO: Yes.

(Laughter.)

COMMISSIONER ASSELSTINE: We can't ...

MR. DENTON: With 200 witnesses, and so I thought today we tried to give you the same views that we gave to the hearing board and set the stage for your judgment about the adequacy of that record.

So we came today not to advocate our position but to repeat what we have told the board.

COMMISSIONER BERNTHAL: I understand. But I think there is value in hearing at least the principal issues raised and hear what the principal responses are.

And we've done that before in meetings. That's one of the purposes of our meetings, and even though we don't pretend to hold the whole hearing here, we do an audit, if you will, of the hearing.

And I think that would be a useful process for us to do.

CHAIRMAN PALLADINO: To help us in this process, would it be appropriate to ask OGC to draft either a letter or an order, if that's appropriate, indicating what we might plan for a subsequent meeting to hear from other parties on this.

MR. MALSCH: Sure, we could wait to see how the Commission's opinions are gelling and the need for further hearing or who might be heard, and then draft an appropriate letter. That would be fine.

CHAIRMAN PALLADINO: I was thinking of trying to do it as a result of today's meeting so that they have some timely warning.

MR. MALSCH: We could put together something that would lay out the possibility of some future hearings.

COMMISSIONER ASSELSTINE: Good.

CHAIRMAN PALLADINO: Okay.

COMMISSIONER ASSELSTINE: I think that would be useful.

CHAIRMAN PALLADINO: All right. Anything more that we should try to cover this morning?

COMMISSIONER ASSELSTINE: No.

CHAIRMAN PALLADINO: Well, thank you again for a very fine presentation. We'll stand adjourned.

(Whereupon, the meeting adjourned at 12:20 p.m.)

CERTIFICATE OF PROCEEDINGS

This is to certify that the attached proceedings before the NRC COMMISSION

In the matter of:

DISCUSSION OF INDIAN POINT PROBABILISTIC RISK ASSESSMENT

Date of Proceeding: SEPTEMBER 5, 1984

Place of Proceeding: WASHINGTON, D.C.

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

JOE NEWMAN

Official Reporter

Joe Newman/ddr

Official Reporter - Signature

SUMMARY OF STAFF TESTIMONY

ON RISK AT THE

INDIAN POINT SPECIAL PROCEEDING

SEPTEMBER 5, 1984

OUTLINE

1. BACKGROUND......................HAROLD R. DENTON, NRR

2. CHRONOLOGY......................JANICE MOORE, ELD

3.0 OUTLINE <u>ET</u> <u>SEQ</u>...............FRANK ROWSOME, NRR
   - 3.1 OUTLINE NARRATIVE

4.1 - 4.3 DISTINGUISHING FEATURES OF INDIAN POINT

5. SYSTEMS ANALYSIS
   - 5.1-2 INTERNAL EVENTS
   - 5.3 EXTERNAL EVENTS
   - 5.4 UNCERTAINTIES
   - 5.5 DOMINANT ACCIDENT SEQUENCES, UNIT 2

6. CONTAINMENT ANALYSIS
   - 6.1 CONTAINMENT FAILURE MODES WITH (6.1)
   - 6.2 AND WITHOUT (6.2) CONTAINMENT COOLING

7. CONSEQUENCE ANALYSIS
   - 7.0 HOW CONSEQUENCE ANALYSIS IS PERFORMED
   - 7.1 UNCERTAINTY IN CONSEQUENCE ANALYSIS
   - 7.2, 3 CONDITIONAL MEAN CONSEQUENCES
   - 7.4 RELEASE CATEGORY INTERPRETATION
   - 7.5 EXPECTED SOCIETAL RISK
   - 7.6 POPULATION STATISTICS TO 10 MILES

8.1, 2 MITIGATION
   - 8.3 UNCERTAINTIES
   - 8.4 CONCLUSION

9.1, 2 PREVENTION

9.3 PREVENTION FIXES

10. SAFETY ASSURANCE PROGRAM

11. VARIETY OF RISK PERSPECTIVES

11.1 - 11.3

12. WEIGHT OF STAFF EVIDENCE

12.1 - 12.10

13. RELIABLE USE OF PRA

13.1 - 13.3

BACKGROUND

9/79	UCS PETITION
2/80	NRR RESPONSE TO PETITION
2/82	CONFIRMATORY ORDERS (DIRECTOR'S ORDERS) TO INDIAN POINT AND ZION
3/80	STAFF TASK ACTION PLAN FOR INDIAN POINT AND ZION - INITIATED MITIGATION STUDIES
6/80	TASK FORCE REPORT ON INTERIM OPERATION (NUREG-0715)
1/81	COMMISSION MEMORANDUM AND ORDER CALLING FOR THE PROCEEDING
11/81	STAFF STUDY OF POTENTIAL ACCIDENT MITIGATION STRATEGIES FOR INDIAN POINT AND ZION PUBLISHED (NUREG-0850)
3/82	INDIAN POINT PROBABILISTIC SAFETY STUDY (IPPSS) SUBMITTED BY LICENSEES

- o SNL REVIEW OF IPPSS "FRONT END"

  NUREG-2934 DRAFT 8/82
  FINAL 12/82

H. DENTON, NRR
49-27691
9/5/84

BACKGROUND (CONT.)

- INDEPENDENT STAFF ASSESSMENT OF CONTAINMENT PERFORMANCE, RELEASES, AND CONSEQUENCES (DEVELOPED BETWEEN 11/81 AND 11/82)
- IDENTIFICATION OF DOMINANT ACCIDENT VULNERABILITIES - 9/82
- DISCUSSION WITH LICENSEES ON FIXES FOR DOMINANT VULNERABILITIES - FALL '82

H. DENTON, NRR
49-27691
9/5/84

CHRONOLOGY

JANUARY 18, 1981:	COMMISSION ORDER SETTING FORTH QUESTIONS TO BE ADDRESSED AND PROCEDURES FOR THE CONDUCT OF PROCEEDING;
SEPTEMBER 18, 1981:	COMMISSION ORDER CLARIFYING COMMISSION QUESTIONS AND APPOINTING THE LICENSING BOARD;
APRIL 1982:	BOARD ORDER ADMITTING THE PARTIES AND THE ORIGINAL CONTENTIONS;
JUNE 1982:	COMMENCEMENT OF HEARINGS ON COMMISSION QUESTIONS 3 AND 4;
JULY/SEPTEMBER, 1982:	SUSPENSION OF HEARINGS AND FURTHER COMMISSION GUIDANCE ON THE NATURE OF THE ISSUES TO BE HEARD;
SEPTEMBER, 1982:	RECONSTITUTION OF THE LICENSING BOARD;
NOVEMBER, 15, 1982:	BOARD ORDER FINALIZING THE CONTENTIONS TO BE LITIGATED RELATING TO COMMISSION QUESTIONS 1, 2, 5 AND 6 IN LIGHT OF COMMISSION GUIDANCE;
JANUARY, 1983:	HEARINGS RECOMMENCE;
FEBRUARY 7, 1983:	BOARD ORDER FINALIZING CONTENTIONS ON COMMISSION QUESTIONS 3 AND 4;
APRIL 29, 1983:	RECORD CLOSED;

CHRONOLOGY (CONTINUED)

JULY, 1983:	PROPOSED FINDINGS AND RECOMMENDATIONS WERE FILED BY THE PARTIES;
OCTOBER 24, 1983:	THE LICENSING BOARD ISSUED ITS RECOMMENDATIONS;
FEBRUARY, 1984:	COMMENTS ON BOARD RECOMMENDATIONS WERE SUBMITTED TO THE COMMISSION.
NUMBER OF HEARING DAYS:	55 DAYS
NUMBER OF WITNESSES HEARD:	APPROXIMATELY 221 (42 STAFF WITNESSES)
NUMBER OF PARTIES:	20

JANICE MOORE, ELD
49-27313

OUTLINE

IN OUR TESTIMONY, WE HAVE PRESENTED EVALUATION MODELS USED TO ANSWER THE COMMISSION'S QUESTIONS ON WHAT IS THE RISK ASSOCIATED WITH OPERATION OF THE INDIAN POINT PLANTS (BEFORE AND AFTER MODIFICATIONS), WHAT ARE THE BENEFITS ASSOCIATED WITH SELECTED MODIFICATIONS, AND COMPARISONS WITH OTHER PLANT SITES. AS NOTED IN OUR TESTIMONY, THESE FINDINGS ARE NOT BASED PRINCIPALLY ON BOTTOM-LINE RISK ESTIMATES, BUT RATHER EVOLVE FROM INSIGHTS OFFERED BY THE MODELS - SOME PROBABILISTIC, SOME DETERMINISTIC, AND SOME QUALITATIVE - AND SENSITIVITY STUDIES MADE WITH THE MODELS TOGETHER WITH AN ANALYSIS OF THE STRENGTHS AND WEAKNESSES OF THE MODELS AND OF THE INFERENCES DRAWN FROM THEM.

WE DISCUSSED THE STRENGTHS AND WEAKNESSES OF THE IP PLANTS TO PROVIDE AN UNDERSTANDING OF THE UNIQUE FEATURES THAT PROVIDE POSITIVE SAFETY BENEFITS, OR LEAD TO PROMINENT ACCIDENT VULNERABILITIES.

F. ROWSOME, NRR
49-28016
9/5/84

OUTLINE (CONT.)

WE DISCUSSED THE SYSTEMS ANALYSIS WHICH ENTAILS CATALOGING ACCIDENT SEQUENCES, TRACING THEM TO THE VARIETY OF POSSIBLE ROOT CAUSES, AND ESTIMATING ACCIDENT SEQUENCE LIKELIHOOD UP TO THE POINT OF CORE MELT AND CONTAINMENT CHALLENGE. THIS IS AN ESSENTIAL PART OF RISK CALCULATIONS, BUT MORE IMPORTANTLY, IT RELATES FEATURES OF PLANT DESIGN AND OPERATION TO CORE MELT ACCIDENT VULNERABILITIES.

WE DISCUSSED THE CONTAINMENT ANALYSIS THAT EMBRACES CORE MELT PHENOMENA, CONTAINMENT CHALLENGE, CONTAINMENT FAILURE MODES, AND FISSION PRODUCT RELEASES TO THE BIOSPHERE. THIS IS NEEDED TO ASSEMBLE RISK PREDICTIONS, AND MORE IMPORTANTLY, TO IDENTIFY STRENGTHS AND WEAKNESSES IN CONTAINMENT PERFORMANCE AND TO EXPLORE THE EFFECT OF HYPOTHETICAL MITIGATION BACKFITS.

WE DISCUSSED THE CONSEQUENCE ANALYSIS THAT RELATES RELEASES FROM THE PLANT TO HEALTH EFFECTS AND PROPERTY DAMAGE, NOT ONLY

F. ROWSOME, NRR
49-28016
9/5/84

OUTLINE (CONT.)

FOR RISK CALCULATIONS BUT ALSO TO EXPLORE THE DISTINGUISHING FEATURES OF THE OUTCOMES OF PARTICULAR ACCIDENT SCENARIOS.

WE DISCUSSED THE FIXES INSTITUTED BY THE UTILITIES THAT ADDRESSED THE RISK SIGNIFICANT SEQUENCES. THESE FIXES REDUCED THE LIKELIHOOD OF SEVERE OFFSITE RELEASES.

WE DISCUSSED THE ESTIMATED RISKS AND COMPARED THEM TO NON-NUCLEAR BACKGROUND RISKS.

WE DISCUSSED OTHER POTENTIAL MODIFICATIONS SUCH AS MITIGATION FEATURES, ACCIDENT PREVENTION, AND LONG-TERM SAFETY ASSURANCE, AND THE BASIS FOR CONSIDERING THEM VIABLE OR NOT.

BASED ON THE CUMULATIVE IMPACT OF THE EXAMINATION OF THE PLANT STRENGTHS, THE MODIFICATIONS OF THAT ADDRESSED THE DOMINANT

F. ROWSOME, NRR
49-28016
9/5/84

OUTLINE (CONT.)

CONTRIBUTORS TO RISK AND THE POTENTIAL OF OTHER MODIFICATIONS, WE CONCLUDED THAT THE PLANT POSED NO UNDUE RISK, AND THAT A SAFETY ASSURANCE PROGRAM WOULD HARVEST MANY CLUES FROM THE PRA FOR SAFE PLANT OPERATIONS AND PROVIDE CONFIDENCE THAT THE LEVEL OF SAFETY WOULD BE MAINTAINED IN THE FUTURE.

WE ALSO PRESENTED INTER-PLANT COMPARISONS ON RISK IN RESPONSE TO COMMISSION QUESTION 5. BECAUSE OF THE UNAVAILABILITY OF COMPARABLE STUDIES FOR OTHER SITES, THOSE COMPARISONS WERE MADE ON THE BASIS OF SEVERAL DISCRETE ASPECTS OF PRAS RATHER THAN ALL ENCOMPASSING BOTTOM-LINE ASSESSMENT.

WE COMPARED CORE-DAMAGE LIKELIHOODS FOR SEVERE RELEASES TO PROVIDE A MEASUF OF THE IMPACT OF PLANT DESIGN ON SEVERE RELEASES.

F. ROWSOME, NRR
49-28016
9/5/84

OUTLINE (CONT.)

WE PROVIDED A COMPARISON OF THE RISKS AT DIFFERENT SITES BASED ON A HYPOTHETICAL RELEASE TO PROVIDE A MEASURE OF SITE EFFECTS.

WE DISCUSSED THE RELIABLE USE OF THE PRA INSIGHTS AND SUGGESTED PERSPECTIVES ON DECISION BASES.

F. ROWSOME, NRR
49-28016
9/5/84

DISTINGUISHING FEATURES OF INDIAN POINT DESIGN

A. UNUSUALLY FAVORABLE FEATURES

- o BACKUP ELECTRICAL POWER SUPPLIES
  - 3 DIESEL GENERATORS PER UNIT
  - 3 GAS TURBINE GENRERATORS AT THE SITE
- o EQUIPMENT LAYOUT AND SURVEILLANCE PRODUCES LOW VULNERABILITY TO UNCONTAINED INTERFACING SYSTEM LOCA
- o MANY INSTANCES OF SAFETY SYSTEM DESIGN WHICH ARE AMONG THE MORE RELIABLE FOUND IN NUCLEAR PLANTS
- o CONTAINMENT FEATURES
  - LARGE VOLUME
  - HIGH FAILURE PRESSURE
  - BASALTIC CONCRETE BASEMAT WHICH RELEASES LESS GAS, UPON ATTACK BY MOLTEN FUEL, THAN THE MORE

F. ROWSOME, NRR
49-28016
9/5/84

DISTINGUISHING FEATURES OF INDIAN POINT DESIGN (CONT.)

A. UNUSUALLY FAVORABLE FEATURES (CONT.)

- o CONTAINMENT FEATURES (CONT.)

  COMMON LIMESTONE CONCRETE, AND SO LEADS TO LOWER POST-MELT-DOWN CONTAINMENT PRESSURE. AN IMPORTANT CLASS OF ACCIDENTS THAT WOULD PRODUCE CONTAINMENT FAILURE AT PLANTS WITH LIMESTONE CONCRETE CAN BE CONTAINED OR MUCH BETTER MITIGATED AT INDIAN POINT.

B. USUALLY UNFAVORABLE FEATURES

- o UNIT 2 CONTROL BUILDING
  - VULNERABLE TO SEISMIC INTERACTION WITH ADJACENT STRUCTURES
  - VULNERABLE TO VERY HIGH WINDS

F. ROWSOME, NRR
49-28016
9/5/84

DISTINGUISHING FEATURES OF INDIAN POINT DESIGN (CONT.)

B. USUALLY UNFAVORABLE FEATURES (CONT.)

- o SINGLE PATH FOR MOST POWER, CONTROL AND INSTRUMENTATION CABLES FROM THE CONTROL BUILDING TO THE PRIMARY AUXILIARY BUILDING THROUGH A TUNNEL AT BOTH UNITS 2 AND 3, LEADING TO FIRE VULNERABILITY

  [THESE VULNERABILITIES HAVE ALL BEEN SUBSTANTIALLY REDUCED BY VOLUNTARY ALTERATIONS.]

F. ROWSOME, NRR
49-28016
9/5/84

SYSTEMS ANALYSIS

INTERNALLY INITIATED EVENTS

EVENT TREES - THESE ARE USED TO CATALOG COMBINATIONS OF INITIATING EVENTS AND SYSTEM SUCCESSES AND FAILURES THAT LEAD TO CORE DAMAGE. THEY PROVIDE A DETERMINISTIC LOGIC MODEL OF ACCIDENT SEQUENCES BEYOND THE DESIGN BASIS ACCIDENTS.

FAULT TREES - THESE PROVIDE LOGIC NETWORKS THAT DEPICT THE MANY WAYS TOTAL SYSTEM FAILURE CAN ARISE AND ILLUMINATE THE MINIMUM COMBINATIONS OF BASIC COMPONENT FAILURES OR HUMAN ERRORS THAT CAN DEFEAT SYSTEM OPERATION.

F. ROWSOME, NRR
49-28016
9/5/84

SYSTEMS ANALY. S (CONT.)

INTERNALLY INITIATED EVENTS (CONT.)

QUANTIFICATION - PROVIDES PROBABILITIES FOR ALL THE BASIC EVENTS CONSIDERED AND INSERTED INTO THE ACCIDENT LOGIC MODELS ABOVE, A WAY TO CALCULATE THE LIKELIHOOD OF THE MANY WHOLE ACCIDENT SEQUENCES UP TO CORE MELT.

EXTERNALLY INITIATED EVENTS

RELIES ON UNDERSTANDING OF ACCIDENT SEQUENCES OBTAINED IN INTERNALLY INITIATED EVENT PHASE TO ILLUMINATE IMPORTANT SYSTEMS.

F. ROWSOME, NRR
49-28016
9/5/84

SYSTEMS ANALYSIS (CONT.)

HAZARD CURVES - THESE PORTRAY THE RELATION BETWEEN LIKELIHOOD AND SEVERITY FOR THE HAZARD UNDER CONSIDERATION (EARTHQUAKE, FIRE, ETC.).

FRAGILITY CURVES - THESE ASSIGN FAILURE PROBABILITIES FOR DIFFERENT POTENTIAL MAGNITUDES OF THE HAZARD UNDER CONSIDERATION. THESE CURVES ILLUMINATE PARTICULARLY VULNERABLE COMPONENTS AND STRUCTURES.

HAZARD CURVES AND FRAGILITY CURVES ARE COMBINED USING APPROPRIATE ACCIDENT SCENARIO LOGIC MODELS TO OBTAIN AN ESTIMATE OF THE IMPORTANCE OF THE EXTERNAL EVENTS INTEGRATED OVER THE POTENTIAL RANGE OF MAGNITUDES OF THE HAZARD.

F. ROWSOME, NRR
49-28016
9/5/84

UNCERTAINTIES

DATA - INITIATING EVENT FREQUENCIES;

COMPONENT FAILURE PROBABILITIES

HUMAN ERRORS

HAZARD CURVES

FRAGILITIES

MODELING - REACTOR COOLANT PUMP SEAL LOCA

FAN COOLERS

FEED AND BLEED COOLING

COMPLETENESS - COMPONENT COOLING WATER PIPE BREAK

SG TUBE RUPTURE WITH STUCK-OPEN SAFETY VALVE

SABOTAGE

DESIGN ERRORS

OPERATOR MISDIAGNOSIS

F. ROWSOME, NRR
49-28016
9/5/84

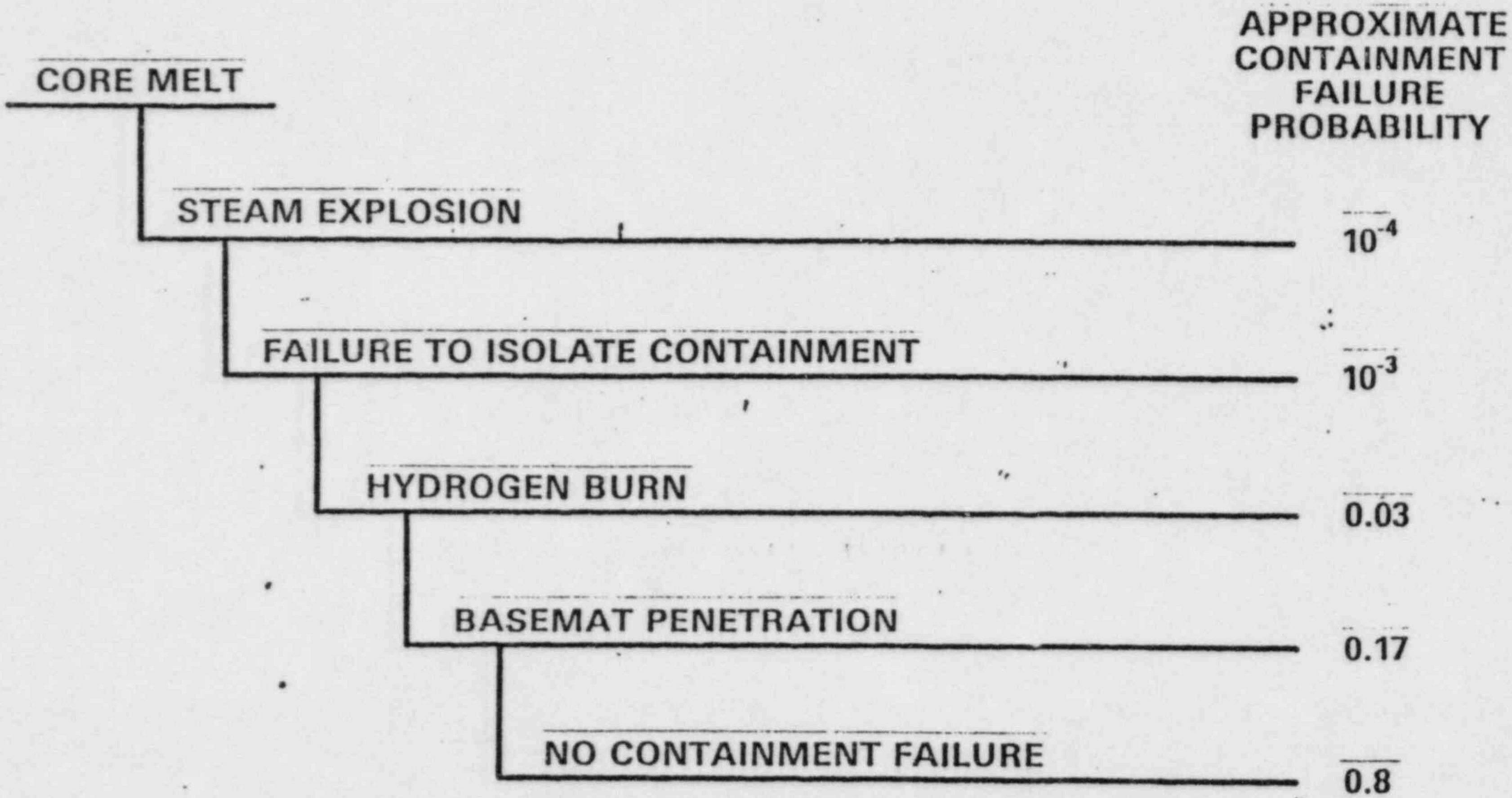
DOMINANT ACCIDENT SEQUENCES

UNIT 2, AFTER FIXES

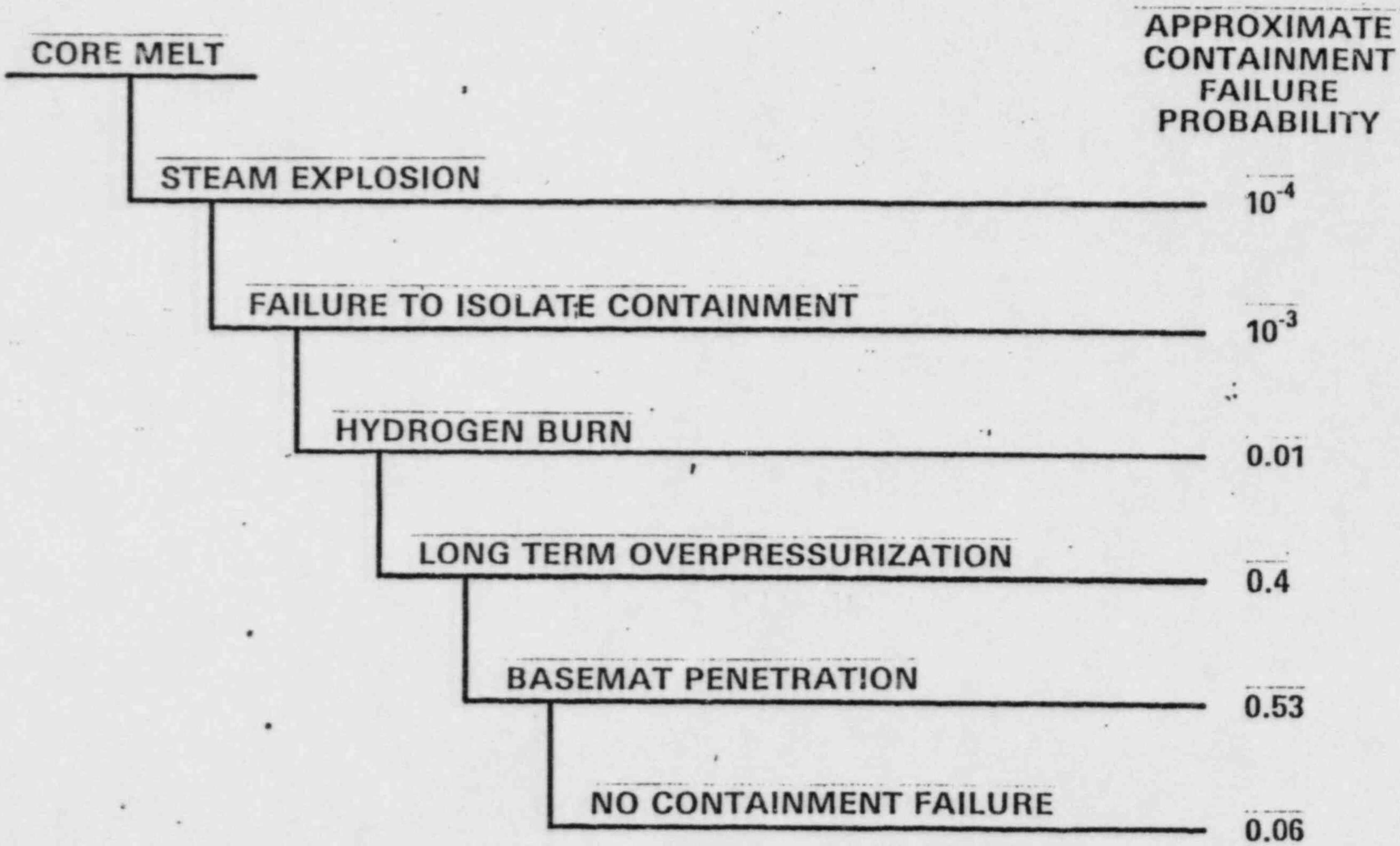
LOCAs, Recirc Failure	1×10^{-4}/RY
Component Cooling Water Pipe Break	3.8×10^{-5}/RY
Fire, RCP Seal LOCA, No Containment Cooling	2.5×10^{-5}/RY
Earthquake, Loss of Control Room or Power, No Containment Cooling	2.5×10^{-5}/RY
ATWS	2.2×10^{-5}/RY
Hurricane, Loss of Power	1.8×10^{-5}/RY
Tornado, Loss of Control Room or Power, No Containment Cooling	1.6×10^{-5}/RY
Intersystem LOCA	4×10^{-7}/RY
Earthquake, Direct Containment Failure	7×10^{-7}/RY
Other Events With Containment Cooling	$\sim 1 \times 10^{-4}$/RY

F. Rowsome, NRR
49-28016
9/5/84

CORE MELT WITH CONTAINMENT COOLING (SPRAYS)



CORE MELT WITHOUT CONTAINMENT COOLING



6.2

3. HOW CONSEQUENCE CALCULATIONS ARE PERFORMED

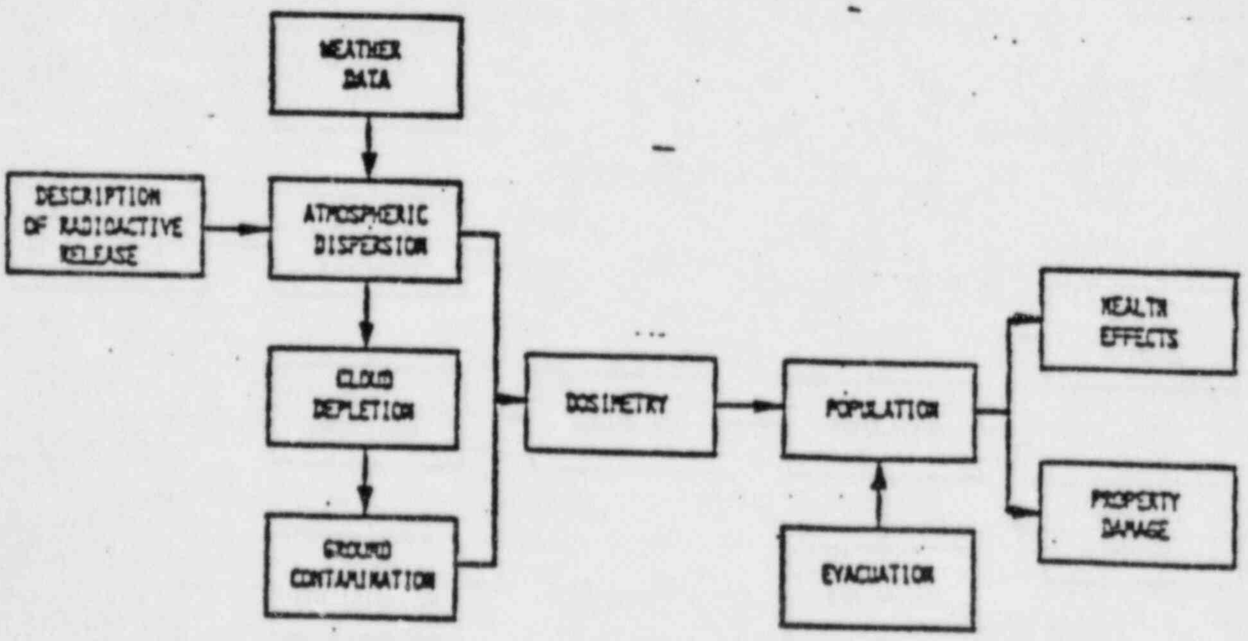
O EACH CATEGORY OF RELEASE ASSUMED TO TAKE PLACE ANY TIME OF THE YEAR.

O CONSEQUENCES OF EACH RELEASE CATEGORY ESTIMATED BY SAMPLING SEVERAL SETS OF WEATHER CONDITIONS OVER ONE YEAR.

O FOR EACH RELEASE CATEGORY AND FOR EACH WEATHER SAMPLE, AIR & GROUND CONCENTRATIONS OF RADIONUCLIDES, RESULTING HEALTH EFFECTS AND ECONOMIC COSTS CALCULATED USING WASH-1400 MODELS. USED A REVISED EVACUTION MODEL.

O SIMILAR CALCULATIONS PERFORMED FOR ALL RELEASE CATEGORIES.

O CONDITIONAL CONSEQUENCES FROM ALL RELEASE CATEGORIES STATISTICALLY COMBINED USING PROBABILITIES OF THE RELEASE CATEGORIES AS WEIGHTING FACTORS



Schematic Outline of Consequence Model

7.0

4. UNCERTAINTY IN CONSEQUENCE ANALYSIS

A. SEVERAL SOURCES OF UNCERTAINTY:

MAJOR:

- O SOURCE TERM OR RELEASE CATEGORY PROBABILITY (INCLUDING EXTERNAL EVENT ANALYSIS)
- O QUANTITY AND CHEMICAL FORM OF RADIOACTIVITY RELEASED
- O ATMOSPHERIC DISPERSION MODELING FOR PLUME TRANSPORT INCLUDING PHYSICAL AND CHEMICAL BEHAVIOR OF RADIONUCLIDES IN PARTICULATE FORM AND EFFECT OF PRECIPITATION

OTHERS:

- O SOURCE TERM TIMING AND ENERGY PARAMETERS
- O METEOROLOGICAL SAMPLING SCHEME
- O EMERGENCY RESPONSE EFFECTIVENESS
- O DOSE CONVERSION FACTORS
- O DOSE-EFFECT RELATIONSHIP FOR EARLY HEALTH EFFECTS INCLUDING EFFECTIVENESS OF MEDICAL TREATMENT
- O DOSE-EFFECT RELATIONSHIP FOR DELAYED CANCER EFFECTS
- O LEVELS AND EFFECTIVENESS OF ENVIRONMENTAL DECONTAMINATION AND FATE OF THE DEPOSITED RADIONUCLIDES
- O ECONOMIC DATA AND MODELING

B. ONLY A LIMITED SENSITIVITY ANALYSIS WAS MADE TO GAIN SOME PERSPECTIVE OF UNCERTAINTY STEMMING FROM EFFECTIVENESS OF EMERGENCY RESPONSE & MEDICAL TREATMENT ON EARLY FATALITY:

- O EVACUATION VS. EARLY RELOCATION DURING ACCIDENTS BY CAUSES OTHER THAN SEVERE EARTHQUAKES & HURRICANES - LESS THAN A FACTOR OF 2.
- O SUPPORTIVE VS. MINIMAL MEDICAL TREATMENT FOR BONE MARROW EXPOSURE UP TO A FACTOR OF 5 FOR "AFTER FIX" (OR 10 FOR "BEFORE FIX")

Conditional mean (meteorology averaged) values of societal consequences from individual release categories for Indian Point Unit 2 with three alternative offsite emergency response modes*

Consequence Category	Offsite Emergency Response Mode	Unit No.	RC-A	RC-B	RC-C	RC-D	RC-E	RC-F	RC-G	RC-H	RC-I
1. Early Fatalities with Supportive Medical Treatment (Persons)	Evac-Reloc	2	2.30(3)	1.30(3)	0.0	4.30(-2)	6.03(-2)	5.33(-2)	0.0	0.0	0.0
	Early Reloc	2	3.07(3)	1.55(3)	1.50(1)	2.60(0)	3.19(0)	3.68(0)	1.08(-3)	0.0	0.0
	Late Reloc	2	8.62(3)	3.87(3)	4.93(2)	1.51(1)	1.79(1)	1.80(1)	1.78(0)	0.0	0.0
2. Early Injuries (Persons)	Evac-Reloc	2	7.92(3)	2.49(3)	1.56(3)	7.68(1)	6.44(1)	6.69(1)	5.49(-1)	0.0	0.0
	Early-Reloc	2	8.90(3)	2.79(3)	1.62(3)	7.90(1)	6.49(1)	6.81(1)	3.57(1)	6.92(-5)	0.0
	Late Reloc	2	1.45(4)	3.93(3)	4.34(3)	2.09(2)	2.39(2)	1.72(2)	6.22(2)	8.11(-1)	0.0
3. Delayed Cancer Fatalities (Excluding Thyroid) (Persons)	Evac-Reloc	2	7.32(3)	3.18(3)	3.77(3)	1.72(3)	1.68(3)	1.47(3)	3.11(2)	3.39(1)	5.42(-1)
	Early Reloc	2	7.70(3)	3.33(3)	3.87(3)	1.72(3)	1.68(3)	1.47(3)	3.39(2)	4.21(1)	5.61(-1)
	Late Reloc	2	8.46(3)	3.66(3)	4.52(3)	1.88(3)	1.87(3)	1.61(3)	3.89(2)	4.63(1)	6.09(-1)
4. Delayed Thyroid Cancer Fatalities (Persons)	Evac-Reloc	2	1.26(3)	1.65(3)	9.61(2)	4.56(2)	4.46(2)	4.17(2)	3.47(1)	2.95(0)	5.67(-2)
	Early Reloc	2	1.25(3)	1.66(3)	1.02(3)	4.50(2)	4.40(2)	4.11(2)	5.16(1)	4.66(0)	8.23(-2)
	Late Reloc	2	1.38(3)	1.72(3)	1.13(3)	4.80(2)	4.76(2)	4.38(2)	6.10(1)	6.61(0)	9.41(-2)
5. Total Person-Rem	Evac-Reloc	2	1.08(8)	5.43(7)	5.90(7)	3.13(7)	3.03(7)	2.66(7)	5.84(6)	7.64(5)	1.03(4)
	Early Reloc	2	1.10(8)	5.55(7)	5.95(7)	3.13(7)	3.03(7)	2.66(7)	6.19(6)	7.87(5)	1.06(4)
	Late Reloc	2	1.26(8)	6.12(7)	6.87(7)	3.36(7)	3.31(7)	2.88(7)	6.93(6)	8.57(5)	1.15(4)
6. Cost of Offsite Mitigation Measures (1981 Dollars)	Evac-Reloc	2	1.23(10)	5.80(9)	6.91(9)	2.21(9)	1.97(9)	1.46(9)	2.06(8)	7.24(7)	6.06(7)
	Early Reloc	2	1.22(10)	5.71(9)	6.82(9)	2.11(9)	1.87(9)	1.37(9)	1.45(8)	1.17(7)	2.12(3)
	Late Reloc	2	1.22(10)	5.71(9)	6.82(9)	2.11(9)	1.87(9)	1.37(9)	1.45(8)	1.17(7)	2.12(3)

Continued

			RC-A	RC-B	RC-C	RC-D	RC-E	RC-F	RC-G	RC-H	RC-I
7. Land Area for Long-Term Interdiction (Square Meters)**	Evac-Reloc	2	1.66(8)	9.00(7)	9.71(7)	2.21(7)	1.81(7)	1.15(7)	2.62(6)	2.18(5)	0.0
	Early Reloc	2	1.66(8)	9.00(7)	9.71(7)	2.21(7)	1.81(7)	1.15(7)	2.62(6)	2.18(5)	0.0
	Late Reloc	2	1.66(8)	9.00(7)	9.71(7)	2.21(7)	1.81(7)	1.15(7)	2.62(6)	2.18(5)	0.0

* Early Reloc mode was used as an alternative to the Evac-Reloc mode to test sensitivity of early health effects to emergency response during accidents initiated by causes other than severe earthquakes and hurricanes. Late Reloc mode was the only emergency response mode during accidents initiated by severe earthquakes or hurricanes.

**2.6 million square meters equals 1 square mile

7.3

RELEASE CATEGORY CONDITIONS

RELEASE CATEGORY	
A	EARTHQUAKE CAUSES CONTAINMENT COLLAPSE
B	CONTAINMENT BYPASSED OR STEAM EXPLOSIONS CAUSING EARLY CONTAINMENT BREACH
C	LONG-TERM OVERPRESSURIZATION OF CONTAINMENT
D	EARLY HYDROGEN BURN (NO SPRAY)
E	LATE HYDROGEN BURN (NO SPRAY)
F	HYDROGEN BURN (WITH SPRAY)
G	FAILURE TO ISOLATE CONTAINMENT
H	BASEMAT PENETRATION
I	NO CONTAINMENT FAILURE

F. ROWSOME, NRR
49-28016
9/5/84

Table III.C.6 Societal risks from Indian Point Unit 2 "After Fix" with "Evac-Reloc" and "Late Reloc" offsite emergency response modes

Consequence Category	Risk per Reactor Year: From Causes Other than Earthquake and Hurricane (Evac-Reloc)	From Earthquake and Hurricane (Late Reloc)	Total
1. Early Fatalities with Supportive Medical Treatment (Persons)	5.58(-4)*	1.42(-2)	1.48(-2)
2. Population Receiving in Excess of 200 Rem Total Marrow Dose from Early Exposure (Persons)	2.21(-2)	1.07(-1)	1.29(-1)
3. Early Fatalities without Supportive Medical Treatment (Persons)	1.56(-3)	3.44(-2)	3.60(-2)
4. Early Injuries (Persons)	2.96(-2) 2.89(-2)**	8.49(-2) 6.59(-2)**	1.15(-1) 9.48(-2)**
5. Delayed Cancer Fatalities (Excluding Thyroid) from Early Exposure (Persons)	3.21(-2)	4.33(-2)	7.54(-2)
6. Delayed Cancer Fatalities (Exclusing Thyroid) from Early and Chronic Exposures (Persons)	8.14(-2)	8.46(-2)	1.66(-1)
7. Delayed Thyroid Cancer Fatalities from Early Exposure (Persons)	1.87(-2)	2.01(-2)	3.88(-2)
8. Delayed Thyroid Cancer Fatalities from Early and Chronic Exposures (Persons)	2.10(-2)	2.19(-2)	4.29(-2)
9. a. Total Person-Rem	1.32(+3)	1.29(+3)	2.61(+3)
b. Genetic Effects (Cases)	3.43(-1)	3.35(-1)	6.78(-1)
10. Cost of Offsite Mitigation Measures (1981 Dollars)	1.55(+5)	1.26(+5)	2.81(+5)
11. Land Area for Long-Term Interdiction (sq. meters)	1.87(+3)	1.79(+3)	3.66(+3)

*5.58(-4) = 5.58 x 10^{-4}

**This estimate is associated with the case w/o supportive medical treatment to reduce early fatalities. The lower risk of injury for this case is due to increase in risk of fatality for lack of treatment.

TABLE 1

Population Statistics Between 0 and 10 Miles

POPULATION STATISTICS- 1979 REVISION 5/79
BASED ON THE YEAR 1970
POPULATION STATISTICS WITHIN 0-10 MILES
TOTAL NUMBER OF SITES- 111
MINIMUM POPULATION- 0 MAXIMUM POPULATION- 218398
MEAN POPULATION- 36931 MEDIAN POPULATION- 24269
90% PERCENTILE POPULATION- 83557
STANDARD DEVIATION- 39164.6 COEF. OF VARIATION- 1.060

NO.	SITE NAME	POPULATION	NO.	SITE NAME	POPULATION	NO.	SITE NAME	POPULATION
1	SUNDESERT	0	38	DAVIS BESSE	15390	75	OYSTER CREEK	36797
2	WPPSS 2	455	39	SKAGIT	16038	76	FORKED RIVER	36797
3	PEBBLE SPRINGS	878	40	CALVERT CLIFFS	16827	77	STERLING	37705
4	PALO VERDE	1892	41	WOOD	16889	78	OCONEE	37831
5	WPPSS 1&4	2648	42	FORT CALHOUN	17401	79	MCGUIRE	39374
6	SOUTH TEXAS	3254	43	PHIPPS BEND	17665	80	ERIE	40206
7	VOGTLE	3500	44	RIVER BEND	19147	81	NEW ENGLAND	41882
8	HATCH	4803	45	PRAIRIE ISLAND	19401	82	HUMBOLDT BAY	45403
9	WOLF CREEK	5260	46	BYRON	20377	83	GREENE COUNTY	45786
10	COMANCHE PEAK	5353	47	MARBLE HILL	20959	84	SAINT LUCIE	46066
11	SUMMER	5656	48	POINT BEACH	21073	85	GINNA	46325
12	RANCHO SECO	6061	49	YANKEE ROWE	21763	86	SUSQUEHANNA	50436
13	LACROSSE	6209	50	BRAIDWOOD	21942	87	PILGRIM	51203
14	DIABLO CANYON	6302	51	BELLEFONTE	22709	88	COOK	53006
15	COOPER	6363	52	ZIMMER	23023	89	SHOREHAM	54251
16	GRAND GULF	7245	53	VERMONT YANKEE	23030	90	HADDAM NECK	60374
17	BIG ROCK POINT	7551	54	ELK RIVER	23890	91	TROJAN	61855
18	WATTS BAR	7674	55	ARKANSAS	24141	92	MIDLAND	62000
19	NORTH ANNA	7713	56	NEW HAVEN	24397	93	CATAWBA	65901
20	HALLAM	8365	57	SAN ONOFRE	25725	94	SURRY	66630
21	FORT ST. VRAIN	8366	58	PEACH BOTTOM	25984	95	HAVEN	67981
22	TYRONE	8632	59	MAINE YANKEE	26000	96	PIQUA	72560
23	YELLOW CREEK	8828	60	ROBINSON	26016	97	PERRY	73600
24	CALLAWAY	8914	61	QUAD-CITIES	26739	98	DUANE ARNOLD	79310
25	FARLEY	9528	62	BROWNS FERRY	27215	99	SEABROOK	79478
26	WPPSS 3&5	9767	63	SALEM	28562	100	BAILLY	83608
27	BRUNSWICK	10000	64	HOPE CREEK	28562	101	PATHFINDER	84117
28	BLACK FOX	10404	65	PALISADES	29528	102	TURKEY POINT	88000
29	HARTSVILLE	11340	66	DRESDEN	31126	103	BONUS	89000
30	CRYSTAL RIVER	11699	67	CHEROKEE	31877	104	BEAVER VALLEY	105000
31	CLINTON	11889	68	DOUGLAS POINT	32020	105	MILLSTONE	105619
32	CVTR	12029	69	SEQUOYAH	32145	106	FERMI	134206
33	SHEARON HARRIS	12132	70	JAMESPORT	33200	107	THREE MILE ISLAND	136400
34	MONTICELLO	12344	71	PERKINS	34369	108	SHIPPINGPORT	143371
35	KEWAUNEE	12759	72	WATERFORD	35678	109	LIMERICK	152644
36	LASALLE	13343	73	NINE MILE POINT	36000	110	ZION	190314
37	CARROLL COUNTY	13999	74	FITZPATRICK	36000	111	INDIAN POINT	218398

7.6

6715

MITIGATION

STUDIES OF WAYS TO IMPROVE THE INDIAN POINT AND ZION CONTAINMENTS HAVE BEEN A MAJOR STAFF EFFORT SINCE THE TASK ACTION PLAN OF 1980.

RESULTS:

- o THE INDIAN POINT CONTAINMENTS ARE PREDICTED TO MITIGATE CORE MELT ACCIDENTS AS WELL OR BETTER - AS BUILT - THAN WE INITIALLY HOPED TO ACHIEVE THROUGH BACKFITS

  - MINIMAL OFFSITE RADIOLOGICAL CONSEQUENCES IF CONTAINMENT COOLING IS AVAILABLE

  - MODEST TO MINIMAL OFFSITE RADIOLOGICAL CONSEQUENCES EVEN IF CONTAINMENT COOLING FAILS

F. ROWSOME, NRR
49-28016
9/5/84

MITIGATION (CONT.)

RESULTS (CONT.)

o EFFECTIVENESS OF MITIGATIONS OPTIONS

SEVERAL CONCEPTS, SUCH AS CONTROLLED FILTERED VENTING, AUXILIARY CONTAINMENT, PASSIVE HEAT REMOVAL, CAN AVERT LATE OVERPRESSURE FAILURE OF CONTAINMENT, WHICH WAS FOUND TO BE THE LEADING CAUSE OF LATENT CASUALTIES AND OFFSITE PROPERTY DAMAGE

COSTS:

o THE MITIGATION CONCEPTIONS COST ROUGHLY $30 - $100 MILLION, VS. $1 TO $3 MILLION FOR COMPARABLE ACCIDENT PREVENTION IMPROVEMENTS

F. ROWSOME, NRR
49-28016
9/5/84

MITIGATION (CONT.)

- o UNCERTAINTIES:
  - IF MORE SEVERE CONTAINMENT FAILURE MODES ARE REALLY DOMINANT, EG STEAM EXPLOSIONS OR EARLY PRESSURE SPIKES, THEN THESE BACKFIT CONCEPTIONS WOULD BE INEFFECTUAL
  - IF CONTAINMENTS LEAK RATHER THAN BURST FOR GRADUALLY INCREASING PRESSURE, OR IF THE SOURCE TERMS COME DOWN, THEN THE VALUE OF MITIGATION COULD BE FAR LESS THAN WE ESTIMATE: $3 TO $20 MILLION
  - NOTE ALSO THAT THE "AFTER FIX" RISKS CALCULATED BY THE STAFF FAIL TO CREDIT SOME FURTHER VOLUNTARY ACCIDENT PREVENTION IMPROVEMENTS MADE BY THE LICENSEES, AND THUS OVERVALUE MITIGATION OPTIONS
  - THERE ARE ATTENDANT RISKS ASSOCIATED WITH MITIGATION BACKFITS

F. ROWSOME, NRR
49-28016
9/5/84

MITIGATION (CONT.)

o CONCLUSION:

NEITHER THE CONTENDED MITIGATION BACKFITS NOR THE MITIGATION CONCEPTIONS DEVELOPED BY THE STAFF LOOK DESIRABLE

F. ROWSOME, NRR
49-28016
9/5/84

PREVENTION

THE STAFF ELECTED TO ENCOURAGE THE LICENSEES TO IMPLEMENT THE LOW-COST PREVENTION FIXES UNDER STUDY FOR THE DOMINANT ACCIDENT VULNERABILITIES RATHER THAN MITIGATION FIXES AFTER THE FOLLOWING CONSIDERATIONS:

1. SPEED OF IMPLEMENTATION
   THE VOLUNTARY PREVENTION FIXES COULD BE IN PLACE BEFORE RESTART IN 1982-1983.

2. COMPATIBILITY WITH REGULATIONS
   SOME FIXES CONSTITUTED PARTIAL COMPLIANCE WITH EXISTING REGULATIONS; OTHERS WERE IN THE SPIRIT OF THE REGULATIONS.

3. RISK LIMITATION EFFECTIVENESS
   CONVENTIONAL ENGINEERING ANALYSIS AS WELL AS PRA SHOWED THE FIXES TO ELIMINATE OR SHARPLY REDUCE THE VULNERABILITY RESPONSIBLE FOR RISK-DOMINANCE IN EACH CASE.

F. ROWSOME, NRR
49-28016
9/5/84

PREVENTION (CONT.)

4. BENEFIT-COST CONSIDERATIONS

   ROUGHLY 100:1 IN FAVOR

5. DEFENSE-IN-DEPTH

   EACH FIX DEALT WITH A COMMON-CAUSE FAILURE.

FURTHER SEARCHES FOR COST-EFFECTIVE PREVENTION IMPROVEMENTS WILL NOT TURN UP HIGH-VALUE FIXES, BUT MAY WELL FIND COST-EFFECTIVE IMPROVEMENTS AMONG LOW-COST, MODEST VALUE OPTIONS, PARTICULARLY IN PROCEDURES, PERSONNEL TRAINING, MAINTENANCE AND THE LIKE.

F. ROWSOME, NRR
49-28016
9/5/84

PREVENTION FIXES

1. SEISMIC - Bumper added between Control Building and Superheater Building to damp interactions - Unit 2

2 and 3. FIRE - Alternate power cables added for component cooling water pump and charging pump to preclude RCP seal LOCA for certain fires - Units 2 and 3.

4. HURRICANE - Technical specification modification to shutdown unit if hurricane threatens site - Unit 2.

F. Rowsome, NRR
49-28016
9/5/84

SAFETY ASSURANCE PROGRAM (CONT.)

DESIRABLE FEATURES

- CALCULATE QUANTITATIVE MEASURES OF IMPORTANCE-TO-RISK FOR SYSTEMS, PRINCIPAL COMPONENTS, MAINTENANCE AND SURVEILLANCE PROCEDURES, OPERATING AND EMERGENCY PROCEDURES, AND TECH SPECS

- EVALUATE BENEFIT/COST FOR ALTERING PROCEDURES AND PERSONNEL TRAINING TO REDUCE VULNERABILITY TO THE MORE RISK-SIGNIFICANT POTENTIAL ERRORS, OMISSIONS, ETC.

- MAINTAIN AND UPDATE IPPSS AS A LIVING SAFETY EVALUATION TOOL

- EMPLOY IPPSS AS A TEST BED TO EVALUATE ACCUMULATING RELIABILITY DATA

F. ROWSOME, NRR
49-28016
9/5/84

SAFETY ASSURANCE PROGRAM

IT WOULD BE HIGHLY DESIRABLE FOR THE LICENSEES TO SET UP, WITH THE ADVICE AND APPROVAL OF THE STAFF, A WELL-PLANNED PROGRAM TO HARVEST INSIGHTS FROM THE IPPSS FOR THE CONDUCT OF OPERATIONS; SUCH PROGRAMS HAVE BEEN CALLED RELIABILITY ASSURANCE OR RISK MANAGEMENT PROGRAMS.

OBJECTIVES

- MAKE THE IPPSS "COME TRUE"
- IMPROVE PROCEDURES, OPERATOR TRAINING, EXPERIENCE FEEDBACK, AND DESIGN
- SENSITIZE PLANT PERSONNEL TO RISK SIGNIFICANCE OF THEIR TASKS

F. ROWSOME, NRR
49-28016
9/5/84

SAFETY ASSURANCE PROGRAM (CONT.)

- EMPLOY IPPSS TO EVALUATE IMPORTANCE TO INDIAN POINT OF PRECURSORS AT OTHER PLANTS

- TRAIN ALL RELEVANT OPERATIONS AND MAINTENANCE PERSONNEL ON IPPSS AND IMPORTANCE-TO-RISK FINDINGS

VALUE

IPPSS HAS ALREADY FOUND VERY COST-EFFECTIVE FIXES, APPLICATION TO SURVEILLANCE, MAINTENANCE, PROCEDURES AND TRAINING IS LIKELY TO FIND MANY MORE, ALBEIT OF MODEST RISK-REDUCTION VALUE AND COST, AND WILL HELP ASSURE THAT THE OMISSIONS AND APPROXIMATIONS IN THE IPPSS DO NOT MASK LARGE RISK CONTRIBUTORS

F. ROWSOME, NRR
49-28016
9/5/84

VARIETY OF RISK PERSPECTIVES

RISK BASED EVIDENCE OF MANY KINDS ON THE QUESTION "SHOULD INDIAN POINT BE SHUTDOWN OR OTHER REGULATORY ACTION TAKEN" WAS DEVELOPED BY THE STAFF FOR THE HEARING:

I. INTRA-PLANT COMPARATIVE RISK

   A. THE RISK CONTRIBUTIONS OF MANY ACCIDENT SCENARIOS TO WHICH INDIAN POINT MIGHT BE SUBJECT WERE COMPARED

   B. COMPARATIVE IMPORTANCE OF DIFFERENT ASPECTS OF BOTTOM-LINE RISK: EARLY CASUALTIES, LATENT CASUALTIES, OFFSITE PROPERTY DAMAGE, ONSITE CLEANUP COSTS, POST-ACCIDENT REPLACEMENT POWER COSTS

II. ABSOLUTE RISK

   A. COMMISSION QUESTION 1 ON THE RISK

   B. BENEFIT COST

      - COMPARISON OF THE COSTS OF SHUTDOWN (QUESTION 6) WITH THE VALUE OF RISK ELIMINATION

F. ROWSOME, NRR
49-28016
9/5/84

VARIETY OF RISK PERSPECTIVES (CONT.)

II.B. BENEFIT COST (CONT.)

- COSTS OF MITIGATION AND PREVENTION BACKFIT OPTIONS COMPARED WITH THE QUALITATIVE CHARACTER, EFFECTIVENESS, AND MONETARY VALUE OF THE ASSOCIATED RISK REDUCTION

III. COMPARISON WITH NON-NUCLEAR BACKGROUND RISKS

A. CONTENTION 1-1: COMPARISON TO 50 MILES

B. MORTALITY RISK GUIDELINES IN THE PROPOSED COMMISSION SAFETY GOALS

IV. INTER-PLANT COMPARATIVE RISK

A. QUANTITATIVE COMPARISONS OF FACTORS INFLUENTIAL TO BOTTOM LINE RISK, E.G., SITE DEMOGRAPHY, SEVERE RELEASE FREQUENCY

B. QUANTITATIVE COMPARISONS OF SOME SELECTED CONTRIBUTORS TO RISK, E.G., RISK FROM INTERNALLY INITIATED EVENTS

C. QUALITATIVE COMPARISONS OF DESIGN OR SITE FEATURES IMPORTANT TO RISK

F. ROWSOME, NRR
49-28016
9/5/84

VARIETY OF RISK PERSPECTIVES (CONT.)

IV. INTER-PLANT COMPARATIVE RISK (CONT.)

D. EXPLORATIONS OF STRATEGIES TO COMPENSATE FOR THE SITE DEMOGRAPHY

1. MITIGATION
2. PREVENTION
3. SAFETY ASSURANCE PROPOSAL

E. NOTE THAT NO PARTY OFFERED AN INTERPLANT COMPARISON OF COMPREHENSIVE, BOTTOM-LINE RADIOLOGICAL RISK, FOR LACK OF FULLY COMPARABLE DATA

F. ROWSOME, NRR
49-28016
9/5/84

WEIGHT OF THE STAFF EVIDENCE

I. INTRA-PLANT COMPARATIVE RISK

A. BASIS FOR CONSIDERATION

THE IDENTIFICATION OF PROMINANT ACCIDENT VULNERABILITIES AMONG THE MYRIAD POSSIBLE ACCIDENT SCENARIOS IS ONE OF THE MOST RELIABLE USES OF PRA, SINCE CONVENTIONAL ENGINEERING ANALYSES CAN EASILY VERIFY, AT LEAST QUALITATIVELY, THAT SUCH VULNERABILITIES ARE REAL AND SIGNIFICANT.

B. EVIDENCE

FOUR DOMINANT CONTRIBUTORS TO RISK WERE IDENTIFIED IN THE IPPSS OR THE STAFF PRA, CONFIRMED BY THE STAFF, AND RECTIFIED BY VOLUNTARY DESIGN AND/OR PROCEDURAL

F. ROWSOME, NRR
49-28016
9/5/84

WEIGHT OF THE STAFF EVIDENCE (CONT.)

I. INTRA-PLANT COMPARATIVE RISK (CONT.)

B. EVIDENCE (CONT.)

ALTERATIONS. A TENFOLD REDUCTION IN THE STAFF ESTIMATES OF SEVERE RELEASE LIKELIHOOD WAS ACHIEVED.

SINCE MOST CORE MELT ACCIDENTS CAN BE EXPECTED TO BE WELL CONTAINED OR LEAD TO WELL-MITIGATED RELEASES, ON-SITE RADIOLOGICAL CLEANUP AND LOSS OF SERVICE OF THE STATION (COSTS LIKE THOSE OF THE TMI ACCIDENT) LOOM LARGER, ON BALANCE, THAN OFFSITE PROPERTY DAMAGE. FEW CORE MELT SCENARIOS LEAD TO SUBSTANTIAL SOCIETAL HEALTH CONSEQUENCES. VERY FEW LEAD TO EARLY FATALITIES.

F. ROWSOME, NRR
49-28016
9/5/84

WEIGHT OF THE STAFF EVIDENCE (CONT.)

II. ABSOLUTE RISK ESTIMATES

A. BASIS FOR CONSIDERATION

COMMISSION QUESTION 1 CALLED FOR AN ASSESSMENT OF THE RISK. BACKFIT GUIDELINES AND WIDELY USED REGULATORY ANALYSIS GUIDELINES FOR REACTOR SAFETY STANDARDS DEVELOPMENT CALL FOR BENEFIT-COST TESTS; BENEFIT ESTIMATES FOLLOW FROM THE VALUE ACCORDED ABSOLUTE RISK REDUCTION. COMMISSION QUESTION 6 EXPLORED THE COSTS OF SHUTDOWN.

B. RESULTS

THE ESTIMATED OFFSITE RADIOLOGICAL RISK, AS DISPLAYED ABOVE, IS QUITE MODEST; SMALL ENOUGH, IN FACT, THAT INTERPLANT COMPARATIVE RISK MAY NOT MATTER.

SHUTDOWN APPEARS TO COST MORE THAN IT IS WORTH BY

F. ROWSOME, NRR
49-28016
9/5/84

WEIGHT OF THE STAFF EVIDENCE (CONT.)

II. ABSOLUTE RISK ESTIMATES (CONT.)

B. RESULTS (CONT.)

ROUGHLY 41:1 TO 100:1.

THE MITIGATION CONCEPTIONS DISCUSSED IN CONTENTIONS AND STAFF STUDIES COST MORE THAN THEIR VALUE, THOUGH SOME ARE IN THE GRAY AREA.

THE PREVENTION IMPROVEMENTS VOLUNTEERED BY THE LICENSEES ARE WORTH ROUGHLY 100 TIMES THE COST. IN FACT, THEIR ROUGHLY QUARTER BILLION DOLLAR VALUE MAKES THE ENTIRE INQUIRY INTO IP RISK, INCLUDING HEARING COSTS, HIGHLY COST-EFFECTIVE, EVEN IF THESE FOUR FIXES WERE THE SOLE VALUE OF THE ENTERPRISE.

F. ROWSOME, NRR
49-28016
9/5/84

WEIGHT OF THE STAFF EVIDENCE (CONT.)

III. COMPARISON WITH NON-NUCLEAR BACKGROUND RISK

A. BASIS

1. CONTENTION 1.1 CALLED FOR AN ASSESSMENT OF WHETHER THE RISK IS "HIGH" AS FAR AS NEW YORK CITY.

2. COMPARISONS WITH BACKGROUND APPEAR IN THE COMMISSION'S MORTALITY RISK GUIDELINES, THOUGH SAFETY GOALS ARE PROSCRIBED BY THE COMMISSION AS A BASIS FOR STAFF DECISION MAKING DURING THE EVALUATION PERIOD.

B. RESULTS

AVERAGED OUT TO 50 MILES EARLY FATALITY RISK AMOUNTS TO ROUGHLY 2.5 PARTS PER MILLION OF THE BACKGROUND ACCIDENTAL DEATH RISK, AND LATENT CANCER FATALITY RISK

F. ROWSOME, NRR
49-28016
9/5/84

III. COMPARISON WITH NON-NUCLEAR BACKGROUND RISK (CONT.)

B. RESULTS (CONT.)

FROM INDIAN POINT AMOUNTS TO ROUGHLY ELEVEN PARTS PER MILLION OF THE BACKGROUND CANCER MORTALITY RISK FROM ALL CAUSES.

STAFF ESTIMATES OF RISK BEFORE THE PRA-INSPIRED PLANT IMPROVEMENTS WERE MADE STRADDLE THE EARLY FATALITY MORTALITY RISK GUIDELINE, AND FALL BELOW IT (BUT NOT BY A SUBSTANTIAL MARGIN) FOR THE CURRENT (AFTER FIX) SITUATION.

STAFF ESTIMATES OF THE CANCER FATALITY RISK FALL WELL BELOW THE CORRESPONDING MORTALITY RISK GUIDELINE.

F. ROWSOME, NRR
49-28016
9/5/84

WEIGHT OF THE STAFF EVIDENCE (CONT.)

IV. INTERPLANT COMPARATIVE RISK

A. MEMORANDUM AND ORDER ESTABLISHING THE HEARING INCLUDES:

"THE COMMISSION INTENDS TO COMPARE INDIAN POINT TO THE SPECTRUM OF RISKS FROM OTHER NUCLEAR POWER PLANTS, SINCE THE PRIMARY BASIS FOR THE COMMISSION'S DECISION WILL BE HOW EXTREME ARE THE INDIVIDUAL AN SOCIETAL RISKS ASSOCIATED WITH INDIAN POINT COMPARED TO THE SPECTRUM OF RISKS FROM OTHER OPERATING STATIONS."

B. EVIDENCE

1. INDIVIDUAL RISK

ALL INDICATIONS ARE THAT THE RISK TO INDIVIDUALS ARE WELL WITHIN THE RANGE OF RISKS POSED BY OTHER PLANTS. SITE DEMOGRAPHY HAS VIRTUALLY NO EFFECT ON INDIVIDUAL RISK.

F. ROWSOME, NRR
49-28016
9/5/84

IV. INTERPLANT COMPARATIVE RISK (CONT.)

2. SOCIETAL RISK

SOCIETAL RISK MEASURES SUM THE INDIVIDUAL RISKS OVER THE POPULATION AT RISK, AND ARE THUS ROUGHLY PROPORTIONAL TO POPULATION DENSITY.

- o FOR THE WIDELY STUDIED INTERNALLY-INITIATED ACCIDENTS, BETTER-THAN-AVERAGE DESIGN FULLY COMPENSATES FOR HIGHER-THAN-AVERAGE POPULATION.
- o FOR THE DOMINANT EXTERNALLY-INITIATED ACCIDENTS, THERE IS LITTLE BASIS FOR COMPARISON, ALTHOUGH WE CAN ESTABLISH SOME PERSPECTIVES:
- o OTHER PLANTS SHARE WITH INDIAN POINT EQUALLY ADVERSE DEMOGRAPHY.

F. ROWSOME, NRR
49-28016
9/5/84

IV. INTERPLANT COMPARATIVE RISK (CONT.)

2. SOCIETAL RISK (CONT.)

- A COMPARISON OF SEVERE RELEASE FREQUENCY AT IP, INCLUDING BOTH INTERNAL AND EXTERNAL CONTRIBUTORS WITH SEVERE RELEASE FREQUENCY FROM OTHER PRAs INCLUDING ONLY INTERNAL CONTRIBUTORS - A COMPARISON PREJUDICIAL TO IP - SHOWS THAT IP IS ROUGHLY AVERAGE IN SEVERE RELEASE FREQUENCY.
- TOGETHER THESE CLUES SUGGEST THAT THE SOCIETAL RISK FROM IP IS NOT OUTSIDE THE SPECTRUM FOR OTHER PLANTS, THOUGH WE CANNOT SAY WHETHER IT IS AVERAGE OR ABOVE AVERAGE.
- PLANT-TO-PLANT VARIATIONS IN SEVERE RELEASE FREQUENCY ARE AT LEAST AS LARGE, AND MAY BE

F. ROWSOME, NRR
49-28016
9/5/84

WEIGHT OF THE STAFF EVIDENCE (CONT.)

IV. INTERPLANT COMPARATIVE RISK (CONT.)

2. SOCIETAL RISK (CONT.)

LARGER, THAN SITE DIFFERENCES IN DEMOGRAPHY. AS A RESULT, DEMOGRAPHY, WHILE IMPORTANT TO SOCIETAL RISK, IS NOT A RELIABLE PREDICTOR OF WHICH PLANTS POSE THE LARGEST RISKS.

F. ROWSOME, NRR
49-28016
9/5/84

RELIABLE USE OF PRA

THE STAFF OFFERED SUGGESTIONS ON THE RELIABLE USE OF PRA, THAT WE USE IN OUR OWN DECISION MAKING. PRAs ARE EVALUATION MODELS BUILT ON A LOGICAL FRAMEWORK OVER WHICH IS STRETCHED A FABRIC OF OFTEN-SIMPLIFIED APPROXIMATIONS. DIFFERENT INFERENCES DRAWN FROM THE PRA EXERCISE THESE APPROXIMATIONS IN VERY DIFFERENT WAYS. SOME INFERENCES MAY REST FIRMLY ON THE UNASSAILABLE LOGICAL FRAMEWORK. OTHERS MAY BE SO SENSITIVE TO UNCERTAIN ASPECTS AS TO BE NO BETTER THAN GUESSES. THUS, EACH INFERENCE ONE MAY WISH TO USE AS A BASIS FOR REGULATORY DECISION MAKING WE TAKE TO BE A CLUE - AN HYPOTHESIS TO BE TESTED AGAINST THE FULL WEIGHT OF SCIENTIFIC EVIDENCE THAT CAN BEAR UPON ITS VALIDITY. WHENEVER PRA-BASED INSIGHTS ARE USED BY THE STAFF TO GIVE SHAPE OR FOCUS TO REGULATORY ACTION, WE FIND IT WISE TO ENTERTAIN THE

F. ROWSOME, NRR
49-28016
9/5/84

HYPOTHESIS THAT THE PARTICULAR PRA INSIGHTS MAY BE WRONG. IN PARTICULAR, WE TRY TO IDENTIFY AND EXPLORE THE ASSUMPTIONS IN THE PRA TO WHICH THE RELEVANT INSIGHTS ARE PARTICULARLY SENSITIVE. IN SHORT, IT IS GENERALLY DESIRABLE TO MAKE A CONTEXT-SPECIFIC ASSESSMENT OF PRA UNCERTAINTIES.

IMPLICATIONS FOR STAFF DECISION MAKING

NEITHER THE BOTTOM-LINE RISK PREDICTIONS NOR THE INTERPLANT COMPARISONS OF BOTTOM-LINE RISK PASS THE TEST SUGGESTED ABOVE FOR RELIABLE USE OF PRA. TOO MANY UNCERTAIN FEATURES ARE IMPORTANT.

HOWEVER, THE UNDERSTANDING OF THE CHARACTER OF THE RISK, CLUES TO ITS MAGNITUDE, THE ASPECTS OF DESIGN, OPERATION, AND SITING

F. ROWSOME, NRR
49-28016
9/5/84

RELIABLE USE OF PRA (CONT.)

INFLUENTIAL TO RISK, THE STRENGTHS AND WEAKNESSES OF THE MORE IMPORTANT FEATURES OF DESIGN, OPERATION, AND SITING, AND THE POWER OF THE PRA TO SHARPEN THE FOCUS OF PLANT OPERATIONS IN THE FUTURE TO REFLECT THE LESSONS LEARNED COMBINE TO PROVIDE A FIRM FOUNDATION FOR A DECISION. THUS, IT IS THE ENSEMBLE OF EVIDENCE, AND THE CONTINUED USE OF THE PRA AS A RISK MANAGEMENT TOOL (THE SAFETY ASSURANCE PROGRAM) RATHER THAN A PROBABILISTIC THRESHOLD TEST THAT SUPPORTED THE STAFF RECOMMENDATIONS.

F. ROWSOME, NRR
49-28016
9/5/84