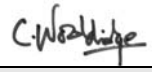
UK EPR	UK EPR GDA PROJECT			
	Title: Resolution Plan for GI-UKEPR-SI02			
	RP unique number:	Revision No.:	Effective Date:	Page No.:
	GI-UKEPR-SI02-RP	1	29.06.2011	1 of 10

Approved for EDF by: A. PETIT	Approved for AREVA by: C. WOOLDRIDGE
Name/Initials  *Date* *28/06/2011*	*Name/Initials*  *Date* *28/06/2011*

Resolution Plan Revision History

Rev.	Description of update	Date issued
0	First revision	23/06/2011
1	Update of Schedule to account for ARG comments	29/06/2011

1.0 GDA ISSUE

GDA Issue Title	Main Assessment Area	Related Assessment Area
RPV Surveillance Scheme – Implications of Change in Neutron Energy Spectrum Caused by the Heavy Reflector.	**Structural Integrity**	

GDA Issue	**Demonstration that the principles of the surveillance scheme adequately take account of the implications of the difference in neutron energy spectra between the location of the specimens and the RPV wall.**

2.0 OVERVIEW OF SCOPE OF WORK

The UK EPR RPV has a heavy reflector situated outside the core but within the core barrel to reduce the ageing effects or embrittlement of the RPV wall caused by neutron irradiation. The effect of neutron irradiation on ferritic steels is a shift to higher temperatures of the brittle to ductile fracture transition temperature and is monitored through an Irradiation Surveillance Program.

The Irradiation Surveillance Program consists of positioning specimens representative of RPV core region materials (base and weld metals) in capsules in the core barrel at the exterior of the heavy reflector. Capsules are periodically withdrawn and progressive impact toughness transition temperature shift is measured ($\Delta RT_{NDTmeasured}$) as the specimens inserted in the capsules are more rapidly irradiated than the RPV wall due to their position close to the core.
The main objective of the Irradiation Surveillance Program is to confirm the conservatism of the ageing formulae used for the fast fracture safety demonstration of the RPV. These specific empirical formulae have been developed on the basis of the available data in the chemical and neutron irradiation ranges of the French RPV materials and take account of uncertainties. It has to be emphasised that the EPR end-of-life design irradiation dose (in terms of fast neutron fluence or dpa) is low, which will result in low ageing effects, in particular in terms of impact toughness transition temperature shift.

Information submitted in GDA Step 4 to analyse the neutron dose in terms of displacements per atom (dpa) and compare with the results based on high energy (E>1MeV) neutrons per cm^2 (n/cm^2) indicated that the EPR surveillance specimens used to monitor progress of embrittlement in service are subject to different neutron energy spectrum than the RPV. The dpa rates in the surveillance specimens are dominated by damage from epithermal neutrons whereas the RPV dpa values are dominated by the damage from high energy neutrons.

EDF & AREVA proposal for relating damage measured in the surveillance capsule specimens to damage predicted in the RPV wall uses a conventional approach based on high energy neutrons (E>1MeV), a quantity derived from experimental dosimetry information. However EDF & AREVA are asked to consider whether this difference in neutron energy spectra between the surveillance capsules and the RPV through the calculated dpa analysis needs to be taken into account when designing the surveillance scheme and interpreting the results.

In their response to this Issue EDF & AREVA will explain the principles of their proposed surveillance scheme and provide :
- evidence showing that the principles of the surveillance scheme adequately take account of the implications of the differences in neutron energy spectra between the location of the specimens and the RPV wall;
- justification of the concepts inherent in the analysis and interpretation of the surveillance scheme results including an explanation of any implications for the withdrawal scheme;

3.0 GDA ISSUE ACTIONS AND RESOLUTION PLAN DELIVERABLES

3.1 **Action GI-UKEPR-SI02.A1**

Action I/D	Action Description
GI-UKEPR-SI02.A1	Demonstration that the principles of the surveillance scheme adequately take account of the implications of the differences in neutron energy spectra between the location of the specimens and the RPV wall. This is expected to include the following activities: • Provision of evidence showing that the principles of the surveillance scheme adequately take account of the implications of the differences in neutron energy spectra between the location of the specimens and the RPV wall; • Justification of the concepts inherent in the analysis and interpretation of the surveillance scheme results including the treatment of uncertainties and consideration of any implications for the withdrawal scheme; • Adequate responses to questions arising from ONR assessment of documents submitted as a result of this Action. With agreement from the Regulator this action may be completed by alternative means.

3.1.1 Deliverables already submitted to ONR/EA in response to GI-UKEPR-SI02.A1

The deliverables submitted in response to this issue action which have not yet been reviewed in detail by ONR are understood to be the following:

	Date of submission
ND(NII) EPR00840R RPV Surveillance Scheme	04/04/2011
This letter explains EDF and AREVA RPV Surveillance Scheme proposal and responds to an initial set of ONR queries on the dpa and fluence analysis and the impact of neutron spectral difference between surveillance capsules and RPV	
PEEM-F 11.0642A HSE Feedback about the potential implications of DORT and MCNP calculations – RP position concerning ISP anticipation factor and dpa issue	06/05/2011

This report describes the principles of the surveillance scheme and the impact of the heavy reflector on the differences of neutron spectrum between the surveillance capsules and the RPV. Based on the results of the ESTEREL Programme, the report examines the effect of epithermal neutrons and their impact and establishes whether dpa or fluence is the more appropriate parameter for monitoring the EPR Irradiation Surveillance Programme.

Neutron Spectrum Effect and damage analysis on pressure vessel steel irradiation behaviour by C Pichon et al – Effects of Radiation on Materials 19th ASTM Symposium 1998 — 06/05/2011

This conference proceedings paper provides an overview of the French experimental programme ESTEREL to determine dose-damage correlations for reactor vessel materials and to assess the potential neutron spectrum effect between surveillance specimens and RPV to determine the most appropriate exposure parameter.

Simulation of irradiation effects in light water reactor vessel steels by S Jumel & JC Van Dyusen – Journal of Nuclear Materials 366 (2007) 256 – 265 — 06/05/2011

This published paper explains the tools which have been developed to simulate irradiation effects on materials and the results of the comparison with the French experimental programme to quantify the neutron effect between surveillance specimens and reactor vessel materials to determine the best irradiation parameter from the results of the surveillance programme.

3.1.2 Planned submissions in response to GI-UKEPR-SI02.A1

3.1.2.1 Description of Scope of Work

The results of dpa rate evaluations on the UK EPR indicate a difference in neutron energy group contribution between the surveillance capsules and the RPV wall. The dpa rates in the surveillance capsule specimens are dominated by the contribution of epithermal neutrons whereas the RPV dpa values are dominated by the effects of high energy neutrons.

Evidence showing that the principles of the EPR surveillance scheme adequately take account of the implications of the differences in neutron energy spectra between the location of the

specimens and the RPV wall has already been provided in report PEEM-F 11.0642A. In particular this report mentions that the design of the surveillance capsules has been modified for EPR in order to make the neutron spectrum seen by the surveillance specimens as representative as possible of that of the RPV wall.

EDF & AREVA will transmit the Final Report on the ESTEREL experimental programme to support the principles inherent in the adopted ISP approach and particularly to justify the concepts inherent in the analysis and interpretation of the surveillance scheme results including consideration of any implications for the withdrawal scheme.

This report presents the experimental work which was carried out in the SILOE and ORISIS experimental reactors to determine the best irradiation damage correlation with fluence E>1MeV, fluence E>0.1MeV or dpa using specimens from two welded mockups made from RPV steel with two different residual element contents. This report presents the objectives and details of the experimental programme, details of preliminary studies, the results of irradiation on materials, neutronic calculations, fluence measurements and mechanical testing (information is provided regarding the number of measurements and the scattering of data to show that the measured effects are significant). The report also includes the interpretation of experimental test results and analysis to derive the relative contributions of different neutron energies and to establish a dose-damage correlation.

The report PEEM-F 11.0642A shows that the neutron spectrum of EPR RPV wall is close to that of OSIRIS reactor, whereas the spectrum of EPR capsules is close to that of SILOE; it is therefore possible to use ESTEREL experimental results to assess the validity of the adopted ISP approach for EPR in terms of spectrum effect.

3.1.2.2 Description of Methodology to be employed

Task 1 – Production of Report and ONR assessment

EDF & AREVA will transmit DRE-SRO-SIEN 95-123 Influence of neutron spectra on the embrittlement of RPV steels - ESTEREL Programme Final Report which evaluates the neutron spectrum effect between surveillance capsules and the RPV wall of the French PWR fleet as well as identifies the most appropriate irradiation exposure parameter (between fluence and dpa) to assess the behaviour of these vessels from the results of the ISP.

The ESTEREL programme has been used to establish the principles of the ISP for the EPR and to quantify the neutron spectrum effect between surveillance capsule specimens and RPV to derive the dose-damage correlation. This report provides detailed test evidence to support the two papers already provided with our main report PEEM-F 11.0642A to support the design basis of the proposed EPR surveillance scheme.

Transmittal date of report – 29/07/2011

ONR are expected to complete their assessment of this action deliverable as well as the reports

related to this action which have already submitted (see 3.1.1) within the indicative timescale of 14 October 2011.

Any questions which are raised by ONR will be clarified by EDF and AREVA with ONR then acknowledged with a committed response date to provide the following:

a) Response to the question

b) Potential draft PCSR updates of subchapter sections impacted by the response

c) Potential Supporting Documents impacted by the response

On the basis that questions will be for clarification and no major concerns are raised, the date for transmittal of all planned EDF and AREVA responses is 25 November 2011

Task 2 – Update of PCSR and Supporting Documents

Any draft updates of PCSR sub-chapter sections and updates of identified Supporting Documents impacted by the responses to this Issue action will be transmitted to ONR for review.

The following PCSR sub-chapter is potentially to be updated :

- Draft PCSR sub-chapter 5.3.7

Transmittal date of the draft PCSR update, if required, is 23 December 2011

Updates to PCSR sub-chapter sections will be finalised taking into account ONR feedback on the previously submitted draft versions.

Transmittal date for final PCSR update, if required, is 31 January 2012

Task 3 – Convergence Meetings

Two convergence meetings will be held to obtain ONR assessment feedback on EDF & AREVA responses to questions as well as potential draft PCSR and supporting document updates which may be provided. The status of the GDA Issue will be reviewed and agreed as well as agreeing any remaining steps to complete and close the action.

Date of preliminary Convergence Meeting 27 October 2011

Date of final Convergence Meeting 10 January 2012

3.1.2.3 Deliverable description	**Submission date to ONR/EA**
DRE-SRO-SIEN 95-123 Influence of neutron spectra on the embrittlement of RPV steels - ESTEREL Programme Final Report	29/07/2011
This report provides details of the experimental programme used to establish the principles of the ISP and to quantify the neutron spectrum effect between surveillance capsule specimens and RPV to derive the dose-damage correlation	
PCSR Sub-chapter 5.3 section 7. (if required)	Draft 23/12/2011
The PCSR section provides details of material irradiation monitoring of the Reactor Pressure Vessel	Final 31/01/2012

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
SSER sub-chapters			
PCSR sub-chapter 5.3.7	U	GI-UKEPR-SI02.A1	Draft 23/12/2011 Final 31/01/2012
Other GDA submission supporting documents			
DRE-SRO-SIEN 95-123 Influence of neutron spectra on the embrittlement of RPV steels - ESTEREL Programme Final Report	C	GI-UKEPR-SI02.A1	29/07/2011

5.0 JUSTIFICATION OF ADEQUACY

The analyses proposed to resolve this GDA Issue action draw on the extensive materials and irradiation embrittlement experience within EDF & AREVA for the design and manufacture of reactor components and operating of the French reactor fleet.

Evidence showing that the principles of the surveillance scheme adequately take account of the implications of the differences in neutron energy spectra between the location of the specimens and the RPV wall of the EPR has been provided through a specific report PEEM-F 11.0642A.

EDF & AREVA will transmit the Final Report on the ESTEREL programme, a substantial and comprehensive experimental programme, to support the principles inherent in the ISP approach adopted by EDF & AREVA for the EPR and particularly to justify the concepts inherent in the analysis and interpretation of the surveillance scheme results consideration of any implications for the withdrawal scheme.

The ESTEREL programme has also been used to quantify the neutron spectrum effect between surveillance capsule specimens and RPV to derive the dose-damage correlation. The experimental work on the SILOE and OSIRIS reactors do not show any correlation between DBTT shifts and dpa rate calculations. The contribution of epithermal neutrons is clearly much lower than that anticipated by dpa rate.

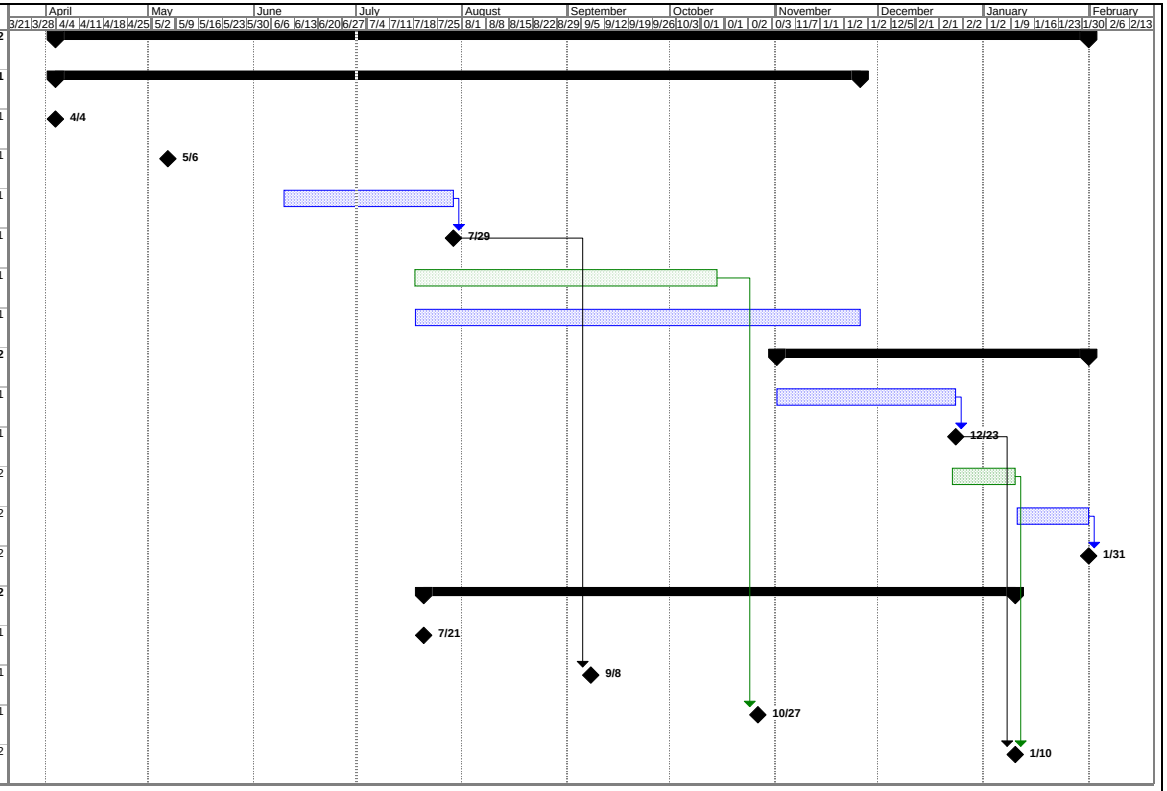
From this observation it is concluded in our main report PEEM-F 11.0642A that the realistic anticipation factors of EPR capsules are much closer to Flux Anticipation Factors (FAF $\approx$ 2) than to calculated Dpa Anticipation Factors (DAF $\approx$ 4). There is therefore no fundamental reason to modify the current scheme proposed on the basis of conventional FAF which has been retained for ISP withdrawal time schedule.

PCSR and supporting documentation impacted by the resolution of the GDA Issue actions will be identified and documents will be updated according to appropriate QA processes.

6.0 TIMETABLE AND MILESTONE PROGRAMME LEADING TO THE DELIVERABLES

.

ID	Task Name	Duration	Start	Finish
1	**Issue SI02 Action 1 Principles of RPV Surveillance scheme**	**247.86 days**	**Mon Apr 4, '11**	**Tue Jan 31, '12**
2	**Task 1 Production of Reports & ONR Assessment**	**194.14 days**	**Mon Apr 4, '11**	**Fri Nov 25, '11**
3	Letter ND(NII) EPR00640R	0 days	Mon Apr 4, '11	Mon Apr 4, '11
4	Action 1.1 Deliverables: Implications of Neutron Energy Spectra - RP Position Report & 2	0 days	Fri May 6, '11	Fri May 6, '11
5	Action 1.2 Deliverables: Justification of the concepts - ESTEREL Programme Report	41 days	Fri Jun 10, '11	Fri Jul 29, '11
6	Transmission to ONR	0 days	Fri Jul 29, '11	Fri Jul 29, '11
7	ONR Assessment of Action deliverables	74 days	Mon Jul 18, '11	Fri Oct 14, '11
8	RP responses to ONR Queries	108 days	Mon Jul 18, '11	Fri Nov 25, '11
9	**Task 2 Update of PCSR & Supporting Documents**	**74.86 days**	**Tue Nov 1, '11**	**Tue Jan 31, '12**
10	Prepare draft PCSR update section 5.3.7	44 days	Tue Nov 1, '11	Fri Dec 23, '11
11	Transmission to ONR	0 days	Fri Dec 23, '11	Fri Dec 23, '11
12	ONR Assessment of draft PCSR update 5.3.7	14 days	Fri Dec 23, '11	Tue Jan 10, '12
13	Prepare final PCSR update integrating ONR comments	17 days	Wed Jan 11, '12	Tue Jan 31, '12
14	Transmission to ONR	0 days	Tue Jan 31, '12	Tue Jan 31, '12
15	**Task 3 Convergence meetings**	**140.86 days**	**Thu Jul 21, '11**	**Tue Jan 10, '12**
16	Feedback teleconference 1	0 days	Thu Jul 21, '11	Thu Jul 21, '11
17	Technical meeting	0 days	Thu Sep 8, '11	Thu Sep 8, '11
18	Preliminary Convergence Meeting	0 days	Thu Oct 27, '11	Thu Oct 27, '11
19	Final Convergence meeting	0 days	Tue Jan 10, '12	Tue Jan 10, '12



Project: RP Schedule GI-UKEPR-SI02
Date: Fri Jul 1, '11

Task | Progress | Summary | External Tasks | Deadline
Split | Milestone | Project Summary | External Milestone