ANPR 31
(74FR40765)

AEKI **Hungarian Academy of Sciences**
KFKI Atomic Energy Research Institute

H-1525 Budapest 114, P. O. B. 49. Phone: +36 1 275 4083 Fax: +36 1 395 9293
Fuel Department

12

Comments on Proposed Rulemaking on
Performance Based Emergency Core Cooling Criteria
RIN 3150-AH42 (NRC-2008-0332)

The ECCS criteria established in the US in 1973 were introduced in many countries operating nuclear power plants with light water reactors and for this reason the current revision of criteria has international importance. I followed with high interest the LOCA program carried out at Argonne National Laboratory (ANL) and the rulemaking process which is based on ANL results.

The Hungarian Academy of Sciences KFKI Atomic Energy Institute has performed several experimental programs on the high temperature behavior of zirconium claddings. Considering our experience and knowledge in this field I would like to make the following comments to the above document.

1. Characterization of ductile-to-brittle transition

Point IV.6.d.2. defines 1% permanent strain as a measure of cladding ductility. Zero ductility (or ductile-to-brittle transition or embrittlement threshold) could be easily determined on the basis of load-displacement curves. The ductile material is characterised by a ductile plateau after elastic section and when it is missing the material has some degree of embrittlement (Fig. 1). The load displacement curves of compression, tensile and bending tests have the same character, and any of them can be used to characterise the ductile-to-brittle transition. If we judge the zero ductility by the shape of the curve we do not need to introduce specific parameters as e.g. permanent strains or strain energy which are derived from the curves.

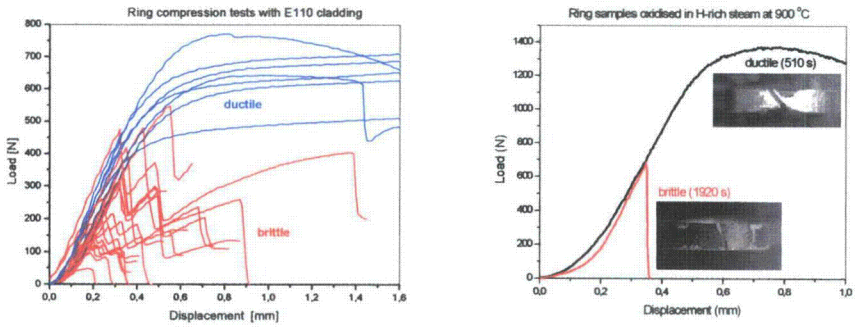


Fig. 1. Load-displacement curves showing the ductile-to-brittle transition in RCT (left) and ring tensile (right) tests (AEKI experiments)

Point IV.6.d.2. also defines that ductility should be measured at 135 °C (saturation temperature during reflood). Since ductility increases with temperature, this temperature can not be considered as a conservative value. After the LOCA accident the reactor will be cooled down and the ductility should be maintained in cold water (e.g. room temperature), too.

Template=SECY-067

DS 10

2. Breakaway oxidation

The document proposes the introduction of a new criterion in order to avoid breakaway oxidation during a LOCA event. Breakaway oxidation leads to spalling of oxide scale and initiates hydrogen up-take by Zr. In this way breakaway oxidation accelerates the embrittlement of cladding. The occurrence of breakaway highly depends on cladding type and varies with oxidation temperature.

The start of breakaway oxidation does not mean automatically that the Zr cladding gets brittle. Breakaway oxidation may start before or after ductile-to-brittle transition. Two conditions can be distinguished:

- In some cases breakaway happens before the ductile-to-brittle transition takes place (e.g. E110 cladding at 900-950 °C). Here the new criterion should not limit the oxidation time (even if breakaway had happened), since the cladding is still ductile.
- In other cases breakaway can be observed only well beyond the transition, when the cladding is brittle (e.g. Zircaloy-4 at 1000 °C). Here the cladding reached already the ECR of ductile-to-brittle transition, so the oxidation time for breakaway would be longer than the oxidation time needed to lose ductility.

In both above cases the breakaway oxidation conditions does not give any new information on the loss of ductility.

Breakaway oxidation is a very interesting phenomenon from scientific point of view. However its safety significance probably should not be overemphasized, once other criteria guarantees the ductility of cladding under high temperature oxidation in steam.

3. Failure of ballooned cladding

The current and the proposed criteria could guarantee that the oxidized cladding will have some ductility and so will not fragment after LOCA. However, this statement is supported with experiments only for the non-ballooned section of the fuel rods. If the cladding balloons and bursts the weakest segment of the cladding during a LOCA would be the ballooned section, especially the "neck" where secondary hydriding takes place. This effect is mentioned in the "Background" section of the document, but was not considered for the criteria.

The effect of secondary hydriding at the location of ballooned section is covered by the Japanese regulation. Their criteria was based on so called quench tests which represent the integral behaviour of fuel rod under LOCA accidents including clad ballooning and secondary hydriding on the inner surface of the cladding after burst. Historically very similar ECR criteria were derived from ring compression tests in the US and quench tests in Japan. However, the two methods give information on different phenomena at different degrees of embrittlement:

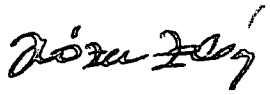
- The final result of ring compression tests is the determination of ductile-to-brittle transition (zero ductility or embrittlement threshold). Here the main cause of embrittlement is the oxidation of Zr in steam.
- The quench tests indicate the conditions where the fragmentation of fuel rod takes place. In order to reach fragmentation the material must be very brittle. The embrittlement of ballooned cladding is caused by oxidation and secondary hydriding.

It is clear that the cladding state of the two samples (from ring compression and quench tests) must be very different, since the fragmentation can be expected only very far from the ductile-to-brittle transition. And the cladding tested in quench experiments is really much more brittle, for its embrittlement was caused not only by oxidation but by secondary hydriding as well.

The main objective of LOCA embrittlement criteria is to prevent fuel rod fragmentation. For this reason the criteria should be derived from experiments in the following way:

- If ballooning and burst do not take place during the LOCA event the results of mechanical testing of oxidised Zr cladding (e.g. ring compression) should be applied.
- If ballooning can not be excluded the criteria should be based on such tests which covers cladding embrittlement due to ballooning and secondary hydriding.

Sincerely:



Budapest, 2 November 2009.

Dr. Zoltán Hózer
Head of Fuel Department
Hungarian Academy of Sciences KFKI Atomic Energy Research Institute
H-1525 Budapest, P.O.Box 49, Hungary
phone: +36 1 275 4083
fax: +36 1 395 9293
e-mail: Hozer@aeki.kfki.hu

Rulemaking Comments

From: Hózer Zoltán [hozer@aeki.kfki.hu]
Sent: Monday, November 02, 2009 5:13 AM
To: Rulemaking Comments
Cc: Voglewede, John
Subject: comments to RIN 3150-AH42 (NRC-2008-0332)
Attachments: To_RIN3150AH42_HZ.pdf

Please find attached some comments on Proposed Rulemaking on 10 CFR 50.46 (ECCS Acceptance Criteria), TIN 3150-AH42.

++++++++++++++++++++++++++++++++++++

Dr. Zoltán Hózer
Hungarian Academy of Sciences KFKI Atomic Energy Research Institute Fuel Department
H-1525 Budapest, P.O.Box 49, Hungary
phone: +36 1 275 4083
mobile: +36 30 9303260
fax: +36 1 395 9293
e-mail: Hozer@aeki.kfki.hu

Received: from mail2.nrc.gov (148.184.176.43) by TWMS01.nrc.gov
(148.184.200.145) with Microsoft SMTP Server id 8.1.393.1; Mon, 2 Nov 2009
05:13:12 -0500
X-Ironport-ID: mail2
X-SBRS: 2.9
X-MID: 8710488
X-IronPort-AV: E=Sophos;i="4.44,665,1249272000";
d="pdf'?scan'208";a="8710488"
Received: from smtp2.kfki.hu ([148.6.0.28]) by mail2.nrc.gov with ESMTP; 02
Nov 2009 05:13:09 -0500
Received: from localhost (localhost [127.0.0.1]) by smtp2.kfki.hu (Postfix)
with ESMTP id 873F41F410F; Mon, 2 Nov 2009 11:13:07 +0100 (CET)
X-Virus-Scanned: Debian amavisd-new at smtp2.kfki.hu
Received: from smtp2.kfki.hu ([127.0.0.1]) by localhost (smtp2.kfki.hu
[127.0.0.1]) (amavisd-new, port 10024) with ESMTP id LG3z0xLn9EWL; Mon, 2
Nov 2009 11:13:07 +0100 (CET)
Received: from [148.6.96.204] (hozer.aeki.kfki.hu [148.6.96.204]) by
smtp2.kfki.hu (Postfix) with ESMTP id 16C371F410D; Mon, 2 Nov 2009 11:13:06
+0100 (CET)
Message-ID: <4AEEB0AE.8040107@aeki.kfki.hu>
Date: Mon, 2 Nov 2009 11:13:02 +0100
From: =?ISO-8859-2?Q?H=F3zer_Zolt=E1n?= <hozer@aeki.kfki.hu>
User-Agent: Thunderbird 2.0.0.23 (Windows/20090812)
MIME-Version: 1.0
To: <Rulemaking.Comments@nrc.gov>
CC: John Voglewede <John.Voglewede@nrc.gov>
Subject: comments to RIN 3150-AH42 (NRC-2008-0332)
Content-Type: multipart/mixed;
boundary="------------080700020501050909070100"
Return-Path: hozer@aeki.kfki.hu