Fuel Dispersal During a LOCA: Generic Issue Proposal

Form for NRC Staff to Propose a Generic Issue (GI)			
Name or Person Submitting Request Patrick Raynaud	E-Mail Address patrick.raynaud @nrc.gov	Position Title Reactor Systems Engineer	Date of Request 10/07/2011
Office/Division/Branch/Section RES/DSA/FSCB	Telephone 301-251-7542	Mail Stop C-3A07M	Supervisor Richard Lee

GENERAL INSTRUCTIONS FOR COMPLETING AND SUBMITTING THIS FORM:
Please contact a Generic Issues Program (GIP) representative at GIP.Resource@NRC.gov for assistance in completing this form. When the form is complete, including supervisor acknowledgment, please submit completed form to GIP.Resource@NRC.gov.

Identify Source(s) of Information for this Proposed GI (Self, NRC process, Independent Oversight Committee, Other) – Please Describe and Provide Contact Information for GIP Representatives to Obtain More Information, as Appropriate.

This issue was discovered during a review of test results from the Halden IFA-650 program and the NRC-Studsvik LOCA research program. The issue of fuel fragmentation, relocation, and dispersal into the core (and subsequently into the coolant during core reflood) was further investigated. A draft NUREG on this topic has been produced and looks at historical and recent LOCA research results. The responses below are based on the research performed to write the draft NUREG (provided as an attachment).

INSTRUCTIONS FOR PROVIDING RESPONSES BELOW:
Describe situation, condition, Issue, or concern by providing the following information to extent practical (i.e., use readily available information; these requests are not intended to cause an imposition). Describe basis for statements as available or indicate opinion or belief, as applicable. Contact a GIP representative at GIP.Resource@NRC.gov for assistance completing these responses.
If you do not know how to respond to any question, then put "Don't know."

What Occurs, Occurred, or What Could Occur (Performance Requirement, Standard, or Expectation Not Met, or Potentially Compromised)?

Fuel particles can be expelled from ballooned and ruptured fuel rods during a LOCA.

When It Occurs, Occurred, or Could Occur (Time and Circumstances)?

Fuel dispersal could occur if fuel rods balloon and burst during a LOCA. This phenomenon likely requires some degree of core uncovery to cause fuel rod failures. The majority of fuel dispersal is expected to occur immediately following fuel rod cladding rupture, concurrent with fuel rod blowdown. Hence, the phenomenon can occur well below the regulatory limits in 10 CFR 50.46.

Where It Occurs, Occurred, or Could Occur (Physical Location from General to Specific and in a Sequence of Process Steps or Activities)?

The phenomenon of fuel dispersal during a LOCA would occur inside the reactor core, at the location of ballooned and ruptured fuel rods.

Adverse Consequences of Occurrence (Actual and Potential Damages and Other Negative Impacts)?

Potential damages include (but are not limited to) increased radiological activity levels in the coolant and containment, displaced heat load potentially causing flashing of coolant (particularly at pump inlets), erosion of pump components due to entrained fuel particles, increased debris load in the containment sump and/or core inlet. The exact amounts of fuel that could be dispersed in to the core and coolant have yet to be precisely evaluated. Best-estimate LOCA analyses have reported 0 to 10 % of rods in the core would fail, but the amount of fuel that would be dispersed from a failed rod has not been evaluated.

Frequency of Occurrence (Relevant Historical Rate, Best Estimate of Rate, and Conditions that Influence the Rate)?

Fuel dispersal is expected to occur in almost every instance where a LOCA results in failed fuel rods (ruptured cladding). Fuel dispersal occurred in the TMI-2 accident, and likely occurred in the Fukushima Dai-Ichi accident (based on indications of severe core damage).

Significance of Occurrence (Reasons it is Important)?

The phenomenon of fuel dispersal is important because of its potential consequences, described above, and because it is currently not taken into account in safety analyses. We believe that fuel dispersal could have a significant impact on debris load, as well as temperature of the coolant, during the reflood and recirculation phases of a LOCA. We believe this phenomenon cannot be dismissed until it is better understood and taken into account in safety analyses.

Ability to Anticipate and Prevent Occurrence (Leading Indicators or Signs)?

One way to prevent fuel dispersal during a LOCA would be to prevent fuel rod cladding rupture. At this time, fuel rod cladding rupture is possible even if plants demonstrate that they do not exceed maximum allowable peak cladding temperature (PCT) and maximum allowable equivalent cladding reacted (ECR). Both old and new proposed 50.46 ECCS criteria are not sufficient to prevent cladding rupture during a LOCA, because this phenomenon is known to occur at temperatures around 700-800 °C, which are below allowable PCT.

Means to Detect or Discover Occurrence (Supporting Evidence)?

Fuel dispersal has been observed experimentally in both in-reactor and out-of-reactor experimental tests. Generally speaking, it is believed that the levels of activity would increase in the coolant and containment if fuel dispersal occurred. In addition, the isotopic composition of the radioactive gases would reveal the presence of fission gases, and the radioactive particulate would include transuranics and actinides.

Estimated Likelihood of Occurrence (Best Estimate of Chance Under Expected Conditions)?

Some fuel dispersal (possibly limited) should be expected under any condition where cladding rupture is expected.

Causes of Occurrence (Set of Necessary and Sufficient Actions and Conditions)?

The necessary conditions for fuel dispersal are:
(1) LOCA with at least partial core uncovery
(2) Combination of rod internal pressure and PCT resulting in cladding rupture
(3) Sufficient cladding diametral expansion (ballooning) to allow fuel relocation
(4) Fuel fragments smaller than the cladding rupture opening
The combination of these conditions is sufficient to result in fuel dispersal during a LOCA.
The likelihood of the first three conditions could be calculated with existing codes, is plant-specific, and is expected to be dependent on break size. The likelihood of the fourth condition is not known with certainty, but is expected to be high.

Suggestions for Corrective Actions (Remedies to Prevent Adverse Consequences)?

One or more of the following actions may be appropriate:
(1) Demonstrate that the consequences of fuel dispersal are of no safety significance
(2) Prevent fuel rod cladding ruptures during a LOCA
(3) Demonstrate that current analysis assumptions are bounding for fuel dispersal

INSTRUCTIONS FOR PROVIDING RESPONSES BELOW:
Describe why issue is suitable for assessment under the GIP (versus other NRC Programs or Processes) by providing the following information to extent practical (i.e., use readily available information, these requests are not intended to cause an imposition). Describe basis for statements as available or indicate opinion or belief, as applicable. If you do not know how to respond to any question, then put "Don't know." When one or more of the following responses are "No," the issue is generally not suitable for assessment under the GIP. In these instances, other NRC programs or processes might be better suited to assessing the issue. Contact a GIP representative at GIP.Resource@NRC.gov for assistance completing these responses.

Issue impacts (or has potential to impact) public health and safety, common defense and security, or environment.

Yes (please explain below)	No	Don't Know

Issue has potential impact on public health and safety, if fuel dispersal is found to adversely impact analysis of the radiological consequences of a LOCA, to aggravate accident progression, or to prevent successful termination of a LOCA.

Issue indicates susceptibility of, or has applicability to, multiple licensees or entities regulated by NRC.

Yes (please explain below)	No	Don't Know

All reactors in the US fleet must consider LOCA in their design basis, and thus cannot a priori exclude fuel dispersal in such an event.

Issue indicates there are gaps, voids, conflicts, or excess in existing regulations or industry standards causing inadequate protection, opportunity to substantially improve safety, or undue regulatory burden.

Yes (please explain below)	No	Don't Know

To date, fuel dispersal during a LOCA is not taken into account in regulations or in licensee safety analyses.

Issue resolution will likely result in new or revised regulation, policy, or guidance to prevent issue's occurrence (Note: dissenting views should be directed to other NRC programs – DPO, NCP, ROP Feedback, etc.).

Yes (please explain below)	No	Don't Know

The issue has been communicated to NRO and NRR, and caused concern among the technical staff of these offices. Potential paths to account for this issue have been discussed in the working group on 50.46 rulemaking, but it was decided that this issue should not be included in the current update to 10 CFR 50.46(b), largely to avoid further delays in rulemaking.

Issue will not require substantial new research to assess risk or safety significance or to gain sufficient understanding to support initial screening assessment (i.e., issue parameters are identified and sufficiently understood to support further assessment of the likelihood that the issue would cause or result in a severe accident).

Yes (please explain below)	No	**Don't Know**

NRC most likely possesses all the computational tools that would be required to assess the risk or safety significance of this issue. However, assumptions may be required in some areas where only limited information is available and uncertainties are large. The level of effort required to produce a risk assessment has not been determined.

Issue is discrete with clear and specific technical scope (bounding physical conditions).

Yes (please explain below)	No	Don't Know
As discussed in the OECD NEA/CSNI/R(2010)5 "Safety Significance of the HALDEN IFA-650 LOCA Test Results", the issue is clear, but resolution is not.		
Issue will likely result in actions by licensees or entities regulated by NRC to address issue.		
Yes (please explain below)	No	Don't Know
Licensees may be asked to take into account fuel dispersal in LOCA safety analyses, or provide proof that this is not necessary.		
Supervisor's Acknowledgment Signature		Date
Supervisor's Comments or Recommendations		
Others Consulted or Contacted RES/DSA: John Voglewede, Harold Scott, Michelle Flanagan, Michael Scott, Kathy Gibson NRO/DSRA: Ralph Landry, Christopher VanWert, Charles Ader NRR/DSS: Paul Clifford, Tara Inverso, Bill Ruland		
Provide Comments, Additional Information, Attachments, or References (as desired and appropriate to support comments above). Attachments: Draft NUREG: "Fuel fragmentation, Relocation, and Dispersal During a Loss-Of-Coolant Accident", ML11279A223 NEA/CSNI/R(2010)5 "Safety Significance of the HALDEN IFA-650 LOCA Test Results", ML11279A224 EHPG paper: "Results of Integral, High-Burnup, Fueled LOCA Tests and Companion Testing with As-Fabricated and Pre-hydrided Cladding" by Peter Askeljung, Michael Billone, and Michelle Flanagan		
Please submit completed form, with supervisor's acknowledgment, to GIP.Resource@NRC.gov.		