AP1000DCDFileNPEm Resource

From: Adams II, Samuel L. [adamssl@westinghouse.com]
Sent: Tuesday, April 29, 2008 9:44 AM
To: Phyllis Clark
Cc: Perry Buckberg; Rhonda Carmon
Subject: FW: RAICh15ML0811302550.pdf - Adobe Reader
Attachments: RAICh15ML0811302550.pdf

Hi Phyllis,

I acknowledge receipt of the attached RAIs on SRP Section 15.3.

I will let you know as soon as possible if a clarification call is needed.

Thanks.

Sam

From: Phyllis Clark [mailto:Phyllis.Clark@nrc.gov]
Sent: Monday, April 28, 2008 3:27 PM
To: Adams II, Samuel L.
Subject: FW: RAICh15ML0811302550.pdf - Adobe Reader

Sam,

Attached are 17 RAIs associated with the review of AP1000 COL Standard Technical Review Report Number 122, "Offsite and Control Room Dose Changes", of AP1000 DCD Revision 16, Section 15.3, Radiological Consequences of Accidents. The RAI's are numbered as follows in the attachment:

RAI-SRP15.3-RSAC-01
RAI-SRP15.3-RSAC-02
RAI-SRP15.3-RSAC-03
RAI-SRP15.3-RSAC-04
RAI-SRP15.3-RSAC-05
RAI-SRP15.3-RSAC-06
RAI-SRP15.3-RSAC-07
RAI-SRP15.3-RSAC-08
RAI-SRP15.3-RSAC-09
RAI-SRP15.3-RSAC-10
RAI-SRP15.3-RSAC-11
RAI-SRP15.3-RSAC-12
RAI-SRP15.3-RSAC-13
RAI-SRP15.3-RSAC-14
RAI-SRP15.3-RSAC-15
RAI-SRP15.3-RSAC-16
RAI-SRP15.3-RSAC-17

Please provide me an e-mail confirming your receipt of the attached RAIs.

P. Clark
Project Manager
U.S. Nuclear Regulatory Commission
Office of New Reactors, DNRL/NEW2
Room T-8J06
Washington, DC 20555
301-415-6447
Phyllis.Clark@nrc.gov

Hearing Identifier: AP1000_DCD_Review
Email Number: 47

Mail Envelope Properties (9950B72C4C6D8D43958795C414DE477A05D44F98)

Subject: FW: RAICh15ML0811302550.pdf - Adobe Reader
Sent Date: 4/29/2008 9:44:18 AM
Received Date: 4/29/2008 9:44:21 AM
From: Adams II, Samuel L.

Created By: adamssl@westinghouse.com

Recipients:
"Perry Buckberg" <Perry.Buckberg@nrc.gov>
Tracking Status: None
"Rhonda Carmon" <Rhonda.Carmon@nrc.gov>
Tracking Status: None
"Phyllis Clark" <Phyllis.Clark@nrc.gov>
Tracking Status: None

Post Office: SWEC9910.w-intra.net

Files	**Size**	**Date & Time**
MESSAGE	1366	4/29/2008 9:44:21 AM
RAICh15ML0811302550.pdf	107835	

Options
Priority: Standard
Return Notification: No
Reply Requested: No
Sensitivity: Normal
Expiration Date:
Recipients Received:

REQUEST FOR ADDITIONAL INFORMATION

AP1000 DESIGN CERTIFICATION AMENDMENT

RAI - SRP 15.3 - RSAC - 01

In Sections 3.2 and 4.10 of APP-SSAR-GSC-642, Revision 0, "Assessment of Basis for Aerosol Plugging in AP1000 Containment Leak Paths for Radiological Design Basis Accidents" (Document 2), you referenced the Morewitz model (Reference 1) for aerosol plugging of containment cracks. However, you did not recognize Novick's critique (Reference 2) of the Morewitz model. Novick shows plugging regimes as a function of Stokes number and relative settling velocity in his "Regimes for Sampling from Calm Air" diagram. The staff finds that aerosol leak rate velocity at 0.1% per day leak from the AP1000 containment with Stokes Number of 1.5 you assumed may not fall within the range of plugging regime as shown in the diagram. Furthermore, you did not note that many of the data used to construct the Morewitz correlation were for aerosol produced in sodium fires and involved concentrations and particle sizes well outside the range of interest for those in AP1000 LOCA analyses. Some of the tests involved concentrations up to 800 g/m^3. Aerosol particle sizes were measured in few of the tests since concentrations were so high that it was challenging to obtain measurements without overloading the sampling device. Please show how the Morewitz model is applicable to conclude that deposition will attenuate aerosol leakage in AP1000 containment leak pathways.

RAI - SRP 15.3 - RSAC - 02

You asserted in APP-GW-GLN-122, Revision 0, "Offsite and Control Room Dose Changes," Technical Report 122 (Document 1) that aerosol particles will impact on the walls of a leak pathway and listed a variety of mechanisms for the deposition. You further stated that only the inertial impaction of particles on the walls of the leak pathway is pertinent to the AP1000 containment leak paths. No geometrical information about the leak paths is provided other than a path height of 0.155 cm, crack size of 4.45 cm, and 1.75 inch crack depth. The staff believes that many of the hypothesized leak paths would be better approximated as orifices rather than passageways. The staff also finds that no sufficient geometrical information is provided to evaluate if leak paths are orifices, capillaries or straight channels. Treated as orifices, there would be no "walls" for the hypothesized inertial impaction of aerosols as you assumed. Please describe geometrical information about the leak paths in more detail with justification.

RAI - SRP 15.3 - RSAC - 03

You hypothesized in Document 1 that aerosol particles impact and adhere to the walls despite the relatively high flow velocities needed to meet the AP1000 containment leak rate of 0.1% per day. The staff believes that large particles will bounce on high velocity impact with walls and be re-entrained in the overall flow. Please address (1) particles bouncing on high velocity impact with walls, (2) re-entrainment of particles into the overall flow, and (3) de-agglomeration of aerosol particles, especially larger composite particles such as are expected in the AP1000 LOCA.

RAI - SRP 15.3 - RSAC - 04

You hypothesized in Document 1 that particles depositing on the "walls" will form a plug. Without geometrical information on the leakage pathways, it is not readily apparent what "walls" are available for plug formation. You also asserted that should any plug re-suspend, it will simply redeposit without any de-agglomeration which is quite different from what has been seen in many re-suspension experiments and what was seen in the ARTIST tests (Reference 3) with aerosol flow through a steam generator tube. Please address "saltation" of deposited aerosol that would be associated with the impact of the large re-suspended "plugs" on the "walls".

RAI - SRP 15.3 - RSAC - 05

You referenced, in Documents 1 and 2, the CSE experiments (References 4 and 5) and observed aerosol deposition without noting that the deposition observed in these experiments was not associated with inertial impaction you assumed and that the aerosol was not similar to the types of aerosol expected in AP1000 DBA LOCA. You further stated that aerosols used in the EPRI-LACE tests (Reference 6) were prototypic, which they are now known not to be. The aerosol used in these tests was deliberately chosen to emphasize hygroscopic effects that depend on chemical speciation of the aerosol that is not observed in the more prototypic tests involving irradiated materials. Please justify the applicability of the CSE experiments and EPRI-LACE tests to the aerosol plugging and impaction for the AP1000 containment leak pathways.

RAI - SRP 15.3 - RSAC - 06

You referenced, in Documents 1 and 2, Toshiba integral tests (Reference 7) and the observed penetration of seals and electrical penetrations. You did not note that leak pathways were growing in these tests as a function of time above critical temperature and pressure thresholds. Again, the aerosol deposition observed in these experiments may not have been the inertial impaction you hypothesized in the documents to be the creditable mechanism. Please justify the applicability of the Toshiba experiments to the aerosol plugging and impaction for the AP1000 containment leak pathways.

RAI - SRP 15.3 - RSAC - 07

You provided, in Document 2, Section 1, "Introduction and Background," a quote from Williams' Progress in Nuclear Energy article (Reference 8) and highlighted comments on formation of plugs and re-suspension. Please examine and provide criteria used by Williams for plugging and the substantial literature on re-suspension of deposited aerosol and describe how the referenced material is applicable to the AP1000. Williams did not address the deposition mechanism emphasized in either Document 2 or TR-122. You noted that aerosol deposition is used to seal leaks in ductwork, but you did not note that typically such methods employ rather larger particles than those in question for reactor accident analyses.

RAI - SRP 15.3 - RSAC - 08

You referenced in Document 2, Section 2, “Experimental Basis for Plugging,” the work by Mitchell and coworkers (Reference 9) on capillary flow tests which did not at all addressed the inertial deposition mechanism except to show that it was not especially important for the quiescent sampling done for the tests. The staff noted that the experiments did encounter circumstances where no plugging was observed for even as small as 30 μm capillaries and that at high differential pressures, such as is calculated to occur in the AP1000 containment following a LOCA, plugging took over an hour to occur if it occurred at all. The staff further noted that the plugging was created by aerosol deposition mechanisms other than inertial impaction. Please justify the applicability of the work performed by Michell to the aerosol plugging and impaction for the AP1000 containment leak pathways.

RAI - SRP 15.3 - RSAC - 09

You compared experimental conditions with typical AP1000 LOCA conditions in Table 1, in Document 2, Section 2. Please state what experiments were considered in this table. The extent data base covers a much wider range than what is implied. Williams as referenced by you analyzed several experiments and noted several cases where no plugging occurred. His analysis was for aerosol deposition other than inertial impaction from the aerosol sampling. Please elaborate in more detail the intent of this comparison.

RAI - SRP 15.3 - RSAC - 10

You showed in Table 2, in Document 2, Section 2, the settling velocity for fully dense spherical particles 10 to 500 μm in size. However, Table 1 indicates that the particles of interest for analysis of the AP1000 DBA LOCA are much smaller (2.3 to 4.6 μm in diameter) and they are not fully dense spheres. The text of Table 2 seems to imply that the settling velocities are applicable to re-suspended deposits which are inconsistent with Williams’ notion of deposits which are highly porous. They would be susceptible to bounce and de-agglomeration as they flow along a passage way. They could cause saltation of other deposited particles that they impact. None of this is mentioned in the document. Please elaborate in more detail the purpose of this table.

RAI - SRP 15.3 - RSAC - 11

In Section 2.2 of Document 2, you provided photographs of the results of the LACE tests with aerosols which are not representative of aerosol expected in the postulated AP1000 LOCA. The 29 meter length of the pipe system used in the tests is inconsistent with leak pathways of AP1000 containment. Please justify the applicability of the LACE tests to the aerosol plugging and impaction for the AP1000 containment leak pathways.

RAI - SRP 15.3 - RSAC - 12

You described, in Document 2, an impaction model that does not draw upon the well-known work for sampling efficiency from a quiescent gas phase by Davies (Reference 10) or on the work of Carrié and Modera for sampling from a flowing gas (References 11 and 12). Carrié and Modera did their experiments to see if aerosol deposition could be used to plug leaks in ducts. It is unclear if you defined a Stokes number with corrections for slip or shape factor. If not, please do so. You concluded that a critical Stokes number is 1.5, based on respirator leakage studies which did not include sonic flow. Novick's paper (Reference 2) does not support the contention that 1.5 is a critical stokes number with regard to plugging of cracks, especially if the system is not in the plugging regime. Please use any of the well-known correlations of penetration efficiency as a function of Stokes number instead of relying on an analysis for leakage around respirators. Please address the fact that deposition is not solely dependent on Stokes number. Please consider that regardless of the Stokes number, there must be time for particles to move from the gas phase to the surface.

RAI - SRP 15.3 - RSAC - 13

The AP1000 LOCA analysis used an aerosol particle size narrowly distributed lognormally around a mean of 0.22 µm. It assumes that sonic velocities prevail in the leak path which immediately puts the aerosol outside the range of applicability of the Morewitz model. Without details of the geometry, the staff is unable to assure that the Stokes number is such that other criteria for sampling are satisfied. Temperatures and pressures are noted in the documents but please address pressure spikes that could lead to re-suspension of deposited particles are not emphasized.

RAI - SRP 15.3 - RSAC - 14

In document 2, you calculated the size of leak needed to produce a leak rate of 0.1% per day assuming isothermal flow through a capillary. Please justify the isothermal assumption.

RAI - SRP 15.3 - RSAC - 15

You stated, in Document 2 (page 22) that the aerosol concentration is 4000 g/m^3. This is unlikely since it would imply about 220 tons of aerosols in the containment atmosphere. Such high concentrations would obviate all the hydraulic analyses shown in the document since at these concentrations the motions of the aerosol and the gas phase are tightly coupled. On a mass basis, there would be about 4 times as much aerosol as there is gas. Since the aerosol is generating heat by radioactive decay, even sedimentation calculations are challenging to do at such astronomical particle concentrations. Please justify the aerosol concentration assumed.

RAI - SRP 15.3 - RSAC - 16

Neglecting the complications of aerosol coupling to gas motions implied by the assumed high aerosol concentrations, you concluded that particles larger than 0.74 μm will not penetrate a leak path regardless of path length. The staff believes that this is very much depends on the leak geometry and the adequacy of the Stokes number model. The staff further believes that the geometries appear to be more like orifices than tubes and the staff has experimental data for particles larger than 0.74 μm penetrating orifices much smaller than the assumed 1500 μm pathways. Data by Sutter et al. (Reference 13) involved tests with aerosol having a minimum diameter of 1 μm. Mitchell's experiments with orifices also involved penetration of smaller flow pathways by larger particles. Even if the tube geometry is accepted as appropriate for the leak pathways, there are ample experimental data showing fairly efficient penetration by larger particles. Accepting the sonic flow arguments made in the document, then aerosol particles with Stokes number well in excess of the value 1.5 will be efficiently sampled according to work by Davies and by Agarwal and Liu (Reference 14). Justify that particles larger than 0.74 μm will not penetrate a leak path regardless of length.

RAI - SRP 15.3 - RSAC - 17

Please consider a leak pathway that develops later in an accident (e.g., 1 hour later), much as observed in the Toshiba experiments (Reference 7). At this later time, much of the aerosol would have been removed by the combination of diffusiophoresis and gravitational sedimentation so that residual aerosol would have a much larger fraction of mass in the smaller size particles. Then, even adopting your analysis as presented, large amounts of radioactive material could be leaked prior to plugging of the emergent leak pathway. Indeed, one could well imagine that as a leak pathway plugs others emerge as the effects of the accident progress. Please provide expected particle size distribution in leak pathways as a function of time up to 30 days.

RSAC RAI References:

(1) H.A. Morewitz, "Leakage of Aerosol from Containment buildings," Health Physics, Vol. 42, Page 195-207, 1982

(2) V.J. Novick, "Plugging Passages with Particles: Refining the Morewitz Criteria," Aerosol Science and Technology, 21 (1994), 219-222.

(3) ARTIST Program Review Committee Meeting, December 2006 (proprietary - to be issued later)

(4) M.E.Whiterspoon, "Leakage Rate Tests on the CSE Containment Vessel with Heated Air and Stream-air Atmosphere," Battelle Pacific Northwest Laboratory Report, BNWL-1475, 1970

(5) R.K. Hilliard and A.K.Postma, "Large-Scale Fission Product Containment Tests," Nuclear Technology, Vol. 53, No. 2, 163-175, May 1981

(6) D.R. Dickinson et al, "Aerosol Behavior in LWR Containment bypass Piping-Results of LACE Test LA3," LACE TR-011, 1987

(7) A.Watanabe, et al, “Fission Product Aerosol Trapping Effects in the Leakage Paths of Containment Penetration under Severe Accident Conditions,” Session IV Aerosol Growth, Transport, and Deposition in the Containment, Third OECD Specialist Meeting on Nuclear Aerosols in Reactor Safety, Germany, 1998
(8) M.R.Williams, “Particle Deposition and Plugging in Tubes and Cracks,” Progress in Nuclear Energy, Vol. 28, No. 1, pp. 1-60, 1994
(9) D.A.V. Morton and J.P. Mitchell, “Aerosol Penetration through Capillaries and Leaks: Experimental studies an the Influence of Pressure,” Journal of Aerosol Science, Vol. 26, No. 3, pp. 353-367, 1995
(10) C.N. Davies, “The Entry of Aerosol into Sampling Tubes and Heads,” Applied Physics, Journal of Physics D, *1* (1968), 921-932.
(11) F.R. Carrie and M.P. Modera, “Particle Deposition in a Two-Dimensional Slot from a Transverse Stream,” Aerosol Science and Technology, 28 (1998), 235-246.
(12) F.R. Carrie and M.P. Modera, “Experimental Investigation of Aerosol Deposition on Slot and Joint Type Leaks,” Journal of Aerosol Science, 33 (2002), 1447-1462.
(13) S.L. Sutter, et al., “Depleted Uranium Dioxide Powder Flow through Very Small Openings,” NUREG-1099, PNL-3177, Pacific Northwest National Laboratory, Richland WA., February 1980.
(14) J.K. Agarwal and B.Y.H. Liu, “A Criterion for Accurate Sampling in Calm Air,” American Industrial Hygiene Association Journal, 41 (1980), 191-197.