Date: 23 April 2018
Validity: until next update or archiving
Version 1

MDEP Design-Specific Common Position CP-EPRWG-07

COMMON POSITION ADDRESSING THE VIENNA DECLARATION ON NUCLEAR SAFETY

Participation

Regulators involved in the MDEP working group discussions:	NNSA (China), STUK (Finland), ASN (France), SSM (Sweden), ONR (UK)
Regulators which support the present common position:	NNSA (China), STUK (Finland), ASN (France), SSM (Sweden), ONR (UK)
Regulators with no objection:	AERB (India)
Regulators which disagree:	-

Introduction

On the 9 February 2015 the Vienna Declaration on Nuclear Safety was adopted at the Diplomatic Conference of the Convention on Nuclear Safety[1]. With regard to new nuclear power plants, the Vienna Declaration proposed the following principle with the objective of preventing accidents with radiological consequences and to mitigate the consequences of such accidents should they occur:

> *"New nuclear power plants are to be designed, sited, and constructed, consistent with the objective of preventing accidents in the commissioning and operation and, should an accident occur, mitigating possible releases of radionuclides causing long-term off site contamination and avoiding early radioactive releases or radioactive releases large enough to require long-term protective measures and actions."*

The MDEP EPR Working Group (EPRWG) members, referred to herein as "regulators", consists of members from the national nuclear safety regulatory authorities of China, Finland, France, India, Sweden and the United Kingdom. Regulators from China, Finland, France, Sweden and the United Kingdom have produced this common position on how the EPR design complies with the Vienna Declaration. It is recognised that not all the members of the MDEP EPRWG have completed their regulatory reviews of the EPR design and how the design meets the Vienna Declaration. This common position therefore represents a preliminary position and will be reviewed and updated as necessary in the future as these reviews are completed.

Common Positions Agreed on the EPR Reactor in Response to the Vienna Declaration

Defence in Depth and Practical Elimination

The regulators have already developed[2] the following common position with regard to the general design objectives of the EPR design:

I. *The Fukushima Daiichi nuclear power plant accident confirms the relevance of the general safety objectives that have been considered for Generation III reactors, such as the EPR (lower probability of core melt, limitation of releases, and management of severe accident conditions).*

This is now supplemented by an additional common position focusing on the requirements of the Vienna Declaration:

II. *The regulators recognise the systematic way in which the EPR reactor design has identified those plant damage states and severe accident fault sequences that could lead to long-term off-site contamination or early releases that cannot be dealt within the frame of an emergency response. Additional design safety features that mitigate the consequences of accidents that may lead to a long-term off-site contamination or practically eliminating[3] situations that may lead to*

[1] Diplomatic Conference to consider a proposal to amend the Convention on Nuclear Safety: Vienna Declaration on Nuclear Safety, on principles for the implementation of the objective of the Convention on Nuclear safety to prevent accidents and mitigate radiological consequences. Adopted by the Contracting parties meeting at the Diplomatic Conference of the Convention of Nuclear Safety, CNS/DC/2015/2/Rev.1, Vienna, Austria, February 9, 2015

[2] Common Position addressing Fukushima Daiichi related issues, MDEP Design-Specific Common Position CP-EPRWG-02, Version 6, October 2015.

[3] The possibility of certain conditions occurring is considered to have been practically eliminated if it is physically impossible for the conditions to occur or if the conditions can be considered with a high degree of confidence to be extremely unlikely to arise (from IAEA NSG1.10)

early releases that cannot be dealt within the frame of an emergency response have been identified. The regulators consider that the approach adopted conforms with the expectations of the Vienna Declaration.

The EPR designers have reinforced the defence in depth compared to generation II reactors, in particular a design objective of achieving a global core damage frequency lower than 10^{-5} per plant operating year, uncertainties and potential failures and hazards being taken into account. In addition there is an objective to achieve a significant reduction of potential radioactive releases due to all reasonably conceivable accidents, including core melt accidents. Accident situations with core melt which would lead to early releases that cannot be dealt within the frame of an emergency response are considered to be "practically eliminated", particularly in the case of high pressure core melt sequences. The consequences of low pressure core melt sequences are mitigated so that the associated maximum conceivable releases would necessitate only very limited protective measures in area and in time for the public.

The deterministic design basis analyses, covered by what is also known as Plant Condition Categories[4] (PCC- 1, 2, 3 and 4), are complemented by two Design Extension Categories[5] (DEC-A and DEC-B). These latter categories consider a set of scenarios due to multiple failure events or involving a core melt with the aim of providing additional defence-in-depth.

The safety demonstration with respect to multiple failure situations and hazards is supported by probabilistic safety assessments. Possible links between internal and external hazards and single initiating events have also been considered.

Analyses of DEC-A events are performed using deterministic and probabilistic considerations and leads to the identification of additional safety features, with the intention of preventing the occurrence of a severe accident in these multiple-failure situations. The DEC-A studies lead to a list of sequences grouped according to functional characteristics, for which the core damage frequency is reduced by the implementation of these additional features. This list has been consolidated using Level 1 PSA studies. Specifically, the predicted Core Damage Frequency (CDF) for each DEC-A sequence is checked against probabilistic criteria.

The EPR design is supported by analyses of DEC-B events using deterministic and probabilistic considerations, and has led to the identification of additional safety features that are intended to mitigate the consequences of accidents that may lead to releases of radionuclides causing long-term off site contamination and practically eliminating early releases that cannot be dealt within the frame of an emergency response. The studies attempt to take into account the uncertainties due to the limited knowledge of complex physical phenomena involved in severe accidents.

In the following sections each key severe accident situation identified for the EPR design is presented together with a common position from the regulators and the associated EPR design objectives. The situations identified are severe accidents leading to high pressure core melt, low pressure core melt, global hydrogen detonations, in-vessel and ex-vessel steam explosions which

[4] The EPR PCCs are equivalent to the IAEA defined normal operation, anticipated operational occurrences and design basis accident sequences.
[5] The EPR defined RRC-A and RRC-B are equivalent to the IAEA DEC-A and DEC-B sequences; it can be noted that "practically eliminated" sequences are not systematically considered within DEC-B scenarios in each country.

threaten containment, as well as accidents leading to rapid reactivity insertion, containment by-pass, and damage to fuel in the spent fuel pool.

Situations related to Severe Accidents

Following the Fukushima Daiichi NPP accident, the regulators have already developed[6] the following common position with regards to severe accident analysis:

III. The regulators recognise that the generic EPR design includes measures to mitigate the consequences of severe accidents. The EPR design benefits from reinforced measures to prevent accident situations such as high pressure core melt, global hydrogen detonations and in-vessel and ex-vessel steam explosions, which would lead to large or early releases. Nevertheless, as some severe accident management systems rely on alternating current (AC) and direct current (DC) power, at least after a few hours, the regulators recognise the need to reinforce existing or proposed provisions to increase the time available before any cliff-edge effects. Due consideration to these cliff-edge effects is to be given while tailoring long term loss of electrical power mitigation strategies.

The EPR plant design has pursued a staged approach to the control of severe accidents with the objective of maintaining containment integrity. This aims at preventing any scenarios which have the potential to threaten the containment integrity early in an accident and thus result in an early release from the reactor building that cannot be dealt within the frame of an emergency response. This also aims at mitigating the consequences of core melt accidents to maintain the containment integrity in the long term.

Specifically, the EPR design addresses the following scenarios:

- High Pressure Core Melt Accident resulting in Direct Containment Heating (DCH);
- Steam explosions leading to failure of the containment (in-vessel and ex-vessel);
- Hydrogen combustion processes endangering containment integrity; and
- Low-pressure core melt scenarios.

This has given rise to the following EPR design objectives to:

- Convert high pressure core melt sequences into low pressure sequences with a high reliability so that high pressure core melt situations can be regarded as practically eliminated. For this reason the EPR design is provided with two depressurisation sets of valves on the Primary Depressurisation System (PDS) connected to the pressuriser (two sets in parallel, each with two valves in series). In addition, measures have been implemented on the design with the aim of limiting the dispersal of corium into the containment atmosphere in the event of a Reactor Pressure Vessel (RPV) failure in order to prevent direct containment heating. The design measures involve the design of the reactor pit and its ventilation system.
- Avoid the possibility of high energy in-vessel and ex-vessel steam explosions linked to core melt. In the case of in-vessel steam explosions, the design has taken into account analysis of in-vessel melt/water interaction considering the geometry of the lower core support plate, the

[6] Common Position addressing Fukushima Daiichi related issues, MDEP Design-Specific Common Position CP-EPRWG-02, Version 6, October 2015

vessel lower head and the downcomer and demonstrated that the reactor vessel can accommodate likely loads. In the case of ex-vessel steam explosions it is claimed that the amount of water that could be present in the reactor pit and spreading compartment prior to RPV failure has been limited by design.

- Prevent high concentrations of hydrogen within the containment through the large volume of the containment, design of containment internal compartments and the use of optimised placement of Passive Autocatalytic Re-combiners (PAR).
- Mitigate low pressure core melt scenarios by the provision of a core catcher designed to collect and spread the molten material outside the vessel which is then cooled by the In-containment Refuelling Water Storage Tank (IRWST) and operation of the Containment Heat Removal System (CHRS). The containment atmosphere temperature and pressure is also maintained by the operation of CHRS.
- Mitigate against high pressure within the containment in case of extended loss of AC power and loss of ultimate heat sink. The EPR design generally provides measures to manage the consequences.

The different solutions proposed are deemed as safety improvements to address severe accident situations.

Situation related to Rapid Reactivity Insertion

IV. *The regulators recognise the importance of ensuring that adequate protection is provided for rapid reactivity insertion fault sequences. They also recognise that the complex simulation computer analysis that supports the safety justifications of these faults (particularly for the intrinsic heterogeneous boron dilution fault) needs to be adequately validated. The participating members believe that the rapid reactivity insertion due to boron dilution resulting from a small break LOCA is of significant safety importance[7]. The participating countries also consider that the EPR design is supported by analysis of relevant phenomena such as mixing in the downcomer and lower plenum, loop seal clearance and natural circulation initiation post LOCA, which are important to demonstrate adequate safety margin. However, given the importance of experimental validation for boron dilution analyses, the participating countries consider that it is therefore beneficial to perform additional uncertainty evaluation analysis in the light of results from the Primaer KreisLauf (PKL) experiments, to demonstrate adequate safety margin to the EPR design for such conditions.*

In a typical PWR design potential for external and intrinsic heterogeneous boron dilution faults exist, that may result in an uncontrolled rapid reactivity insertion. The EPR design has recognised the potential for this sequence to occur. In the case of external heterogeneous boron dilution faults, the EPR design objective is to ensure that a maximum slug size cannot be exceeded to prevent re-criticality, the EPR being equipped with dedicated instrumentation. In the case of intrinsic heterogeneous boron dilution, the dilution mechanism can occur in certain accident situations such as small break Loss of Coolant Accident (LOCA) and requires further analysis with the objective of demonstrating adequate safety margins.

[7] *A common position on the adequacy of the analysis of inherent heterogeneous boron dilution faults on the EPR is being developed.*

Situations related to Containment Bypass

V. *The regulators recognise that the generic EPR design has attempted to systematically identify those fault sequences that lead to containment bypass and has provided mitigation to protect against the consequences of these sequences. In particular, it is recognised that the design has provided protection to ensure that Steam Generator Tube Rupture (SGTR) faults with the potential to result in core damage and containment bypass are automatically detected and isolated. This is a considerable improvement on the previous generation of PWRs which generally require operator action to isolate the affected steam generator.*

The EPR design objective is to identify accidents with core damage involving bypassing of the containment and to ensure adequate design provision is made to ensure reliable isolation of the affected steam generator and the prevention of piping failures. These situations involve LOCA faults with the potential to lead directly to containment by-pass through interfacing systems with the reactor cooling system. The EPR design considers consequential SGTR faults following a steamline break, SGTR faults with failure of safety valves to reclose, failure of the safety injection lines in accident conditions. The EPR design has proposed an updated mitigation strategy aimed at demonstrating a reduction of the radiological risk from SGTR faults and has made progress against the detection and management of SGTR faults that may potentially lead to containment by-pass in PCC scenarios. In addition, the EPR design has addressed containment bypass that could potentially be induced by severe accident sequences such as single or multiple SGTR failures induced by core damage or breaks in lines connected to the primary system, or the thermal seals on the main reactor coolant pumps, resulting in design improvements. .

Situations related to Fuel Damage in the Spent Fuel Pool

VI. *Following the Fukushima Daiichi NPP accident, the regulators recognise that additional improvements such as provision of mobile equipment have been incorporated to the spent fuel pool water make-up system of the EPR design in extreme external events including Station Black-Out (SBO) sequences. In addition the spent fuel pool water level indication has been implemented to give operators monitoring capability to inform emergency procedures. The regulators have already developed*[8] *a common position with regards to spent fuel pool accidents.*

The EPR design objective is to prevent the total loss of cooling to the Spent Fuel Pool (SFP) and to maintain SFP water inventory recognising that the SFP is not located in the containment building. The design of the EPR reactor includes safety improvements as regards the prevention and control of SFP draining accidents. The SFP is located in an aircraft protective shell. The reactor and fuel buildings are also built on a common foundation slab, reducing the risk of differential movement of these buildings and limiting the forces exerted on the transfer tube in the event of an earthquake.

The EPR SFP design incorporates a redundant cooling system to remove the decay heat (Fuel Pool Cooling System). Each independent and physically separate train has two pumps, each providing 100% of the circulation nominal flow, and a water make-up system to maintain adequate cooling capability to the SFP during faulted scenarios, as appropriate.

[8] Common Position addressing Fukushima Daiichi related issues, MDEP Design-Specific Common Position CP-EPRWG-02, Version 6, October 2015

In addition to the SFP cooling systems, the EPR design incorporates additional Structures Systems and Components (SSC) or dedicated procedures to cope with the effects of extreme external events to maintain the water coverage of the stored spent fuel such as earthquakes, tornados, hurricanes, floods, tsunamis and seiches.

This completes the Common Position covering the Vienna Declaration on Nuclear Safety.