Multinational Design Evaluation Programme (MDEP) Design-Specific Common Position

CP-HPR1000WG-02

HPR1000 Working Group

Common Position of the IRWST Strainer Performance and Downstream Effects of HPR1000 after LOCA

Participation

Regulators involved in the MDEP working group discussions:	ARN (Argentina), NNSA (China), NNR (South Africa), ONR (UK)
Regulators which support the present common position:	ARN (Argentina), NNSA (China), NNR (South Africa), ONR (UK)
Regulators with no objection:	none
Regulators which disagree:	none

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COMMON POSITION OF THE IRWST STRAINER PERFORMANCE AND DOWNSTREAM EFFECTS OF HPR1000 AFTER LOCA

1 Purpose

MDEP is a multilateral nuclear safety cooperation mechanism involving the nuclear safety regulatory agencies of major international nuclear energy countries and aiming at promoting the coordination of safety requirements and regulatory practices among countries in the design, construction, and commissioning of new nuclear power plants.

MDEP HPR1000 working group was established in September 2017 at the initiative of China. The editing of "Common Position of The IRWST Strainer Performance and Downstream Effects of HPR1000 after LOCA", as a response to the work plan of the Steering Technical Committee (STC) for reaching MDEP consensus, is an important task of this working group. The common position aims at:

1 Improving the knowledge and understanding of the issues related to IRWST strainer among the member states of the MDEP HPR1000 working group (Argentina, China, South Africa and The United Kingdom).

2 Determining the regulatory expectations regarding the IRWST strainer performance and downstream effects of HPR1000 after LOCA.

3 Reducing the risk of excessive blockage of the IRWST strainer and ensuring core cooling.

2 Background

For some PWR nuclear power plants, the containment sump strainer is specially designed to ensure the safety functions of emergency core cooling and containment heat removal in the long-term after LOCA. Debris, foreign materials and other debris generated during the LOCA process or already existing in the containment before the accident are transported to the containment sump strainer and reactor core.

Debris could also be generated in the main steam line break accident of PWR, however, it is enveloped by the debris source items of LOCA and thus the debris source items of LOCA are detailed in this common position.

The following potential safety risks during the long-term recirculation cooling phase of PWR are prevalent, or exist:

1 The debris transported to the containment sump strainer will cause excessive blockage on the strainer and affect the operability of ECCS and containment heat removal system, i.e. reduce the net positive suction head (NPSH) at the inlet of pumps.

2 The adverse effects on downstream devices including pumps, valves, and reactor core, such as blockage, wear, or obstruction of heat transfer.

The early design of the PWR is usually evaluated and analysed based on the assumption that the blockage rate of the sump strainer is 50%. Due to the designers' insufficient understanding of the potential safety risks in the long-term recirculation cooling phase after LOCA, the problem of excessive blockage of sump strainer in the design of the emergency core cooling system and the containment heat removal system has been gradually exposed in the operational phase later operation of PWR. Since the serious consequences of this problem to the safety of nuclear power plants were realised, the problem of containment sump strainer blockage has become a common concern in the international nuclear power community.

3. Discussions

Regarding the problem of the internal refuelling water storage tank (IRWST) strainer blockage, the use of relevant in-containment materials which can generate the debris are restricted in order to reduce the amount of debris reaching the IRWST strainer and the reactor core, as well as improving the filtration capacity of the IRWST strainer. The performance of the IRWST strainer is evaluated to ensure the safety function of long-term core cooling. This is also the international common practice.

HPR1000 has taken the following measures to reduce the risk of excessive blockage of the IRWST strainer and loss of long-term core cooling :

1 For the aspect of the use of relevant in-containment materials that can generate debris source items, HPR1000 restricts the generation and transport of debris through the selection of thermal insulation materials in the containment, such as using RMI as thermal insulation material. Certified coatings are used to reduce the amount of debris generated by jet impact and in accident environmental conditions after LOCA. The generation of chemical deposits is reduced in the design such as restricting the use of aluminum-containing materials. A high level of cleanliness in the containment is maintained by management to limit the amount of potential debris. Through the above measures and methods, as well as the intercepting measures on the debris transport path, the excessive blockage of the IRWST strainer caused by the debris generated after LOCA can be prevented, and the adverse effect on the long-term core cooling can be reduced.

2 For the aspect of evaluating the performance of the IRWST strainer to fulfil relevant nuclear safety function, the challenges caused by debris to the IRWST strainer and long-term core cooling cannot be completely eliminated despite the above-mentioned control of relevant materials that can produce debris. The fluid ejected from the breach can wash away the debris, and some debris will enter the IRWST. The accumulation of the debris and the chemical deposits on the IRWST strainer will reduce the effective net positive suction head (NPSH) of the ECCS pump. The debris passing through the strainer will adversely affect the functions of downstream pumps, valves and other equipment. The accumulation of the debris in the core active area may adversely affect the long-term core cooling. The designer of HPR1000 is expected to demonstrate that the performance of equipment and the capacity of core cooling can be ensured via experiments and/or analytic methods.

a Upstream Analysis

Based on the failure characteristics of the in-containment debris sources, combined with the consideration of different positions of breach, the debris is categorised, counted and analysed. The categories, compositions, characteristics and total amount of the debris reaching the IRWST strainer are acquired. The enveloping debris amount is retained as the input for the following analytic calculations and experiments.

b Head Loss Test of Strainer

The head loss test of strainer should be carried out on the proper scaled prototype of IRWST strainer. Through the head loss test, combined with the calculation results of the flow path resistance of the confluence groove, it is verified whether the head loss caused by the accumulation of debris on the strainer meets the design limit of the system function.

c Chemical Effects Test

The chemical effects test should be carried out to evaluate the impact of new chemical product generated in the chemical reactions among debris in high temperature water environment on the head loss of strainer.

d Analysis of Downstream In-vessel Effects

The impact of the blockage at core inlet on the long-term core cooling and the risk of the debris and chemical deposits adhered to the fuel assemblies or accumulated at the structure interval of fuel assemblies to damage the fuel cladding integrity should be evaluated via proper experiments and/or theoretic analysis.

e Analysis of Downstream Ex-vessel Effects

It should be evaluated via analytical methods that the malfunction of safety system caused by the tiny debris (fibres, particles) and chemical product through the IRWST strainer will not occur, such as the blocking and wearing of downstream pumps, valves, heat exchangers, orifices etc.

4 Regulatory positions of member states

Argentina

According to ARN experience, the main safety concerns about long-term recirculation cooling following a LOCA are LOCA-generated and pre-LOCA debris materials transported to the emergency core cooling strainers, the containment spray system (CSS), and the reactor core, resulting in adverse heat transfer, blockage, or wear effects or some combination of all three effects.

ARN's expectation in this regard, is that the HPR-1000's Licensee evaluates debris generation, debris transport, upstream and downstream effects, and attendant blockage of emergency core cooling strainers to ensure that they do not jeopardise the ability of the system to provide long-term, post-LOCA core cooling.

The plant's potential debris sources must be justified and further evaluated. These sources may include, but not limited to, insulation materials (e.g., fibrous, particulate, and metallic), fire barrier materials, filters and other fiber-bearing materials, latent debris, shielding blankets, corrosion products, chemically reactive materials and their reaction products, and paints or coatings.

ARN agrees that the practice to replace fibrous thermal insulation materials with RMI in any ZOI (zone of influence) reduce the impact of the debris source upon the strainer performance. However evaluation of HPR-1000 strainer performance must be broader demonstrated including break selection, debris characteristics, debris transport, net positive suction head (NPSH), upstream effects, etc.

China

China's nuclear safety regulations require that in the LOCA, debris generated by the LOCA impact should be reduced to avoid excessive blockage of debris on the sump strainer, and excessive accumulation of debris passing through the strainer into the core active area, which could adversely affect the long-term core cooling and to ensure the heat removal capability of the core and containment.

NNSA considers the containment sump strainer as a very important nuclear safety issue, and it is critical to the control of related materials that can generate in-containment debris source items. RMI should be used as in-containment thermal insulation materials, only certified coatings are allowed to be used and the use of aluminum-containing materials is limited. The licensee is also recommended to reduce the in-containment amount of debris that migrates to the strainer and enters the core by maintaining a high level of in-containment cleanliness to limit the potential debris amount.

However, NNSA believes that the above measures cannot eliminate the generation of in-containment debris and its adverse effects completely.

Therefore, the licensee of HPR1000 are required to demonstrate that the NPSH margins of the pumps and the capacity of long-term core cooling can be ensured from the aspects of sump strainer performance, downstream effects and reliable heat removal from the core via experiments and analytic methods, so as to meet relevant nuclear safety requirements.

South Africa

NNR considers the selection of materials related to debris generation after LOCA in-containment as an important consideration in determining the source items of debris, for improving the post-LOCA strainer performance and for minimising adverse downstream effects in-vessel after LOCA.

In addition to controlling materials that can generate debris source items in the containment, examples of further measures that could be considered are:

- When considering the layout and configuration of the containment, the minimisation of water retention in-containment to facilitate water and condensates flowing back to the containment sumps.

- For a spray system designed to operate in a recirculation mode, the spray nozzles should be designed to prevent clogging by pieces of debris that can reach them through the intake screens and filters.
- A cleaning system for the filters should be installed, taking into account the large uncertainties about the types and amount of debris that could clog the filters.

The reduction of the risk of excessive blockage of the IRWST strainer and of loss of long-term core cooling must be demonstrated by experiments and analytic methods.

United Kingdom

In the UK there is a legal requirement to reduce risks so far is reasonably practicable. ONR agrees that to reduce the risks associated with debris in the IRWST during accidents the focus should be on the selection of in-containment materials. The UK Requesting Party for GDA has modified the generic UK HPR1000 design to replace all in-containment fibrous insulation with Reflective Metallic Insulation, progressing a "zero fibre" philosophy. Although the "zero fibre" approach does not completely eliminate the risks associated with blocking the strainer or downstream effects, ONR considers that the significant safety benefits for a new reactor design are apparent. Further work is required to develop qualification testing associated with containment debris and the filtration system and to understand the implications of the design choice on other factors (e.g. chemistry effects). Much of this work can only be performed once detailed design of the insulation and cable tray wrapping is complete.

5 Common positions

HPR1000 relies on ECCS to maintain emergency core cooling and the in-containment materials that can generate debris (thermal insulation materials, coatings, aluminum-containing materials and potential debris, etc.) have impact on the design of strainer and core cooling. Based on the high level of regulatory requirements and the consideration of the design characteristics of HPR1000, the Member States of the HPR1000 Working Group have developed the common positions on the selection of the in-containment materials and the performance requirements of the IRWST strainer.

1. Based on the regulatory practices of the Member States, it is agreed that the selection of in-containment materials is the primary factor in solving the issue of the IRWST strainer blockage, and the amount of debris that transport to the strainer and vessel should be reduced as much as possible.
   a. Thermal insulation material. Thermal insulation material debris will be generated by the impact of the jet fluid in LOCA. Therefore, insulation materials that can reduce the generation and transport of debris should be used as far as possible in the containment. Due to high density, it is not easy for RMI debris to transport to the strainer. The use of RMI can effectively reduce the amount of debris transported to the strainer after LOCA.

b Coating materials. Due to impact or accidental conditions after LOCA, the coating materials may fall off and form debris. Qualified coatings shall be used in the containment to reduce the generation of coating debris.

c Aluminum-containing materials. After LOCA, the aluminum-containing materials will be sprayed or immersed by alkaline solution, and the chemical reactions will produce chemical deposits. The use of aluminum-containing materials in the containment should be limited. It is a good practice to replace the aluminum-containing equipment nameplates in the containment with that aluminum free.

d Potential debris. The potential debris refers to the dust and foreign matters in-containment. The licensee is recommended to limit the amount of potential debris by maintaining a high level of in-containment cleanliness and removing the foreign matters left in the construction and maintenance process.

1 Although the above requirements can significantly reduce the amount of debris generated in the containment after LOCA, but the in-containment debris cannot be eliminated completely.

Therefore, tests and analysis including upstream analysis, head loss tests of strainer, chemical effects tests and analysis of downstream in-vessel and ex-vessel effects are needed to demonstrate that the NPSH of ECCS pumps and the capacity of core cooling are ensured.

a Analyse the source items of in-containment debris after LOCA and determine the amount of debris transported to the strainer conservatively.

b Ensure proper NPSH for ECCS pumps by ensuring adequate filtering area of strainer and determining the maximum head loss of strainer by tests.

c Demonstrate that downstream equipment such as ECCS pumps, heat exchangers are still capable of fulfilling their functions under the influence of bypass debris.

d Perform the head loss analysis of fuel assemblies and evaluate the impact on the core heat removal because of the accumulation on the fuel assemblies for the debris passing through the strainers.

Contributors to drafting and review

Chai Guohan	NNSA, China
Yang Peng	NNSA, China
Liu Zejun	NNSA, China
Li Juan	NNSA, China
Zhao Danni	NNSA, China
Robert Whitham	ONR, UK
Mark Drummond	ONR, UK
Aidan Parkes	ONR, UK
Jean Joubert	NNR, South Africa
Adriana Politi	ARN, Argentina