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MDEP Common Position CP-EPRWG-05

Related to: EPR Working Group activities

COMMON POSITION ON IRWST pH CONTROL IN ACCIDENT CONDITIONS

Participation

Countries involved in the MDEP working group discussions:	China, France, Finland, the United Kingdom and the United States
Countries which support the present common position	China, France, Finland, the United Kingdom, and the United States
Countries with no objection:	India, Sweden
Countries which disagree	
Compatible with existing IAEA related documents	

IRWST pH control in Accident Conditions

Summary

- **General expectations regarding containment integrity**
- **Main EPR design characteristics**
- **EPR Common Position**
- **Appendix 1: IRWST pH control in Accident Conditions - Finland**
- **Appendix 2: IRWST pH control in Accident Conditions - France**
- **Appendix 3: IRWST pH control in Accident Conditions - UK**
- **Appendix 4: IRWST pH control in Accident Conditions - USA**
- **Appendix 5: IRWST pH control in Accident Conditions - China**

General expectations regarding reduction of radioactive releases in case of a severe accident

The importance of the integrity of the containment as a fundamental barrier to protect the people and environment against the effects of a nuclear accident is well established. In this regard, an essential objective is that the necessity for off-site counter-measures to reduce radiological consequences be limited or even eliminated. The design should provide engineering means to address those sequences which would otherwise lead to large or early releases[1], even in case of severe external hazards.

The plant shall be designed so that it can be brought into a controlled and stable state and the containment function can be maintained, under accident conditions in which there is a significant amount of radioactive material in the containment, i.e. resulting from severe degradation of the reactor core.

In order to reduce the release of radioactive substances, the regulators believe that the primary means should rely on provisions to minimise the amount of fission products in the containment atmosphere and to reduce the pressure inside the containment.

Main EPR design characteristics

All EPR designs include measures to prevent and mitigate the consequences of severe accidents. The EPR design includes measures to prevent accident situations such as high pressure core melt, global hydrogen detonations and ex-vessel steam explosions, containment bypass which would lead to large or early releases. The EPR design is equipped with a core catcher, aiming to stabilize the situation in case of vessel melt-through. The containment is designed to withstand a global hydrogen combustion taking into account the implementation of hydrogen recombiners that limit the hydrogen risk. The containment heat removal system (CHRS) / severe accident heat removal system (SAHRS) is the primary mean, under severe accident conditions, of drawing heat from the containment and maintaining the pressure inside within the design limits.

The in-containment refuelling water storage tank (IRWST) of EPR is used as a source of borated water to the reactor plant. In accident conditions, the IRWST water can be used to remove heat from the reactor core using CHRS/SAHRS.

[1] **"Large radioactive release"**: a release for which off-site protective measures limited in terms of times and areas of application are insufficient to protect people and the environment. **"Early radioactive release"**: release for which off-site protective measures are necessary but are unlikely to be fully effective in due time

During an accident, the role of pH control in the IRWST is to reduce the risk of further corrosion damage to reactor components, and significantly reduce the gaseous iodine release from the IRWST water pool to the containment atmosphere.

A number of diverse IRWST pH control strategies are employed for different EPR plants:

- Active addition of Sodium Hydroxide in IRWST water (France, UK) designed for all accident situations (even in case of SBO),
- Passive addition of Tri-Sodium Phosphate (TSP) in IRWST (US) designed for DBA,
- No provisions for IRWST pH control (Finland). However, increased pH (alkaline pH) is applied in the filtered containment venting system of the Finnish EPR design.

The following common position addresses the IRWST pH control.

EPR Common Position

The existing research has concluded that a high IRWST pH is likely to lead to lower radiological consequences than that with an acidic pH.

The regulators acknowledge that maintaining an alkaline pH of IRWST water results in one to two decades' reduction of gaseous iodine concentration in the containment atmosphere in accident conditions.

The regulators have also noted that in case of station blackout (SBO), consideration could be given to other features to maintaining the pH of the IRWST water alkaline, where appropriate.

The regulators note that the choice to implement provisions for an alkaline IRWST pH results from different regulatory requirements.

Appendix 1
IRWST pH control in Accident Conditions

FINLAND

Summary

1. Glossary

IRWST: In-containment Refueling Water Storage Tank

LOCA: Loss Of Coolant Accident

LBLOCA: Large break LOCA

SBLOCA: Small Break LOCA

LOOP: Loss Of Offsite Power

MELCOR: An integral computer code developed by Sandia National Laboratories for severe accident analyses

YVL: the current Finnish Regulatory Guides

2. Regulatory requirements

There are no explicit requirements for accident pH control in the Finnish legislation. The requirements are only set for doses (anticipated transients, Design basis accidents) or releases (severe accidents). The most important severe accident requirements are given in the Government Decree on the Safety of Nuclear Power Plants (717/2013), Section 10:

> *"The release of radioactive materials arising from a severe accident shall not necessitate large scale protective measures for the population nor any long-term restrictions on the use of extensive areas of land and water. In order to limit the long term effects, the limit for atmospheric releases of cesium-137 is 100 terabecquerel (TBq). The possibility of exceeding the set limit shall be extremely small."*

The STUK Regulatory Guide on deterministic safety analyses (YVL B.3) further requires that "*Part of the iodine, which is released to the airspace, shall be assumed to be in inorganic and part in organic compounds. The distribution into the various types of compounds shall be justified.*"

3. Design

There is no pH control designed for accidents in the Olkiluoto 3 containment. However, increased pH is applied in the containment filtered venting system. The filtered venting system consists of a venturi section (pool of liquid), and of a metal fibre filter section within a vessel.

The vendor has estimated evolution of the pH in the IRWST in some severe accident scenarios (LBLOCA, SBLOCA, LOOP). The pH value after activation of CHRS (IRWST water mixed) is estimated 6.3.

STUK has conducted an independent analysis of the containment pH evolution. The analysis was done by the Technical Research Centre of Finland (VTT) by using the ChemPool tool. Boundary conditions (pressure, pool and atmosphere temperatures) were taken from MELCOR analyses. LBLOCA and LOOP scenarios were investigated. In both scenarios, severe accident systems including SBO diesels were assumed available. pH in the IRWST water stabilised in the long term to about six on both analysed cases. Figure 1.1 shows the pH evolution in the LOOP case.

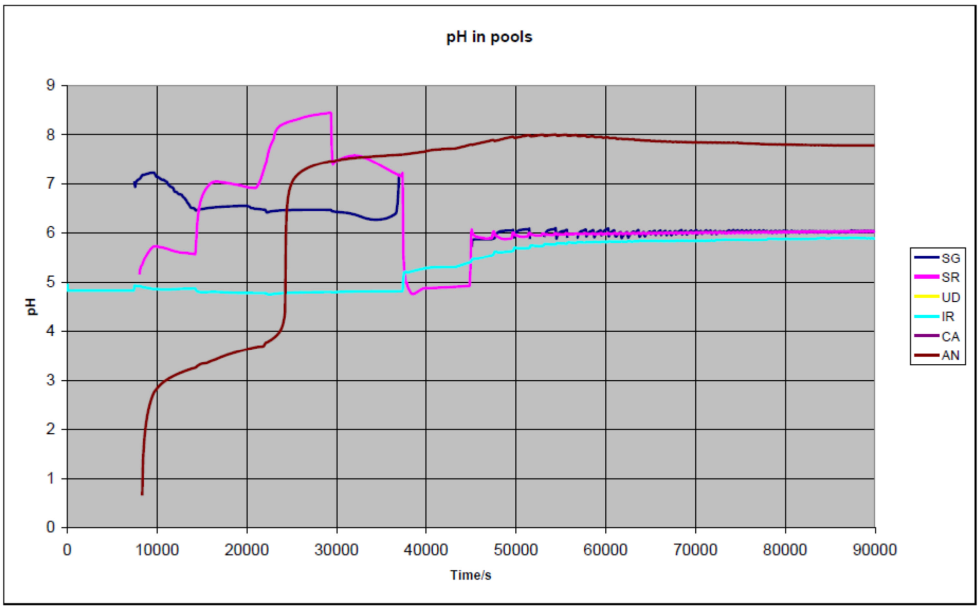


Figure 1.1. pH evolution in containment pools in LOOP. VTT Calculations.
SG = steam generator compartment; SR = spreading room;
UD = upper dome (no pools); IR = IRWST;
CA = reactor cavity (no pools); AN = annulus

The initial pH in IRWST is about five due to boric acid. The pH of the IRWST pool increases then slowly to about six due to cesium accumulation into the pool and formation of CsOH.

Releases of radioactive species remained small (< 2 TBq I-131; < 0.002 TBq Cs-137) in the vendor and VTT analyses for the LBLOCA and LOOP scenarios with and without containment annulus ventilation.

4. Compliance with the regulatory requirements and Safety Authority position

pH control during accident is not required by the Finnish legislation. Therefore the Olkiluoto 3 design has been accepted without this feature.

The current Finnish Regulatory Guides (so-called YVL Guides) explicitly specify a release limit in severe accidents for Cs-137 only. Release of noble gases and iodine are limited by the requirement considering protective measures.

As the release limits have been met, there has not been need for further reduction of releases of volatile iodine species. Furthermore, the presence of pH additives in the IRWST would require evaluation of the risk for sump strainer clogging.

5. Post-Fukushima considerations

STUK has recently updated the YVL Guides to fulfil the new Government Decree 717/2013, Section 10:

> *"The radioactive release arising from a severe accident shall not result in need for extensive protective actions for the public to protect the public nor long-term restrictions on the use of extensive areas of land and water."*
>
> *"To limit long-term effects, the limit for atmospheric release of cesium-137 is set to 100 terabecquerel. The possibility to exceed this limit shall be extremely small."*
>
> *"The possibility for such a release to occur, that would require protective actions for the public in the early phase of an accident, shall be extremely small."*

This is further clarified in Guide YVL A.7 (Req. 306):

> *"Such accident sequences, in which the atmospheric release of cesium-137 exceeds 100 TBq, shall have the expectation value of the total frequency of less than 5.10^{-7}/yr."*
>
> *"Such severe accident sequences, in which the containment function is lost at the early phase of the accident, shall contribute a small fraction to the total core damage frequency."*

and in Guide YVL C.3 (Req. 310):

> *"The design of the nuclear power plant shall show that the releases arising from a severe accident do not require evacuation beyond the precautionary action zone* [5 km in Finland] *and sheltering beyond the urgent protective action planning zone*

> [20 km in Finland]*, and that the release of Cs-137 remains below the set limit* [of 100 TBq]*.”*

The updated YVL Guides, however, do not have an explicit requirement for containment pH control.

Appendix 2

IRWST pH control in Accident Conditions

FRANCE

Summary

1. Glossary

CHRS: Containment Heat Removal System

EDF: Electricité de France

EOPs: Emergency Operating Procedures

F1 function: is F1A or F1B function

F1A function: all safety functions, including supporting functions, needed to reach the controlled state after any internal events PCC-2 to PCC-4.

F1B function: all safety functions needed beyond achievement of the controlled state to reach the safe shutdown state, and to maintain it after any internal events PCC-2 to PCC-4.

FA3: Flamanville 3

IRSN: Institut de Radioprotection et de Sûreté Nucléaire

IRWST: In-containment Refueling Water Storage Tank

LHSI: Low Head Safety Injection

LOCA: Loss Of Coolant Accident ; LOOP: Loss Of Offsite Power

MIV: Motorized Isolation Valve

OSSAs: Operating Strategies for Severe Accidents

PCC: Plant Condition Category 1 to 4 (design basis accident)

PSA: Probabilistic Safety Assessment

RCS: Reactor Coolant System

SBO: Station Black-Out

SIS: Safety Injection System

TG: Technical Guidelines

TSO: Technical Safety Organization

2. Regulatory requirements

In France, the regulatory requirements for the EPR reactor are mainly contained in a document called "*Technical guidelines for the design and construction of the next generation of nuclear power plants*" (TG).

The TG outlines in particular the following objectives about severe accident for low pressure core melt sequence: "*low pressure core melt sequences have to be dealt with so that the associated maximum conceivable releases would necessitate only very limited protective measures in area and in time for the public. This would be expressed by no permanent relocation, no need for emergency evacuation outside the immediate vicinity of the plant, limited sheltering, no long term restrictions in consumption of food*".

3. Design

Goals

The IRWST water pH control is part of the strategies used to reduce the release of radioactive substances. Indeed, the NaOH injection into the IRWST water ensures an alkaline pH of this water reducing the production and the release of gaseous iodine from IRWST to the containment atmosphere. The IRWST pH control function belongs to CHRS.

During a LOCA (PCC-4), the LHSI pumps allow NaOH injection into the IRWST water via the RCS breach.

During a severe accident, dedicated pumps allow direct NaOH injection in the IRWST water.

Situations to cope with

In case of a LOCA (PCC-4), NaOH is injected into the IRWST water via the RCS breach, by the LHSI pumps using a connection with the CHRS system and after manual opening of a dedicated valve by an auxiliary operator followed by the opening of the MIVs from the control room.
In case of severe accident, NaOH is injected directly into the IRSWT water using dedicated pumps.

IRWST water pH target

In case of a LOCA (PCC-4), the target is to reach a minimum IRWST water pH of 7 at 100°C (373 K). The NaOH injection function consists of two 100 % separated trains each one connected to a separate NaOH tank. The NaOH injection using one injection train (i.e. one NaOH tank) allows to fulfill the IRWST water pH target.

In case of a severe accident, the target is to reach a minimum IRWST water pH of 7.5 at 70°C (343 K). The NaOH injection function consists of two 50 % separated trains each one connected to a separate NaOH tank. The NaOH injection using two injection trains allows to fulfill the IRWST water pH target.

Single failure criterion

In case of a LOCA (PCC-4), for components performing F1 functions, as the NaOH injection, the single failure criterion must be postulated in order to ensure a sufficient degree of redundancy.

In case of severe accident, the single failure criterion is not applied.

Emergency-supplied power supplies

In case of a LOCA (PCC-4), the NaOH MIVs connected to the LHSI pumps are power supplied by two separate electrical divisions. In case of LOOP, all those components are emergency power supplied by the main diesel generators.

In case of severe accident, the specific pumps used to inject NaOH into the IRWST water are power supplied by two separate electrical divisions. In case of LOOP, all those components are emergency power supplied by the main diesel generators. In case of loss of the main diesel generators, the dedicated pumps are power supplied by two ultimate emergency diesels generators. In case of loss of the two ultimate emergency diesels generators, the dedicated pumps are power supplied by the 12 h batteries using the severe accident I&C.

4. Compliance with the regulatory requirements and Safety authority (or TSO) position

Questioned about the justification of the target pH of 7.5 at 70°C of the IRWST water during a severe accident, the answer was that if pH is controlled and maintained at 7 or more, a weak quantity of dissolved iodine (less than 1%) will be converted into gaseous iodine. The target pH during a severe accident is consequently justified to be 7.5 at 70°C because:

- the neutral pH decreasing with the water temperature increase, a pH target of 7.5 at 70°C is conservative,
- the margin between the pH target of 7.5 and a pH of 7 allows to take into account the effect of acidic species that may be created during the severe accident.

Questioned about the relevance to use two 50 % separated trains to perform the NaOH injection system in case of severe accident, the answer was that, complementary to the fact that the single failure criterion is not required in severe accident, pH calculations using only one NaOH tank show also an alkaline pH.

The review of FA3 CHRS is still ongoing (the NaOH injection function belongs to CHRS) and the French Safety Authority has not taken its position. Such position is expected beginning 2016.

5. Post Fukushima considerations

Compared to the original design, in order to also ensure an alkaline IRWST water in case of severe accident with station black-out independently of the recovery time for power supply, EDF has decided, for each CHRS train, to add a line allowing the direct NaOH injection in the IRWST by means of a pump power supplied by the 12 h batteries using the severe accident I&C.

Appendix 3

IRWST pH control in Accident Conditions

UK

Summary

1. Glossary

ALARP – As Low As Reasonably Practicable

FA3 – Flamanville 3

GDA – Generic Design Assessment

HSE – Health and Safety Executive

HSWA – Health and Safety at Work Act (1974)

IRWST – In-containment Refuelling Water Storage Tank

LOCA – Loss of Coolant Accident

NIA – Nuclear Installations Act (1965)

ONR – Office for Nuclear Regulation

PCSR – Pre-Construction Safety Report

SAP – Safety Assessment Principle

SFAIRP – So Far As Is Reasonably Practicable

SIS – Safety Injection System

TAG – Technical Assessment Guide

2. Regulatory Requirements

There are no specific requirements related to pH control in accident situation in the UK.

The UK regulatory regime is “goal setting, none prescriptive” and therefore the fundamental regulatory requirement is to ensure that risks are reduced "As Low As is Reasonably Practicable" (ALARP).

The Health and Safety at Work etc. Act 1974 [HSWA] is the basic legal requirement concerning health and safety related to work activities in the UK. Other legislation such as the Nuclear Installations Act 1965 (as amended) [NIA] are subordinate to it. The HSWA places duties on employers to ensure the health, safety and welfare of their employees (Section 2) and to conduct their operations so that persons not in their employment are not exposed to risks to their health and safety (Section 3). The employer is required to ensure that these duties are met "so far as is reasonably practicable". This principle, abbreviated to SFAIRP, is therefore the basic legal requirement to which an employer needs to conform. ALARP and SFAIRP require the same tests to be applied and are effectively the same thing.

The Office for Nuclear Regulation (ONR) is responsible for judging whether measures put in place or proposed, by those who are under a duty to control and reduce risks ALARP, are acceptable.

The ONR Safety Assessment Principles (SAPs) provide ONR inspectors with a framework for making consistent regulatory judgements on nuclear safety cases. The principles are supported by Technical Assessment Guides (TAGs), and other guidance, to further assist decision making by the nuclear safety regulatory process. The SAPs also provide nuclear site duty holders with information on the regulatory principles against which their safety provisions will be judged. However, they are not intended or sufficient to be used as design or operational standards, reflecting the non-prescriptive nature of the UK's nuclear regulatory system. In most cases the SAPs are guidance to inspectors, but where guidance refers to legal requirements they can be mandatory depending on the circumstances.

The SAPs describe the numerical targets and legal limits that ONR inspectors should use when judging whether the duty holder is controlling radiological hazards adequately and reducing risks ALARP. The targets and legal limits are defined for normal operations, design basis analysis, individual risk and societal risk. The targets are not mandatory, but in some circumstances may be legal limits. The targets are guides to ONR inspectors to indicate where there is the need for consideration of additional safety measures.

3. Design

The Containment Heat Removal System (CHRS) is described in the Pre-Construction Safety Report (PCSR). The CHRS is used to control the containment pressure and achieve long-term cooling of the IRWST and the molten corium in the spreading compartment. The CHRS also provides a function to scrub fission products from the containment atmosphere. Two trains of CHRS are included in the UK EPR design, both taking supply from the IRWST. Each train consists of a pump and heat exchanger (cooled by a dedicated cooling system) which supply the dome spray system (when operated to remove FPs) or two other outlets can be used, depending on the accident conditions. In all cases the water is returned to the IRWST.

In postulated accidents, the pH of the IRWST directly affects the retention of inorganic and elemental forms of iodine. The UK EPR CHRS includes a sodium hydroxide injection circuit for this purpose (two trains of equipment). Each train consists of an atmospheric pressure sodium hydroxide tank, a venting line, a sodium hydroxide mixing device and three injection lines; two directed towards the Safety Injection System (SIS) and one towards the CHRS downstream of the main pump.

The CHRS is described in the (PCSR) which gives one of the safety functions of the CHRS as:

- The CHRS contributes towards minimising the production of volatile iodine within the containment atmosphere from the liquid phase by means of sodium hydroxide injection in the IRWST during a Loss of Coolant Accident (LOCA) via the SIS or during a severe accident via the CHRS. The target is to obtain an alkaline pH of the In-containment Refuelling Water Storage Tank (IRWST).

This sodium hydroxide injection is intended to bring the pH value of the IRWST water to a minimum value of 7.5 at a temperature of 70°C.

Whether during a LOCA or a severe accident, the sodium hydroxide injection must be started by lining up the necessary tank via a series of manual and automatic valves.

For LOCAs the injection via SIS corresponds to two 100% trains. One train is required to reach the target pH.

For severe accidents injection via the CHRS corresponds to two 50% trains. Both trains are required to meet the target pH.

4. Compliance with the regulatory requirements and Safety Authority position

ONR have considered the CHRS and pH control in the IRWST during accident conditions as part of the Generic Design Assessment (GDA) for UK EPR in both the severe accident and chemistry technical areas.

It is worth noting that site specific radiological consequence assessments were not part of GDA and will be required from the Licensee for each UK EPR. EDF and AREVA provided bounding estimates as part of GDA.

The chemistry assessment considered whether the pH control provided by the UK EPR approach was adequate to maintain an alkaline pH in the IRWST. The quantity of alkali should be sufficient to counteract all the boric acid within containment. However other acidic gases can be produced through pyrolysis and radiolysis in some circumstances. ONR requested quantification of this effect. EDF and AREVA responded by providing their calculations which didn’t include alkaline compounds of lithium and caesium hydroxides, that should cancel out any acidic products. Overall, EDF and AREVA did not provide adequate assurance of the thermodynamic data and production rate of acids and fumes in the containment by pyrolysis or radiolysis. They also stated that ignoring these effects tended to cancel the un-quantified effects of alkaline fission products on iodine chemistry of the In-Reactor Water Storage Tank. ONR considered this response to be inadequate and raised an Assessment Finding to provide this information:

- AF-UKEPR-RC-50 - Estimate the quantities of all possible chemical species that could degrade the performance of the IRWST and analyse their downstream effects on cooling and radioactive release. Possible sources from different events include; acidic fumes from radiolysis or pyrolysis, working materials introduced during shutdowns and leaching from solid materials trapped in the strainers. Each of these could reduce the quality of the water in the IRWST and impair heat transfer or iodine retention.

Additionally, ONR considered that further work was necessary in relation to iodine retention and release during accident conditions (including for example, reactions with silver, organic iodine formation, iodine oxide formation etc). There is also a need to consider the specific features of the UK EPR design and the accident mitigation approach decided upon by the Licensee, as well as further consideration of longer term accidents. These resulted in additional related Assessment Findings:

- AF-UKEPR-RC-48 - Demonstrate that the source term takes account of other sources, such as plant rooms, painted surfaces and the spreading compartment, at different times and examine the sensitivity of their existing analyses to re-release of captured iodine.
- AF-UKEPR-RC-49 - Ensure that equilibrium levels of airborne fission-products within the containment are calculated and verified both for prolonged transients and events over longer timescales.

These Assessment Findings are intended to be resolved by any UK Licensee wishing to build and operate a UK EPR design. Currently, NNB GenCo, planning to build a UK EPR design at HPC, are in the process of resolving these Findings as part of the site specific detailed design programme of work. Further assessment will be required of Licensee's responses and safety submissions to these Assessment Finding and will be carried out as part of normal regulatory business. GDA Assessment Findings are expected to be resolved within a pre-defined milestone.

5. Post-Fukushima considerations

Further assessment of the UK EPR will be required during the development of the detailed design as part of the site specific phase. This requires assessment of the responses to the extant Assessment Findings, any implications arising from the Fukushima accident review and the considerations of the EOPs and OSSA, as appropriate. This will include the availability of power supplies to initiate the operations of the supporting systems in accident conditions.

Appendix 4

IRWST pH control in Accident Conditions

USA

Summary

1. Glossary
2. Regulatory requirements
3. Design
4. Compliance with the regulatory requirements or Guidance
5. Post Fukushima considerations

1. Glossary

ECCS: emergency core cooling system

IRWST: In-containment Refueling Water Storage Tank

TSP-C: granulated trisodium phosphate dodecahydrate

2. Regulatory requirements or guidance for Design Basis Accidents

For Design Basis Accidents

10 CFR 50, GDC 41 establishes the design requirements for containment atmosphere cleanup systems which function to reduce the concentration and quality of fission products released to the environment following postulated accidents.

Standard Review Plan 6.5.2, Containment Spray as a Fission Product Cleanup System. Containment Sump and Recirculation Spray Solutions

The pH of the aqueous solution collected in the containment sump after completion of injection of containment spray and emergency core cooling system (ECCS) water and all additives for reactivity control, fission product removal, or other purposes should be maintained at a level sufficiently high to provide assurance that significant long-term iodine reevolution does not occur. Long-term iodine retention may be assumed only when the equilibrium sump solution pH, after mixing and dilution with the primary coolant and ECCS injection, is above 7.

Branch Technical Position 6-1. pH for Emergency Coolant Water for Pressurized Water Reactors

The minimum pH level of ECCS water to reduce the probability of stress-corrosion cracking of austenitic stainless steel components, nonsensitized or sensitized, nonstressed or stressed, should be 7.0.

For Severe Accidents

There are no requirements or guidance specific to severe accidents for pH control of ECCS solutions.

3. Design

ECCS pH adjustment baskets containing granulated trisodium phosphate dodecahydrate (TSP-C) are strategically placed in the inlet flow path to the IRWST within the boundary perimeter of the weirs at the four heavy floor openings of the containment. Break flow through the baskets dissolves the TSP-C into the coolant that returns to the IRWST to passively neutralize entrained acids and maintain the alkalinity of the coolant. The pH of the recirculated coolant is maintained above 7.0.

The control of pH in the recirculated coolant reduces the potential for stress-corrosion cracking of the austenitic stainless steel components, limits the generation of hydrogen attributable to corrosion of containment metals, and minimizes the re-evolution of iodine in post-LOCA containment solution, maintaining the radioiodine in solution to reduce radioactive releases to the environment. The minimum amount of granulated TSP-C for this pH control is 12,200 lbm.

Following a DBA-LOCA, the pH of the IRWST water remains at a pH of 7.0 or above for 30 days. The post DBA-LOCA pH is evaluated at pre-accident temperature conditions. The post accident pH ranges from 7.5 at the beginning of the accident to 7.1 thirty days later.

The pH of the IRWST water is calculated considering the boric acid and TSP-C in the water, as well as the H+ added from radiolysis of the containment materials in the post-LOCA environment. IRWST liquid pH is a major factor in determining the amount of elemental iodine (I_2) that is re-evolved from the liquid solution. A pH value greater than 7.0 for a thirty-day period is sufficient for controlling re-evolution.

For the U. S. EPR design, severe accident mitigation strategy considers the effect of the pH control in the IRWST on the potential presence of Iodine in the water, as described in the following document: "*AREVA Technical Report ANP-10314, rev. 0, The Operating Strategies for Severe Accidents Methodology, section 3.10 Management of Radiological Releases*".

The containment stands as the last barrier preventing releases of fission products. The final defense-in-depth goal is the mitigation of such radiological releases. The design goal of the U.S. EPR and associated SAMGs is that large early releases are practically eliminated. The U.S. EPR design has several features and available emergency response actions to address the mitigation of large radiological release. A strategy for reducing the inventory available for release in the containment commonly considered in conventional PWRs, is the initiation of containment sprays. For the U.S. EPR, the SAHRS has been primarily designed for steam condensation and pressure suppression in the containment during a severe accident, the sprays can produce effective aerosol deposition due to interception of droplets. Sprays can remove some of the gaseous molecular Iodine. The effectiveness of sprays will depend on the availability of AC power and the extent of the areas covered by the spray system. Iodine volatility can be reduced by additives that are included in the design of IRWST or the SAHRS.

4. Compliance with Regulatory Requirement or Guidance

For the design basis accident, compliance with the regulatory requirements and guidance is satisfied for pH control in the IRWST.

There are no severe accident specific regulatory requirements for pH control in the IRWST. While the SAHRS is credited in the severe accident analysis with providing containment spray for the purposes of source term reduction, no credit is taken for the pH of the water in the IRWST.

5. Post Fukushima considerations

At this time, there are no additional regulations or requirements for the control of pH in the IRWST in the post Fukushima environment.

Appendix 5

IRWST pH control in Accident Conditions

CHINA

Summary

1. Glossary

IRWST: In-containment Refueling Water Storage Tank

LOCA: Loss Of Coolant Accident

LBLOCA: Large break LOCA

SBLOCA: Small Break LOCA

LOOP: Loss Of Offsite Power

COCOSYS: An integral computer code for severe accident analyses

HAF/HAD: the current Chinese Nuclear safety rules and codes

2. Regulatory requirements

HAD 102/06: Design of the Reactor Containments for Nuclear Power Plants (1990)

> *Important design parameters of the containment spray system include spray coverage, spray droplet size, spray retention time and the chemical composition of the spray water. Sodium hydroxide, sodium thiosulfate or hydrazine and other chemical reagents are usually added in Spray water to improve the ability of removal of radionuclides in air. The removal of radioactive iodine is of special significance due to serious consequences. Chemical reagent adding system must be designed so that it can maximize the dissolved radioactive iodine, and maintain the chemical composition of pit water and suppression pool water to make the radioactive iodine in the accident after the long term not escape from solution.*

HAD 102/06: Design of the Reactor Containments for Nuclear Power Plants (draft, IAEA No. NS-G-1.10)

> *Once iodine is trapped in water pools inside the containment, it may revolatilize in the medium to long term if appropriate pH conditions are not maintained. It is therefore necessary to assess all conditions that could change the pH of the water pools during an accident and, if necessary, provide the necessary means to keep the water pools alkaline.*

3. Design

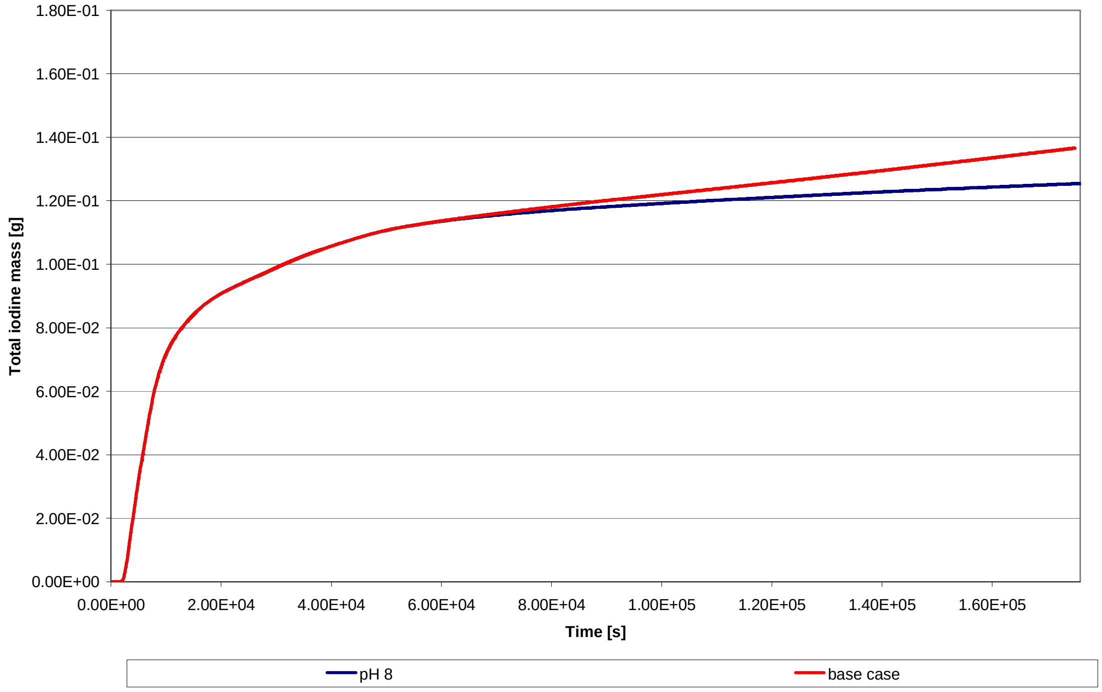
There is no pH control designed for accidents in the Taishan containment. The reasons by EDF and Taishan NPP is given below:

Iodine source term in the environment

Since the alkalinization of the containment sumps is realized through spraying, these alkaline conditions in the containment sumps while reducing the in-containment source term, only have a low effect in the iodine source term to the environment. This is because the leakages, responsible for the source term to the environment, are pressure driven and the higher pressures in a severe accident progression occur before spray activation, falling considerably from this point on:

- Up to spray activation there is no difference with or without sump conditioning, since it is through the spray system that the alkalinization medium (soda) is injected.
- The spray system reduces the pressure very efficiently, hence the release rates drop after its activation.

Indeed, the difference in iodine masses (before filters) released to the environment is in the range of 5% two days after initiation of the postulated severe accident.



Releases to the Environment Before Filters

Therefore it can be stated that alkalinization of the containment sumps has a marginal impact on radiological releases and hence consequences.

The absolute effect on the radiological releases of the implementation of a sodium injection system is quite limited and the radiological consequences in severe accidents remain considerably below any thresholds or requirements, regardless of the implementation of a soda injection system.

Furthermore, the risks involved in the maintenance of such an alkalinization system regarding corrosion are difficult to address, as experience has shown where such systems have been implemented in the past with a trend towards removal from service. Considering these arguments, the implementation of a soda injection system is not recommended and therefore not realized on Taishan project.

4. Compliance with the regulatory requirements and Safety Authority position

The review of Taishan IRWST pH control is still ongoing. Such position is expected in 2015. NNSA will review this item according to HAF/HAD, based on the analysis result.

5. Post-Fukushima considerations

Further assessment of the Taishan EPR will be required for passive additional of Tri-sodium phosphate (TSP) in IRWST designed for DBA. It is a study work until now.