To: Collins, NRR
Appropriate Action

OFFICE OF THE SECRETARY
CORRESPONDENCE CONTROL TICKET

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AUTHOR:	Bob Leyse		
AFFILIATION:	ID		
ADDRESSEE:	Nils Diaz		
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Date: Sat, Jun 21, 2003 1:33 PM
Subject: Paks-2 Fuel Damage, April 10, 2003

Greetings from Sun Valley, Idaho, USA:

Recently I read about the Paks-2 incident in a highly sanitized (somewhat censored) report by the American Nuclear Society in Nuclear News, page 40-41, June 2003.

Next I went to www.google.com and entered "Paks-2 Hungary" and that led to a more detailed account of the incident and ultimately to your e-mail addresses.

In the USA it is difficult to get the USNRC to admit that fouling of nuclear fuel elements is a precursor to very dangerous accidents. I have several Petitions for Rulemaking on the NRC's web site that you may read by proceeding as follows:

www.nrc.gov

Then in the blue box on the right side click on "Current Rulemakings"

Then on the bottom of the left column click on "Rulemaking Petitions Active"

You will then find a list of petitions including 3 under the name "Robert H. Leyse" with dates, 1/29/2002 2/9/2002 10/31/2002

And if you find this of interest, (and you should) you may continue clicking and reading.

One key paragraph from 1/29/2002 is:
Performance-based experience reveals that when unusually heavy crud deposition on fuel bundles occurs during normal operation of an LWR, there are likely to be indications of fuel element cladding defects by increases in the offgas activity. However, this increase in the offgas activity is not regarded as an indicator of a possible heavy crud deposition. Thus, an LWR may be operated within its Licensing Basis and the Technical Specifications until the transition from unusually heavy crud deposition to severe crud deposition is effected. At this point it is likely that rapid localized core melting will be initiated while the LWR is at power. There will likely be delays (several seconds) before the LWR is shut down. However, by then the rapid propagation of the meltdown will likely be well underway and it will likely continue even though the LWR is shut down.

Perhaps with the above background you will understand my interest in the recent experience at Paks-2. So, if you have any details that you are free to talk about, I would like to hear from you.

Some questions:

What is the nature of the crud deposits in the Paks reactors?
How much boron is "hidden" in those deposits? How do you calculate the thermal resistance of those deposits and the heat transfer through the porosity?
Do the fuel rods bow in service? Of course, I could generate a host of questions, but the first question about the nature of the deposits really covers the

territory. I have not been able to get answers to those questions for reactors in the USA that have extensive fouling of fuel rods. In the USA several reactor plants resort to ultrasonic fuel cleaning in many instances.

Are you members of the Relap 5 International Users' Group? Here is their web page for a forthcoming late August 2003 meeting:
http://www.inel.gov/relap5/call2003.pdf

I would like to find out how the Relap crowd would analyze the Paks experience with fouling of fuel elements and when I get some further details, I will ask them.

If you have time, I would appreciate receiving your comments regarding the attachments. The first, attachment, "relap1" is an abstract that I submitted for the late August 2003 Relap conference. The second, "relap5" is the rejection of my abstract. In that rejection it is clear that the Relap crowd regards fouling of fuel elements as irrelevant in reactor safety analyses. Quoting from that rejection, "because it has not been demonstrated conclusively that this effect should be considered." Well, I'm wondering what they will say after ask them to evaluate Paks-2 and issue their preliminary findings at the late August Users Meeting.

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Name	Size	Modified	Comment
relap1.doc	129,024	6/1/2003 11:23 PM	
relap5.doc	69,632	6/20/2003 10:31 AM	

Deficiencies in Calculations of Core Damage Progression in SCDAP/RELAP5-3D

The SCDAP/RELAP5-3D series of codes do not evaluate the impact of severe fouling of fuel elements on the path of severe accidents such as Reactivity Insertion Accidents, Loss of Coolant Accidents and the recently identified Loss of Cooling at Full Power. Operation of nuclear power reactors with significant fouling deposits is commonplace. In fact, patented systems are in use for ultrasonic fuel cleaning.[1,2] Thus it is vital to not employ SCDAP/RELAP5-3D in evaluating the accident sequences of these power reactors.

For example, a licensed boiling water reactor has operated with unusually heavy crud deposits within several fuel bundles.[3] These deposits were found and partially classified during a refueling outage. If the deposits had continued to build during normal reactor operation at power, the unusually heavy crud deposits would have become severe crud deposits. Blockage of the flow channels within the fuel bundles would likely have developed. Severe crud deposits within the fuel bundles can lead to a loss of coolability with consequent overheating of zirconium cladding within fuel bundles, autocatalytic zirconium-water reactions of the fuel cladding, chemical reactions between the fuel cladding and the uranium oxide fuel pellets, initiation of zirconium water reactions involving zirconium core structures such as fuel bundle spacer grids and channel boxes, melting of certain control element materials, melting of braze materials in certain fuel bundle spacer grids, metallurgical reactions between certain fuel bundle spacer grid springs and the zirconium cladding on the fuel pins, and, very likely, additional sources of structural degradation. These factors can initiate substantial and rapid localized core melting while the LWR is at power. Even if the LWR is then shut down, the core meltdown will rapidly propagate among the fuel bundles and core structures with sequential and parallel destruction of the barriers that constitute defense in depth. Thus, the single entity, unusually heavy crud deposits on the fuel pins, is only one step before the unusually heavy crud deposits thicken and become severe crud deposits. Severe crud deposits then threaten the integrity of all of the barriers that in total constitute the classical defense in depth. This sequence, a Loss of Coolant Accident at Full Power, cannot be tracked with the current SCDAP/RELAP5-3D.

Right now, SCDAP/RELAP5-3D unfortunately relies on early test results from LOFT, SEMISCALE, TLTA, etc. More recent work by Shumway, Ransom, Oh, Hochreiter and others is likewise useless in modeling the heat transfer conditions in fouled cores prior to and during severe accidents..

Currently the Nuclear Regulatory Commission is evaluating several related Petitions for Rulemaking[4,5,6] that have been initiated by Leyse regarding these matters and the results of those studies should be available at the 2003 RELAP5 International Users Seminar, West Yellowstone Meeting. In addition, Leyse[7] and Leyse, Meduri, Warrier, and Dhir[8] have produced microscale heat transfer data at very high heat fluxes to water under a range of pressures. The results appear significant in reactor accident analyses, especially Reactivity Insertion Accidents, and these factors are under study.

1. United States Patent, US 6,396,892, Robert D. Varrin, May 28, 2002.
2. Ultrasonic Fuel Cleaning Process, EPRI Press Release, March 19, 2003.
3. USNRC Licensee Event report 50-458/99-016-00, March 1, 2000.
4. Leyse, Petition for Rulemaking to USNRC, PRM 50-73, September 3, 2001.
5. Leyse, Petition for Rulemaking to USNRC, PRM 50-73A, November 4, 2001.
6. Leyse, Petition for Rulemaking to USNRC, PRM 50-76, May 1, 2001.
7. Leyse, R., 2001, Microscale Heat Transfer to Subcooled Water, 200-6000 Psia, 0-3500 W/CM^2, *Annals of the New York Academy of Sciences, Microgravity Transport Processes in Fluid, Thermal, Biological Sciences II*, 974, 260-273.
8. Leyse, R., Meduri, P., Warrier, G. and Dhir, V., Microscale Phase Change Heat Transfer at High Heat Flux, *Proceedings of the 5th International Conference Boiling Heat Transfer*, Montego Bay, Jamaica, May 4-8, 2003.

Attachment

REVIEW OF ABSTRACT "DEFICIENCIES IN CALCULATIONS OF CORE DAMAGE PROGRESSION IN SCDAP/RELAP5-3D"

First, the author is incorrect about the capabilities of SCDAP/RELAP5-3D©. A proficient user can model the phenomena described in this abstract with SCDAP/RELAP5-3D©, although we are not aware of any user who has modeled crud on fuel elements with SCDAP/RELAP5-3D©. However, INEEL successfully applied an earlier version of SCDAP/RELAP5-3D© (SCDAP/RELAP5 MOD 3.1) to model crud on steam generator tubes (see "SCDAP/RELAP5 Evaluation of the Potential for Steam Generator Tube Rupture as a Result of Severe Accidents in Operating Pressurized Water Reactors," INEEL/EXT-98-00286, Rev. 1). The fact is, that a layer of material on the outside of a fuel rod can be modeled, and the user can specify its thickness and thermal properties.

Second, the author should state what other severe accident analysis codes, such as MELCOR and MAAP, have been applied to consider fuel crud buildup and report results from these analyses. We suspect that none of the other codes have been applied to consider this effect (because it has not been demonstrated conclusively that this effect should be considered). If no severe accident analysis codes have been applied to consider this phenomenon, then the author should revise the emphasis of this abstract (because SCDAP/RELAP5-3D© can be used to consider this effect, it is simply that users have not chosen to consider this phenomena).

Third, the abstract requires more technical substance. For example, a possible revision could emphasize that fouling is important, cite data to validate the importance of this fouling in accident analysis (and results from the NRC rulemaking, if available), and provide some estimate of the importance of this fouling (preferably with a SCDAP/RELAP5-3D© analysis because this is a user's meeting, although other severe accident analysis code calculations are acceptable). Such a revised paper would be a noteworthy contribution to the upcoming meeting. Note that the current abstract only cites data that demonstrates the potential existence of this crud (not its impact).