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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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BRIEFING ON SPENT FUEL POOL STUDY

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PUBLIC MEETING

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Nuclear Regulatory Commission
Room 1F15
11555 Rockville Pike
Rockville, Maryland

Thursday, November 14, 1996

The Commission met in open session, pursuant to notice, at 2:05 p.m., the Honorable SHIRLEY A. JACKSON, Chairman of the Commission, presiding.

COMMISSIONERS PRESENT:

SHIRLEY A. JACKSON, Chairman of the Commission
KENNETH C. ROGERS, Member of the Commission
GRETA J. DICUS, Member of the Commission
NILS J. DIAZ, Member of the Commission
EDWARD McGAFFIGAN, Member of the Commission

STAFF AND PRESENTERS SEATED AT THE COMMISSION TABLE:

ANDREW BATES, Acting Secretary

MARTY G. MALSCH, Deputy General Counsel

JAMES TAYLOR, EDO

ED JORDAN, AEOD

ERNIE ROSSI, AEOD

JOSE G. IBARRA, AEOD

GARY HOLAHAN, NRR

P R O C E E D I N G S

[2:05 p.m.]

CHAIRMAN JACKSON: Good afternoon, ladies and gentlemen.

The purpose of this meeting is for the NRC staff to brief the Commission on the results of its assessment of the likelihood and consequences of an extended loss of spent fuel pool cooling inventory.

As you all are aware, fuel handling and spent fuel pool issues have been the subject of considerable recent attention and has highlighted the need to better understand issues such as spent fuel pool design, fuel handling practices and the contribution of the spent fuel pool to overall plant risk. This assessment is one part of our ongoing effort to enhance our performance in these areas and we look forward to hearing the results of your study.

I understand copies of the presentation slides are available at the entrances to the room.

Do any of my fellow commissioners have any comments at this point? If not, Mr. Taylor, please proceed.

MR. TAYLOR: Good afternoon.

With me at the table are Ed Jordan, Ernie Rossi, Jose Ibarra from the Office of AEOD and Gary Holahan from NRR.

As the Commission may be aware, earlier in August

of this year the staff presented the NRR Spent Fuel Storage Pool Action Plan, which covered the issues outlined at the beginning by the Chairman but, to provide an independent assessment of this issue of spent fuel cooling, also earlier this year I asked AEOD to perform an independent study of the likelihood and consequences of loss of spent fuel cooling and this assessment was provided to the Commission on October 3.

The staff will now present that information.

Ed Jordan will continue.

MR. JORDAN: The AEOD study and the August 1 briefing are complementary since the action plan was design and requirements based and the focus of the AEOD assessment was a collection and analysis of operating experience related to fuel pool cooling.

Our assessment attempts to characterize what is happening at reactor sites as it impacts fuel cooling. Our findings are based on site visits to specific plans, a probablistic risk assessment of a single plant and the operating experience collected from all plants.

The summary of the lessons that you will hear through this are that, first, a loss of spent fuel inventory, the pool inventory, may be more important than previously thought. And, second, that operator actions for both prevention and mitigation are of primary importance in

spent fuel events.

The assessment was a team effort by members of the reactor analysis branch of AEOD. Jose Ibarra was the team leader and will make the presentation.

Jose?

MR. IBARRA: Thank you, Mr. Jordan.

In February of this year, the Executive Director for Operation requested that AEOD perform an independent assessment of loss of spent fuel pool cooling. We formed a team to do this assessment.

All through this assessment, we were in contact with NRR. We wanted to make sure NRR understood what we were doing but, more important or equally important, we wanted to get the latest information that was available from the licensees.

The assessment itself had six major tasks.

Slide number 2, please.

[Slide.]

MR. IBARRA: The first of the major tasks was we had to deal with 74 different configurations and we developed two generic configurations, one for a pressurized water reactor and then one for an ordinary water reactor. And another of our important tasks was to review our over 12 years of operating experiments and in doing this we reviewed about 700 separate documented operating events. In addition

to this, we also looked at the foreign experience.

A very important task was to go to the licensees and to gather information and we were interested in looking at the physical configuration of the pools and understanding the practices and procedures that the licensees were doing and we conducted six site visits.

In addition to this, we conducted two more additional trips to interview two individuals who had formerly submitted a Part 21 on Susquehanna.

We reviewed the regulations. Basically, this is reviewing the standard review plan and going through 10 CFR 50, Appendix A, to identify the general design criteria and we also identified the applicable regulatory guides.

Now, when we talk about the spent fuel pool cooling, loss of cooling, there is a lot of calculations involved in this and we felt it was important for us to do our own independent assessment and we did this for the electrical system, the instrumentation system, we performed some heat load calculations and also radiation levels.

And then one of the last major tasks was to assess the risk of losing spent fuel pool cooling and for this we contracted with Idaho National Engineering Labs to assist us.

Slide number 3.

[Slide.]

MR. IBARRA: Like I mentioned before, we had to deal with 74 different designs that covers 109 operating plants. Basically all the designs are a little bit different so we developed two generic diagrams and what we have in front of us is the pressurized water reactor. This was a basis for our assessment in the sense that we had to identify the important components and how they relate to loss of spent fuel pool cooling.

I would like to point out some of the important features. For the pressurized water reactor, let's start off with the right-hand side.

The reactor is in a separate building from the spent fuel pool. On the reactor side important components are refueling cavity seal. And then you have the fuel manipulation area and then the fuel transfer tube.

In a separate building adjacent to the containment building would be the spent fuel pool. They usually call this the fuel handling building or the auxiliary building. Here we have a fuel transfer canal, we have the gates, the pool structure itself with a liner. The pool structure is reinforced concrete. And then we have the fuel racks. The fuel racks are basically under 20 feet of water. And then on the left-hand side, we have the forced cooling, the components consisting of the spent fuel pumps and a head exchanger.

Also we have various sensors. This includes the temperature, the level and the radiation.

A very important component for us is the connected systems. Connected systems would be like the purification system, the make-up sources and the reactor itself when it is undergoing refueling.

When we talk about plant differences, what are some of those differences? Well, the dimensions of the pool sometimes vary and then the number of pumps varies, number of heat exchangers varies, number of loops within that varies. We have different make-up sources.

Some licensees have a different number of transfer tubes and then, if this wasn't enough within, outside the structure itself of the spent fuel pool, we might have equipment that varies with the different plants.

Slide number 4.

[Slide.]

MR. IBARRA: What we have here now is the generic boiling water reactor configuration and basically the left-hand side is what we saw in the pressurized water reactor. There are some differences and one of the major differences is that the reactor and the spent fuel pool are in the same building, one difference from the pressurized water reactor.

And some other differences are we have two gates. When they actually do refueling, they will flood the reactor

side up to the level of spent fuel pool and then they will remove those gates.

In order to simplify our assessment of losing cooling, we had to break it up into two different areas, loss of inventory and loss of cooling. And loss of inventory would be the connected systems, we have the gates and then we have the structure itself, the pool structure.

For loss of cooling, we are talking about the coolant flow and the heat sink.

Next slide, slide number 5, please.

[Slide.]

MR. IBARRA: We reviewed over 12 years of operational experience. This is looking at the licensee event reports. We looked at 5072 reports, inspection reports, industry reports and basically any other document that described operational events. This included looking at 700 separate documented operational experiences and we were able to screen these down to about 260 events.

This is in addition to looking at the international community to find out how they were doing and they are consistent with our operating experience.

What we have a slide here of is a table of where the events would fall. And we have two columns. The actual one, one named actual and one precursor. And I will explain a little about what we mean by precursor.

If we look at the -- under inventory, structure or liner, precursor column, we have 35 events. One of these events was a report to us from a licensee that stated that under certain temperatures the liner could buckle and, if buckled enough, it would cause coolant loss. In contrast to the eight on the actual column and there we do have leaks in the coolant.

Slide number 6, please.

[Slide.]

MR. IBARRA: This is a final breakdown of a loss of inventory and you can see once again the different categories of where the events would fall. Some numbers I would like to point out is the configuration control. That's 16 of the 20 of the connected systems would be configuration control and we found this was mostly due to human error.

CHAIRMAN JACKSON: You mean gates being open?

MR. IBARRA: Gates being open and so forth, wrong alignments.

Under gates and seals, it's mostly the gate seals that have failed there or that have leaked and in pool structure or liner, like I mentioned in the slide before, there was leaks, actual leaks to the liner. And, of course, we haven't had any earthquakes or any seismic events and there has never been any failure due to that nature.

Another number that sort of stands out is the 32 under precursor under load drops and what we see there are tech spec violations, the licensee moving heavy loads over the fuel.

Slide number 7.

COMMISSIONER ROGERS: Excuse me, before you leave that.

MR. IBARRA: Sure.

COMMISSIONER ROGERS: Would the precursor data include allegations?

MR. IBARRA: No.

COMMISSIONER ROGERS: No? You wouldn't treat an allegation as a precursor?

MR. IBARRA: No.

COMMISSIONER ROGERS: Unless it was substantiated in some way?

MR. IBARRA: We do find like a lot of precursor like analysis where they determine something can go wrong but it actually has not gone wrong but allegations, no.

MR. ROSSI: Well, I think it would include an allegation if, as a result of the allegation, the licensee then filed a report of some sort based on what he really found. So in that respect, if the allegation was substantiated and then it was put in one of the reports that we researched then it would be included. But an allegation,

in and of itself --

COMMISSIONER ROGERS: Yes, just a raw allegation.

MR. ROSSI: No, it would not constitute a precursor.

MR. IBARRA: Slide number 7.

[Slide.]

MR. IBARRA: Now, a lot of the events and times, we were not able to extract sufficient information to do plots but we were able to extract some level decreases here from some of the events and we feel the most significant of the events. None of these have led to fuel uncovery.

CHAIRMAN JACKSON: What is there about 12 to 60 inches?

MR. IBARRA: That is just the way we broke it up, even though I think one foot is pretty substantial.

If you go look at the spent fuel pools, they have a gauge there and you could see that. A few inches, you probably couldn't see. So, you know --

CHAIRMAN JACKSON: I guess what I am really looking at is this big bump in the one to five feet level decrease.

MR. IBARRA: That's just the way they fell.

CHAIRMAN JACKSON: But you are saying already the 12 inches is significant.

MR. IBARRA: You could see that. Yes, you could

see that visually.

MR. ROSSI: Again, there is a lot of water over the fuel, before you get down.

CHAIRMAN JACKSON: I know, it's about 20 feet.

MR. ROSSI: About 20 feet.

CHAIRMAN JACKSON: But still, five, if you get up to five and you didn't break it down, that's a lot of water.

MR. ROSSI: Yes.

MR. IBARRA: We would be concerned, of course, anything over a foot but here we have two events that are really of concern, they went over five feet.

One of them was Hatch in 1986. It was an inflatable seal. Then River Bend, 1987, this was a configuration control problem and there we lost from 60 to 120 inches.

We calculated the frequency of losing more than a foot of water from our operating experience to be one --

COMMISSIONER DIAZ: Excuse me, why this range, 60 to 120?

MR. IBARRA: We couldn't nail it down. We just knew it was within this range.

COMMISSIONER DIAZ: Within five feet?

MR. IBARRA: More than five feet.

We calculated the frequency now of losing over one foot of water, of coolant, is about one occurrence in 100

reactor years.

Slide number 8.

[Slide.]

MR. IBARRA: Once again, we were able to plot the duration of some of these events and we would be concerned --

CHAIRMAN JACKSON: Basically, this one per 100 reactor years, Commissioner Dicus points out, is essentially one per year, right?

MR. IBARRA: Yes.

COMMISSIONER DICUS: That's an easier way to look at it?

MR. IBARRA: Yes.

On slide number 8, what we have now, we plotted duration and the -- of concern to us, of course, any duration that is not picked up right away. But eight hours is important to us because, at that point, some pools can start boiling. And we have two -- three incidents here that lasted over eight hours. Two in particular lasted over 24 hours. We had Wolf Creek in '87, configuration control problem, that lasted 72 hours. And then we had Hatch, 1986, an inflatable seal problem, over 24 hours.

Slide number 9.

[Slide.]

CHAIRMAN JACKSON: Did the water boil in either of

these cases?

MR. IBARRA: No.

COMMISSIONER ROGERS: But that comment about eight hours, that depends on how long the fuel has been allowed to cool in the vessel before it is brought in.

MR. IBARRA: Surely, it is more critical when you are doing refueling than when you are in normal operations. Normal operations, you have lots of time, right.

COMMISSIONER ROGERS: Well, you could have lots of time in refueling if you wanted to.

MR. IBARRA: In slide number 9, now we are plotting loss of cooling and temperatures increase. And of concern to us would be the one that increased 50 degrees and this occurred in Farley in 1983. A configuration control problem again.

And we calculated now for a frequency of occurrence that would increase the temperature over 20 degrees would be two to three in 1,000 reactor years.

Slide number 10.

[Slide.]

MR. IBARRA: And the other one, you know, we were able to cut off at zero.

Slide number 10, we are plotting loss of cooling, now, duration again. Once again, eight hours to us is an important point. We do have here three events that went

over eight hours. Hadden Neck in '86, a pump failure that went 32 hours. River Bend in 1989, a configuration control problem, 30 hours. And then Seabrook in '94 went 24 hours and Seabrook was a configuration control problem also.

Slide number 11.

[Slide.]

MR. IBARRA: We did six site visits. We visited North Anna --

COMMISSIONER ROGERS: Excuse me, if I could just go back to loss of cooling event?

MR. IBARRA: Yes.

COMMISSIONER ROGERS: What is the meaning of those hours? I mean, when did the clock start ticking to measure those hours, from the time that the loss of cooling took place, started, whatever, failed or whatever, or until it was noted?

MR. IBARRA: Well, it's from the point of noted until the point of being corrected.

COMMISSIONER ROGERS: But it could be longer than that.

MR. IBARRA: The end point we know; the beginning point might be a little bit -- you know, the information is not there, we don't know. But we do know within certain, you know, limits.

COMMISSIONER ROGERS: What I am really trying to

get at was how alert was the licensee to the fact that this took place and are these just simply measures of how long it took to correct the problem after they discovered it or does it also include some time when they should have known it?

MR. IBARRA: Well, a little bit of both. You know, it does take time to correct the problem once you know.

COMMISSIONER ROGERS: Right.

MR. IBARRA: And, of course, that would be in there. But in our opinion, of course, it was too long.

COMMISSIONER DIAZ: When you said loss of the coolant pump, you mean both coolant pumps were inoperable because these all have redundant systems?

MR. IBARRA: It would be loss of a pump.

COMMISSIONER DIAZ: One pump?

MR. IBARRA: One pump.

COMMISSIONER DIAZ: And the other pump was operable?

MR. IBARRA: In some cases, one pump is more than enough for cooling.

COMMISSIONER DIAZ: I know that it is more, but they normally have two pumps, right?

MR. IBARRA: Or three.

COMMISSIONER DIAZ: Right. So we didn't lose complete cooling capability; we just lost one pump?

MR. IBARRA: In some cases you lost one pump, yes.

MR. JORDAN: My understanding of the study was that this is a case when no pump was available. Whether the other pump was operable, it wasn't connected. You have to manually back these up; there is no automatic transfer. That's how you're normally running, with one pump and one heat exchanger and if there is a failure then you have to first detect it and then you have to take manual actions to valve the other pump in and start it.

COMMISSIONER DIAZ: Actually you lost coolant because one pump that was operating, was not operating and the other pump which should come and be switched was not switched?

MR. JORDAN: Not yet switched.

MR. ROSSI: Jose, is that --

MR. IBARRA: That's correct.

COMMISSIONER ROGERS: Well, that still doesn't totally give me the full picture. Namely, what this 32 hours, say, in that particular instance, I don't care whether it is 30 or 32, but how -- what portion of this time was there no cooling available and what portion of the time was there ordinary cooling not available?

MR. IBARRA: Well, the --

COMMISSIONER ROGERS: Do you know what I'm saying? If they had to switch over, was the 32 hours -- did that

include the time in which -- was that the time in which there was no pump available at all to get switched over to the other?

MR. IBARRA: That's correct. Time without cooling.

COMMISSIONER ROGERS: Thirty-two hours?

MR. IBARRA: From the --

COMMISSIONER ROGERS: You could fly in from the West Coast in that time.

MR. IBARRA: Yes, a lot of it is being aware that it's occurring.

MR. ROSSI: The biggest part of the time, I believe, was the time to detect that they were without cooling.

COMMISSIONER ROGERS: Well, that was what I was asking. How much of the time was the time they didn't know they had the problem?

MR. ROSSI: The biggest amount of the time is the time it took to detect they had no cooling.

That, I believe, is the biggest time in all these cases because once they know they have lost the cooling then I think it is reasonably quick to start cooling. They catch it real quick, after they know they have the problem.

COMMISSIONER DICUS: Do we know how quick that is?

MR. IBARRA: Some of the LER, you know, do not

give you enough detail to be able to gather some of that information but it is true that once you find it, the correction is rather quick, versus, you know, the time to detect that it was occurring.

MR. ROSSI: There is one other thing I think I will see if I can clarify and that is that there is the question of pumps being available and then there is the question of pumps running and I believe what you have here is a situation where these are the number of hours that no pump was running. But there might have been a pump available to run and, as a matter of fact, I think in most cases there was. It was a matter of someone turning that pump on.

These are the times when no pump was running and the majority of this time is the time to detect that fact and then once you have detected it, you can then turn a pump -- another pump on or restart the pump that had been turned off and available. Let me just make sure I am clear on that. "Available" means that even though it may not be running, you can turn it on if you want to. It's not torn down for maintenance or a seized bearing or anything of that sort.

CHAIRMAN JACKSON: But detection of when the pump -- the availability of the pump is by inference or some back-calculation. If they didn't know it was not running,

they didn't know it was not running so there was some, you know, going back to infer or try to calculate that loss.

MR. ROSSI: That is basically correct. I am not sure it would be a calculation. I think if it had not been available because it was broken in some way, that would generally have been included in the report --

CHAIRMAN JACKSON: Right, but what I am trying to say is what we have been talking about for the last few minutes had to do with the fact of most of the time that we see reflected here being the time to detect that there is no pump running?

MR. ROSSI: That's correct.

CHAIRMAN JACKSON: So I am saying if one had not detected that the pump is not running, then that means there is some period of time before I came and looked and said, oh, this pump is not running. Then you have to go back and try to figure out --

MR. ROSSI: Yes, you have to deduce when it probably started. Right.

CHAIRMAN JACKSON: That is what I am saying.

MR. JORDAN: That will be reflected when we get to the end, in terms of part of the corrective action may be better instrumentation.

CHAIRMAN JACKSON: Okay.

MR. JORDAN: There is not a great deal of active

instrumentation indicating the condition of the pumps.

COMMISSIONER DIAZ: Most of the systems did not have an automatic switchover --

MR. JORDAN: That's correct.

COMMISSIONER DIAZ: -- from one pump to the other pump is what you're saying. I know that some do but a lot of them did not have them.

MR. IBARRA: It's not typical.

So the six site visits included North Anna, South Texas project, Susquehanna, River Bend, TMI and Calvert Cliffs and basically this covers all the reactor vendors, big and small architect engineers, single and shared pools and you have old and new plants.

And we were interested in looking at the physical configuration of the pools when trying to understand the practices and procedures that the licensees were using in their activities.

And one thing I would like to point out, the information that NRR had was a tremendous amount of information that assisted us in doing our assessment. It would have caused us problems if we wouldn't have had that information. But, by the same token, the NRR information were dealing with information and compliance and our focus was on operating experience. So we needed to go talk to the licensees and we talked to them at length, we sat down for

two days and talked to anybody that touched upon the spent fuel pool activities.

This included talking to the reactor operators, talking to the analysts, all sorts of engineers. We even talked to the outage planners and basically anybody that had anything to do with spent fuel pool activities.

Slide number 11.

MR. IBARRA: There was a good lot of good practices that we saw. There was one utility that had a loss of coolant event in 1987 and they learned very well from this experience.

Right now in the control room, they have a diagram that shows all the different alignments, all the different ways that spent fuel coolant could be aligned and nobody is allowed to make changes to that alignment until they come into the control room and discuss these alignments with the control room operator.

CHAIRMAN JACKSON: Where was this?

MR. IBARRA: This is River Bend.

CHAIRMAN JACKSON: Did they also have good procedures?

MR. IBARRA: From what we gathered, yes. River Bend was one of the better plants that we had that included a lot of these good operating practices. However, I must mention that not everybody had one of each of these.

Another important thing that we saw, a positive step, was risk assessments, spent fuel pool risk assessments that are included in their outage plant and several licensees had formal classroom training and similar training prior to refueling.

Also, a very important point to us was to get information to the operator that he could easily read. A lot of licensees had good graphs that you could quickly look and determine time to boil.

Several had very effective programs for analyzing their problems, plus analyzing what's been happening in the industry. One plant in particular had almost 11 years ago -- over 10 years ago done an analysis on their own to determine all the different pathways that you can lose coolant in the spent fuel pool.

COMMISSIONER ROGERS: I have a question on the simulator training. Is it possible to simulate total fuel transfer from the reactor to the spent fuel racks on the simulator?

MR. JORDAN: Not to my knowledge.

COMMISSIONER ROGERS: What aspects of simulator training then would be --

MR. IBARRA: Well, a lot of the aspects is being able to provide backup power, being able to go through all these procedures they would have to do the realignment of

the spent fuel pool and then allowing they still had higher level operating procedures.

Slide 12.

[Slide.]

MR. IBARRA: We've reviewed the regulations and this included reviewing the standard review plan, going through 10 C.F.R. Part 50, Appendix A and identifying the general design criteria. Also, we identified the applicable regulatory guides.

Like I mentioned before, we did our own engineering assessments. The first thing we looked at was the electrical system and we wanted to determine what kind of power supplies were being provided to the spent fuel pool system.

We determined that about 80 percent of them have safety-related power going to the pump safety -- spent fuel pumps, but these loads are shed when there is a loss of outside power, so you have to manually reload them, manual action.

We wanted to determine what kind of parameters are being monitored and where they're being monitored. We determined that there was temperature level radiation, coolant flow and leaked detection being monitored and they were monitored either locally or in the control room.

When they are monitored in the control room, they

are usually grouped together to one enunicator window and when that window alarms, then you have to send the control room operator down the local panels to determine which of the signals triggered this.

Now, some of the licensees do separate temperature and levels from that grouping and then some of them even go farther and put it to a meter or to an instrument. We feel, though, it's very important for the operator to continuously know where these temperature levels are. Some utilities do not have that.

For radiation levels, here we compiled a bunch of calculations from the licensees themselves to determine what kind of levels, radiation levels we're going to see in the spent fuel pool when the coolant decreases.

We found that at 1 foot, we have about 900 rem per hour. This is one 1 foot above the fuel. We covered that with about 8-1/2 feet, that drops down to about 20 milirem per hour.

Then one of the more important calculations was the heat load calculations. We performed a calculation for a pressurized reactor and a boiling water reactor. The time to boil on a pressurized water reactor is about 12 hours; for a boiling water reactor, it's about 7.4 hours.

This is just to the point that the coolant starts to boil. You still have room on top of the fuel. To boil

to the top of the fuel, we calculated for a pressurized reactor to be about 80 hours and about 50 hours for a boiling water reactor. These calculations are consistent for the industry.

Slide 13.

[Slide.]

MR. IBARRA: This is a slide that dramatically shows what can happen when you offload sooner into the outage. This was actual data we were able to compile from Nine Mile Point, Unit 2.

In their outage Number 1, we see they had about 108 hours to boil, but this is when they offloaded in 23 days. Their last outage was Outage Number 4 and that 108 had dropped down to 8 hours. This was due to the fact that now they offloaded in 5 days. This is very crucial because all utilities are now going to shorter refueling outages.

COMMISSIONER ROGERS: Before you leave that slide, where did these numbers come from.

MR. IBARRA: These numbers, we got them from Nine Mile.

COMMISSIONER ROGERS: I mean are they calculated numbers?

MR. IBARRA: They are actual numbers from their outage planning.

MR. ROSSI: I'm sure they're calculated.

MR. IBARRA: They're calculated. I'm sorry, they are calculated.

COMMISSIONER ROGERS: Then I think there's something wrong with them because in the first place, I think it's the wrong way to plot them. The interesting number is the days to offload and hours to boil, not the outage number.

If you look at them, you can see that there is something wrong here with this Outage 3 number or the Outage 4 because there's just too big a difference between the days to offload and the hours to boil.

There ought to be a nice, smooth curve, and it looks deceptively smooth by the way you plotted it, but if you plot it up the hours to boil versus days to offload, you see there's a big discontinuity. That number 29 doesn't fit on there very well at all, so there's something odd about these numbers.

MR. IBARRA: This data was from Nine Mile Point, Unit 2.

MR. JORDAN: But it's just a weaker curve --

COMMISSIONER ROGERS: I understand. Something is wrong.

MR. JORDAN: I'm agreeing with you.

COMMISSIONER ROGERS: With one of those numbers.

MR. JORDAN: It's a fundamental curve that we all

have in the textbook. We'll verify the number and get back --

COMMISSIONER ROGERS: It looks like the 29 is the one that's off.

CHAIRMAN JACKSON: You say the qualitative trend.

MR. IBARRA: What we wanted to point out there was the fact that if you offload in 5 days, there's a tremendous difference from offload in 23 days.

COMMISSIONER ROGERS: Yes, I think the point is an important one, but the details of it, I suggest you go back and look at again because there's something wrong.

MR. ROSSI: That we will do, we will recheck it.

MR. JORDAN: But the real point of this is that the time is reducing at plants with outages.

COMMISSIONER ROGERS: Sure. Oh, absolutely.

MR. JORDAN: So it's a big pressure on the utilities.

COMMISSIONER ROGERS: The sensitivity to it is because they are starting to work right down towards where these times are very short, so you really want to be sure that --

MR. TAYLOR: Generally, that's happening as they proceed.

COMMISSIONER ROGERS: Qualitatively, it's right; quantitatively, it doesn't look right to me.

CHAIRMAN JACKSON: You can use it at an outage plant.

MR. HOLAHAN: I suspect there are other elements to this. For example, for the fourth outage, the fuel from the third outage is still in the pool. That's a nonlinear effect and the operating history probably changes from cycle to cycle. So these are probably actual experience. I think if you were to use the same assumptions and do a calculation, you'd get --

MR. JORDAN: Numbers of fuel assemblies that they offload changes. We'll provide the data.

COMMISSIONER ROGERS: But I think it's worth looking at little more closely because there may be something in there particularly when you're going down to the low end here.

MR. JORDAN: Yes.

CHAIRMAN JACKSON: It's almost as if there's another axis which has to do with the load existing.

MR. ROSSI: There clearly would be another one. It depends on how much fuel is there and how much is offloaded in each refueling, so that is indeed the case.

CHAIRMAN JACKSON: So it exists in peak load is the missing element.

MR. TAYLOR: The constant is usually the level of the coolant and you know, how much it can absorb.

MR. IBARRA: Slide 14, please.

[Slide.]

MR. IBARRA: We contacted with Idaho National Engineering Lab to assist us in the risk assessment. INEL looked at existing PRAs but they concentrated on a PRA that was done by Pacific Northwest Laboratory on Susquehanna. This PRA was funded by NRR.

This PRA actually was the starting point of our assessment, so PNL had calculated near boiling frequencies. Let me explain what near boiling would mean. It would be the point before boiling where there's substantial number of substantial vapor being generated.

INEL looked at the PNL work and they did some corrections, both in methodology and in updating the data. Some corrections in methodology was to account for common cost failure and they also used a better human reliability model.

The updated data actually comes from us. As we were doing our assessment, we were feeing them the information, especially the frequency data on loss of cooling.

CHAIRMAN JACKSON: How does the concept of near boiling frequency relate to some other measure of risk like for damage frequency?

MR. IBARRA: Well, I'm about to get to that.

CHAIRMAN JACKSON: Okay.

MR. IBARRA: It's a lot easier to calculate near boiling frequency than it is damage to the fuel. We did not progress beyond the near boiling frequency, but we feel very confident that to the magnitude of this. Let me point out, this is just Susquehanna.

From the near boiling frequency, the risk of damage to the fuel and the spent fuel pool due to spent fuel pool accident is one to two orders of magnitude below the core damage frequency due to reactor accident.

If we look at this from the previous work and the current work, we see that the total near boiling frequency, the risk increases by 2-1/2 times. Then the two major components of the total near boiling frequency is loss of offset power and inventory losses according to the INEL work.

The Loop increased a risk factor of 3, but the big factor here is loss of inventory. We have a jump of about twentyfold. Part of that is due to the updated data from our operating experience to what we're feeding to INEL. The methodology, we can account for common cause failure and human reliability modeling.

Slide 15.

[Slide.]

MR. IBARRA: There was another important aspect

coming out of the Susquehanna PRA. PNL was able to do calculations on the configuration before and after they did some modifications. There were some modifications done by Susquehanna on instrumentation procedures and training. The calculation shows there is a risk reduction of a factor of 4 according to their improvements.

Another important factor coming out of the PRA, it showed vulnerability of an operating unit from a defueled unit. What we have in Susquehanna are two different units, two different pools that can be connected and basically you can have like one body of water.

If you have a situation where one unit is operating and the other one is in an outage situation, and that happens to boil, that could affect the operating unit. That's what we mean by that bullet.

Slide 16.

[Slide.]

MR. IBARRA: Our findings and conclusions we have divided this into likelihood and consequences, prevention and response. The consequences of actual events have not severe. That is according to our review of the upper end experience.

One thing I must point out, all these events we looked at were very slow developing events, so we didn't have like rapid drain down. The primary cause has been

configuration control and this is mainly due to human error.

According to our near boiling frequency calculations, the relative risk of fuel damage is low compared to other reactor events. We find that the likelihood and consequences are highly dependent on the human and on the various plant designs.

We calculated the frequency of losing coolant that is greater than 1 foot. It would be 1 per year, per reactor year, for 100 reactor years. The frequency of loss of coolant down that results in an increase greater than 20 degrees would be two to three occurrences in 1,000 reactor years.

CHAIRMAN JACKSON: If you went back to Slide 6 where you looked at the loss of coolant inventory event and you pointed out that these actual events were not ones where you had rapid loss of inventory, which of these event types would be the ones -- did you look at which ones are the ones that would have the highest probability of causing what you would call a rapid loss of coolant?

MR. IBARRA: Well, none has occurred, but we have -- when we're talking about cavity seals, that can be dramatic loss of coolant right away. We haven't had any of those, but that would be a very drastic event.

CHAIRMAN JACKSON: The reason one asks is because in principle, what one wants to look at is where the

greatest vulnerabilities are.

MR. TAYLOR: I think that is where it is. We've had some of those leak significantly in some of these events. If that goes completely, you lose water fairly fast.

CHAIRMAN JACKSON: Are those seals subject to any kind of catastrophic failure over time or you don't know?

MR. TAYLOR: I guess I can't answer that. Some of them are inflatable.

MR. HOLAHAN: The worst event in this category, I think it is also referred to in the report, was a problem at Hadden Neck in 1984. I remember sitting in Mr. Jordan's office the next day writing a bulletin to have all the plants rereview their seals for the potential for gross failures. I think there have been a number of improvements back in that time frame.

MR. HOLAHAN: That pretty well drained the transfer canal. Unfortunately, there was fuel in it.

MR. IBARRA: 200,000 gallons.

MR. HOLAHAN: Yes.

CHAIRMAN JACKSON: So, in some sense, then on Slide 16 when you talk about frequency of coolant loss, then that is based on your actual -- the database from the study that you used, is that correct?

MR. IBARRA: Operational type.

MR. JORDAN: Yes.

MR. ROSSI: There is one other thing I'm not sure has been pointed out and that is that the geometry of the spent fuel pools a lot of times is such so that you can drain down to a certain point where there is a Weir or something of that sort that makes it more difficult to boil down before that, so in order to get down below the top of the fuel, you have to drain down to this Weir and then from then on, you would boil-down. So it's not like -- many of them -- I don't know that I can say every one -- but many of them are such that for things like gates, cavity seals and that kind of stuff, you wouldn't just go right down --

MR. TAYLOR: Yes, you would still have some water left.

MR. ROSSI: You'd have water and then you'd have to boil-down.

MR. TAYLOR: There's a ledge.

MR. ROSSI: Now, there are situations that have to be looked at in terms of siphoning-down below the Weir because if the antisiphoning device does not work, then there's a mechanism for perhaps going down.

Again, as Jose pointed out, all of these things are quite plant specific, exactly what exists at each plant. Different plants have different things.

CHAIRMAN JACKSON: I understand. So I guess then

the follow-on question would be, as you point out, these are very much plant-specific. What did you come away with in terms of the understanding then by the plant operators, the licensees, of where their greatest vulnerabilities are?

You talked about some good practices, but the question is how uniform is the knowledge or appreciation for the given plants of where their greatest vulnerability is?

MR. IBARRA: Well, we feel that there needs to be -- an issue or an awareness of what can happen. In our trips, we did find some licensees had a good understanding and awareness of the configuration and what can happen, but we still feel that industrywide, that needs to occur. You need training and procedures.

MR. ROSSI: There were differences from plant to plant, I believe, in terms of the knowledge of the actual people that were dealing -- would have to deal with the events. I believe you went to at least one site where they had done a lot of good engineering work to determine how long it might take to boil and so forth, but some of that information had not been conveyed on to the operators that would be the ones responsible for doing it, which is why, as Jose will go on, training and procedures can be very, very important because just making people aware of the kinds of things that can happen and the things they already have within the plant to deal with those things can perhaps do a

lot.

CHAIRMAN JACKSON: Are any of the events that you discuss on page six a surprise? Did anything jump out at you?

MR. IBARRA: Well, what jumped out at us, because it's interesting when you compile the data and look at it, there were some things that jumped out like the number of tech-spec violations. Licensees were still moving heavy loads over fuel, so there's a potential for a drop and damaging the fuel. But some of them know, there were not surprises, and some were surprises.

CHAIRMAN JACKSON: Thank you.

MR. IBARRA: Slide 17.

[Slide.]

MR. IBARRA: For prevention, we believe configuration control improvement can prevent or mitigate spent fuel pool accidents. We believe evaluations may be needed at some multiunit sites for potential spent fuel pool boiling effects and safe shutdown. This is the Susquehanna scenario.

For a response, we believe there has to be attention paid to time to boil now that the licensees are doing shorter outages. We believe improved procedures and training may be needed, and improvement to instrumentation and power supplies.

In particular, instrumentation, we believe that the operators need to know at all times where the level and temperature are and for power supplies, as I mentioned before, 20 percent would not have reliable power supplies.

Slide 18.

[Slide.]

MR. IBARRA: The followup to our assessment and what we're going to be doing, we do plan to put an information notice out to the industry to let them know what the findings were from our assessment that is ongoing right now.

We will be making our study into a NUREG. I think this lends a little bit of visibility to the study. In addition, we're going to be making the INEL risk assessment a NUREG. In the international community, we will be submitting a report to the instant reporting system, so the International Committee knows what we're doing in our assessment. We will continue to work with NRR in implementing whatever we come up with in our report.

CHAIRMAN JACKSON: Thank you. Let me ask you two quick questions. You mentioned the surprise at the number of tech-spec violations and there is this whole issue about differences between actual fuel handling practices and say the FSAR.

Did you find any correlation between the plants

that actually had the spent fuel pool events or precursors and those that had the tech-spec violations or these nonconformances relative to the FSAR?

MR. IBARRA: No, we didn't follow that.

CHAIRMAN JACKSON: You didn't specifically look at it?

MR. IBARRA: No.

CHAIRMAN JACKSON: Okay. Let me ask you this punitive question. I understand that to compensate for degraded boron flex, that some PWR licensees are considering amendments to technical specifications for spent fuel pool shutdown reactivity margins that would allow a credit for soluble boron.

If we were to then grant these amendments, how would that complicate a licensee's recovery from an inventory loss in a spent fuel pool?

Then, sort of the follow-on question is, would existing borated water sources be sufficient to compensate for worse case loss of spent fuel pool inventory under this scenario where we would have allowed amendments to take credit for soluble boron relative to reactivity margins?

MR. HOLAHAN: I could give that a try.

MR. IBARRA: Well, we didn't look at any reactivity, so our report did not cover that at all.

CHAIRMAN JACKSON: This is a favorite kind of

question of mine because it's a linked kind of thing.

MR. HOLAHAN: Yes. The staff has or was the recipient of a topical report from Westinghouse proposing a generic approach to taking some credit for soluble boron in spent fuel pools. That report was recently reviewed with the CRGR because it was really a new staff position. It would be a change in a standard we have established for many years.

We've made some modifications to the Westinghouse approach, but the staff still is inclined to accept some credit for soluble boron and the way we've done that is to assure that -- we've reduced our standard in the effect that says previously it was necessary to show that the fuel remained 5 percent subcritical with no credit for boron.

Now what we're saying is, we would allow sufficient credit for boron, so that the reactor only needed to remain subcritical -- not 5 percent subcritical, but subcritical with a high degree of confidence -- we're asking for a 95/95 type of statistical analysis to show that if the boron were not in the pool or, for example, what's of most concern is if you were responding to an event by putting fire water or service water or some other water into the spent fuel pool, you could lose boron to the point of approaching but never going critical, so it would give some credit but never so much credit that it was necessary to

keep the subcritical.

CHAIRMAN JACKSON: I guess the question I'm asking in evaluating this proposal, was it explicitly evaluated relative to the kinds of scenarios we're talking here, particularly the rapid loss of coolant?

MR. HOLAHAN: Yes, very much so. We looked at the boiling in the pool and our first conclusion was that boron is not loss if you boil the water down in the pool. It tends to stay --

CHAIRMAN JACKSON: You're talking about the catastrophic --

MR. HOLAHAN: The catastrophic draindown is the one of concern because probably something like one-half to two-thirds of the water could be replaced with unborated water and we found even if all the water was replaced with unborated water, the fuel in the pool would not go critical, had a very high confidence.

So we felt that we were reducing our requirement but still maintaining a very safe level.

CHAIRMAN JACKSON: Is that something that has a time factor associated with it, the amount of soluble boron is a function of time relative to say the further degradation of the boroflex?

MR. HOLAHAN: It would allow some credit for the boroflex that's existing in the spent fuel pools. I think

it wouldn't change that. The licensee would still take credit for the amount of boroflex that they could show was appropriate.

CHAIRMAN JACKSON: Well, you understand what happens to boroflex?

MR. HOLAHAN: Yes.

CHAIRMAN JACKSON: It's throughout the pool as a suspension or something like that, if it breaks off or degrades?

MR. HOLAHAN: Yes, and it can -- there have been such problems. There's been some loss --

CHAIRMAN JACKSON: So if the Commission gets some anonymous letter, we can have confidence that you guys have evaluated all of these scenarios? That's what I'm trying to say?

MR. HOLAHAN: Yes.

CHAIRMAN JACKSON: Okay. This is November the --

MR. HOLAHAN: I believe we're being recorded.

MR. JORDAN: I would add that the CRGR review process did, in fact, bring this experience from this work into that meeting, so it was part of the basis for bringing back some of the conservatism into that review.

CHAIRMAN JACKSON: Okay. Thank you. Mr. Rogers.

MR. JORDAN: I would add that the CRGR review process did in fact bring this experience from this

report --

CHAIRMAN JACKSON: Into that --

MR. JORDAN: -- into that meeting.

CHAIRMAN JACKSON: Okay.

MR. JORDAN: And so it was part of the basis for bringing back some of the conservatism into that review.

CHAIRMAN JACKSON: Okay, thank you. Commissioner Rogers.

COMMISSIONER ROGERS: Just you say that went to CRGR?

MR. JORDAN: Yes.

COMMISSIONER ROGERS: So that is one good reason to have CRGR, isn't it?

MR. JORDAN: Yes.

[Laughter.]

COMMISSIONER ROGERS: Do you expect anything beyond recommendations to come out of this? Do you expect any new requirements to emerge from this study?

MR. JORDAN: No.

COMMISSIONER ROGERS: No specific requirements?

MR. JORDAN: We are not recommending any specific requirements.

COMMISSIONER ROGERS: When you say attention to timed boil you are not thinking about setting some time limits or things of that sort?

MR. HOLAHAN: What I would add is I think this study supports the conclusions in NRR's August or July study and August presentation to the Commission, so to the extent that we said we were going to go ahead with the ten general areas to study for potential backfits, I think this is supporting information.

COMMISSIONER ROGERS: Consistent with that.

MR. HOLAHAN: Right -- and I think it adds emphasis in some areas to focus our review to some extent.

CHAIRMAN JACKSON: That's good. Commissioner Dicus.

COMMISSIONER DICUS: No.

CHAIRMAN JACKSON: Commissioner Diaz?

COMMISSIONER DIAZ: Yes, I have a couple of questions.

I think this is a very good start on this area, which is of concern, but is the event frequency analysis you did that was based on 12 years' experience, is an effort made to correlate the frequency of the events with plant age or plant configuration or any other possible indicator that you are actually going to have a degraded condition? Are there correlations available?

MR. IBARRA: We didn't attempt to do that.

COMMISSIONER DIAZ: That brings me to the next question then. How do we know that there are not some

plants out there which are a lot less safer than what this seems to indicate, that there's some plants that might have, you know, some plant configurations, age, or other particular indicators that might put them in a category in which they are, quote, "less safe," than what the report seems to indicate?

MR. JORDAN: I guess maybe I would comment on that.

It is true that the risk or the issues are dependent on the design very largely and that some of the designs are less forgiving than others, and so that is a reason for causing the utilities to do the review against the experience and see where their design may be weaker.

For instance, if they have no alarms and instrumentation and only one train and you have to rely on repairs then they are in much worse shape than a utility that has two trains and alarms or if there is a greater susceptibility to a seal failure, for instance, so they are very, very design dependent and the designs are so different.

COMMISSIONER DIAZ: I know they are design dependent. Shouldn't then we make an effort in really determining which ones are really more vulnerable because there might be some plans that have higher vulnerability because of the design configuration?

MR. JORDAN: The sequence I hope would be that we communicate to the utility. The utilities then are responsible for doing the review against the experience and then we follow up through our inspection programs to see that in fact utilities are using that experience.

MR. HOLAHAN: I think you should also be aware that the earlier report done in July of this year was based on, I would say, a much broader scope but less depth and detail when compared to the AEOD study, but there was a survey done of all the plants to look at the design features with respect to spent fuel pools, anti-siphon devices, whether they were seismically qualified, how many pumps were available, size of the pool.

There was a considerable amount of information collected for every plant and the project managers and the resident inspectors put that information into a survey-type vehicle, and then the technical staff looked over that to identify potential outliers, plants which had an unusual features that might lead to a concern, and that is what led to the ten categories of -- that we want to follow up on, so there is an ongoing program to identify plants with potential weaknesses.

COMMISSIONER DIAZ: Based on that, if, you know, since I think we require all spent fuel pools to have redundant cooling systems, and based on the fact that human

error or lack of, you know, instrumentation information seems to be major causes, would that justify at least indicating that plants should operate their instrumentation to prevent early notification of degradation of the systems?

MR. HOLAHAN: I think that is a fair statement.

We did identify both temperature and level instrumentation as potential areas for improvement on a number of plants.

Whether when we look at those plants in detail we can justify a specific change or not remains to be seen and I think also what the AEOD study does is it clarifies the issue a little bit in the context that if there is information that there is an ongoing event it looks like these events are not so difficult to recover from, in most cases, and so when we go through these issues and look at the plants we will be focusing on instrumentation and recovery type actions.

COMMISSIONER DIAZ: Except that there are no catastrophic issues in here and of course there could be, you know, from an earthquake -- in which case the probability to rapidly recover or initiate another system action will become imperative.

MR. HOLAHAN: Yes. Well, we do look at the seismic capability of the pools, but I think probably that the most important contribution from the AEOD study in my

view is focusing on the cavity seals.

I am not prepared to endorse the two times ten to the minus five number, but it is clear that when you think about that event the rapidity of the event and the difficulty of recovering in the high radiation environment, et cetera, makes it an important event to follow up on, so we'll pick that up as part of our plant-specific reviews.

COMMISSIONER DIAZ: All right.

MR. ROSSI: But that is one that we have sent out, as you indicated before, a bulletin at one point in time, to have it looked at --

COMMISSIONER DIAZ: Yes.

MR. ROSSI: -- across the industry, so --

MR. HOLAHAN: Well, we have been talking a little bit about maybe going back and making sure about the effectiveness of the bulletin.

It's been more than 10 years.

COMMISSIONER DIAZ: Yes.

[Laughter.]

CHAIRMAN JACKSON: Also I think that there is another piece that I heard you talk about, and that does have to do with the human performance aspect of this, you know, what people do.

If you are moving heavy loads over the spent fuel pool, that's people doing that. That doesn't have to do

with degraded cavity seals. That's people lifting heavy loads, so we can't lose sight of that.

Commissioner McGaffigan?

COMMISSIONER McGAFFIGAN: If I could just ask one question, as I understand it there are certain plants -- Oconee is one -- where the spent fuel inventory is used in certain event scenarios. I guess you pull down the inventory in the spent fuel pond to deal with something worse happening somewhere else.

How many cases are there like that?

MR. HOLAHAN: I believe all of the big power plants, Oconee, Maguire, and Catawba, have various arrangements in which they have put what is put a safe shutdown facility -- that is, if a plant has a complete loss of offsite power with the diesels not working for a station blackout, and I think they also use it to cover fire protection type concerns that could broadly affect the plant, they have a separate facility which provides water to the steam generators for decay heat removal and it also provides injection of water for the reactor coolant pump seals, and because they want clean purified water for that reason, they draw water off the spent fuel pool.

That is generally something like maybe 30 gallons per minute.

COMMISSIONER McGAFFIGAN: Okay.

MR. HOLAHAN: So that is not, if it is working properly, that is not a big concern, although we will look at the potential for a pipe break or something that would inadvertently drain water out of the pool, but we have identified those plants for some follow-up.

COMMISSIONER McGAFFIGAN: And the other event that was called to my attention was Dresden I some years back, a frozen pipe.

Is there a problem with the shutdown condition, you know, that we have to be wary of?

MR. HOLAHAN: Yes. I'll have to do the Dresden one from memory but my recollection is that the Dresden I facility was -- I think it would be fair to say -- ignored by Commonwealth Edison for some period of time, and I believe they had some commitment to heating of the system, which had fallen by the wayside at some point, and they had an event with freezing in the pipes, and what we realized -- it didn't actually occur, but we realized that there were pipes which could freeze and for which, if they were to fail, would drain water from the spent fuel pool.

I believe we issued a bulletin to the decommissioned plants to address two things -- to address the configuration, to look for areas in which because these are generally very old plants not meeting sort of current standards, they might have a pipe that could drain in the

spent fuel pool, so look at both the configurations and also look into the concern that there may be an important piece of the facility that is not getting our proper attention.

So I believe all those plants got a bulletin, responded, and I believe all of them had been inspected a year or two ago.

COMMISSIONER McGAFFIGAN: Thank you.

CHAIRMAN JACKSON: Commissioner Diaz?

COMMISSIONER DIAZ: Yes, I guess I have one more comment on the issue that since there's so significant a difference between plants and although the risk is much lower than a reactor accident, we all agree with that and it should be and it is and that's why they don't have a containment or a way of injecting pressurized water into the systems. Still it seems like, you know, we should make a further attempt to determine whether there are unacceptable risks to the public or the workers from, you know, accidents in which those plants don't have the appropriate configuration or the appropriate detection system, and I believe that might be something that the Staff could look at.

CHAIRMAN JACKSON: Any other comments?

[No response.]

CHAIRMAN JACKSON: Well, I would like to thank the Staff for this very informative briefing. It was very good.

Today you presented a great deal of information to us on spent fuel pool operating events and their implications in terms of risk.

As we have been discussing, we understand that you will take the findings and conclusion of this in your other earlier reviews to determine what additional action may be required.

I think as you see as we formulate future actions in this area, we do need to consider, as Commissioner Diaz has said, the wide variations in spent fuel pool configurations in specific circumstances against our limited database of spent fuel pool events, and so I think we have to guard against, on the one hand, imposing industry-wide changes that, though beneficial at one facility result in only a marginal improvement in risk at another, or vice versa, do not capture the vulnerabilities and risks on a plant-specific basis.

So unless my fellow Commissioners have any further comments, I think we are adjourned.

[Whereupon, at 3:15 p.m., the briefing was adjourned.]

CERTIFICATE

This is to certify that the attached description of a meeting of the U.S. Nuclear Regulatory Commission entitled:

TITLE OF MEETING: BRIEFING ON SPENT FUEL POOL STUDY - PUBLIC MEETING

PLACE OF MEETING: Rockville, Maryland

DATE OF MEETING: Thursday, November 14, 1996

was held as herein appears, is a true and accurate record of the meeting, and that this is the original transcript thereof taken stenographically by me, thereafter reduced to typewriting by me or under the direction of the court reporting company

Transcriber: Christopher Cutchall

Reporter: Jon Hundley

ASSESSMENT OF SPENT FUEL COOLING

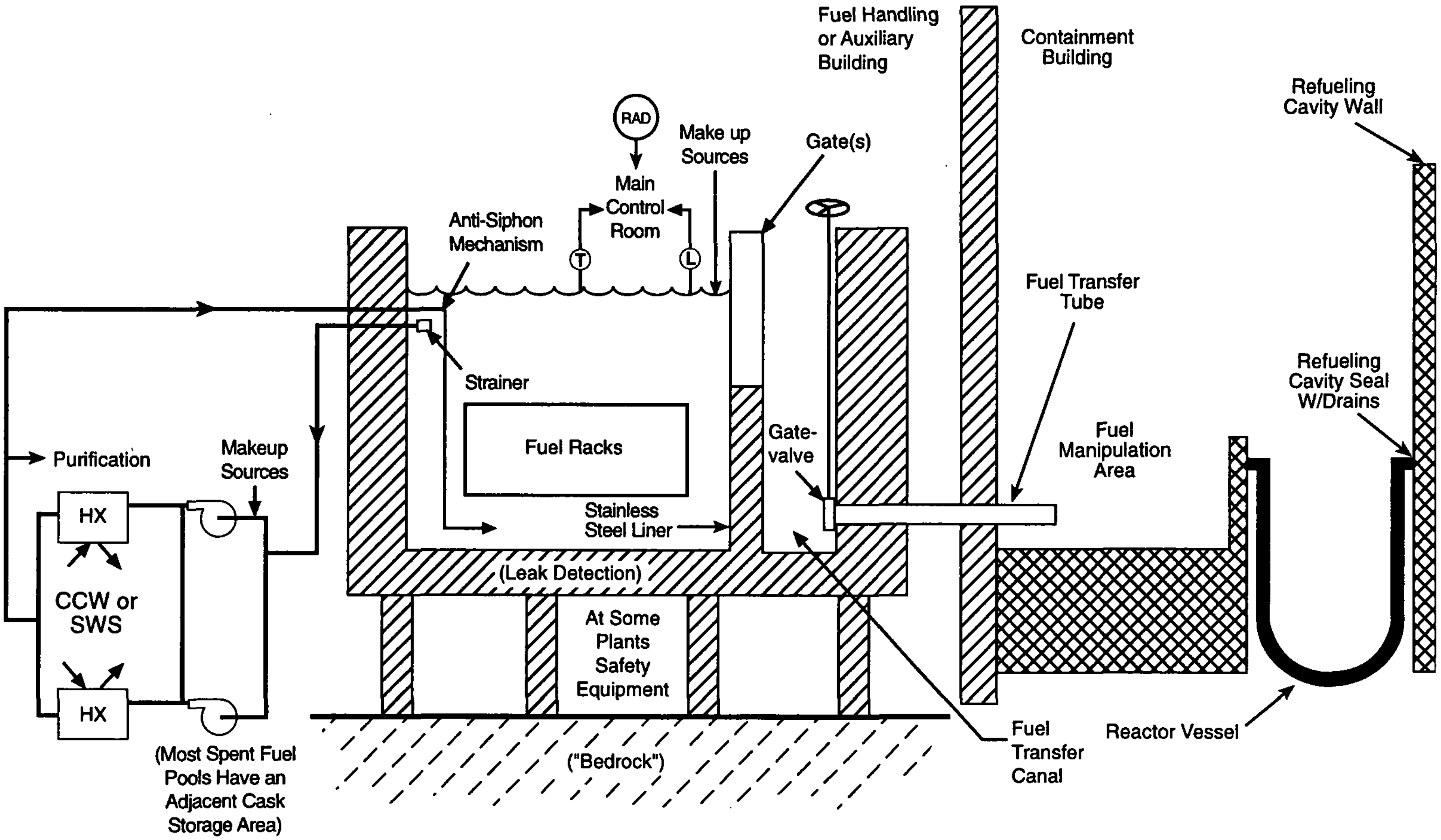
Jose G. Ibarra
Reactor Analysis Branch
Safety Programs Division
Office for Analysis and Evaluation of Operational Data

November 14, 1996

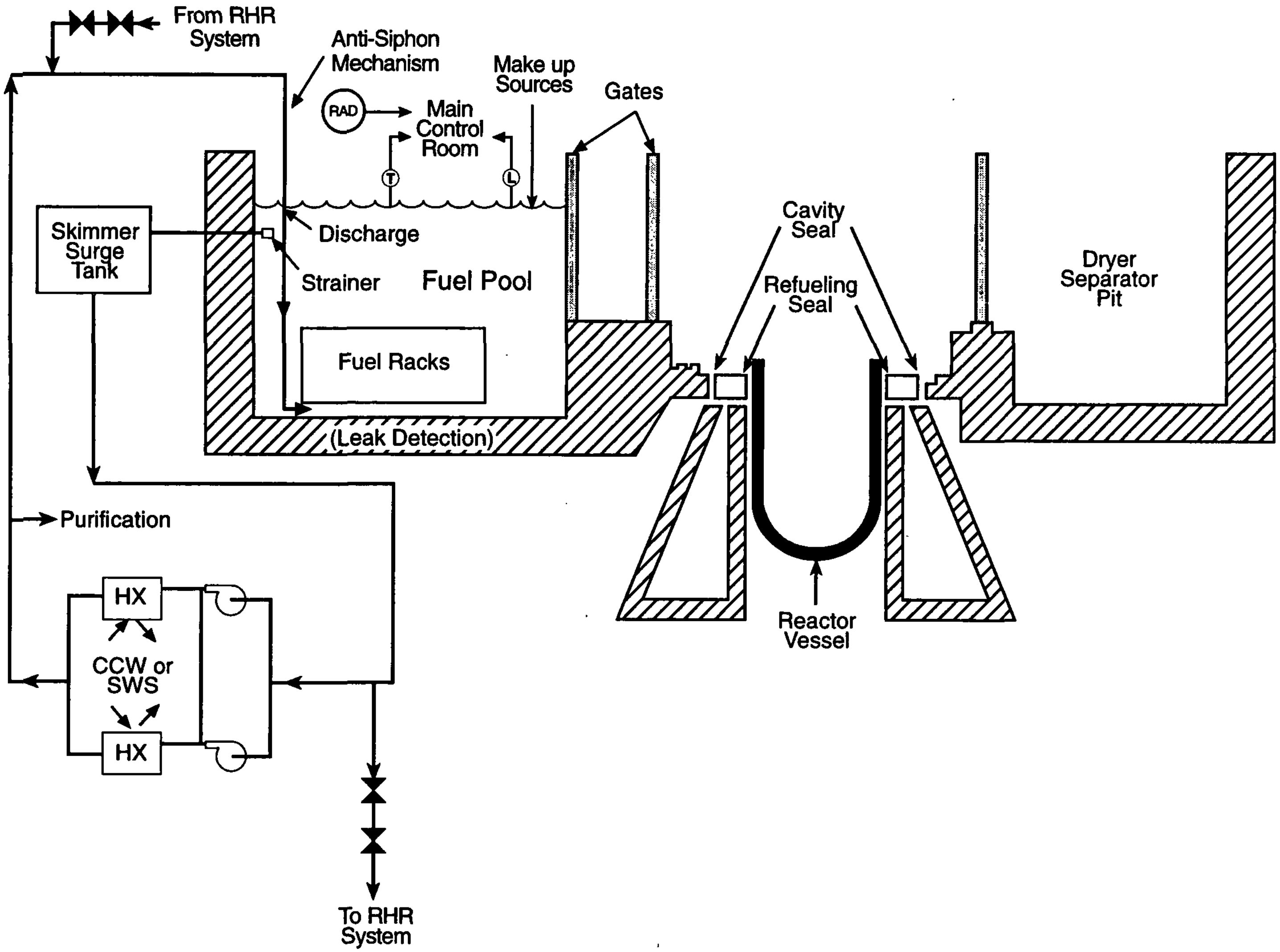
SPENT FUEL COOLING ASSESSMENT

- AEOD study requested by Executive Director for Operations.
- Developed generic configurations to assess loss of spent fuel pool cooling and inventory.
- Assessed 12 years of operational experience.
- Performed site visits to gather information on physical configuration, practices, and procedures.
- Reviewed regulations, standard review plan and regulatory guides.
- Performed assessments of electrical systems, instrumentation, heat loads, and radiation.
- Evaluated risk of losing spent fuel cooling.

PWR SPENT FUEL COOLING SYSTEMS



BWR SPENT FUEL COOLING SYSTEMS



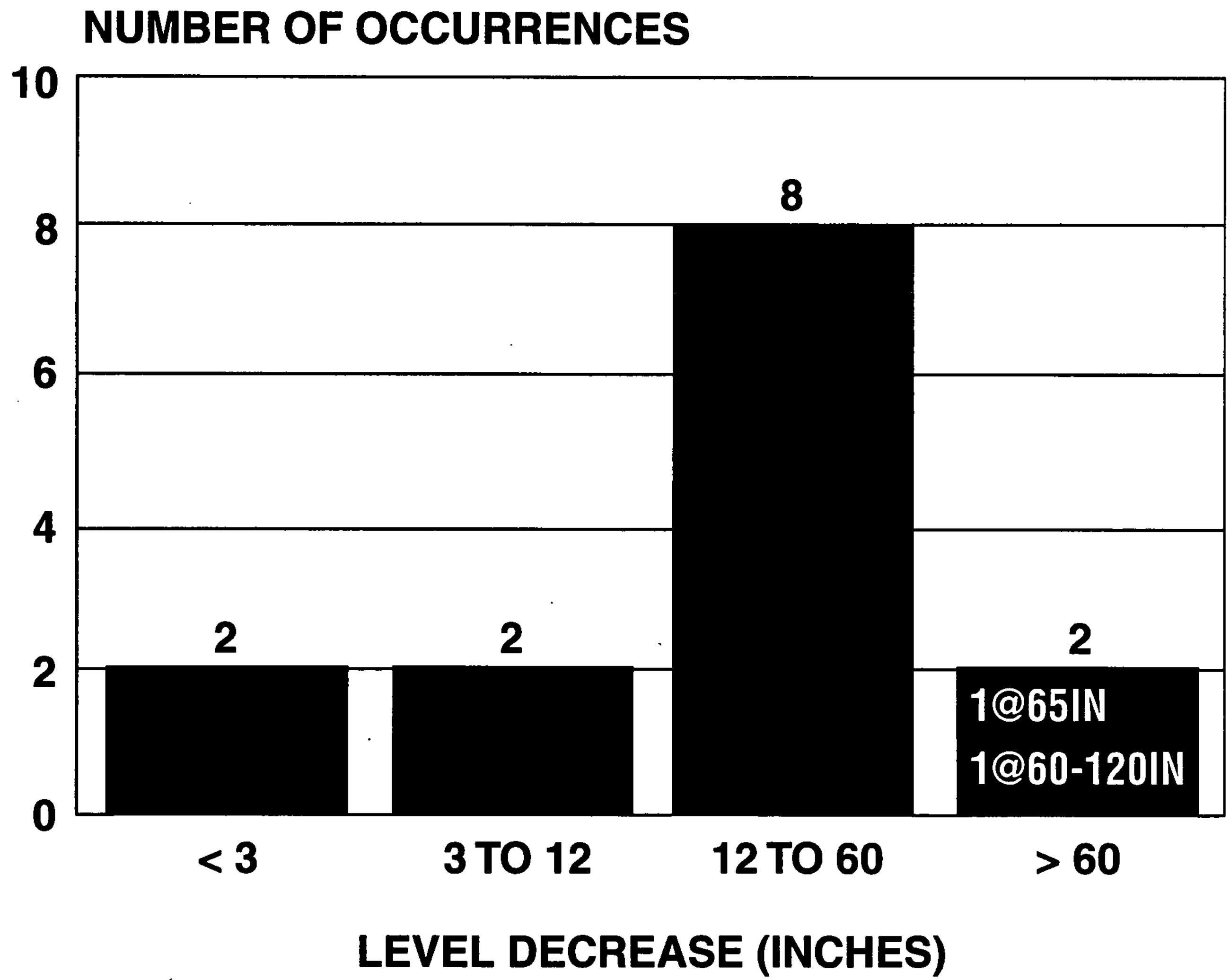
SPENT FUEL POOL EVENTS

TYPE EVENT	ACTUAL	PRECURSOR
<u>SFP Inventory</u>	<u>38</u>	<u>55</u>
Connected Systems	20	12
Gates & Seals	10	8
Structure or Liner	8	35
<u>SFP Cooling</u>	<u>56</u>	<u>22</u>
Cooling Flow	50	20
Heat Sink	6	2

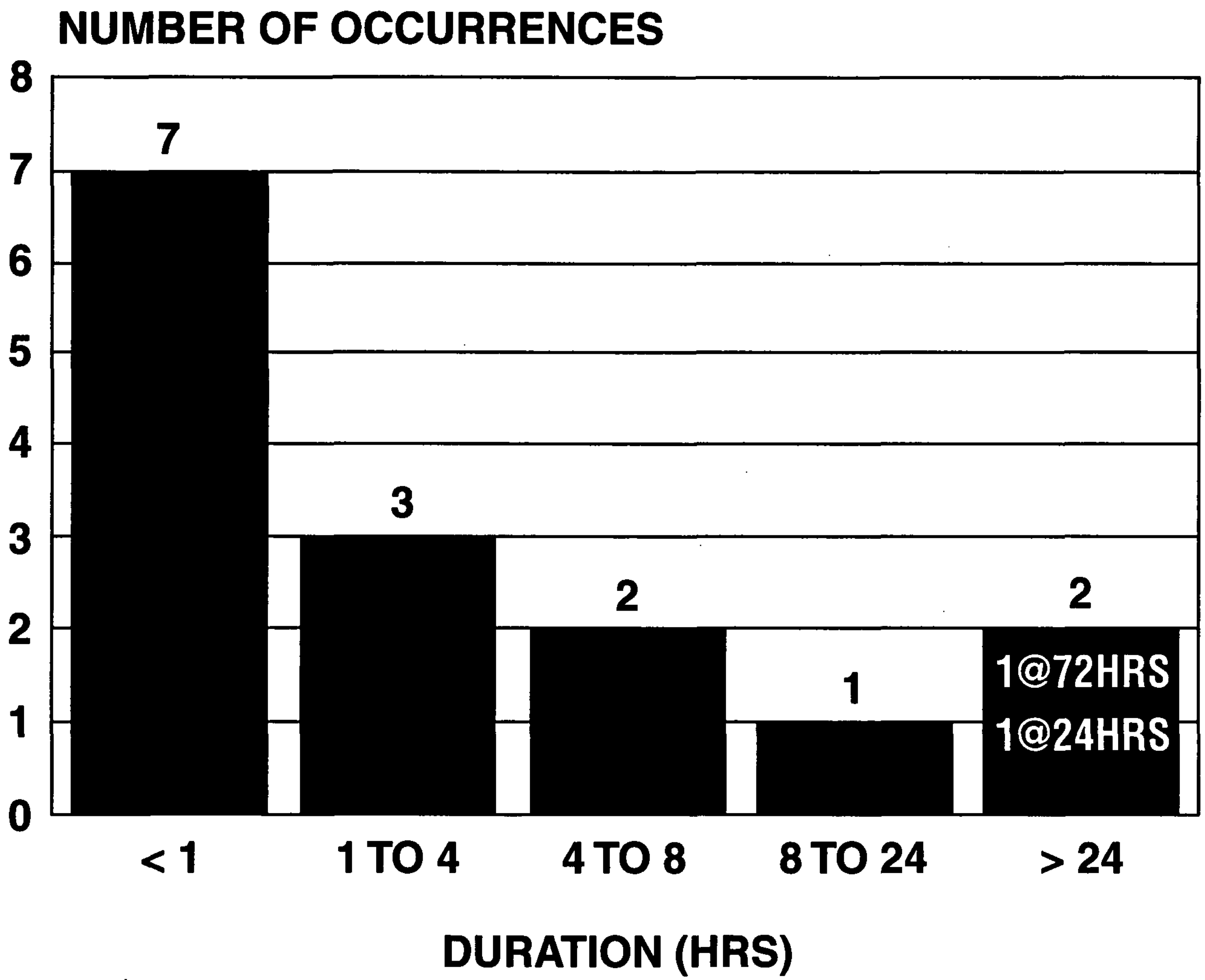
LOSS OF COOLANT INVENTORY EVENTS

TYPE EVENT	ACTUAL	PRECURSOR
Connected Systems	20	12
Configuration Control	16	2
Siphoning	3	1
PWR Transfer Tube	1	1
Piping	0	1
Piping Seismic Design	1	1
Gates & Seals	10	8
Cavity Seals	0	6
Gate Seals	10	2
Pool Structure or Liner	8	35
Liner Leaks	7	1
Load Drops	1	32
Pool Seismic Design	0	2

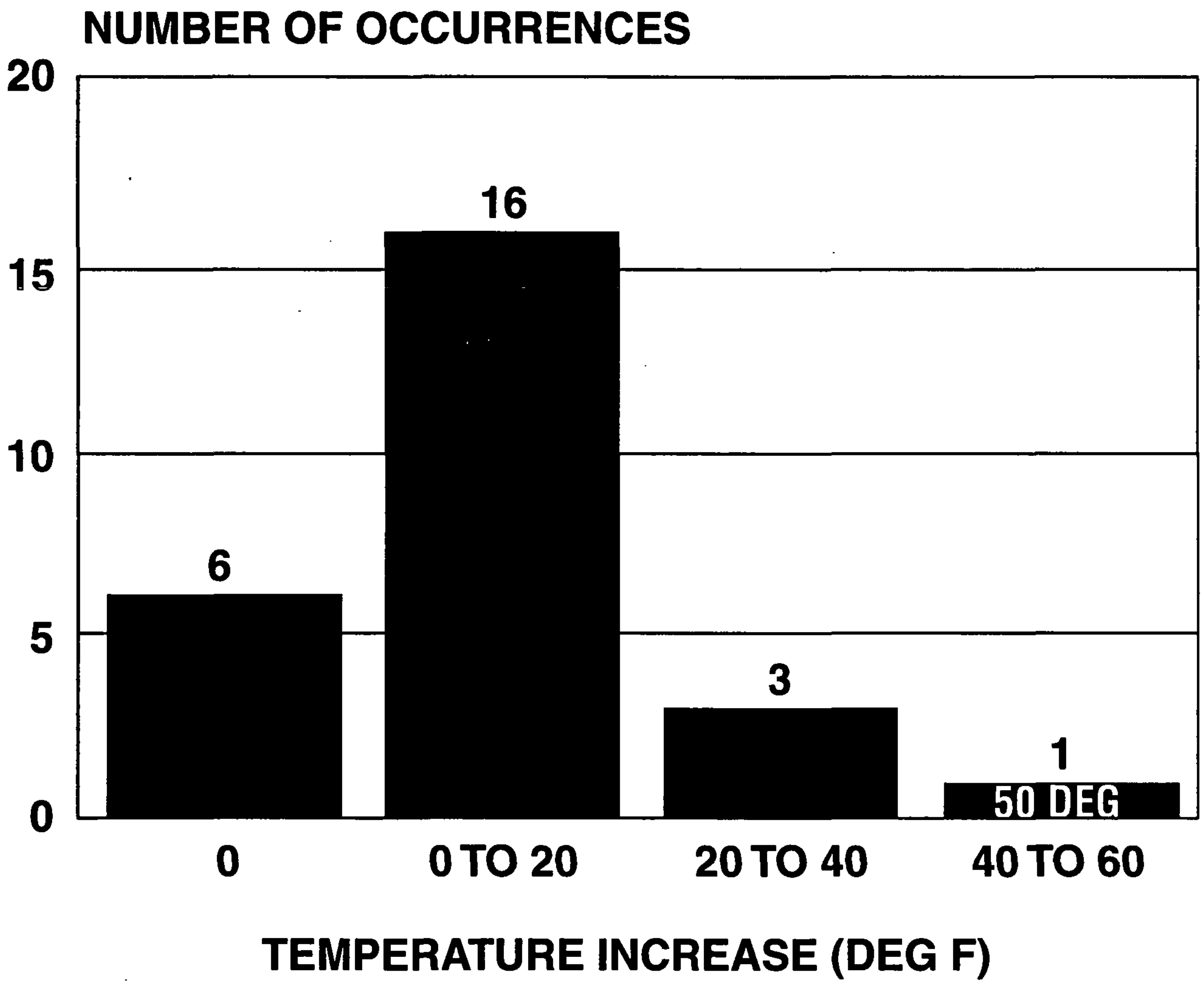
LOSS OF INVENTORY LEVELS



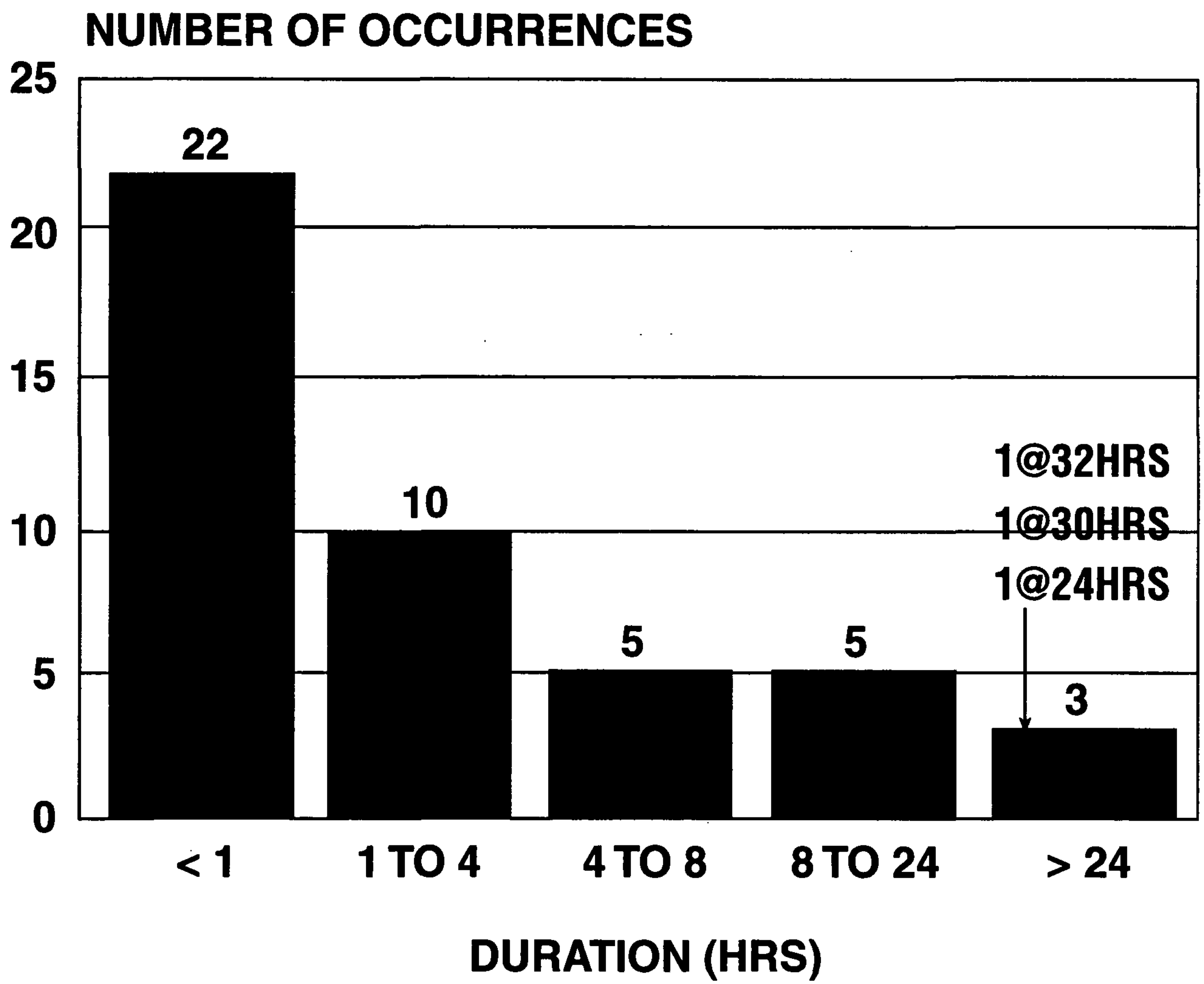
LOSS OF INVENTORY EVENTS



LOSS OF COOLING EVENTS



LOSS OF COOLING EVENTS



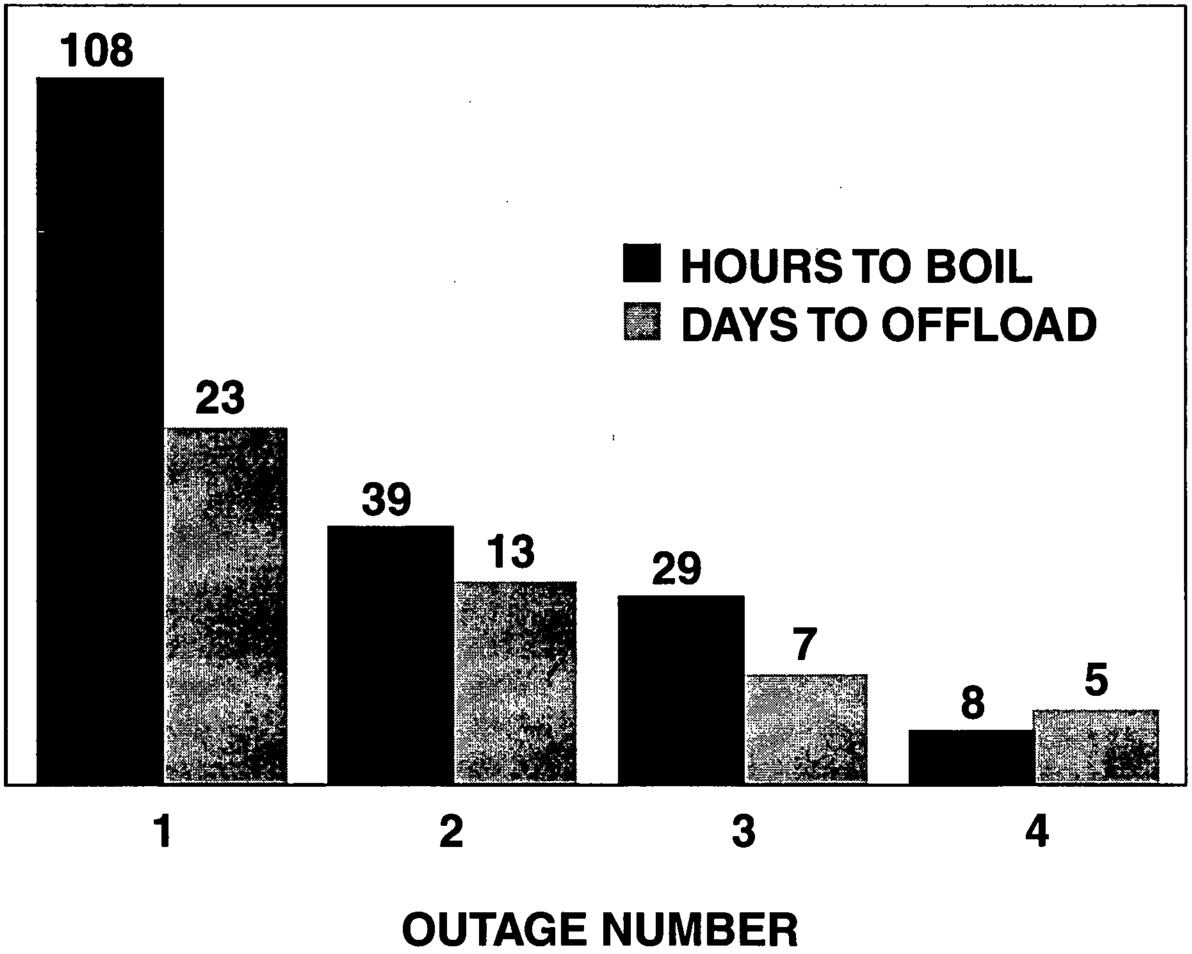
PARTIAL LISTING OF GOOD PRACTICES OBSERVED DURING PLANT VISITS

- Utilization of system diagram prior to all alignment changes
- Including SFP risk during outage planning.
- Classroom and simulator training to prepare for outage.
- User friendly graphs of pool heatup.
- Effective program for feedback of internal and industry operating experience.
- Detailed review at some plants found significant inventory loss vulnerabilities.

REGULATION REVIEW AND ENGINEERING ASSESSMENTS

- Identified applicable guidance and regulations.
- Surveyed 14 plants to determine power supply.
- Surveyed 14 plants to determine instrumentation.
- Assessed radiation levels with varying water levels.
- Performed heat load calculations.

REDUCED TIME TO BOIL AT NINE MILE POINT UNIT 2



NEAR-BOILING FREQUENCIES

	CURRENT INEL WORK	PREVIOUS PNL WORK
Total Near-Boiling Frequencies	5 E-5	2 E-5
LOOP	3 E-5	1 E-5
Inventory Losses	2 E-5	1 E-6

SUSQUEHANNA SPENT FUEL POOL RISK ASSESSMENT

- **Showed benefits from:**
  - improved instrumentation
  - improved procedures
  - improved training
- **Showed vulnerability of operating unit from defueled unit**

FINDINGS AND CONCLUSIONS

Likelihood and Consequences

- Consequences of actual events have not been severe.
- Primary cause of events has been human error.
- Relative risk of fuel damage is low compared with other reactor events.
- Highly dependent on human performance and plant design.
- Frequency of coolant loss > 1 foot, 1/100 reactor years.
- Frequency of cooling loss > 20 °F, 2-3/1000 reactor years.

FINDINGS AND CONCLUSIONS (CONT.)

Prevention

- Configuration control improvements can prevent and/or mitigate SFP events.
- Evaluations may be needed at some multiunit sites for potential SFP boiling effects on safe shutdown.

Response

- Attention to time to boil with shorter outages.
- Improved procedures and training may be needed.
- Improvements to instrumentation and power supplies may be needed.

FOLLOW UP

- NRC Information Notice being prepared.
- Study made into a NUREG.
- Report being submitted to Incident Reporting System.
- Working with NRR on implementing recommendations.