<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#ixzz1V6IQGmua viewed on August 15, 2011.

[3] http://www.youtube.com/watch?v=J8RIcnC6kcA

[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:

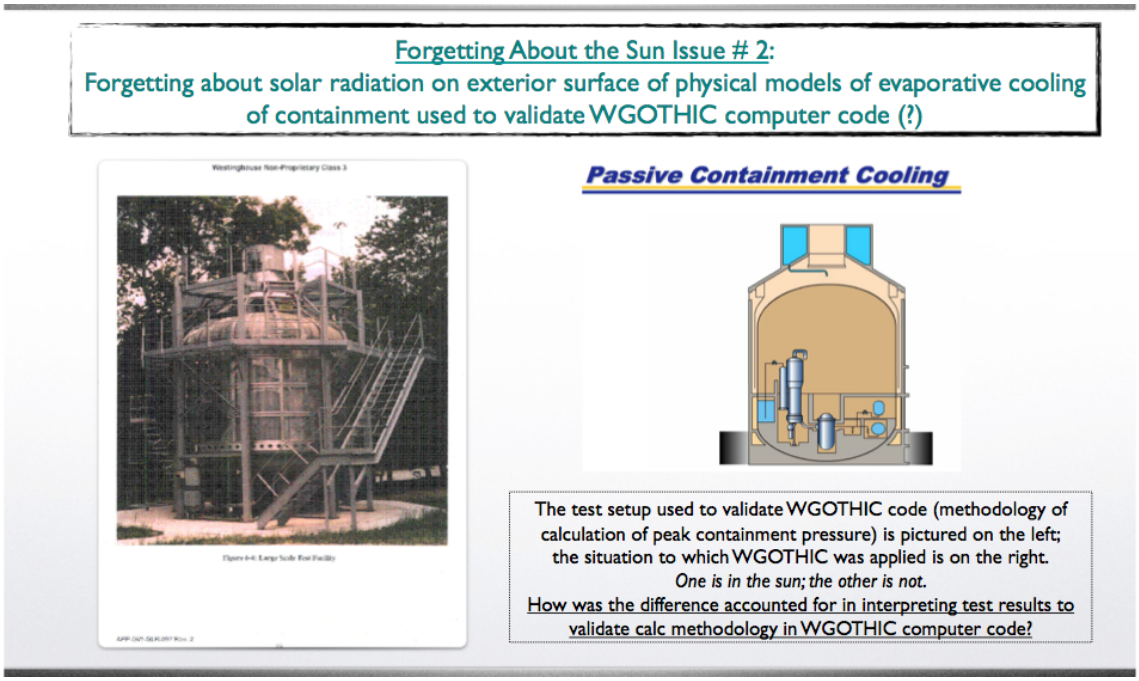
Forgetting About the Sun Issue # 2:
Forgetting about solar radiation on exterior surface of physical models of evaporative cooling of containment used to validate WGOTHIC computer code (?)

- 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.

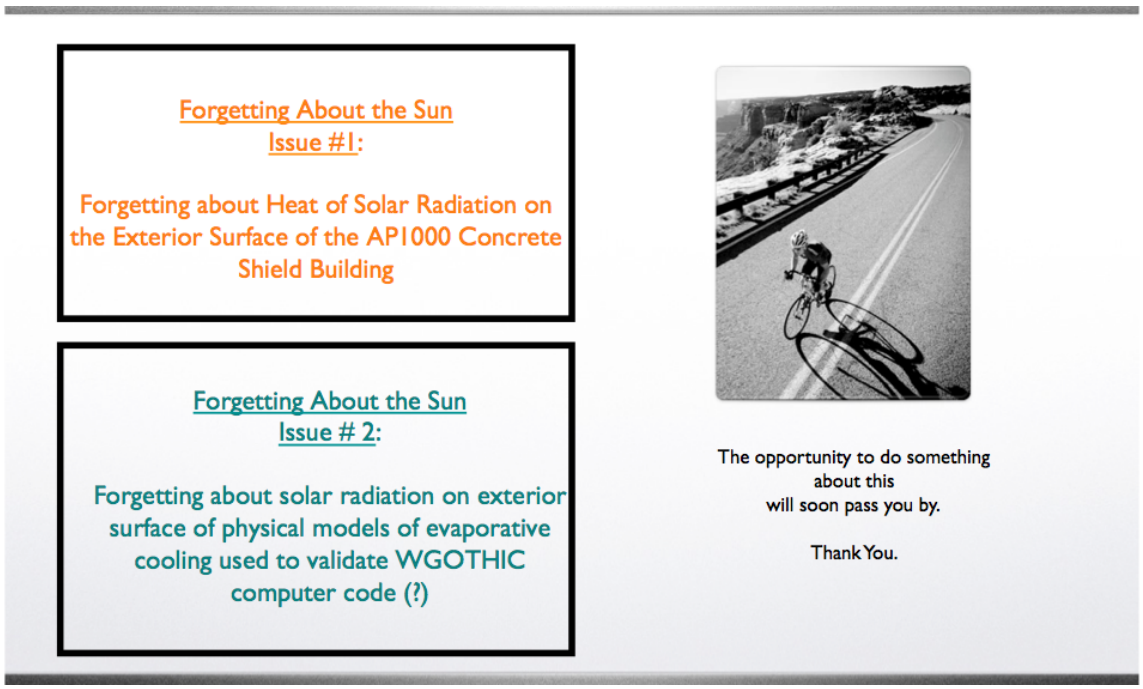
As explained in the rev 19 submittal, WGOTHIC was validated using a physical model test in which the dome was wetted -- but this experimental test appears to have been run outdoors, in the sun. I could find no discussion of, nor any recognition of, the significance of this difference between the experimental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