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MFN 08-695
September 11, 2008

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Office of Administration, Mail Stop T6–D59
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Washington, DC 20555–0001

Subject: NRC–2008–0332, Notice of Availability and Solicitation of Public Comments on Documents Under Consideration To Establish the Technical Basis for New Performance-Based Emergency Core Cooling System Requirements

Enclosure 1 provides GE Hitachi Nuclear Energy (GEH) and Global Nuclear Fuel-Americas (GNF) comments on the documents attached to the subject request.

If you have any questions, please contact Yang-Pi Lin at (910) 675-5806 or myself.

Sincerely,

James F. Harrison

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Enclosures

1. Comments on Documents Under Consideration To Establish the Technical Basis for New Performance-Based Emergency Core Cooling System Requirements

cc: MC Honcharik (NRC)
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Add = P. Clifford (PMC3)

ENCLOSURE 1

MFN 08-695

Comments on Documents Under Consideration To Establish the Technical Basis for New Performance-Based Emergency Core Cooling System Requirements

Comments on Documents Under Consideration to Establish the Technical Basis for New Performance-Based ECCS Requirements

This document is prepared in response to the Notice of Availability and Solicitation of Public Comments on Documents Under Consideration To Establish the Technical Basis for New Performance-Based Emergency Core Cooling System Requirements published in Federal Register / Vol. 73, No. 148 with reference to NRC–2008–0332. Although there is no imminent safety issue under the present criteria, a revision to the current regulations will enable alloys other than Zircaloy or Zirlo to be more readily used and therefore is an encouraging development. The main requirement changes being proposed address the need for a hydrogen dependent ECR limit, the use of the Cathcart-Pawel equation, periodic testing of the cladding material, use of two-sided oxidation for high-burnup fuel, and an additional limit on breakaway oxidation.

The need for a hydrogen dependent ECR limit and the use of the Cathcart-Pawel equation appear to be appropriately supported by test data. The technical bases for requiring periodic testing and a breakaway oxidation limit appear to be lacking and the proposed requirements appear to be in contradiction with results shown in NUREG/CR-6967 as discussed in the following pages, which follow the structure provided in Federal Register / Vol. 73, No. 148. The generic requirement on two-sided oxidation for both PWRs and BWRs appears to be unnecessarily conservative for BWR fuel as discussed in the next section.

Double-Sided Oxidation. The requirement for double-sided oxidation appears to be based on results from Halden IFA 650-5 test on a PWR rod with ~85GWD/MTU burnup. The ANL results on high burnup BWR fuel rods described in NUREG/CR-6967 are ignored. The ANL result on a Limerick rod with ~57GWd/MTU rod average burnup, typical of current discharge burnup for BWR fuel, did not show the presence of ID alpha-layer (Fig 231), despite the presence of fuel bonding prior to testing (Fig 128). One figure (Fig 234) is said to show a localized region of alpha layer; however, the exact location of the localized alpha region is difficult, if not impossible, to identify definitively. The extent of the fuel bond layer in the Limerick rod was not discussed in the NUREG. However, the fuel bond layer in companion Limerick rods with similar burnup was not uniform axially and circumferentially. The absence of a bonded layer after HT oxidation testing is indicative of either chemical reduction of the bonded layer or absence of the bonded layer prior to testing. Although the assumption of a bonded layer as an oxygen source is viable, this source of oxygen does not appear to be sufficient for the formation of an alpha layer in high burnup BWR fuel rods. The requirement for two-sided oxidation to account for the fuel-clad bond layer is therefore unnecessarily conservative for BWR fuel.

I. Technical Basis

1. *RIL 0801 Figure 1 provides the measured embrittlement threshold for all fresh and irradiated cladding specimens investigated during the ANL research program. Hydrogen dependent post-quench ductility regulatory criteria, similar to the lines on this figure, may be established from these experimental results.*

   a. *Is the technical information presented within NUREG/CR-6967 sufficient in scope and depth to justify specific regulatory criteria applicable to all current zirconium cladding alloys?*

   Yes with respect to ECR varying as function of hydrogen concentration and with respect to no dependency on alloy composition for the alloys investigated. The levels of hydrogen concentration in irradiated cladding tested do not adequately cover the hydrogen concentration range; however, these gaps can be filled in with pre-hydrided samples. Figure 1 of RIL0801 doesn't include any ductility measurements for the irradiated or pre-hydrided Zr-2 material. Although the available Zr-4, ZIRLO and M5 data doesn't indicate any alloy dependency, it will be prudent to use Zr-2 data for the Zr-2 specific hydrogen dependent ECR limit development. The lack of irradiated Zr-2 samples can be easily substituted by the pre-hydrided fresh Zr-2 samples.

   b. *Is the technical information presented within NUREG/CR-6967 sufficient in scope and depth to justify periodic testing on as-fabricated cladding material?*

   The justification for periodic testing (PQD and breakaway oxidation) as presented in the NUREG/CR-6967 appears to come from concerns on manufacturing variability and trace elements effects rather than inherent variability in material response. However, some inconsistencies have been observed in the interpretation of the available data, especially when hydrogen dependent ductility criteria are considered. Some of these inconsistencies related to manufacturing variability and trace element effects are discussed below.

   - The concern on manufacturing variability was raised in relation to different Zry-4 lots tested in the as-fabricated condition (e.g. Fig 28); however NUREG/CR-6967 also showed that in the hydrided state (Fig 120), differences between Zry-4 variants were no longer observed. Placing new testing requirements on as-fabricated cladding when the potential variability is shown to be absent in hydrided cladding appears to be inconsistent with the introduction of a hydrogen dependent ductility criterion.

- The concern on trace elements appears to be related to comparison of breakaway oxidation between M5 and E110, which share similar alloy composition but could differ in trace elements. NUREG/CR-6967 attributes the poor (HT oxidation) performance of E110 to the surface conditions; significant improvement was found following significant surface layer removal (e.g. Figs 94 and 95). The trace element concern was raised because E110 still performed worse than M5 following ANL's machine-and-polish treatment on E110 (Fig 98). However, in ANL's machine-and-polish treatment, significant surface removal was only applied on the ID, rather than both inside and outside tube surfaces (see description at top of page 135) leaving open the question of the effect of the remaining OD surface layer. Since the detrimental effect due to the surface condition of E110 was not eliminated in the ANL evaluation, it follows that a trace element effect based on the difference in HT oxidation behavior between M5 and E110 is not established. The NUREG did not consider if such poor oxidation performance would show up in lower temperature corrosion testing.

GNF recognizes the importance of surface condition of Zr-alloys. Prior experience has shown that inadequate surface conditions can result in poor corrosion resistance under GNF's special lower temperature corrosion test. Routine, lower temperature corrosion testing would be expected to catch poor surface conditions more readily than PQD and breakaway oxidation tests.

It will be prudent to perform bounding, qualification types of tests to define tolerable surface conditions, rather than the periodic testing on as-fabricated cladding material. Routine lower temperature corrosion tests can be performed to identify any deviation in the surface conditions from the previously qualified domain.

c. *Is the technical information presented within NUREG/CR-6967 sufficient in scope and depth to address sensitivities to alloy composition, trace elements, manufacturing practices, fuel rod burnup, and transient temperature profile?*

Sensitivities of PQD to alloy composition, trace elements, manufacturing practices, fuel rod burnup and transient temperature profile appear to be not well supported by the ANL data.

i. alloy composition,

The hydrogen dependent ECR criterion being developed is based on PQD data generated from Zry-4, M5, Zirlo and Zry-2 in the unirradiated condition and from Zry-4, M5 and Zirlo in the irradiated condition (e.g. Figs 237 and 238). The use of data from different alloys to develop the new criterion is a confirmation of insensitivity to alloy composition. In the ANL work, Zry-4 data was extensively used for the design of test conditions for other alloys. Subsequent testing generally showed consistency with expectations based on Zry-4, confirming the absence of significant alloy sensitivity.

ii. trace elements,

See I.1.b above. Sensitivity of PQD and breakaway oxidation to trace elements does not seem to be well established. The poor performance of E110 appears to have been a major consideration for trace element effects. However, ANL test results indicated surface condition (roughness and/or contamination) of E110 was a significant factor (e.g. Figs 94 and 98). The concern on trace element appears to be based on machine-and-polished E110 not performing as well as M5 with similar composition in high temperature oxidation tests (Fig 98). However, the ANL machining modification was limited to the inside surface only and did not include machining the outer surface, which was only polished. The ANL results clearly show that polishing of the OD surface was only partially effective in improving the performance of E110; in Fig 97, one half of a OD polished sample showed no breakaway oxidation, while the other half of the same test piece showed breakaway oxidation. The implication is that further improvements of E110 performance can be expected from more OD surface removal, for example, by machining. With sufficient surface removal, the differences between the two alloys would diminish further, thereby reducing the apparent differences based on trace element effects. Overall, it is difficult to rationalize sensitivity to trace elements in the absence of sensitivity to alloy composition.

iii. manufacturing practices,

See I.1.b above. NUREG/CR-6967 showed good agreement (trend of embrittling ECR with hydrogen) amongst variants of Zry-4 in irradiated or hydrided states and also with M5 and Zirlo in the irradiated condition (e.g. Figs 237 and 238). The Zry-4 variants and alloys were manufactured at different times by different vendors. The good agreement provides strong evidence that manufacturing variability is not a significant factor; i.e. the potential difference due to manufacturing practices is less than what the overall PQD test procedure is able to differentiate.

iv. fuel rod burnup

Fuel rod burnup affects cladding hydrogen content due to cladding corrosion. There is limited test data for hydrogen content less than ~400ppm; this is the concentration range of primary interest for BWR fuel rods, and also is the range over which the transition ECR changes rapidly with hydrogen. NUREG/CR-6967 presented no ductility measurement data for irradiated BWR cladding. The only irradiated cladding data of relevance (in hydrogen content) is from M5 at ~110 ppm hydrogen (e.g. Fig 237). The implication appears to be that testing of unirradiated, prehydrided cladding could be used as surrogate for irradiated cladding. If pre-hydriding cannot be used as a surrogate for irradiation, then much hot cell testing would be required to establish the embrittling ECR vs. hydrogen trend for BWR applications.

v. transient temperature profile

Only one cooling profile was considered (with quench from different temperatures). Cooling rate is known to have an effect on PQD. NUREG data suggest rate of cooling below 600°C is important, but other transient profiles should be considered.

2. *Section 2 of NUREG/CR-6967 details the experimental techniques and procedures employed at ANL to assess cladding properties.*

   a. *Were the experimental techniques and procedures adequate for their intended purpose of defining acceptable fuel criteria (e.g., specimen preparation, specimen size, heating/cooling rates, ring-compression techniques, test temperature, acceptance criteria for post-quench ductility and breakaway oxidation, etc.)?*

      Only one cooling profile to quench temperature was used – the current discrepancy with CEA results may be partly or fully resolved by investigating other cooling profiles. The heating rate used has problems associated with testing for low embrittling ECR at high hydrogen contents. For the proposed acceptance criterion of 200 ppm hydrogen for breakaway oxidation (hydriding), the cladding is shown to have significant ductility (Fig 63); the proposed criterion appears to be inconsistent as a criterion for embrittling ECR.

   b. *Is the technical information presented within NUREG/CR-6967 sufficient in scope and depth to address uncertainties related to and repeatability of measured results?*

      Limited duplicate tests were conducted. The consistency between different prehydrided Zry4 variants and with irradiated Zry4, M5 and Zirlo suggest that the overall combination of oxidation exposure and the use of ring compression tests can resolve the primary effect due to hydrogen but cannot resolve uncertainties related to test conditions, nor can manufacturing variability or alloy composition effects be discerned.

II. Performance-Based Testing Requirements

1. *Due to potential sensitivities to manufacturing processes, performance based testing may be required to characterize the loss-of-coolant accident (LOCA) performance of new cladding alloys.*

   a. *Section 2.1 of NUREG/CR-6967 details all of the fresh and irradiated cladding specimens investigated during the ANL research program. Is the extent of the ANL material database sufficient to justify the applicability of experimental results to future cladding alloys?*

Since the tested alloys did not appear to show a composition effect, the trend of ECR varying as function of hydrogen appears to be applicable to future alloys, if the new alloy is Zr-based and particularly if its composition does not deviate significantly from the tested Zr-alloys.

The technical justification for an additional breakaway oxidation requirement is weak. Breakaway oxidation is a potential embrittling mechanism. The concern for considering an additional breakaway oxidation requirement for new clad alloys appears to stem from the poor performance of the Russian E110 cladding (e.g. Figs 92 and 98). For existing cladding alloys, the ANL results show that the transition ECR is limiting and breakaway oxidation has not been shown to be limiting. The ANL results show the poor breakaway oxidation performance of E110 to be reflected in low embrittling ECR (Fig 92), such that the current 17% ECR limit was not satisfied. The current 17% ECR criterion is thus capable of identifying poor performing cladding, and the need for an additional breakaway oxidation criterion is therefore questionable. While an additional requirement on breakaway oxidation could be considered for new alloys, the technical justification for such an additional requirement is weak.

b. *Conducting testing on irradiated specimens is more difficult and expensive than similar tests performed on unirradiated specimens. Does a sufficient technical basis exist to justify testing on hydrogen charged, unirradiated cladding specimens as a surrogate for irradiated fuel cladding?*

Yes, since irradiated cladding (Zry-4, Zirlo and M5) show similar transition ECR as unirradiated Zry-4 prehydrided to similar hydrogen contents (e.g. Figs 237 and 238).

2. *Due to potential sensitivities to manufacturing processes, routine testing may be required to verify material performance. Are there difficulties or limitations with periodic testing that would make such a requirement impractical?*

The main issue is with maintaining an established and qualified test facility. See also comments on cost-benefit (III.1).

III. Implementation

1. *Implementing new regulatory criteria for 10 CFR 50.46(b) may necessitate further testing and new licensing activities (e.g., revised methods, updated safety analyses, etc.). What is the cost-benefit for implementing new regulatory requirements similar to those discussed in RIL 0801?*

   To meet the requirements discussed in RIL 0801, corrosion and hydrogen models require further development as discussed further in the next section. Since hot cell investigations are required, the cost impact will be high. In addition, test facilities for pre-hydriding, for HT oxidation and associated post-oxidation characterization and for ring compression tests will need to be established, qualified and maintained. The embrittling ECR curve for prehydrided Zry-2 will likely need to be generated by GNF, at least up to the highest likely hydrogen content of relevance. The cost incurred will be on a one-time basis for each existing or new alloy. The benefit will be demonstration of the adequacy of each existing alloy or a new alloy when it is being introduced. The proposed periodic testing will be in addition to existing quality control measures that address, for example, surface contamination and surface roughness. Periodic testing will incur additional carrying costs with few, if any, benefits. The ANL results suggest that little variation in the embrittling performance due to manufacturing variability is to be expected at end-of-life conditions as represented by pre-hydriding (Fig 120). Given that quality controls are already in place to address surface roughness and contamination, it is not expected that the proposed periodic testing will capture any deviations resulting in breakaway oxidation (hydriding).

   There will also be significant cost impact associated with revising methods and to incorporate new regulatory criteria into safety analyses.

2. *Implementing hydrogen-based regulatory criteria may require the development of high confidence corrosion and hydrogen pickup models.*

   a. *What type of information is needed to develop such (corrosion and hydrogen pickup) models and is such information readily available?*

      Poolside inspection techniques such as eddy current could provide a ready method for assessing the cladding corrosion layer thickness. However, the presence of crud, in particular, ferrimagnetic crud, could make the measured oxide thickness unreliable. Even when the eddy current oxide thickness is considered reliable, a direct correlation to cladding hydrogen concentration is not always achievable. For some zirconium alloys, for example Zry-4, the hydrogen pickup fraction is relatively constant and use of oxide thickness as a surrogate for hydrogen is likely reasonable. However, for typical Zry-2 applications in BWRs, hydrogen pickup fraction tends to be variable and the cladding hydrogen content cannot be readily deduced from eddy current oxide thickness; hot cell examination is therefore required to obtain the necessary hydrogen data. While corrosion and hydrogen data are available from selected plants, more data is needed to develop high confidence corrosion and hydrogen models. There will be significant cost impact if a number of plants need to be used to develop the models.

b. *What performance indicators (e.g., pool-side measurements, hot cell examinations, etc.) could be used to validate models?*

Currently, there is no technique available for assessing cladding hydrogen at poolside. Hot cell examination would be required.

c. *What additional regulatory requirements would be necessary to assure that the fuel is performing in accordance with the approved models? How will compliance with the rule be demonstrated on a cycle by cycle basis?*

LOCA assessments are performed generically for each fuel type for each specific plant. However, to ensure fuel behavior as projected, periodic poolside fuel inspections are performed. Typically this inspection includes fuel profilometry and oxide thickness measurements. Any deviation from the operating experience will be flagged during such inspections and will be evaluated before the continued operation. This current practice of periodic poolside inspection will adequately capture any deviation in fuel performance.

Cladding hydrogen content related to embrittling ECR and presence of fuel bond layer related to two-sided oxidation are the two criteria that can be conceptually considered in relation to demonstration on a cycle-by-cycle basis. As discussed in the previous section, poolside assessment of cladding hydrogen is currently not available. Likewise, a poolside evaluation technique for evaluating the presence of fuel bonded layer has yet to be developed. Hot cell examination is currently the only viable evaluation method for both cladding hydrogen and fuel bond layer.

3. *Crud deposits on the fuel cladding surface may affect fuel stored energy, fuel rod heat transfer, and cladding corrosion.*

    a. *What role does plant chemistry and crud deposits play on these items (fuel stored energy, fuel rod heat transfer, and cladding corrosion)?*

    b. *How should normal and abnormal levels of crud deposits be addressed from a regulatory perspective?*

    These factors were not part of the ANL assessment. Crud deposition is dependent on plant water chemistry. For normal water chemistry, the effects of crud deposition are adequately addressed. EPRI is working with the industry to refine water chemistry guidelines to minimize the occurrences of abnormal crud deposition.