PR 52
(76FR10269)

Rulemaking Comments

From: John Runkle [jrunkle@pricecreek.com]
Sent: Thursday, September 29, 2011 11:54 AM
To: Rulemaking Comments
Cc: CHAIRMAN Resource; CMRSVINICKI Resource; CMRAPOSTOLAKIS Resource; CMRMAGWOOD Resource; CMROSTENDORFF Resource; NRCExecSec Resource; Hackett, Edwin; said.abdelkhalik@me.gatech.edu
Subject: DOCKET ID NRC-2010-0131 - AP1000 certification
Attachments: Sterrett presentation to ACRS.pdf; Revision 19 to the AP1000 Design Control Document and the AP1000 Final Safety Evaluation Report.pdf; Sterrett comments to ACRS.pdf; Lyman article BoAS 9-11.pdf; AP1000 Supplemental Comments 9-29-11.pdf

Attached please find the SUPPLEMENTAL COMMENTS BY THE AP1000 OVERSIGHT GROUP ET AL. REGARDING FAILURE OF RULEMAKING ON CERTIFICATION.

By copy of this email, we are filing these comments with the NRC Commissioners and the ACRS.

For Oversight Group,

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DOCKETED
USNRC

September 29, 2011 (3:15 pm)

OFFICE OF SECRETARY
RULEMAKINGS AND
ADJUDICATIONS STAFF

Template = SECY-067

DS 10

September 29, 2011

UNITED STATES OF AMERICA
U.S. NUCLEAR REGULATORY COMMISSION
BEFORE THE COMMISSION

In the Matter of	)	
AP1000 Design Certification Amendment	)	NRC-2010-0131
10 CFR Part 52	)	RIN 3150-A181

SUPPLEMENTAL COMMENTS BY THE AP1000 OVERSIGHT GROUP ET AL.
REGARDING FAILURE OF RULEMAKING ON CERTIFICATION

NOW COME the AP1000 Oversight Group, the North Carolina Waste Awareness and Reduction Network (NC WARN) and Friends of the Earth (collectively the "Oversight Group") with supplements comments regarding the failure of the rulemaking on the certification of the AP1000 reactor design and operating procedures, Docket NRC-2010-0131, and raising the issue of thermal loading in the rulemaking record.

In its Memorandum and Order, CLI-11-05, September 9, 2011, the Commission addressed the Oversight Group's concerns by referring its comments and petitions to the Staff to be resolved in the Rulemaking Docket, NRC-2010-0131. In its Order the Commission ruled that

> [we] *Refer* to the NRC Staff those elements of the Petition that relate specifically to design certification, for consideration as rulemaking comments. *Refer* to the NRC Staff for resolution as comments in the AP1000 rulemaking proceeding, all additional filings relevant to the AP1000 rulemaking proceeding.

The Oversight Group has diligently submitted comments into the rulemaking record as issues affecting the safety and reliability of the AP1000 reactors. In addition to other comments in the rulemaking record, we urge the Commission and the NRC Staff to review the following:

- On April 6, 2011, the Oversight Group filed its Petition to Suspend AP1000 Design Certification Rulemaking Pending Evaluation of Fukushima Accident Implications on Design and Operational Procedures and Request for Expedited Consideration.
- On April 20, 2011, the Oversight Group filed additional comments in conjunction with the Emergency Petition regarding the Fukushima lessons learned filed in the various licensing and rulemaking dockets. On May 9, 2011, the Oversight Group filed a reply to the NRC and industry responses to the Emergency Petition.
- On May 10, 2011, the Oversight Group filed comments that included reports by Union of Concerned Scientists, "Safer Storage of Spent Nuclear Fuel: The Problems of Spent Fuel Pools"; the statement of David Lochbaum, Union of Concerned Scientists, to the U.S. Senate Energy and Natural Resources Committee; Alvarez et al., "Reducing the Hazardous from Stored Spent Power-Reactor Fuel in the United States"; Thompson, "Robust Storage of Spent Nuclear Fuel: A Neglected Issue of Homeland Security"; and National Academies of Science, "Safety and Security of Commercial Spent Nuclear Storage (Public Report)."
- On May 10, 2011, Friends of the Earth filed comments on behalf of itself and Fairewinds Associates.
- On May 24, 2011, the Oversight Group filed additional comments the Markey report, Chairman Jaczko's Statement on Fukushima of May 20, 2011 and news reports on the Fukushima accident.
- On June 16, 2011, the Oversight Group filed a Request to Reexamine the Rulemaking on Certification of AP1000 Reactors and Declare it Null and Void based on unresolved problems with the AP1000 design and operations, the Ma Nonconcurrence (redacted version), the changes in Revision 19 and the

Fukushima "lessons learned."

- On August 11, 2011, the Oversight Group filed Supplemental Comments by the Ap1000 Oversight Group et al. Regarding NEPA Requirement to Address Safety and Environmental Implications of the Fukushima Task Force Report, supported by a declaration of Arjun Makhijani, Institute for Energy and Environmental Research.

These earlier comments and petitions were submitted in the rulemaking docket and with the Commission, and are adopted herein by reference.

I. INTRODUCTION AND SUMMARY.

The Oversight Group provides the supplemental comments herein to describe the failure of the rulemaking process for the certification of the AP1000 reactor.[1] Initially the NRC expected the final design would be certified prior to the final reviews of the combined operating licenses (COLAs). See *Backgrounder on New Nuclear Plant Designs*.[2] This has not occurred as the certification process has become bogged down by design changes, unresolved issues and rapidly escalating costs to meet even basic safety considerations. The process has been excessively, even arbitrarily, fluid as Westinghouse-Toshiba has submitted various revisions to the Design Control Document (DCD) for the AP1000 reactor over the past five years and as noted in our earlier filings in this docket, still has not begun to address the Fukushima "lessons learned" in any meaningful way. The NRC staff review and review by the Advisory Committee on Reactor Safeguards (ACRS) have not been able to address critical issues in a timely manner, especially as Westinghouse-Toshiba has changed the design and operating procedures repeatedly over the past five years.

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[1] Additional information on the AP1000 DCD is available at www.nrc.gov/reactors/new-reactors/design-cert/amended-ap1000.html

[2] www.nrc.gov/reading-rm/doc-collections/fact-sheets/new-nuc-plant-des-bg.html

On January 27, 2006, the Commission issued the final design certification rule AP1000 design, DCD Revision 15, in the Federal Register, 71 FR 4464, and adopted the rule on March 10, 2006. .Applicants or licensees intending to construct and operate a plant based on the AP1000 design could do so by referencing the rule as set forth in 10 CFR Part 52, Appendix D. However, on May 26, 2007, Westinghouse-Toshiba submitted a Revision 16 of the AP1000 DCD; on September 22, 2008, Westinghouse-Toshiba updated its application with Revision 17; on October 14, 2008, Westinghouse-Toshiba provided the DCD Revision 17; on December 1, 2010, Westinghouse-Toshiba submitted DCD Revision 18; and on June 13, 2011, Westinghouse-Toshiba submitted DCD Revision 19. It is important to note the current certification rulemaking in Docket NRC-2010-0131 is on the AP1000 Revision 18 but subsequent to the end of the comment period on the rulemaking, May 10, 2011, Westinghouse-Toshiba submitted Revision 19 containing 100's of substantive changes to Tier 1 and Tier 2 components from Revision 18. ATTACHED. The Revision 19 changes have not been part of the certification rulemaking process to date.

Not only has the certification process constantly changed, recent actions to accelerate the certification process have called into question the ultimate results of the process. Pressure has apparently increased in order to certify the AP1000 reactors so combined operating licenses ("COLs") can be issued. In an August 5, 2011, letter from the NRC's Office of New Reactors to Westinghouse-Toshiba, the NRC said that "the final rulemaking package [for the AP1000] is in preparation, and is expected to be provided to the Commission for their deliberation no later than October 5, 2011, and the projected time frame for publication of the final rule in the Federal Register is January 2012." The NRC staff response to public comments apparently will not be provided to the public prior to the Commission decision. The NRC staff even requested the ACRS to waive its authority to sign off on the latest DCD revision so that the Commission could certify the design. As noted above, on May 10, 2011, Westinghouse-Toshiba filed

Revision 19, and yet only 85 days later, on August 5, 2011, the NRC issued a Final Safety Evaluation Report (FSER) which purported to address the Revision 19 changes.[3] Expediting the process near its end – and at the same time ignoring safety concerns – shows the failure of the certification process to date. The Oversight Group contends that public health and safety necessitate that all problems must be addressed before the reactor is "certified" by the NRC and not during construction.

On September 19, 2011, the ACRS sent a letter to Chairman Jaczko signing off on the AP1000 reactors yet at the same time discussed concerns related to the shield building, the passive cooling system tank, seismic and thermal load combination, radiative effects on thermal loads (see discussion below), inclusion of design details in the DCD, the containment accident pressure analysis, radiative effects on containment evaluation model validation and the reactor coolant pump testing.[4] These issues, and other changes between DCD Revisions 18 and 19, have not been subject to a rulemaking process and the Commission cannot certify the AP1000 design and operating procedures without availing the public with the opportunity to comment on Revision 19.

As demonstrated by the comments and petitions by the Oversight Group, the Fukushima accident requires a further reexamination of the AP1000 reactor design and operating procedures. As a result, the Oversight Group fully expects a DCD Revision 20 containing significant changes required from the Fukushima lessons learned to be forthcoming. As described in Lyman, *Surviving the One-Two Nuclear Punch: Assessing Risk and Policy in a Post-Fukushima World*, Union of Concerned Scientists, September 19, 2011, the AP1000 design would not have been an advantage in a Fukushima-type

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[3] FSER Related to Certification of the AP1000 Standard Plant Design, Docket No. 52-006, NUREG-1793 Supplement 2, August 5, 2011. ADAMS No. ML112061231.

[4] ACRS, Revision 19 to the AP1000 Design Control Document and the AP1000 Final Safety Evaluation Report, September 19, 2011. ADAMS No. ML11256A180.

scenario. ATTACHED. Directly contrary to the long-standing process of certified design before issuance of the COL, the process suggested in the NRC Task Force Report, *Recommendations for Enhancing Reactor Safety in the 21st Century: The Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident*, July 12, 2011 pushes the Fukushima lessons learned into the COL stage rather than resolved at the certification stage; each reactor then becomes a prototype as case-by-case review of potential design and operational changes are made after construction begins. The legal and policy question is whether changes stemming from the NRC review process of the Fukushima accident will occur after any of the reactors planning to utilize the AP1000 design receives its combined operating license.[5]

As demonstrated in the earlier comments and petitions by the Oversight Group, the safety issues related to the DCD Revision 18 and the earlier versions were glossed over. As an example, one of the ACRS's fundamental concerns about Revision 18 was the possibility of debris clogging up the "passive" water circulation system. Westinghouse-Toshiba relies on its claim that operators could "walk away" from an AP1000 accident due to its passive emergency cooling systems. This claim is seriously flawed as an earthquake, attack or loss of coolant accident could destroy those systems, including the water tanks on top of the reactor, and as the Fukushima accident demonstrated, debris could include the entire supporting structures and even the water tanks themselves, rendering the passive system inoperable. See Lyman, *supra*, p. 52.

In its comments and petitions, the Oversight Group presented several unresolved

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[5] The primary reactor applications being actively pursued using the AP1000 reactors are Plant Vogtle in Georgia, and the V.C. Summer reactor in South Carolina. Even without certification of the reactor design or licensing approval for the specific project, the companies are now being allowed to assemble the reactors' containments. Because of the nuclear financing laws in those states and the United States taxpayer loan guarantee for the Vogtle reactor, these reactors put federal taxpayers and state electricity customers at risk of massive cost overruns and project abandonment. The subsequent structural changes expected from Fukushima lessons learned will compound the cost factors.

issues with the DCD Revision 18, some of which were structural problems with the AP1000 design and others related to the Fukushima reactor:

- the fundamental design flaw with the AP1000 design, by which radioactive steam in some scenarios is vented directly into the environment through cracks and through holes in the containment structures.
- the brittleness of the concrete containment structures, as evidenced in the Nonconcurrence of Dr. John Ma.
- the inability of the shield building to withstand external forces, ranging from tornadoes and earthquakes to airplane crashes and terrorist attacks.
- the vulnerability of spent fuel pools, amplified by high density racking
- the lack of adequate emergency planning.
- the lack of consideration of severe accidents, i.e., beyond design basis accidents.

These issues were not resolved in the lately-filed DCD Revision 19, and the cursory review of that revision by the NRC staff demonstrates the failure of the certification process to date.

II. New Issue – Thermal Loading.

The shield building design is flawed as thermal loading has not been properly analyzed by Westinghouse-Toshiba or the NRC staff as part of its containment accident pressure analysis. One of the significant changes between DCD Revisions 18 and 19 stemmed from the result of the NRC staff requirement that Westinghouse-Toshiba recalculate pressure in the containment structures. Westinghouse-Toshiba has kept these calculations proprietary so the Oversight Group does not know the assumptions going into the calculations, although assumptions both increasing and decreasing the calculated pressure were made in DCD Revision 19.[6] The conclusion of the

[6] See also ACRS discussion in its letter of September 19, 2011, referenced in footnote 4 above.

Westinghouse-Toshiba calculations was that the pressure in the containment fell barely below the maximum design pressure limit of 59 psig, resulting in little margin for error. It is apparent that modeling assumptions, such as finding that metal grates were "new heat sinks," were changed over several computer runs to come in under the wire.

The issue of radiative effects on thermal loads was presented to the ACRS by Dr. Susan Sterrett at the ACRS subcommittee meeting of August 16, 2011 and the ACRS meeting of September 8, 2011, and in comments to the ACRS. ATTACHED, Transcript to the September 8, 2011 meeting of the ACRS, pp. 251-269, 490-512. At the ACRS meeting, Dr. Sterrett, a former design engineer for Westinghouse-Toshiba, indicated that the pressure calculations in DCD Revision 19 appear to disregard a significant component to the integrity of the shield building, i.e., thermal changes caused by solar heating and nighttime cooling. This is crucial because the AP1000 reactors have only been referenced by the utilities in the Southeastern states, where both daily and seasonal heat differentials are a reality. Dr. Sterrett demonstrated that the heat loading of the shield building could result in weakness and failure under external stresses, such as an earthquake, and could cause the reactor containment to exceed maximum design pressure during various accident conditions. Loss of the shield building or damage to it could mean loss of the water tank on top of the structure and thus loss of the key passive cooling feature. She noted that this summer, solar heating caused concrete to buckle at airports and bridges, and water pipes across the US to burst open, but that the NRC is ignoring this "simple matter of basic physics" in its review of the nuclear plant design.

Dr. Sterrett maintained that heat transfer to and from the reactor building is a very important factor in the safety analysis of this plant involving many calculations. The major omission of ignoring solar heating in the calculations has serious material consequences. First, solar heating is important to the structural integrity of the shield building, which supports the 7 – 10 million pound water tank for the passive containment cooling system. Dr. Sterrett's stated the "testing for emergency cooling of the reactor containment was performed in a way that tends to overestimate the ability for water sprayed from the overhead tank to cool the containment dome, thus leading to the underestimation of peak pressure within the dome during an accident." She concluded that "both are important for predicting the heat removal capability of the passive containment cooling system to remove decay heat after an accident ACRS. It is more crucial on keeping the containment cooled in this passive design than on other operating plants, which have double-walled containments and powerful pumps to drive emergency cooling.

On pp. 3 and 4 of its letter of September 19, 2011[7], the ACRS evaded fundamental issues concerning the radiative effects on thermal loads by first stating the most limiting case was the winter ambient temperature differences, but then "resolving" the issue by addressing the maximum summer surface temperatures. The ACRS simply does NOT address the radiative heat transfer for the case that it, and Westinghouse-Toshiba, maintain has the most impact. Nor does the ACRS resolve the issues of temperature differentials over time and the stresses those place on the shield building. It appears that from the graph provided by Westinghouse-Toshiba to the ACRS, the ACRS did not examine the effect of radiative heating over more than the course of a single day. This is significant for two reasons: first, the concrete failures in other concrete structures occurred only after many days of sunny hot weather, and, second, there can be cumulative temperature increases over the course of an extended period of hot sunny weather, such as the 2011 heat waves experienced throughout the southeastern US in 2011. Looking only at the solar gain over the course of one day does not provide sufficient information.

The ACRS letter relied upon an estimate from an unidentified ASHRAE table rather than the higher temperatures concrete surfaces have actually reached in various

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[7] Referenced in footnote 6 above.

parts of the United States this past summer. The ACRS does not provide any basis for relying solely on the estimate table rather than on using methodologies to calculate temperatures developed by other Federal agencies and cited in Dr. Sterrett's comments, such as the Oak Ridge Laboratory and the National Institute of Standards and Technology, for comparison. The Oversight Group suggests that the ACRS checks whether the ASHRAE table correctly predicts the much higher temperatures on the concrete surfaces that failed this past summer. These temperature differences becomes critical in assessing the integrity of the shield building over its operating life.

The corollary issue raised by Dr. Sterrett and not addressed by the ACRS is the differential thermal expansion of steel as compared to concrete in the concrete-filled steel panels. At page 186 of the transcript of the September 8, 2011, ACRS meeting[8], Westinghouse-Toshiba indicates that the only consideration it checked regarding differential thermal expansion was the differential temperature through the wall, not the much more problematic question of the differential thermal expansion of the steel with respect to the concrete in the SC panels:

> And we'd look at both the winter condition and the summer condition. And you will see here -- this slide is showing that the winter -- the delta T across the structure, across the wall, for the winter condition is the most limiting. And it is 110 degrees across the structure, degrees on the inside of the 18 shield building and minus 40 degrees on the outside. For the summer case, we look at the delta T as 45 degrees out and 70 degrees inside and 115 outside. And so you see our limiting case is the winter condition.

Differential expansion for steel and concrete was suspected as the cause of buckling of concrete bridges with steel joints or connections, and cannot be discounted.

The assumptions used by Westinghouse-Toshiba in calculating containment pressures and radiative effects, a fundamental part of the DCD Revision 19, have not been available for public review and comment. The cursory review by the NRC staff

[8] ADAMS No. ML11256A117

and the ACRS is deficient, and as a result, the Oversight Group recommends outside expertise to analyze the thermal loading issue.

III. CONCLUSION.

For the foregoing reasons, the comments of the Oversight Group should be considered in the Commission's deliberations on the necessity of initiating a rulemaking on Revision 19 and then another on the lessons learned from Fukushima (DCD Revision 20?) in order to lawfully certify the AP1000 reactor design and operating procedures. These comments supplement the earlier comments and petitions the Oversight Group and others have filed in this docket, and demonstrate that the present certification process is a failure and the AP1000 design should not be certified.

Respectfully submitted this 29th day of September 2011.

/signed electronically by/

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ATTACHMENTS

1. Westinghouse AP1000 Design Control Document Rev. 19, ADAMS No. ML11157A500.

2. Lyman, *Surviving the One-Two Nuclear Punch: Assessing Risk and Policy in a Post-Fukushima World*, Union of Concerned Scientists, September 19, 2011

3. Dr. Sterrett presentation, transcript to the September 8, 2011 meeting of the ACRS, pp. 251-269.

4. Dr. Sterrett comments, transcript to the September 8, 2011 meeting of the ACRS, pp. 490-512

CHAIRMAN ABDEL-KHALIK: No.

MEMBER RAY: All right. We have been advised and I think everybody has received at their place a written statement with some slides by a member of the public who I will now ask, hoping that the line has been opened so she can respond to us, if Dr. Sterrett is on the line and prepared to provide us the oral comments.

DR. STERRETT: Oh, can you hear me?

MEMBER RAY: We can, indeed. Thank you. Go ahead.

DR. STERRETT: Okay. I just joined about a minute ago so I don't know what you have been talking about.

MEMBER RAY: Almost everything. But it doesn't matter because we are now attentive to what you would like to say to us.

DR. STERRETT: Oh, okay. So some of the things I have to say may be things that I really do not need to emphasize. I don't know.

So let's see, I didn't give you slides for what I was going to present today. The slides that I would have given were from the presentation to the committee.

MEMBER RAY: Yes. Yes, and by the way, I

believe you had estimated you would need not more than ten minutes. Is that correct?

DR. STERRETT: I didn't say but I think that should be sufficient for today.

MEMBER RAY: All right. Well we are running a little late. So if you would please proceed.

DR. STERRETT: Okay. All right. So I am saying this, I didn't know how much you talked about it so I will just give the written text that I have prepared.

All right. This is Susan G. Sterrett. I am at Carnegie-Mellon University. And there is some noise on the line. I wonder --

MEMBER RAY: I don't believe we can do anything about it. We have experienced it before and it would be best if you just proceed.

MEMBER SHACK: You are clear. You are quite audible.

MEMBER RAY: You are clear. There is noise on the line. I agree.

DR. STERRETT: Okay. All right. So just to introduce myself prior to my academic structural mechanics including systems design. I did some work on Westinghouse passive plant design but I never worked specifically on the AP1000. So the information I have is just the information available to the public through the NRC's website.

To summarize the presentation last time, there were two issues. The first one was radiation on the concrete chilled buildings that wasn't accounted for in the analysis. And I said that because looking at the temperatures that were considered, they only considered the temperatures to be the same as ambient air; whereas I pointed out that the range will be wider. It will be colder in the ambient air or can be and can be significantly higher than the ambient air when the sun is shining.

The second issue was the large-scale test and actually the small scale test, too, that were used in WGOTHIC were outdoors in the sun. And the thing is that the main effect these were not scale model tests in the normal sense. They were meant just to understand certain effects. And one of those was the coefficient representing evaporative losses. The sun aids in evaporation and the test result was the main way that this was being carried out was through evaporative losses.

So I would like to just say a few things about each of these and they may be moot by now but I guess it doesn't hurt to have the reasons down.

The first one was the response that was given previously, hopefully not today, was that normal thermal loads don't need to include this extra 30 or 40 degrees, that somehow you would only worry about that if there was some sort of extreme heat wave that only occurs once in a great while. These are everyday things. Surface temperatures in the sun and the ambient air temperatures and ones at night can be lower than the air temperature.

The other thing was that some people just felt that the effect would be negligible. And I had pointed out to the subcommittee there were a vast number of cases, not just a handful, but many in the news about this year there is concrete roadways, bridges, ramps, and other structures, have buckled. Now in those cases, the risk to public safety isn't large because they closed down the highway. They demolished the old buckled portion and they replaced it. But of course, a shield building is different. You can't use the same standard of acceptability. It is a water tank. It forms a passageway to the airway needed for heat removal.

So that is why I felt that it couldn't be ignored that the attitude well what we are doing in the AP1000 with the SC models conforming to normal practice for concrete use in these other industries, that to me is not an acceptable response because it is different, even if it is true. I didn't check it was true.

So the technical cases that I cited in my long letter, I think the eight-page one, shows that that attitude of complacency that if we need you know the sort of the way that concrete is normally designed with respect to the temperatures we consider,. is already not the norm at the other federal agencies and institutions. So I found papers that came out Oak Ridge and out of the National Institute of Standards in Technology to illustrate this. Okay and I said I wanted to say that if you have trouble getting those, I can send you a copy.

The second thing regarding issue two about the large-scale test, there were several remarks that seemed either puzzled by the concerns or missed it because of the intuition that surely if the sun is shining on the physical model, wouldn't that be unhelpful in providing cooling. And I do understand that argument but it is first of all kind of complicated. But second of all, Westinghouse was always saying that their analysis using WGOTHIC which was validated by this test was that worst case was cold and if they counted in extra heat from the sun, it would help. So it is hard to see how you could accept what Westinghouse says the results of WGOTHIC is and yet have the intuition that sunlight is going to make evaporation worse. So I wanted to say that it shouldn't be dismissed on that basis.

I personally think that no generalizations about whether a certain increase or decrease in any single factor is going to reduce containment or not, I don't see how that can be made. And the reason is that -- So I don't make a statement either way because containment cooling involves humidity and other factors that affect conduction through the shell. Radiation is only one of the mechanisms.

So the thing is that if all you were doing was measuring temperature and if what you were doing is measuring temperature in the large-scale test, I mean, it is going to matter what the humidity is and what the sunlight is. If you have intense sunlight and low humidity, that is going to be very different from the case of no sunlight and high humidity, even if they are exactly the same temperature. That is why I don't see how you can really draw too much if all you have and I don't have access to the detail that you ACRS members do, but it looked like they were just measuring temperatures. I don't see how you can make any conclusions and correlate cases on the basis of temperature. And I think if you understand the review on the basis of heat transfer, you have to agree with that.

And so the problem I am wondering, and again I don't have access to the data, but just what people wrote in discussing how they applied it to WGOTHIC, but if what they have is just temperatures, then I would worry that the test is measuring the things that you need to make the inferences to cases that are not exactly like the actual large-scale test.

So what I said or meant to say is that if they are going to use the large-scale test to determine the coefficients of evaporative effectiveness then whether or not it is in the sunlight does need to be taken into account because into sunlight would aid evaporation. I hope by now no one considers that an objectionable statement.

Secondly, I point out the purpose of the large-scale test is limited to certain aspects of mass and heat transfer effects. And here I am going to quote from the FSER. I think it was stated at some point that Chapter 21, which is about the test and validation of the computer codes has not changed since the 2004 FSER and here is quote from that.

"The experimental large-scale test is designed to induce similar containment dome heat transfer processes and circulation stratification patterns. However, it is not meant to simulate specific AP600 accident scenarios. The large-scale test data is used to validate WGOTHIC computer code, which will be used to analyze the containment."

And I note that the main conclusion of the test is and I quote, "evaporation was the primary mode of heat removal from the outside of the vessel; approximately 75 percent of the total."

So it looks to me like the situation is this, that because the test, the large-scale test is not, and I guess the large-scale test did not separate out heat of solar radiation which was present in the large-scale test but will not be present in the AP1000 leaded steel containment from the effects of ambient air temperature and humidity of air, we just don't know. And I don't know how you are going to figure out how to do that from the data if the data didn't include humidity and solar radiation.

Now you might say well let's run some WGOTHIC. Well you can't use WGOTHIC to answer that because that would be circular.

And the test data, I am just wondering if you have enough there if you didn't measure solar radiation. Now you might ask how do you measure solar radiation. And the way meteorologists do it is by using evaporation. They should have done that when they ran the LST if they were doing it outside. But I don't see any indication that they did. So I am wondering if the data isn't there, I don't know what you are going to do.

The test concluded that most dominant factor is cooling via evaporation but assumed it was the same whether the equipment was in the sun or in the dark. So it looks to me as though WGOTHIC uses coefficients for evaporative loss based on the test performed in the sun for which the data is not available on how much of the evaporation was due to the sun. So that is just conveying the problem.

So I have a lot more I could add but I am assuming that the time is limited. So let me just add one more thing. That why this has to get done before design cert is granted is because that is it. I don't think there are checks and balances until real nature comes along, the real challenge in nature would come along. And that is a concern, that there would be no check and balance on it, no check on it or checks of it until the real challenges comes in nature.

And why would I worry about this? Because as far as I know, the ITAACs are not going to check this error. And here is my worry, that they don't test for actual heat removal capabilities in the containment by this PCS, per se. The ITAAC criterion is whether or not certain system parameters like flow rates and so on, the flow rate of water being delivered over the steel containment dome and such things.

Now if you think about it, the claim of adequacy of heat removal from the containment, that is going to be based on this error. And it is really, really important in the AP1000 and 600 because unlike in any other operating plant, this is the ultimate heat sink. It means every other system performing post-accident heat removal, all it is doing is collecting the heat and then passing it on to the containment so that the passive containment can remove the heat.

So the validity of conclusions about the effectiveness of those systems in removing decay heat is going to be based on these calculations performed using WGOTHIC, too. And the WGOTHIC analysis calculations about evaporative heat losses are exactly what are in question by this error about forgetting about the sun.

And I am going to stop there due to time.

MEMBER RAY: Thank you. Yes, you've used the time and I think I would just say this to you. Can you hear me all right, Dr. Sterrett? Evidently we have been muted, although Dr. Sterrett hasn't been. So she is not able to hear us in response.

MEMBER BROWN: We were told the mute was on a little while ago.

MEMBER RAY: Yes, I know. Is there any way to un-mute it before she hangs up? Can you hear me Dr. Sterrett?

DR. STERRETT: I'm sorry. I can't hear anything. Is the connection good on your end? Can you hear me?

MEMBER RAY: Evidently we --

MEMBER BROWN: We are all nodding our heads.

MEMBER RAY: Our control room operator went for coffee or something.

DR. STERRETT: I can't hear anything.

MEMBER RAY: Dr. Sterrett, can you hear us? We will try one more time here.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

September 19, 2011

The Honorable Gregory B. Jaczko
Chairman
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: REVISION 19 TO THE AP1000 DESIGN CONTROL DOCUMENT AND THE AP1000 FINAL SAFETY EVALUATION REPORT

Dear Chairman Jaczko:

During the 586th meeting of the Advisory Committee on Reactor Safeguards (ACRS), September 8-10, 2011, we reviewed those portions of the NRC staff's Final Safety Evaluation Report (FSER) for the AP1000 Design Control Document (DCD) amendment which were affected by Revision 19 to the DCD. The Westinghouse Electric Company (WEC) submitted Revision 19 on June 13, 2011, and the NRC staff's FSER is dated August 5, 2011. Our Subcommittee on AP1000 also reviewed changes contained in Revision 19 during a meeting on August 16, 2011. During these meetings, we had the benefit of discussions with representatives of the NRC staff, WEC, and members of the public. We also had the benefit of the documents referenced.

We have previously reviewed other changes contained in the DCD amendment, as documented in our letters dated December 13, 2010; December 20, 2010; and January 19, 2011.

CONCLUSION

The changes proposed in the AP1000 DCD amendment, including those made in Revision 19, maintain the robustness of the previous certified design. We conclude that there is reasonable assurance that the revised design can be built and operated without undue risk to the health and safety of the public.

BACKGROUND

Most of the changes to the DCD contained in Revision 19 involve editorial corrections and inclusion of conforming items previously identified in the Advanced FSER which was the basis for our prior letters. A few of the Revision 19 changes include new information, and several of these changes are discussed further below.

DISCUSSION

Enhanced Shield Building (ESB)

There have been no changes to the ESB design since the review documented in our letters of December 13, 2010, and January 19, 2011. However, WEC has performed additional analyses and included Tier 2* information, as requested by NRC staff.

Passive Cooling System (PCS) Tank

The ESB rooftop PCS tank wall is identified in the DCD as a critical structural section. The overall behavior of the building is obtained by a response spectrum analysis of a global finite-element model, which is referred to as the NI05 model. Results for the tank wall from this model were reported in Revision 18 to the DCD.

Revision 19 included new results based on an equivalent static analysis of a more detailed finite-element model of the tank and ESB roof. The analysis applied the maximum acceleration from time-history calculations with the hydrodynamic loads due to sloshing of water in the tank applied as a pressure on the tank wall. Because of the symmetry of the tank and roof, a quarter of the structure was modeled.

This new, more detailed, analysis confirmed that the design of the PCS tank is acceptable, and no changes to the design were required. We agree with the NRC staff that the more detailed analysis of this area of the ESB was appropriate and should be included in the DCD.

ESB Seismic and Thermal Load Combination

Prior to Revision 19, the ESB was analyzed for a number of loads including those due to a safe shutdown earthquake (SSE) and those due to extreme ambient temperatures. At the request of the NRC staff, these loads were combined and the analysis results were included in Revision 19.

The worst-case ambient conditions are represented by a winter condition with an external temperature of -40°F and an internal temperature of 70°F, and a summer condition with an external temperature of 115°F and an internal temperature of 70°F. The analysis shows that the winter condition is the most limiting due to the larger temperature difference. For this case, the out-of-plane shear capacity of the structure exceeds the out-of-plane shear demand in the regions of the structure with steel composite modules.

The governing demand-to-capacity ratio in the critical region for thermal loading is steel plate yielding, which is a ductile limit state. We agree with the staff's conclusion that the WEC's analysis of the thermal and seismic load combination for the shield building satisfies ACI 349 code provisions and is acceptable.

Radiative Effects on Thermal Loads

A concern was raised by a member of the public (Ref. 6) that the estimation of thermal loads on the ESB did not include the effects of radiative heating or cooling. WEC performed additional calculations to quantify the impacts of these effects.

An American Society of Heating, Refrigerating and Air-Conditioning Engineers publication includes tables of effective temperatures that provide the same rate of heat transfer into the surface as would the combination of solar gain, radiant energy exchange with the sky and other outdoor surroundings, and convective heat exchange with the outdoor air. These tables were used to estimate the temperature history of the ESB wall.

WEC calculated that the resulting maximum ESB surface temperature, including solar gain, is approximately 129°F. Their stress analysis using this surface temperature showed that the solar gain has no significant effect on the load combination of ambient thermal plus SSE, and there is no significant reduction in the overall design margin. This result is consistent with our expectation that any change would be relatively small, as compared to that due to the winter ambient temperature difference of 110°F. We therefore conclude that this issue can be considered resolved.

Inclusion of ESB Design Details in the DCD

Revision 19 includes additional Tier 2* material describing the steel modules that comprise the bulk of the ESB wall and the connection of the modules to both the basemat and the conventional reinforced concrete roof of the auxiliary building.

As we noted in our December 13, 2010, letter, there are no consensus standards governing the steel module construction used in the ESB, although the DCD does commit to use of AISC-N690, ACI-349, and AWS structural and reinforcing steel welding codes as applicable to the modules and their connections. The added Tier 2* information provides regulatory control over additional details of the module design to address the lack of specific code requirements for some features.

As examples, the added information includes a performance requirement of the tie bar to steel face plate welds, which have no counterpart in AISC-N690, and a weld geometry requirement on the plate-to-plate welds for modules. This information, together with the other Tier 2* information, including 14 critical structural sections, provide appropriate regulatory control over the design of the ESB.

The staff and WEC have expended substantial efforts in deciding which details need to be included in the DCD, in lieu of reference to codes and standards which presently do not address such details for the design used. We again note, as we did in our December 13, 2010, letter, that it would be preferable to have codes and standards for such structures that have broad consensus concerning such details.

Containment Accident Pressure Analysis

The calculation of containment accident pressure was updated in Revision 19, increasing the peak pressure to 58.3 psig as compared to 57.8 psig previously. The most significant contributions to the increase resulted from the increase in time assumed to reach steady-state PCS water coverage and from updates of the estimates of the mass and energy release into containment during a loss of coolant accident. The first of these contributions arose from the resolution of an earlier ACRS comment.

Changes were also made in the evaluation model which tended to decrease the peak pressure, the most important of these being the inclusion of certain heat sinks such as floor gratings.

These changes to the containment evaluation model inputs took into account the updated plant design information. The analysis, primarily done using WGOTHIC, including the consideration of heat sinks, was performed using a previously accepted methodology which results in conservatively high containment pressures. Independent calculations performed by NRC staff using MELCOR also confirmed that the WGOTHIC-based results were conservative. The heat sinks added in the Revision 19 calculation update were incorporated as Tier 2* information.

While the containment peak pressure of 58.3 psig is close to the containment design pressure of 59 psig, we find the re-evaluated containment pressure documented in Revision 19 to be based on a sufficiently conservative methodology and to be acceptable.

Radiative Effects on Containment Evaluation Model Validation

An additional concern was raised by the member of the public (Ref. 6) regarding the effect of radiative heating due to insolation and radiative cooling on the quality of the data obtained from the Large Scale Tests (LSTs) which were performed outdoors.

The LSTs provided data on condensation in the presence of non-condensable gases inside large containment-like vessels cooled by an evaporating water film flowing down the outside surface. The test vessel itself was surrounded by an acrylic enclosure that formed an annulus through which air was drawn to simulate the natural convection of air between the containment and ESB. While the LSTs were reduced in scale compared to the plant, they were still large enough to assess the validity of the evaluation model correlations, which were developed from much smaller scale tests.

The concern was that solar radiation incident on the evaporating water film, which cools the outside of the LST vessel, would cause a higher evaporation rate than would otherwise result, thus leading to non-conservatively high heat transfer coefficients.

The LST heat fluxes used to estimate the heat transfer coefficients both on the inside and outside of the pressure vessel, and on the outside of the pressure vessel due to the water film, were evaluated in three different ways. The first involved measuring the amount of steam condensed within the pressure vessel, the second involved measuring the heat transfer through the wall using embedded thermocouples, and the third involved performing a heat balance on the water and air cooling the outside of the pressure vessel. If insolation had an effect, the heat balance on the water and air would yield a markedly higher value than the other measures of heat flux.

Examination of the data indicates that the heat fluxes measured by these three independent methods were the same, within the scatter of the data, over the whole range of conditions. Following our assessment and an independent assessment provided by WEC, we conclude that radiative heating or cooling had no effect on the LSTs and the data from the tests are suitable for validating the evaluation model.

We also considered whether insolation on the ESB exterior would affect the removal of accident heat load by the PCS. WEC provided analyses that showed this effect was negligible for two reasons. First, because the ESB has a large thermal mass, the temperature changes on its inside wall resulting from insolation are very small. Second, because the heat removal from the containment is due primarily to evaporative cooling, even significant increases in the air temperature at the ESB inlet to the annulus would have a small effect on the peak containment pressure. Prior parametric analyses by WEC showed that an increase of 10°F in inlet air temperature results in an increase in peak containment pressure of only ~0.05 psi. We therefore conclude that solar heating will not result in an unacceptable increase in peak containment pressure.

Reactor Coolant Pump (RCP) Flywheel Retaining Ring Material Testing

In our letter dated December 13, 2010, we recommended that the material selected for an RCP flywheel retaining ring designed for long term service without periodic inservice inspection should be qualified by testing in a reactor coolant environment. WEC responded to this concern by implementing a testing program. We commented on this program in a letter to the EDO dated May 19, 2011, and WEC responded with an updated plan during the August 16, 2011, subcommittee meeting. We concur with the updated WEC test program as described to us.

In summary, we agree with the staff's FSER, including Revision 19 to the DCD. The changes incorporated by Revision 19 maintain the robustness of the previously certified design. We conclude that there is reasonable assurance that the revised design can be built and operated without undue risk to the health and safety of the public.

Sincerely,

/RA/

Said Abdel-Khalik
Chairman

REFERENCES

1. AP1000 DCD Revision 19 Sensitive Version, June 13, 2011 (ML11171A287)

2. The Final Safety Evaluation Report for the AP1000 DCD Revision 19, FSER for the DCD, August 2011 (ML112061231)

3. Design Report for the AP1000 Enhanced Shield Building, APP-1200-S3R-003, Revision 4, June 15, 2011 (ML111950098)

4. AP1000 Shield Building Design Details for Select Wall and RC/SC Connections, APP-GW-GLR-602, June 14, 2011 (ML111680018)

5. Evaluation of the Effect of the AP1000 Enhanced Shield Building Design on the Containment Response and Safety Analyses, APP-GW-GLR-096, Revision 3, June 14, 2011 (ML111680190)

6. Statement and materials presented to the 586th Full Committee Meeting by Dr. Susan Sterrett (ML11256A256, ML11256A258, ML11256A266)

7. ACRS Letter, Report on the Final Safety Evaluation Report Associated with the Amendment to the AP1000 Design Control Document, December 13, 2010 (ML103410351)

8. ACRS Letter, Long-Term Core Cooling for the Westinghouse AP1000 Pressurized Water reactor, December 20, 2010 (ML103410348)

9. Letter, Report on the Safety Aspects of the Aircraft Impact Assessment for the Westinghouse Electric Company AP1000 Design Certification Amendment Application, January 19, 2011 (ML110170004)

10. ACRS Letter, Response to the February 5, 2011, EDO Letter Regarding the Final Safety Evaluation Report Associated with the Amendment to the AP1000 Design Control Document, May 19, 2011 (ML11136A214)

REFERENCES

1. AP1000 DCD Revision 19 Sensitive Version, June 13, 2011 (ML11171A287)

2. The Final Safety Evaluation Report for the AP1000 DCD Revision 19, FSER for the DCD, August 2011 (ML112061231)

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10. ACRS Letter, Response to the February 5, 2011, EDO Letter Regarding the Final Safety Evaluation Report Associated with the Amendment to the AP1000 Design Control Document, May 19, 2011 (ML11136A214)

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Letter to The Honorable Gregory B. Jaczko, NRC Chairman, from Said Abdel-Khalik, ACRS Chairman dated September 19, 2011

SUBJECT: REVISION 19 TO THE AP1000 DESIGN CONTROL DOCUMENT AND THE AP1000 FINAL SAFETY EVALUATION REPORT

ML# 11256A180

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August 12, 2011

Mr Weidong Wang, Senior Engineer
ACRS/TSB, Nuclear Regulatory Commission
Mailstop 2 E26 TWFN
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References:
1. Email from Billy Gleaves, Sr Project Manager dated 28 June 2011, "RE: Request to listen via teleconference [PUBLIC MEETING WITH WESTINGHOUSE ELECTRIC COMPANY ON THE AP1000 DESIGN CERTIFICATION - SHIELD BUILDING ROOF PASSIVE CONTAINMENT COOLING WATER STORAGE TANK ANALYSIS Thursday, June 30, 2011 9:00 a.m. - 11:30 a.m.]"
2. "Evaluation of the Effect of the AP1000 Enhanced Shield Building Design on the Containment Response and Safety Analysis", APP-GW-GLR-097, Rev. 1, submitted to the NRC as part of docket on AP1000 rulemaking, as enclosure 4 to DCP-NRC-002998, August 6, 2010.
3. "A Review -- Cooling by Water Evaporation Over Roof" by G. N. Tiwari, A. Kumar, and M. S. Sodha, in *Energy Conversion Management*, Vol. 22, pp. 143 to 153, 1982.
4. Letter from S G Sterrett to Billy Gleaves dated 7 July 2011 "Thermal loads and effects due to radiative heating and cooling of AP1000 shield building exterior surface, which are in addition to all thermal loads and effects due to ambient air temperature" (Written question submitted regarding PUBLIC MEETINGS WITH WESTINGHOUSE ELECTRIC COMPANY ON REV 19 OF THE AP1000 DCD that were held on June 30, 2011)

SUBJECT: **Question for ACRS Meeting on August 16th, 2011 (Rev 19 of AP1000 DCD) concerning whether solar radiation on the physical model was accounted for in interpretating experimental data in the "Large Scale Test" that was used to validate WGOTHIC, which is used in Rev 19 calculations for predicting heat and mass transfer aspects of the effectiveness of Passive Containment Cooling System in reducing containment pressure.**

1. Background to the Problem (from which the question about WGOTHIC validation using the PCS (Passive Containment Cooling System) Large Scale Test (LST) arises)

In the meetings about Rev 19 of the AP1000 DCD held on June 30, 2011, the topic of including thermal loads on the AP1000 shield building was discussed, and various sections of revision 19 of the AP1000 DCD were cited, including Appendix 3H. In an earlier letter addressed to the NRC's Billy Gleaves, (Ref. 4), which I attach to this letter for convenience, I discussed that issue as it related to the AP1000 nuclear safety accident analyses and analysis of the shield building structure: It is clear from looking at the values of the thermal loads listed in Appendix 3H of Rev 19 of the AP1000 DCD that Westinghouse assumed the building exterior surface temperatures to be bounded by the ambient air temperatures. It is also a matter of very basic science that doing so is not correct.

The quantitative values of the neglected quantities are not small (~ 30 degrees F or more difference added onto the high end of the range; about half that added on the low end of the range). The data presented by Westinghouse in Appendix 3H of Rev 19 of the AP1000 DCD implies that Westinghouse and/or the NRC staff did not consider, and/or did not realize that it was relevant to take into account the fact that there can be radiative heating of an exterior surface due to the sun, and radiative cooling of an exterior surface due to radiation to the night sky. These temperature changes are distinct from, and in addition to, seasonal and daily temperature changes due to seasonal and daily temperature changes in the ambient air temperature.

The fact that Westinghouse made this error (neglecting the effect on building exterior surface temperatures due to radiative heat gains due to the sun (solar radiation) and radiative losses to the night sky) in the work done for the Rev 19 changes raises the question of whether there is a more fundamental problem with the safety analysis of the AP1000: if they really didn't know that they needed to consider the effect of heat of solar radiation for the Rev 19 calculations for the shield building exposed to the sun, did they know to do so when interpreting the test results of the Large Scale Test of the Passive Containment Cooling System? The steel containment as installed is inside the concrete shield building and is not exposed to the sun, so there would be a problem if the scale model of the steel containement was exposed to the sun during the test.

In a Westinghouse document submitted as part of Rev 19, the following photograph of the Large Scale Test Facility is provided:

Westinghouse Non-Proprietary Class 3

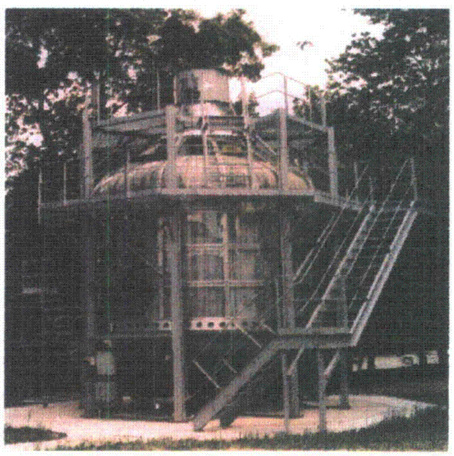


Figure 6-4: Large Scale Test Facility

APP-GW-GLR-097 Rev. 2

If the above is a photograph of the site on which the test was performed (i.e., if the test was performed outdoors during the day), which I believe it is, then the wetted surface of the Large Scale Test (LST) of the Passive Containment Cooling System (PCS), was in the presence of the sun when the experimental test data was taken. The figure below, which is from an article in an engineering journal (Ref. 3) is applicable to that situation, and the factors depicted in it need to be taken into account when interpreting the test data:

146 TIWARI *et al.*: A REVIEW

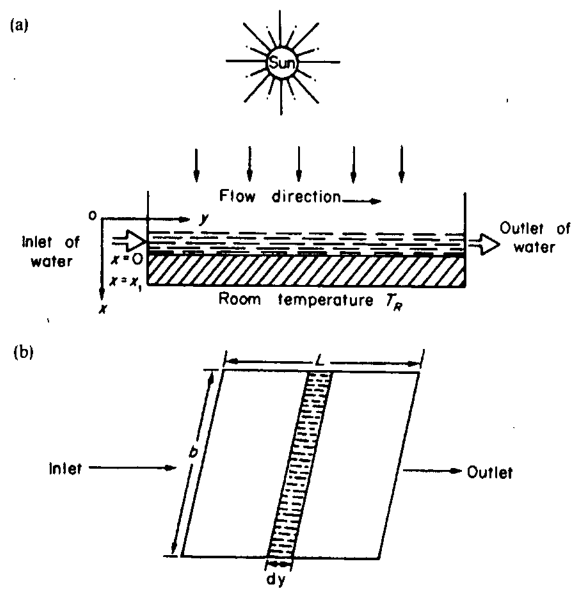


Fig. 1. (a) Schematic sketch of, "Flowing water over the roof" system. (b) Overside view of the flowing water system.

Now, compare the two situations: the PCS LST physical model in the outdoors, and the PCS under the conditions at which it is supposed to operate:

<u>Large Scale Test (LST) -- Outdoors in Presence of Sunlight</u>

The above figure (Figure 1 of Tiwari 1981) correctly depicts the role of the sun in the **Large Scale Test situation** of the Passive Containment Cooling System (PCS) **LST**, which, it appears, was performed outdoors, in the presence of sunlight.

In the LST model, which is a physical model, the baffle/shield building was represented, if at all, using a *transparent* material. **The physical model's being in the presence of sunlight thus aided evaporation in the PCS LST test.**

Conditions under which AP1000 PCS is designed to operate -- Inside shield building, largely shielded from Sunlight

> The **installed situation** for which the AP1000 Passive Containment Cooling System is to perform its safety function of heat removal from the steel containment is *inside* the concrete shield building, and the concrete shield building is *opaque* to solar insolation. Whatever the weather outdoors, the wetted surface of the steel containment from which evaporative losses are taken credit for in the AP1000 safety analysis is largely shielded from receiving the benefit of sunlight (solar insolation) in the situation in which the PCS operates, as installed in an AP1000 nuclear power plant.

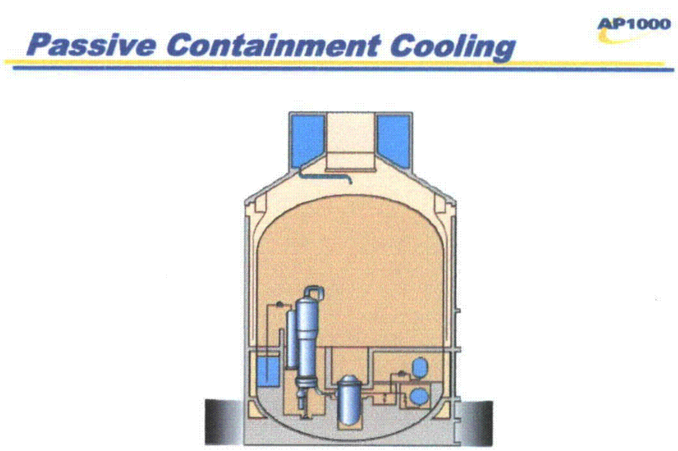
Thus there might well have been more evaporation, and more heat removal, earlier, in the LST experimental test situation than there will be in the situation in which the PCS is actually to operate when installed in an AP1000 nuclear power plant. At any rate, accuracy calls for considering the important relevant factors in a calculation, and the factor of whether or not a surface is in the presence of solar radiation or not is a relevant factor in the calculation of heat transfer.

I have so far not run across any discussion of the fact that the test model of the steel containment shell was located in the sun whereas the actual containment is located within the shield building, largely shaded from sunlight.

2. Technical Discussion of the Problem

2a. WGOTHIC Validation of Indoor Systems Using Outdoor Test

The problem is that it appears that in the test situation (PCS LST) against which the computer code WGOTHIC was compared, the wetted surface was exposed to solar insolation (i.e., radiative heating from sunlight was present), whereas the situation WGOTHIC is being used to make predictions about is one in which it is not: inside the shield building, which is where the PCS delivers the water film over the steel containment. The interior is largely shielded from sunlight. The Westinghouse presentation at an NRC meeting on 30 June 2011 presented this figure:



It was also stated that the computer code WGOTHIC was used in the safety analysis for the AP1000 to predict PCS effectiveness in removing heat from the containment, and thus to predict its effectiveness in reducing containment pressure. Per the docket materials submitted describing the analysis performed in calculating containment pressure for Rev 19 changes, the computer code was validated by comparing the results that WGOTHIC predicted for the LST test with the results obtained experimentally in the LST test.

Since the LST test was conducted in the presence of sunlight, and the WGOTHIC model of the PCS performance was validated against it, won't the WGOTHIC model of the AP600/AP1000 containment response tend to *overestimate* the evaporative losses that will occur when the PCS operates as installed in the AP1000 plant? I ask this because, in the AP1000 plant, as in the AP600 plant, the wetted containment surface is indoors, in the dark, inside the shield building. Since evaporative losses *reduce* containment pressure, doesn't this mean that, unless the effect of the sunlight is quantified and accounted for in some way, using this approach to validate a computer code such as WGOTHIC results in a computer code that *underestimates* the containment pressure ?

2b. Some Points of Basic Physics

The symbol for solar radiation in the cited paper (Tiwari 1981) is H_s, as indicated in the nomenclature list on the first page of the paper. H_s occurs in the general energy balance equation for figure 1(b) in Tiwari 1981's paper (reproduced above). The general energy balance is equation (2) of the Tiwari 1981 paper; **the energy balance is basic physics and not a matter of controversy or interpretation.**

Refering to Fig. 1b, the energy balance equation for water moving over the roof along y-direction is

$$\left(bd\rho_w c_w \frac{\partial T_w}{\partial t} + \dot{m}_w c_w \frac{\partial T_w}{\partial y}\right) dy = [\tau_1 H_s - Q_r - Q_e - Q_c + h_0(\theta|_{x=0} - T_w)]\, b\, dy \quad (2)$$

where

I would like to emphasize something I said as a participant via telephone in the NRC public meeting that was held on the morning of June 30th, 2011: that *neither the effect of radiative heat gains (via solar radiation) nor the effect of radiative heat losses (via radiation to the night sky) is captured by considering the effect of ambient air temperature.*

To get this point across, I draw your attention to the portion of Tiwari's paper on cooling by water evaporation over roofs that makes a general comment about the cycles of solar radiation and cycles of temperature change due to daily night-and-day cycles. This paragraph of the paper (p. 146) makes clear that they are two distinct factors. H_s is the symbol for solar radiation, and T_a is the symbol for ambient air temperature:

On account of their periodic natures, solar insolation and ambient air temperature can be Fourier analysed in the form

$$H_s = a_0 + \sum_{n=1}^{\infty} a_n \exp(in\omega t) \qquad (7a)$$

and

$$T_a = b_0 + \sum_{n=1}^{\infty} b_n \exp(in\omega t) \qquad (7b)$$

To put this in nontechnical terminology: The *difference between ambient air temperature in night and in day* is one thing *(diurnal cycling, indicated by (7b)),* and *the difference due to the very presence or absence of solar insolation* is another thing. The *presence or absence of solar insolation* is the difference between *being in the shade* and *being in direct sunlight, at the same ambient air temperature* (indicated by (7a)).

Both diurnal *thermal cycling* (due to ambient air temperature daily cycles) and daily temperature variation due to *solar insolation* can be periodic for a particular engineering project, and both are in some manner due, ultimately, to the heat of solar radiation. They are, however, two *distinct*, quantifiable effects whose variation does not coincide in time and place, and neither includes the other.

<u>2.c. Conclusion of the above considerations:</u> The effects of solar insolation (sunlight hitting the surface of something) that were present in the Large Scale Test of the Passive Containment Cooling System (and so aided evaporation), but which are not going to be present in the actual situation to which the safety analysis applies (since the wetted surface from which evaporation is supposed to take place is indoors, shielded from sunlight), should be quantified and subtracted from the LST test results before comparing it to the WGOTHIC analysis. The question is: was this done? Did the ACRS check whether it was done when they approved the designs based upon the analyses using the computer models whose validation appealed to this test? The difference between the test situation and the situation for which WGOTHIC is to be used for prediction needs to be taken into account in some manner. Otherwise, the LST does not serve to validate the WGOTHIC analysis for the PCS as it will perform when it is installed and used in the AP1000 plant.

The photograph of the Small Scale Test Facility, also taken from material submitted for rev 19 of the AP1000 DCD, likewise portrays it outdoors, so agreement between the small scale test experiments run on this facility, and the large scale tests cannot be appealed to in order to dismiss the significance of the test being performed outdoors:

Westinghouse Non-Proprietary Class 3

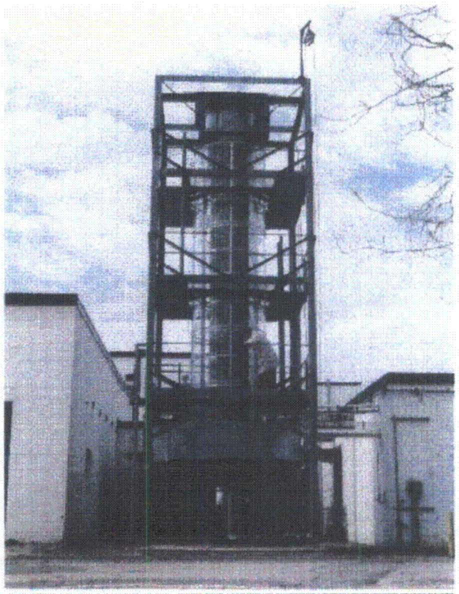


Figure 6-3: Small Scale Test Facility

APP-GW-GLR-037 Rev. 2

3. <u>Question to the NRC ACRS about WGOTHIC validation for Rev 19 Containment Pressure Calculations</u>

QUESTION: Did the NRC review how the difference between:

(i) the Passive Containment Cooling System Large Scale Test (PCS LST) test situation, in which solar insolation (the presence of sunlight, i.e., solar radiation) aided evaporation,

and

(ii) the situation to which the AP1000 computer-based safety analysis (using the WGOTHIC computer code) applies, in which the wetted surface is not exposed to sunlight and solar insolation does *not* aid evaporation,

is accounted for when appealing to the PCS LST experimental test results to validate the use of the WGOTHIC computer code analyses for predicting the effectiveness of the PCS in reducing containment pressure? Radiative effects act in addition to convection and conduction, and affect the calculated peak containment pressure.

I note that the analysis for Rev 19 shows that the margins on containment pressure have been further narrowed to the point of almost vanishing, even after much so-called "pencil sharpening" (taking credit for things for which credit was not previously taken).

Can the ACRS Committee members say whether, and, if so, how, the effects of solar insolation were quantified and subtracted from the LST test results when using the PCS LST to validate the WGOTHIC results for use in the AP1000 design certification? Or, whether this dissimilarity between the test and the situation about which WGOTHIC is being used to make predictions in the safety analysis is accounted for in some other way? If not, can you indicate what the NRC staff ought to do (or require of the applicants) concerning quantifying these effects to determine how they would change the NRC's safety evaluation of Rev 19 of the AP1000 safety analysis?

4. Concluding remark on significance of the question

Put briefly, the question above arises because it appears that on the AP1000 a scale model test of evaporative effectiveness performed outdoors in sunlight was used to validate predictions for a process that does not occur in the presence of sunlight. (I.e., a computer program was validated for the purpose of predicting quantitative values arising from a physical process *in which evaporation is important* and that occurs in the *absence* of sunlight, using a scale model test that was performed in the *presence* of sunlight.) I emphasize that the factor that was neglected is a matter of basic science, not a matter of interpretation or analysis methodology.

Put in terms of an everyday example, it seems to me that this would be akin to validating computer model predictions for a device that its manufacturer claims will rapidly dry clothing indoors in a darkened room, by constructing a physical model of the device and setting it outdoors in sunlight. That is, saying that the PCS LST scale model test validates the predictions of a WGOTHIC computer analyses of the effectiveness of the PCS in removing heat via evaporative heat losses is analogous to referring to the experimental tests of a clothes-drying device from data collected on a model of it used while outdoors in the sun, and then saying: look, my computer predictions were confirmed and I have thus proved how speedily this device works! My computer model calculations predicting how quickly water will evaporate when using this device indoors in the dark are now validated!

S G Sterrett
Special Faculty - Research Associate
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Attachment -- Reference 4 is an attachment to this letter.

<u>Remarks by S G Sterrett, Carnegie-Mellon University, Pittsburgh PA</u>
<u>(slide images have been incorporated into the text below)</u>

(to accompany slideshow of SterrettSlidesACRSMeeting16August2011.pdf)

[conveyed via telephone from Pittsburgh around 3:50 pm on August 16th, 2011 to the meeting of the ACRS (Advisory Commitee on Reactor Safeguards) Subcommittee on the AP1000, held at the Nuclear Regulatory Commission headquarters in Rockville, MD]

Thank you for allowing me time to speak today.

For the record, this is Dr Susan G Sterrett, of Carnegie Mellon University. Prior to my academic career, I worked in the nuclear power industry, including work in structural mechanics and work in fluid systems design. Although I did some work on Westinghouse passive plant designs, I never worked specifically on the AP1000. I obtained the information referred to here from the materials made available to the public on the NRC's website.

ACRS members have been given two letters laying out detailed reasoning and technical references for the two issues I raise; my oral remarks will be brief summaries.

Forgetting About the Sun:

two different issues that arise for AP1000 Rev 19 Calculations

S G Sterrett, Carnegie-Mellon University
ACRS Meeting August 16th, 2011
Rockville, MD

In the midst of the severe heat waves our nation has been experiencing this summer, there have been news reports of road and bridge surface temperatures exceeding 140 degrees F, of airports that have closed because their concrete runways buckled[1], of concrete roads, ramps, and bridges that have buckled[2] [3] [4] [5], and of water pipes across the US that have burst open from thermal loads[6] . These effects remind us *of the powerful effects of the sun* because they are effects that are not due to air temperatures alone, but to the effects of sunlight heating up surfaces,

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1 "Tim McClung with the Iowa Department of Transportation's Office of Aviation said at least two airports have reported buckling concrete runways, shutting down both." http://journalstar.com/news/state-and-regional/nebraska/article_c4dca640-2d40-52eb-b3e8-e48a84962414.html#ixzz1V6JhQXaW viewed on August 15, 2011.

2 http://www.myfoxdfw.com/dpp/traffic/080311-heat-causes-roads-to-buckle. The high temperatures were a surprise to many, and are known only because of sensors put in for another reason: "Lege said the NTTA roadway sensors were originally installed to detect problems in freezing temperatures. She never imagined they'd record such high measurements." Read more on myFOXdfw.com: http://www.myfoxdfw.com/dpp/traffic/080311-heat-causes-roads-to-buckle#ixzz1V6lQGmua viewed on August 15, 2011.

3 http://www.youtube.com/watch?v=J8RlcnC6kcA

4 "Excessive heat also will cause concrete to expand, which can lead to buckling along roads, bridges, sidewalks and other thoroughfares made of the material." http://www.constructionequipmentguide.com/Midwest-Roads-and-Rails-Buckle-Under-Intense-Heat/16696/

5 There are far too many events of concrete roads, bridges, and other structures buckling in the heat this year (summer 2011) to list. They have occurred across the nation, from the southern regions in Texas to the northern ones in Wisconsin, and lots of places in between. Articles reporting these events can easily be located using a search engine for items in the "news" category, and limiting the search to the past few months.

6 http://www.cnn.com/2011/US/08/13/water.infrastructure/index.html

i.e, of solar thermal radiation. There is a heat influx due to the sun that is not captured by considering air temperatures alone. Correct engineering design and analysis must recognize that.

The problem is that the AP1000 analysis seems to have forgotten about the sun.

Today I want to talk about how this error -- this false assumption -- affected rev 19 calculations. The error must be corrected, and today I will try to explain why.

Forgetting About the Sun Issue #1: Forgetting about Heat of Solar Radiation on the Exterior Surface of the Concrete Shield Building

- Rev 19 analyses per Appendix H (as of June 30th, 2011):
  - falsely assumes that range of exterior surface temps of concrete shield building is same as range of the outdoor ambient air temperatures.
  - analyses and conclusions incorrect because temp of concrete shield building exterior surface can be much hotter than ambient due to solar radiation, and much cooler than ambient due to radiation to night sky.
  - variety of calcs should be affected: calculation of peak containment pressure, thermal loads, stresses & displacements of concrete shield building, concrete max temperature, PCS water tank temperature, etc.

"Forgetting about the sun Issue #1

-- The calculations of thermal loads on the shield building in the rev 19 documentation submitted to the NRC reveal that a false assumption had to have been employed, since the maximum temperature used in the calculations is never higher than the maximum ambient air temperature, nor lower than the minimum ambient air temperature. Whereas, we *know* that the building exterior surface can get hotter than the ambient air due to solar radiation -- *much* hotter -- and that it can get much cooler than the ambient air due to radiation to the night sky.

-- It is important to understand the significance of this error; I worry that the NRC staff does not understand that **many** calculations are affected by this **false assumption**, not just the concrete temperatures. The safety significance is the role of the heat input from the sun -- it is a flux, a heat RATE, into the reactor building, not merely an initial temperature condition. I've listed some affected calculations on the slide; notice that peak containment pressure is one of them. Heat transfer to and from the reactor building is a very important factor in the safety analysis of this passive plant. Throughout all of the AP1000 supporting technical documents I have seen, I have not once seen the radiative heat fluxes from the sun or to the night sky depicted. They are important to the conclusions of the safety evaluation of the effectiveness of the Passive Containment Cooling System in removing decay heat in an accident situation. This must be corrected.

Forgetting About the Sun Issue #1: Forgetting about Heat of Solar Radiation on the Exterior Surface of the Concrete Shield Building

The sun heats surfaces exposed to it by radiation.

It increases surface temperatures of the things it shines on.

The AP1000 concrete shield building is no exception.

(Similarly, when sun not shining, heat is radiated back to night sky, decreasing surface temperatures.)

Here is the applicant's sketch of an AP1000 on a sunny day. There is a nuclear fission reactor inside the shield building. There is also the nuclear fusion reactor 92 million miles away. Both are sources of heat input.

The error I am pointing out is a simple matter of basic physics: The sun shining on the AP1000 reactor building will add heat to it by the mechanism of thermal radiation; by the same mechanism of thermal radiation working in the opposite direction, the AP1000 reactor building will lose heat to the night sky. These thermal transfers are **in addition to** heat transfer due to convection and conduction. It is that simple. Yet this simple fact seems not to be reflected in the AP1000 calculations. It seems to be missing from analyses sketches setting up heat balances that are used to derive equations or upon which reasoning of all sorts, including reasoning from experimental test results, is based.

It leads one to ask: is it just the understanding of the effect of solar radiation on the shield building that is affected by the error of forgetting about the sun? The answer is no. That leads to issue #2.

"Forgetting about the sun Issue #2:

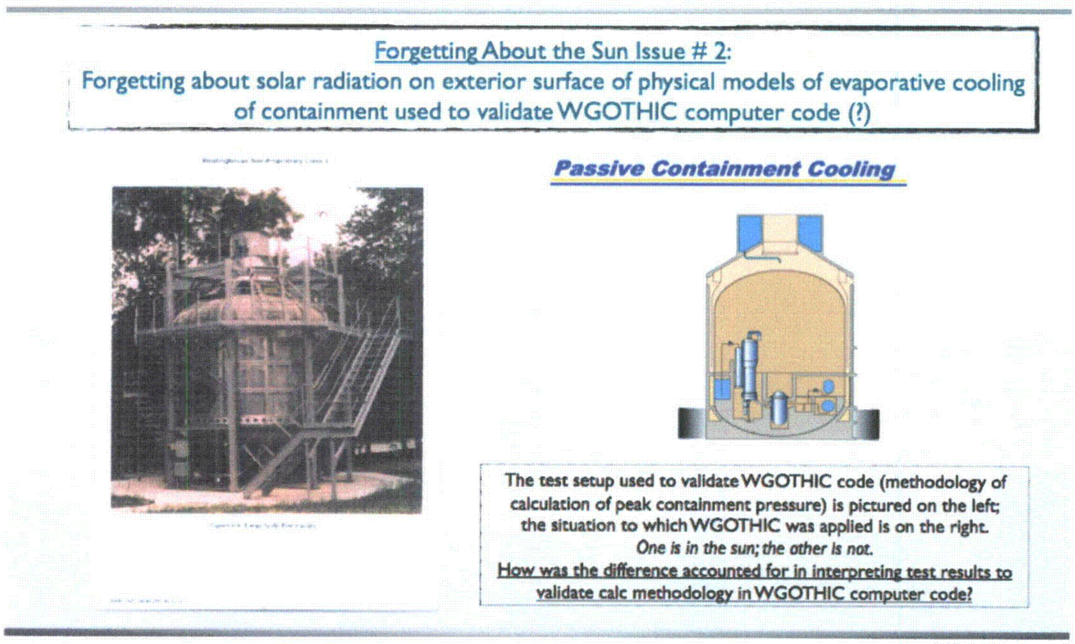
Forgetting About the Sun Issue # 2:
Forgetting about solar radiation on exterior surface of physical models of evaporative cooling of containment used to validate WGOTHIC computer code (?)

- Calculations of peak containment pressure, which depends upon evaporative cooling of the steel containment dome wetted by Passive Containment Cooling System flow, were redone for AP1000 Rev. 19.
- AP1000 Rev 19 calcs of peak containment pressure used WGOTHIC computer code; WGOTHIC was validated by comparing its calculated results to experimental ones for a physical model test in which dome was wetted.
- But test model was out in the sun (?), so solar radiation would have aided evaporation -- how did the validation of WGOTHIC account for that? If effect of the sun not accounted for, the validation of WGOTHIC for analyses of Passive Containment Cooling System effectiveness in accident mitigation is not valid. *Did they remember to account for the sun or did they not? If so, how?*

According to the applicant's submittal of the rev 19 changes, the peak containment pressure, which is extremely important to public safety, was calculated using the WGOTHIC computer code. Keeping peak containment pressure sufficiently low to protect the public relies upon evaporative cooling of the steel containment, which is wetted by flow from the Passive Containment Cooling System. The steel containment is located *inside* the concrete shield building.

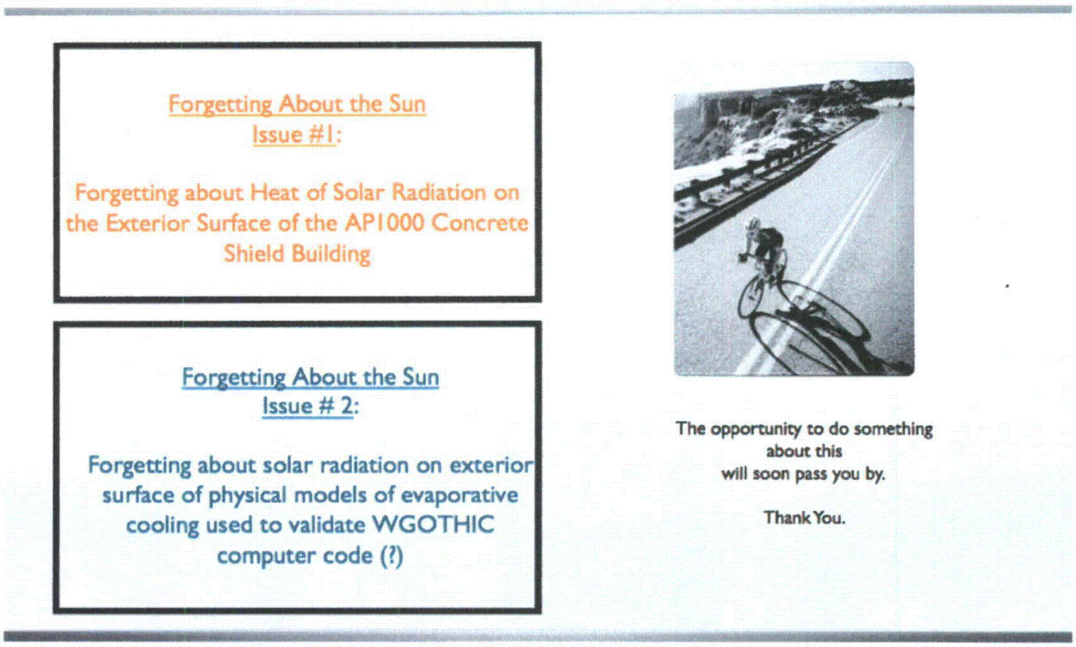
As explained in the rev 19 submittal, WGOTHIC was validated using a physical model test in which the dome was wetted -- but this experimental test appears to have been run outdoors, in the sun. I could find no discussion of, nor any recognition of, the significance of this difference between the experimental setup and the situation for which the calculations were made.

The side by side pictures on this slide may help make the point clear: "The test setup used to validate the applicant's WGOTHIC computer code (i.e., the methodology of calculation of evaporative losses and of peak containment pressure) is pictured on the left; the situation for which WGOTHIC was used for calculations is on the right.



One is in the sun -- the other is not. Evaporation in the test model will be *aided by* the sun. Since WGOTHIC was validated using this model, the tendency may be for

WGOTHIC to *overestimate* evaporative losses and thereby to *underestimate* peak containment pressure. What, if anything, was done to account for this? From photographs the applicant submitted, it appears that the small-scale test facility was out in the sun, too, so agreement between those two tests doesn't aid us in answering this question. The same questions apply to analyses by the NRC staff using the NRC's own computer codes.



These two issues are important. One is important to the structural integrity of the shield building, which supports the water tank for the passive containment cooling system. Both are important for predicting the heat removal capability of the passive containment cooling system to remove decay heat after an accident.

More hangs on keeping the containment cooled in this passive plant design than on other PWRs: I remind you that there is no core catcher on the AP1000. I remind you that, unlike other PWRs, the concrete shield building does not function as an airtight secondary containment on the AP1000, backing up the steel containment. The containment integrity plays a much more important role in ensuring public safety, so public safety depends heavily on the passive containment cooling system being able to remove decay heat. I have just explained to you that the analysis and interpretation of test results upon which claims of its ability to do so are predicated are incorrect.

You have the opportunity to do something about what is certainly a serious omission, and what might be a error that has serious consequences.

Here is why it is so important that you do so now: the only check and balance left at this point in the 10CFR52 process are the ITAACS[7] and the ITAACS -- the criteria the system capabilities have to meet to be deemed acceptable, such as flowrates --- were developed based on the same false assumptions. The ITAAC for the PCS heat removal capability is stated just in terms of providing a certain flowrate, not in terms of demonstrating actual heat removal capability in a realistic environmental context. The ITAACs will NOT provide a check on this error, and so won't necessarily indicate whether or not this omission meant that the safety systems won't be able to remove a sufficient amount of decay heat using the passive containment cooling system. Neither the structural testing of component capabilities nor the ITAACS are designed to let you know that this kind of error -- forgetting about the sun --- has serious safety consequences.

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[7] ITAACS stands for Inspection, tests, analysis and acceptance criteria. The rule governing how this only remaining step after Design Certification and COL issuance, prior to plant operation is still undergoing change: http://www.federalregister.gov/articles/2011/05/13/2011-11678/draft-regulatory-guide-guidance-for-itaac-closure

You don't want to find out that this serious omission does in fact have serious consequences via a serious accident. I don't, at least. I urge this committee to use whatever means it has to try and get this error corrected now. This might really be the last opportunity for anyone to do so.

Thank you.

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July 7, 2011

Billy Gleaves, Sr Project Manager
AP1000 Projects Branch 2
Division of New Reactor Licensing
Office of New Reactors
Nuclear Regulatory Commission
Rockville, Maryland 20852

References:

1. Memorandum from Billy Gleaves, Sr Project Manager, AP1000 Project Branch 2, NRO/DNRL to Eileen McKenna, Chief, AP1000 Projects Branch 2, NRO/DNRL dated June 21, 2011. "PUBLIC MEETING WITH WESTINGHOUSE ELECTRIC COMPANY ON THE AP1000 DESIGN CERTIFICATION – SHIELD BUILDING ROOF PASSIVE CONTAINMENT COOLING WATER STORAGE TANK ANALYSIS"

2. Materials (slides) prepared by Westinghouse for subject meeting, entitled "AP1000 Shield Building Roof PCS Water Storage Tank - June 30, 2011" (included in pdf format as Attachment I)

3. APPENDIX 3H "AUXILIARY AND SHIELD BUILDING CRITICAL SECTIONS", AP1000 Design Control Document, Revision 19, Westinghouse Electric Corporation. (http://pbadupws.nrc.gov/docs/ML1117/ML11171A441.pdf)

4. "Guide for Estimating Differences in Building Heating and Cooling Energy Due to Changes in Reflectance of a Low-Sloped Roof", ORNL-6527, by E. I. Griggs, T. R. Sharp, and J. M. MacDonald, for Oak Ridge National Laboratory, August 1989. (http://epminst.us/otherEBER/ornl6527.pdf)

5. "A Computer Model to Predict the Surface Temperature and Time-of-Wetness of Concrete Pavements and Bridge Decks", by Dale P. Bentz, August 2000. National Institute of Standards and Technology Report No. NISTIR 6551 (http://fire.nist.gov/bfrlpubs/build00/PDF/b00037.pdf)

SUBJECT: **Thermal loads and effects due to radiative heating and cooling of AP1000 shield building exterior surface, which are in addition to all thermal loads and effects due to ambient air temperature.**
(Written question submitted in regard to: PUBLIC MEETING WITH WESTINGHOUSE ELECTRIC COMPANY ON THE AP1000 DESIGN CERTIFICATION – SHIELD BUILDING ROOF PASSIVE CONTAINMENT COOLING WATER STORAGE TANK ANALYSIS on June 30, 2011)

I. Background

II. Technical Discussion

III. Relevance to AP1000 meeting topic of including thermal loads

IV. Question addressed to NRC by means of this letter

1. Background

In the subject meeting held on the morning of 30 June 2011, the topic of thermal loads on the AP1000 shield building was discussed, in that the presentation stated that the AP1000 DCD had been revised (from rev 18 to rev 19) to include thermal loads in some load combinations used in the shield building roof analysis. I raised a question as to the variety of thermal loads and effects that the term "thermal loads" was meant to include. The purpose of this letter is to follow up on *one aspect* of that question -- how surface radiative gains and losses were computed -- by providing more detail. In doing so, I have made a special effort to cite references from sources that are both readily available on the internet and whose authority I expect all involved would accept without question.

Slides for the meeting were provided in pdf format, which are extremely helpful (included in Attachment 1, for convenience). On slide 8, the first bullet notes that in its review of rev 18, the NRC had **"... requested Westinghouse to provide additional justification to demonstrate that the load combination requirements for inclusion of thermal loads were satisfied."** During the meeting, it was stated that details about the thermal loads considered could be found in Appendices 3G and 3H of rev 19 of the AP1000 DCD.

2. Technical Discussion

Referring to the table 3H.5-1 "NUCLEAR ISLAND: DESIGN TEMPERATURES FOR THERMAL GRADIENT" On page 3H-24 of Appendix 3H of rev 19 of the AP1000 DCD (Ref, 3, downloaded from http://pbadupws.nrc.gov/docs/ML1117/ML11171A441.pdf on 6 July 2011), it can be seen immediately that the outside surface temperatures considered never exceed the maximum ambient air temperature and are never less than the minimum ambient air temperature. **This indicates that the analyses and/or calculations of roof and wall surface temperatures are incorrect.** Here is why: Thermal inputs to and thermal losses from a roof located outdoors will occur due to all three heat transfer processes: convection, conduction, and radiation. Temperature effects arise *not only* from the fact that the ambient air is at a certain temperature, but also from the fact that there is radiative heating of the surface of a roof from the sun during the day and radiative losses from the surface of the roof to the sky at night.

In response to this point, which I brought up at the meeting, someone in the meeting mentioned that "diurnal changes" were included. Now, it is true that the diurnal changes *in the ambient temperature* are, ultimately, due to radiative gains and losses of the *earth's* surface. However, these diurnal changes in *ambient air* *temperature* do not include the changes in *roof surface temperatures* due to the radiative gains and losses. The topic of radiative heating and cooling of *exterior surfaces of building and structures* does not seem to be mentioned in the sections of the AP1000 DCD relevant to the analysis discussed in the meeting of 30 June 2011. Nor did the participants in the discussion from industry or the NRC during the public meeting seem to recognize that this deficiency or error in the analysis presented in rev 19 of the DCD existed.

Another comment made at the meeting was that solar radiation would "help." I assume the speaker meant that increased temperatures would result in reduced peak containment pressure. I understand that point, which may well be true, but even if it is true, it does not mean that shield building radiative gains and losses can be neglected, for two reasons: (i) radiative losses can cause the minimum temperature to be lower than the ambient air temperature, which, by the same token, might *increase* peak containment pressure, and (ii) there are other design considerations, such as limits due to structural effects, that need to be considered besides the limit on peak containment pressure. The additional temperature rise is not of the magnitude that it can be dismissed as insignificant. Its magnitude depends on the features of the surface, but it could easily be 20 or 30 degrees F *additional* temperature rise *above* the ambient air temperature for a concretized surface in a southern latitude.

The role of radiative gains and losses from building surfaces is explained more precisely in many basic references on roof engineering; to cite a paper that specifically discusses the situation of an *external concrete roof surface exposed to the outside atmosphere* from an organization whose technical authority on this matter I trust you will agree to recognize, I refer to a report from Oak Ridge National Laboratories' Energy Division "Guide for Estimating Differences in Building Heating and Cooling Energy Due to Changes in Solar Reflectance of a Low-Sloped Roof" (ORNL-6257, Ref. 4). On page 13, we find the following comments that I hope will make the point that roof surfaces can get hotter than the ambient air during the day, and cooler than the ambient air at night:

> " A roof surface radiates infared energy to the sky and the surroundings. During the day incident solar energy more than makes up for this infared radiation, and a roof can be heated well above the ambient air temperature. During the evening, however, with no solar radiation, the loss of radiant energy to the sky can cool a roof below the ambient air temperature. Evening surface temperatures 20 [degrees] F below air temperature on clear, low humidity nights are common for well insulated roofs. " (p. 13, ref. 4)

From another source I trust you will accept, I cite the NIST report "A Computer Model to Predict the Surface Temperature and Time-of-Wetness of Concrete Pavement and Bridge Decks" (Section 3.1 of ref. 5):

> "[. . .] during the day, the concrete surface temperature generally rises above the ambient temperature due to the incoming solar radiation. At night, the concrete temperature falls due to

radiation from the concrete surface to the sky, sometimes falling below the ambient air temperature and occasionally falling below the dewpoint. " (ref. 5, p. 5)

3. Relevance to AP1000 meeting topic of including thermal loads

In the June 30, 2011 morning meeting, the NRC staff stated that they are still evaluating the information submitted in rev 19 of the AP1000 DCD. As explained above, the thermal loads reported in rev 19 cannot be correct. The NRC staff should examine the methodology and calculations of temperatures and thermal loads provided in the DCD in light of the above points, all of which are a matter of very basic science and not a matter of opinion, convention, or interpretation.

These additional temperature changes will *add* to the *thermal gradients* currently listed in rev 19 of the AP1000 DCD, which may add to the stresses and thermal loads. Since the correct temperature range is larger at *both* ends than the values reported in rev 19 of the DCD (the correct lows are lower and the correct highs are higher) the effect on the calculation of peak containment pressure cannot be dismissed by saying it "will help"; the corrected value for calculated peak containment pressure could *increase*, as well.

There may be other design limits and licensing commitments that need to be reviewed, to see how calculated magnitudes are affected by using the corrected temperatures and thermal loads. One limit mentioned in the meeting was thermal stresses and loads due to any differences in coefficients of thermal expansion between different materials; perhaps whether material properties at extreme temperatures using corrected values are the same as the values used needs to be examined, etc. The NRC staff doing detailed reviews are in a better position to identify these than I am; I note only that of course any other ones affected should be identified and reviewed as well.

4. Question addressed to the NRC by means of this letter

Question: From the considerations in this letter, it is clear that the values of the temperatures and thermal gradients reported in rev 19 of the DCD cannot be correct. I have indicated some corrections that need to be made to the analyses. These considerations also raise a larger question as to whether any of the other analyses and rationales for the AP1000 safety and nonsafety analysis that involved exterior building temperatures directly or indirectly used an inappropriate methodology. Can you please inform me as to how the NRC plans to handle the error identified herein?

Sincerely,

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Surviving the one-two nuclear punch: Assessing risk and policy in a post-Fukushima world

Edwin S. Lyman
Bulletin of the Atomic Scientists 2011 67: 47
DOI: 10.1177/0096340211421470

Bulletin
of the
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IT IS 6 MINUTES TO MIDNIGHT

Feature

Bulletin of the Atomic Scientists
67(5) 47–54

DOI: 10.1177/0096340211421470
http://thebulletin.sagepub.com
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Surviving the one-two nuclear punch: Assessing risk and policy in a post-Fukushima world

Edwin S. Lyman

Abstract

The nuclear industry has claimed that a Fukushima-type event is unlikely to happen in the United States, because few US nuclear power plants are vulnerable to tsunamis. But to some degree, every nuclear plant is vulnerable to natural disaster or deliberate attack, and no nuclear plant can be assumed to withstand an event more severe than the "design-basis accidents" it was engineered to withstand. Many US nuclear plants appear to be subject to greater risks than they were designed to handle, particularly in regard to earthquakes. The author suggests that the US Nuclear Regulatory Commission should expand the universe of events that new and existing nuclear plants must be designed to survive and require reactors to be upgraded accordingly.

Keywords

design-basis accident, Fukushima, nuclear regulation, Nuclear Regulatory Commission, safe shutdown earthquake, small modular reactor, Westinghouse AP1000 reactor

The mammoth wave that struck Japan on March 11, 2011 not only caused a profound human tragedy and an unprecedented nuclear plant crisis but also threw cold water on the prospects for a "nuclear renaissance" any time soon. The spectacle of four reactors in a row blowing up, amid the display of the crude and desperate measures employed by the plant personnel to contain the disaster, belied the reassuring platitudes that the industry had served up for decades about the inherent safety and cleanliness of nuclear power and the competence of its overseers. Public trust in nuclear power, which had grown steadily as the years passed since Chernobyl without another serious nuclear accident, seems to have plummeted overnight, with polls showing, quite understandably, that a majority of not only the Japanese public but also people around the world now oppose nuclear power (Layne, 2011; Reaney, 2011). Fukushima has pushed nations that were teetering on the edge of major decisions on nuclear power, like Germany, off the cliff. Potential new entrants into the nuclear power enterprise, including Italy and

Thailand, got cold feet. It seems unlikely that the nuclear industry and its regulators will regain public support in many nations without a dramatic change in the way they do business: Fundamentally, they must be more honest about what is known, and what isn't known, about the safety of nuclear power.

Unfortunately, early signs don't suggest the industry is going to transform the way it deals with the public. Soon after Fukushima, the Nuclear Energy Institute, the chief lobbying organization of the US nuclear industry, began to run advertisements defending the status quo by lauding the "state-of-the-art technology that layers precaution on top of precaution" at US nuclear plants. The ads did not note that many US nuclear plants were 1970s-vintage boiling-water reactors nearly identical in design to those at Fukushima Daiichi.

Certain vendors of new nuclear reactors took a different tack, opportunistically claiming that their designs were superior to the current generation of reactors and would have been able to withstand a catastrophic event such as that which afflicted Fukushima. These statements were also fundamentally misleading.

The truth of the matter is that no nuclear plant, old or new, can be assumed to be able to survive any event more severe than the "design-basis accidents" that it was designed to withstand. This is little different from the design process for any engineered facility. The scope of the "design basis" of a nuclear plant is set by regulators, who determine the necessary level of safety by choosing factors such as the type, severity, and likelihood of the events that the plant must be able to survive. In addition, since the analyses that plant designers must perform to demonstrate compliance with the design basis are sometimes quite uncertain, another major consideration is the "safety margin" between the results of these analyses and the safety goals. Greater margins mean larger buffers against uncertainties that may cause outcomes to be worse than designers predict.

If a nuclear plant experiences an event that is beyond its design basis, however, then all bets are off. This is what happened at the Fukushima Daiichi Nuclear Power Station, which was subject to a huge earthquake and a series of enormous tsunami waves less than an hour later. According to the preliminary report of the International Atomic Energy Agency (IAEA), only three of the six reactors experienced a level of shaking greater than their design bases. But the peak water level of the ensuing tsunami was about 46 feet, whereas the plant was not prepared to withstand a level greater than 33 feet high (IAEA, 2011). The resulting flood caused the failure of all but one of 12 available emergency diesel generators and damaged the plant's electrical circuitry and other vital equipment. Coupled with the loss of external power caused by the initial earthquake, Units 1–5 lost all AC electrical power, a condition known as station blackout. Without eventual restoration of a power source, current-generation nuclear plants will lose the ability to provide sufficient water to keep the reactor cores cool, resulting in core overheating and meltdown. This sequence of events ultimately occurred at each of units 1, 2, and 3.

Fukushima has already revealed a number of issues that regulators around the world should have been aware of but apparently weren't. At Fukushima, current regulatory policies failed in the following ways:

- Station blackouts lasted far longer than regulators assumed.
- Strategies to prevent core damage or hydrogen explosions were far less successful than expected.
- Lack of accurate or functional instrumentation posed far greater challenges than projected.
- Restoration of stable core cooling was far more difficult and took far longer than assumed.
- Management of contaminated cooling water was a much more serious issue than expected.
- Significant levels of radiation exposure occurred much farther from the release site than projected.

Current designs: Calculating the likelihood of another Fukushima

After the accident, US industry spokespeople claimed that a Fukushima-type event was very unlikely to happen in the United States because few US plants are vulnerable to tsunamis. This claim misses a vital point: Every nuclear plant is vulnerable to some degree to natural disasters like earthquakes, floods, and high winds or to deliberate disasters (including terrorist attacks), and the possibility always exists that an unexpectedly severe event will occur. The risk to the public from such occurrences depends on the likelihood of such extreme events and on how plants would respond should such events occur. Significant uncertainties exist in regard to both these factors.

For example, the Nuclear Regulatory Commission (NRC) requires that US plants identify what is known as the "safe shutdown earthquake" (SSE) and ensure that certain systems would function after such an earthquake occurs. SSEs are determined for each plant at the time of licensing, and the NRC requires plants to have an "adequate margin" to survive one (US NRC, 2011a).

The NRC Fukushima near-term task force, however, concluded that "significant differences may exist between plants in the way they protect against design-basis natural phenomena and the safety margin provided" (US NRC, 2011b: 29). Not knowing the size of the safety margin makes it difficult to predict how vulnerable these plants would be to natural disasters like earthquakes that exceed their SSE. This is a major concern now, because new information on seismic hazards indicates that many nuclear plants may be subject to greater earthquake risks than they were designed to handle. According to a recent NRC assessment, there is about a 3 percent chance each year that one of the 104 US nuclear reactors will experience an earthquake that exceeds its safe shutdown earthquake. While many of these are in the eastern and southern United States, the plant that has the highest risk of experiencing an earthquake exceeding its SSE—nearly 0.4 percent per year—is Diablo Canyon in California. If this plant receives the 20-year license renewal it has requested from the NRC, it will have about a 13 percent chance of being subjected to an earthquake more severe than its SSE before the end of its extended operating lifetime in 2045.

At first glance, it would appear that regulators could address this problem by expanding the universe of events that nuclear plants must be designed to survive and requiring reactors to be upgraded accordingly. Both the NRC's Fukushima near-term task force and the Union of Concerned Scientists have recommended changes along these lines. But this is easier said than done. Regulators would have to decide how far to raise the safety bar. The last time the NRC went through such an effort was after the September 11 terrorist attacks, when the NRC determined that the level of security at nuclear plants was inadequate. The process to set the new level of required protection, by upgrading the "design-basis threat," was a tortuous exercise in negotiation with industry that took two years to accomplish and ended up with a result that was far below the terrorist threat level actually faced by US infrastructure.

The NRC has always had difficulty processing new information suggesting that the design basis was not adequate. The 1979 Three Mile Island accident, which involved multiple system failures and operator errors leading to core damage and a hydrogen explosion, was a beyond-design-basis accident. Although the NRC subsequently did enact some new regulatory requirements addressing specific problems that came to light during the accident, it declined to strengthen requirements that would have reduced the risk of severe accidents across the board. In its 1985 policy statement on severe accidents, the NRC declared by fiat that "existing plants do not pose an undue level of risk to the public" and that "operating nuclear power plants require no further regulatory action to deal with severe accident issues unless significant new safety information arises to question whether there is adequate assurance of no undue risk" (US NRC, 1985). This policy was sharply criticized by NRC Commissioner James Asselstine, who voted against it (US NRC, 1985), saying, "The commission's action today fails to provide even the most rudimentary explanation of, or justification for, these sweeping conclusions. As a basis for rational decision-making, the commission's severe accident policy statement is a complete failure."

This policy created a very high barrier for the institution of new regulations to address severe accident risks. By failing to expand the scope of what it designates as "adequate protection," the NRC would not be able to impose any new requirement on nuclear plants (what is known as "backfitting") unless it found that "there is a substantial increase in the overall protection of the public health and safety or the common defense and security to be derived from the backfit and that the direct and indirect costs of implementation for that facility are justified in view of this increased protection."

In other words, such regulations must meet a cost-benefit test, where the benefits are interpreted by the NRC as a reduction in the number of deaths from cancer that would result from the safety improvement. This rule was developed to conform to a 1981 executive order by President Ronald Reagan that blocked regulations with costs exceeding their projected benefits. Asselstine criticized this heavy reliance on cost-benefit analysis because it was based on average values of calculated safety risks and did not take uncertainties into account (US NRC, 1985). "Factoring into the decision the uncertainties in estimating the level of core meltdown risk would lead to a decision to search for ways to reduce the risks," Asselstine wrote. "However, given the current political climate, there is little sympathy for backfitting existing plants. Thus, the Commission chooses to rely on a faulty number which supports the outcome they prefer and to ignore the uncertainties."

The NRC's reluctance to expand the somewhat arbitrary historical list of design-basis accidents has led to gaps in the way severe accidents are treated, even when new information reveals serious safety concerns.

For instance, the NRC recognized decades ago that a station blackout could pose a grave danger to a nuclear plant and decided that new requirements were needed. Because such events were considered to be highly improbable, however, the standards imposed by the NRC were weak. The NRC required that plants be able to cope with a blackout only for a short period of time, based on an assessment of how long it would take for power to be restored. As a result, most US plants only have four to eight hours of electric power—provided by batteries and additional generators—to cope with a blackout. But, even worse, the equipment needed to cope with a station blackout does not have to be what the NRC calls "safety-related"—that is, it doesn't have to meet the high availability and reliability and quality assurance standards required for equipment that mitigates design-basis accidents, such as earthquakes and floods. As a result, no US nuclear plant would have been in a position to cope with an event like Fukushima, which caused a station blackout that lasted on the order of 10 days and in any event would likely have destroyed the equipment in place to cope with the blackout.

A similar situation exists with regard to the equipment that the NRC required nuclear plants to acquire to be able to mitigate a 9/11-style aircraft attack that could cause loss of large areas of the plant from explosions and fire. Because the NRC determined that type of attack to be "beyond-design-basis," the equipment and procedures were not required to be highly reliable, and NRC's post-Fukushima inspections indeed revealed that much of this equipment would probably not be able to withstand a large seismic or flooding event either.

New reactors, old disasters, and lessons to learn

One might think it would be easier to address Fukushima-related issues in reactors that are still on the drawing board than in operating reactors, since any design-related changes could be implemented without the need for backfitting existing structures. Because of the NRC's reactive approach to reactor safety, however, the opportunity to implement design enhancements in next-generation reactors could be lost. The NRC's policy on advanced reactors is that they do not have to be safer than operating reactors, because operating reactors are already safe enough. As a result, the current crop of new reactor designs is not clearly safer than what's in use. New reactor vendors have advertised that their reactors are significantly safer—but this turns out to be true only if the threat of extreme natural phenomena, such as large earthquakes, is not taken into account. In the absence of regulatory requirements, new reactors simply will not be designed with a sufficiently robust capacity to withstand events beyond the current design basis, because if they were, they would likely be too expensive to compete with reactors that meet only minimum standards.

For example, Westinghouse has claimed that its AP1000 reactor would be able to withstand a station blackout for 72 hours. The AP1000 is a light water reactor with passive safety features, which means that its design-basis cooling functions do not require the use of active systems like motor-driven pumps, relying only on gravity-driven systems and natural convection cooling. The plant is able to maintain core cooling without electrical power because it has a large tank of water above the reactor vessel and other systems that passively provide coolant flow for 72 hours.

After 72 hours, however, the tank needs to be replenished—a task that requires electricity and operator actions. The AP1000 would not have been in a better position to withstand a 10-day station blackout than the Mark I boiling water reactors at Fukushima Daiichi. Also, Westinghouse was only required to show that the passive cooling systems would work in design-basis events, so there is no basis for assuming they would be able to work after a beyond-design-basis natural disaster. And the NRC does not require the active equipment that would be needed after the 72-hour period to be safety-related, so there would be no guarantee that it would be available and reliable after either design-basis or beyond-design-basis events. The AP1000 or any other new design is only as robust as the set of requirements that it must meet.

Some vendors of small modular reactors (SMRs) have argued that their designs also have inherent capabilities to protect against Fukushima-type accidents. SMRs are defined as reactors that have a power level of less than 400 MW-electric and are compatible with assembly-line manufacture. One of the main advantages of SMRs is that they could be used by utilities to add nuclear power in smaller increments that would be better matched to gradual increases in demand. The vendors claim that small reactors would be easier to passively cool than large reactors because of the lower amount of heat that they would generate. Also, the vendors say, the smaller reactors could be built underground, providing additional protection against certain natural events. While there is a grain of truth in these claims, once again they do not tell the whole story.

For instance, although underground siting could enhance protection against aircraft attacks and earthquakes, it could also have disadvantages in other circumstances. Emergency diesel generators and electrical switchgear at Fukushima Daiichi were installed below grade to reduce their vulnerability to seismic events, but this increased their susceptibility to flooding. And in the event of a serious accident, emergency crews could have greater difficulty accessing underground reactors.

Moreover, accidents affecting multiple small units at a site may cause complications that could outweigh the advantages of having lower heat-removal requirements per unit. Fukushima has demonstrated the additional challenges presented at nuclear plant sites when multiple reactors are affected. In its June 2011 report to the IAEA, the Nuclear and Industrial Safety

Agency of Japan wrote, "The accident occurred at more than one reactor at the same time, and the resources needed for accident response had to be dispersed. Moreover, as two reactors shared the facilities, the physical distance between the reactors was small.... The development of an accident occurring at one reactor affected the emergency responses at nearby reactors" (Nuclear Emergency Response Headquarters, 2011: XII-5).

A safer future

It is highly unlikely that a technological magic bullet will inoculate nuclear power against the eventuality of another Fukushima. Regulators and the public worldwide should work together to come to a consensus regarding the level of risk of nuclear power that is acceptable, and nuclear energy will have to adjust to this new, higher design basis or face obsolescence. One should heed the words of the Kemeny Commission, which was convened to examine the Three Mile Island (TMI) accident: "[T]his accident was too serious. Accidents as serious as TMI should not be allowed to occur in the future" (The President's Commission on the Accident at Three Mile Island, 1979).

Since these words were written, four nuclear reactors have experienced accidents far more serious than those at Three Mile Island. The world's response to that accident was clearly inadequate to fulfill the Kemeny Commission's mandate. If history repeats itself and regulators now take steps that are too timid to address the root causes of the Fukushima accident, they must bear full responsibility when the next nuclear disaster occurs. And the NRC should keep this in mind as it considers its next steps in response to Fukushima.

Acknowledgements

This article is part of a special issue on the disaster that occurred at the Fukushima Daiichi Nuclear Power Station in March 2011. Additional editorial and translation services for this issue were made possible by a grant from Rockefeller Financial Services.

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