Dept of Philosophy
135 Baker Hall
Carnegie Mellon University
Pittsburgh PA 15213

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,

Dr S G Sterrett
Special Faculty - Research Associate
Department of Philosophy
Carnegie-Mellon University
Pittsburgh PA