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| <b>UK EPR</b>  | <b>UK EPR GDA PROJECT</b>                    |   |                               |                     |
|  | Title: Resolution Plan for GI-UKEPR-FS01     |   |                               |                     |
|  | RP unique number:<br><b>GI-UKEPR-FS01-RP</b> | Revision No.:<br>0  | Effective Date:<br>29.06.2011 | Page No.:<br>1 of 9 |
| Approved for EDF by: A. PETIT<br><br>Name/Initials  Date 29/06/2011 |  | Approved for AREVA by: C. WOOLDRIDGE<br><br>Name/Initials  Date 29/06/2011 |                               |                     |

### Resolution Plan Revision History

| Rev.  | Description of update | Date issued |
|-------|-----------------------|-------------|
| Rev 0 | First revision        | 29/06/2011  |

#### 1.0 GDA ISSUE

| GDA Issue Title                                 | Main Assessment Area | Related Assessment Area |
|---|----------------------|-------------------------|
| <b>HETEROGENEOUS BORON DILUTION SAFETY CASE</b> | Fault Studies        | PSA<br><br>Chemistry    |

|                  |   |
|------------------|---|
| <b>GDA Issue</b> | A safety case for heterogeneous boron dilution events is required. Both external dilution events and intrinsic dilution mechanisms from certain accident situations need to be addressed. |
|------------------|---|

#### 2.0 OVERVIEW OF SCOPE OF WORK

Heterogeneous boron dilution events are characterised by the formation of an un-borated slug in a loop of the RCS while the boron concentration in the rest of the RCS is unchanged and while RCPs are not operating (contrary to homogeneous dilution).

The dilution can be either external (secondary side water) or intrinsic to a fault sequence (reflux condensation in SB LOCA for instance). If the unborated slug is transported without any mixing into the core, a very rapid reactivity insertion could occur.

Both phenomena are not discussed in PCSR chapter 14 fault studies. Since they these cases are practically eliminated via a probabilistic demonstration, they are discussed in PCSR chapters 15 and 16.

RO-UKEPR-65 was raised to request submission of a full safety case but this information was not provided during step 4. However, dedicated meetings were held during Step 4 to present the planned approach to ONR and to explain the proposed structure of the safety case.

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More precisely, during the Step 4 meetings and exchanges with the ONR, the following considerations were presented:

- Inherent heterogeneous boron dilution: the approach is based on:
  - o System calculation to assess the dynamics of the phenomenon
  - o CFD calculation to assess the consequences of transportation and mixing of the unborated slug into the core.
  
- External heterogeneous boron dilution: the approach is based on:
  - o Determination of the maximum acceptable slug size based on CFD calculations,
  - o Systematic analysis of system measures limiting the occurrence of the event (creation of the unborated slug and its transportation into the core inlet),
  - o Probabilistic assessment of the risk associated with the events concluding that the issue can be practically eliminated.

The proposed scope of work for this GDA issue is therefore:

- For inherent boron dilution during a SB-LOCA: AREVA/EDF will provide ONR with an updated safety case consistent with the frequency of the initiating event (PCC-3),
- For external boron dilution: AREVA/EDF will provide ONR with an updated safety case to reinforce the relevance of the CFD modelling (validation, qualification) and to provide evidence that the claimed devices and administrative measures are capable of delivering their functions to the requisite reliability.

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### 3.0 GDA ISSUE ACTIONS AND RESOLUTION PLAN DELIVERABLES

#### 3.1 Action GI-UKEPR-FS01.A1

| Action I/D              | Action Description   |
|-------------------------|--|
| <b>GI-UKEPR-FS01.A1</b> | <p>EDF and AREVA to provide ONR with a safety case for heterogeneous boron dilution faults. This needs to consider both external and intrinsic faults. ONR's expectation is that faults are identified as being within the design basis based on their initiating frequency and their unmitigated consequences. Arguments that heterogeneous boron dilution faults are practically eliminated and do not need a full design basis analysis treatment due to probabilistic arguments taking benefit for engineered safety measures are unlikely to be accepted.</p> <p>CFD analysis is a developing methodology, which offers insights into complex scenarios like heterogeneous boron dilution faults. However it can be sensitive to many variables, for example the skill of the practitioner, fine details of the model, the assumed boundary conditions etc. Validation of the CFD model is both important and difficult. ONR therefore encourages EDF and AREVA not to provide a safety case heavily reliant on claims derived directly from CFD analysis.</p> <p>ONR's assessment of the heterogeneous boron dilution safety case will inevitably generate questions and request further evidence. EDF and AREVA shall respond to ONR's queries on the supplied safety case and provide further evidence, especially related to:</p> <ul style="list-style-type: none"> <li>- EDF and AREVA are claiming that the size of any un-borated slug of water will be limited by safety classified boron meters. EDF and AREVA need to provide evidence that these devices are capable of delivering this function to the requisite reliability.</li> <li>- For those faults where the size of an un-borated slug is restricted by other means, for example following a steam generator tube plugging error, EDF and AREVA also need to provide evidence they too are capable of delivering this function to the requisite reliability. A heavy reliance on administrative controls is likely to be subject to scrutiny by ONR.</li> <li>- For dilution events resulting from intrinsic mechanisms, EDF and AREVA will need to provide evidence of adequate validation for any CFD derived claims used as part of a multi-legged safety case.</li> </ul> <p>EDF and AREVA shall update the PCSR in accordance with the agreed safety case. With agreement from the Regulator this action may be completed by alternative means.</p> |

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### 3.1.1 Planned submissions in response to GI-UKEPR- FS01.A1

#### 3.1.1.1 Description of Scope of Work

Faults will be identified as being within the design basis based on their initiating frequency and their unmitigated consequences. Supporting CFD analysis will be sufficiently validated and qualified. Mitigating engineering devices and administrative controls will be sufficiently classified to deliver their function to the requisite reliability.

EDF and AREVA will respond to HSE's queries on the supplied safety case

EDF and AREVA will update the PCSR accordingly with the agreed safety case.

#### 3.1.1.2 Description of Methodology to be employed

##### - Inherent boron dilution

The methodology document "Calculation Procedure For Assessing The Risk Of Inherent Heterogeneous Dilution In SB/IB LOCA for EPR" will be transmitted to the ONR.

This document presents a complete description of the methodology used to assess intrinsic dilution consequences in case of a Loss of Coolant Accident, and gives a complete view of the sensitivity study reinforcing the approach.

**Planning:** document to be sent in July 2011.

##### - External boron dilution

#### Task 1: Complements on current safety case:

The current safety case claims that:

- boron dilution faults with a slug less than 2m<sup>3</sup> are acceptable (since CFD calculations conclude that there is no risk of recriticality in the core),
- boron dilution faults with a slug larger than 2m<sup>3</sup> are practically eliminated situations (PSA claim).

It is proposed to reinforce / complement the current safety case with two (2) additional elements:

1. **Reinforcement of CFD safety case:** The Star CD qualification report sent to ONR during Step 4 focussed mainly on inherent boron dilution. Another document dedicated to qualification of Star CD for external heterogeneous boron dilution will be submitted.
2. **PSA analysis:** each scenario potentially leading to a boron dilution fault will be re-analyzed with focus on available protections and their classification: alarms, automatism, operator actions, etc. This will be done in a fault schedule format (main / back up line) with emphasis on available protections against each sequence of event.

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**Task 2: Update of UK EPR safety case:**

The updated safety case for external heterogeneous boron dilution will be transmitted to ONR. This updated safety case will consist of the revised set of documents supporting assessment of the faults:

- The PSA analysis will be replaced by the fault schedule mentioned in Task 1,
- An updated systems analysis will be transmitted together with the boron dilution fault schedule (22/07/2011),
- The updated CFD analysis will be transmitted with the Star CD qualification report at the end of October 2011.

**Task 3: Additions to current safety case:**

In parallel with the aforementioned actions, several ALARP options will be investigated: detection of a water slug after its formation in the U-leg or prevention of transport of a potential water slug to the core.

1. Modification in start up procedure to allow draining of U-leg prior to start-up.
2. Detection of water slug in U-leg via a boron meter
3. Feasibility of additional drain line on loop #3

**Planning milestones:**

1. Creation of a boron dilution fault schedule with identified protections (main) for each scenario – July 2011
2. Consolidation of qualification for Star CD for external heterogeneous boron dilution faults – October 2011
3. Analysis of optioneering and ALARP analysis of potential modifications for detection and treatment of boron dilution faults – November 2011
4. Progress meetings will be held throughout 2011 to discuss resolution of the GDA Issues. A dedicated meeting will be scheduled following submission of the main deliverables in November 2011 (date to be defined)
5. Update of PCSR chapters (14 to 16) as required following chosen solution - March 2012

Any required updates to the PSA safety case (PCSR, PSA model) will be included during site licensing after the end of GDA

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### 3.1.1.3 Deliverable description

### Submission date to HSE/EA

|  |                               |
|--|-------------------------------|
| PEPR-F DC XXX - Risk Of Inherent Heterogeneous Dilution In SB/IB LOCA for EPR – Methodology and calculations.  | 29/07/2011                    |
| PEPD-F-DC XXX – Star CD analysis of slug transport in the core<br>Updated Star CD analysis for transport of water slug in the core.  | 28/10/2011                    |
| PEPD-F-DC XXX – Qualification of Star CD<br>Additional elements on STAR CD qualification for heterogeneous boron dilution faults.  | 28/10/2011                    |
| XXXX – Countermeasures against heterogeneous dilution initiators<br>System analysis of countermeasures available against heterogeneous dilution initiators.                              | 22/07/2011                    |
| PEPR-F DC XXX - Boron dilution fault schedule<br>Creation of a boron dilution fault schedule with identification of all potential initiating events and main / back up lines of defence  | 22/07/2011                    |
| PEPR-F DC XXX – ALARP analysis for boron dilution faults<br>Analysis of optioneering and ALARP analysis of potential modifications for detection and mitigation of boron dilution faults | 30/11/2011                    |
| Updated PCSR Chapters according to chosen solution   |                               |
| PCSR – Chapter 14 – Design basis analysis  | Advanced copies<br>16/03/2012 |
| PCSR – Chapter 15 – Probabilistic safety analysis  | Final                         |
| PCSR – Chapter 16 – Risk reduction and SA analysis   | 19/04/2012                    |

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#### 4.0 SUMMARY OF IMPACT ON GDA SUBMISSION DOCUMENTATION

##### 4.1 GDA submission documents impacted by GDA Issue and scheduled to be created (C) or updated (U) within GDA

| GDA Submission Documents   | C/U | Related GDA Issue Action(s) | Submission Date to HSE/EA                            |
|--|-----|-----------------------------|--|
| <b>SSER sub-chapters</b><br>PCSR – Chapter 14 – Design basis analysis<br>PCSR – Chapter 15 – Probabilistic safety analysis<br>PCSR – Chapter 16 – Risk reduction and SA analysis         | U   | GI-UKEPR-FS01.A1            | Advanced copies<br>16/03/2012<br>Final<br>19/04/2012 |
| <b>Other GDA submission supporting documents</b><br>PEPD-F-DC XXX – Qualification of Star CD<br>Qualification for Star CD for external heterogeneous boron dilution faults               | C   | GI-UKEPR-FS01.A1            | 28/10/2011   |
| PEPD-F-DC XXX – Star CD analysis of slug transport in the core   | U   |                             | 28/10/2011   |
| XXXX – Countermeasures against heterogeneous dilution initiators   | U   |                             | 22/07/2011   |
| PEPR-F DC XXX - Risk Of Inherent Heterogeneous Dilution In SB/IB LOCA for EPR– Methodology and calculations  | C   |                             | 29/07/2011   |
| PEPR-F DC XXX – Boron dilution fault schedule  | C   |                             | 22/07/2011   |
| PEPR-F DC XXX – ALARP analysis for boron dilution faults<br>Analysis of optioneering and ALARP analysis of potential modifications for detection and mitigation of boron dilution faults | C   |                             | 30/11/2011   |

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## 5.0 JUSTIFICATION OF ADEQUACY

This resolution plan proposes to perform a systematic review of all the initiating events / sequences leading to boron dilution faults and to identify main and back up lines for each fault. The use of a fault schedule will allow systematic review and analysis.

Appropriate classification and agreed rules for fault studies (e.g.; diversity for frequent faults) will be applied to the boron dilution faults. PCC studies will be performed, if needed, according to PCSR rules and assumptions outlined in Chapter 14.

The methodology described for intrinsic boron dilution faults will be detailed as well as its application to UK EPR, in accordance with PCC studies rules.

Any necessary design change will be processed according to the GDA Design Change Process (UKEPR-I-003) and the PCSR will be updated accordingly with the revised study.



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## 6.0 TIMETABLE AND MILESTONE PROGRAMME LEADING TO THE DELIVERABLES

See attached schedule

