JANSI'S SAFETY IMPROVEMNT ACTIVITIES WITH IAEA SRS-46

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ABSTRACT

In order to improve Japanese nuclear plant safety, JANSI has been performing the plant safety evaluation with IAEA SRS-46 "Assessment of Defence in Depth for Nuclear Power Plants". The evaluated result shows that safety levels of Japanese plants are going to reach comparable levels of Europe and US plants. Because Japanese utilities have installed many severe accident measures to their plants after Fukushima Daiichi accident. As a result of this evaluation, JANSI has confirmed that SRS-46 is able to evaluate the comprehensive plant safety evaluation based on DiD with limited resources.
JANSI will pursue the safety improvement of Japanese plants with SRS-46.

1. Introduction

Defence-in-Depth(DiD) is a concept that provides multiple layers to protect the life and / or critical functions of a facility, and this term has been utilized for long period. This concept has been developed through many nuclear plant operational experiences and accidents. And IAEA proposed the five levels DiD through TMI-2 and Chernobyl-4 accident.

Before Fukushima Daiichi accident, Japanese nuclear utilities prepared the severe accident (SA) management guideline and installed some SA measures as voluntary basis. Japanese society believed that SA leading to core melt would never occur in Japan because perfect countermeasures were adopted for the first through third levels of DiD. The direct cause of Fukushima Daiichi accident was considered to be the loss of all AC and DC powers caused by unexpected huge tsunami, and insufficient measures for the fourth and fifth level of DiD could not mitigate Fukushima Daiichi accident consequences. Reflecting upon Fukushima Daiichi accident, Japan Nuclear Safety Institute (JANSI) was established in 2012 under the consensus of Japanese nuclear industries with the resolution that "accident like Fukushima Daiichi should never occur again".

JANSI has been conducting safety improvement activities for the domestic plants as shown in Figure 1. In order to improve Japanese plants safety, JANSI has been performing the evaluation with SRS-46 "Assessment of Defence in Depth for Nuclear Power Plants"(1). This paper reports JANSI's approach how to use SRS-46 for evaluation of SA measures in Japanese plants.

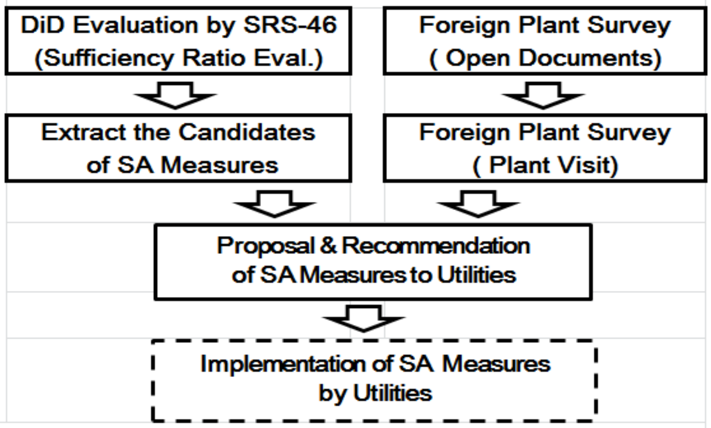

Figure 1 Safety Improvement Approach

2. Measures for the Severe Accident

Severe accidents occurred successively such as TMI-2, Chernobyl-4 and Fukushima Daiichi accident. From lessons learned of the accidents, it is recognized that independence and robustness for each level of DiD are quite important. Then, how do we enhance the independency and robustness of DiD? There are two rational methods to evaluate robustness of safety measures, namely quantitative probabilistic risk assessment (PRA) and DiD assessment. PRA is well known as Rasmussen Report (WASH-1400) [(2)] , and has been widely used for the safety assessment of nuclear power plants. Since Japanese utilities have applied PRA method for their plant safety assessments, JANSI has decided to assess the domestic plants safety from the viewpoint of DiD using SRS-46.

In case of design basis accident, thermal hydraulic and other phenomena have been clarified by many simulation tests. On the other hand, some unknown phenomena and too much complicate phenomena could be existed in case of SA. So it is effective for us to use SRS-46, because this report has been developed through multilateral standpoint discussion by many experts from different and wide technical points of view. Furthermore the developed objective trees have been extensively reviewed enabling to apply to PWR, BWR, and etc.

3. Overview of SRS-46

The specific safety principles are defined in IAEA INSAG-12 [(3)] " Basic Safety Principles for Nuclear Power Plant" which is an upper class report of SRS-46. INSAG-12 covers every plant stage of the lifetime of the plant such as "siting", "design", "manufacturing/ construction", "licensing and operation". And the safety principles are developed for each plant stage with considering first through fifth levels of DiD.

SRS-46 proposes various provisions with the objective trees in a comprehensive and systematic format. In SRS-46, the structure of objective trees are described as a set of "challenge-mechanism-provision". Namely, each tree includes challenges that attack its safety functions. And mechanisms have roles not to actualize the challenges, and provisions have mission to prevent the occurrence of such mechanisms.

Figure 2 and Figure 3 show an example of objective tree Fig.46 "OT-46: protection of confinement function" .

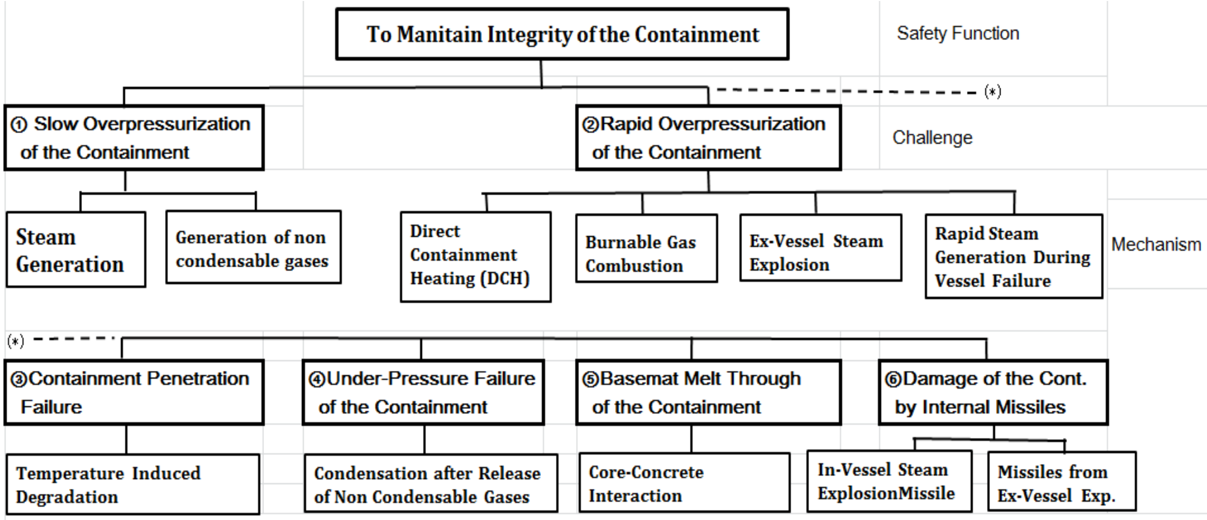

Figure 2 Structure of the Objective Tree (Part1:Safety Function,Challenge,Mechanism)

As shown in Figure 2 , there are six challenges which attack the safety function "to maintain integrity of the containment" as "①Slow Over-pressurization, ②Rapid Over-pressurization, ③Containment Penetration Failure, ④Under-Pressure Failure, ⑤Base mat Melt Through, ⑥Damage by Internal Missiles". According to SRS-46, six provisions are nominated to the first challenge " Slow over-pressurization of the Containment " as shown in Figure 3. Namely, "①Internal Spray System, ②External Spray System,③Fan Cooler System" for gaseous phase cooling , "④Suppression Pool Cooling System, ⑤Sump Cooling System" for liquid phase cooling, and "⑥Filtered Venting System " for pressure relief by gas venting.

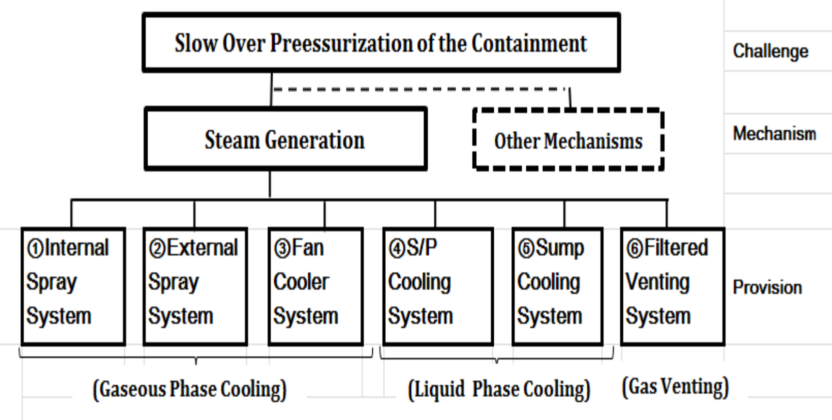

Figure 3 Structure of the Objective Tree (Part2:Challenge,Mechanism,Provision)

In SRS-46, the objective trees are composed logically and systematically as shown in Figure 2 and Figure 3.

4. Assessment using SRS-46

Although there are 68 objective trees in SRS-46, JANSI has selected 18 objective trees which closely related to DiD level 4.
JANSI pays attention to the following notifications for SRS-46 assessment.

- **SRS-46 does not provide any guidance on the prioritization of the provisions.** (Namely, SRS-46 does not give preference to individual provisions nor specifies the way to implement or quantify the efficiency of a provision.)
- **The adequacy of provisions has to be determined by the utilities.**
- Objective trees developed to provide a comprehensive list of the possible options for provisions. **Not necessarily all of them are to be implemented in parallel.**

Since SRS-46 does not show the technical importance and priority for each provision, the utilities should read SRS-46 carefully and recognize the vulnerability of their plants, and implement suitable safety measures by themselves.
Based on the above notifications, JANSI has assessed domestic plant safety with following steps.

- Screening
- Sufficiency Ratio
- Mechanism Analysis
- Area for Safety Improvement

(1) Screening
Aim of the objective tree is to list up conceivable provisions as much as possible. JANSI assessed the extent of fulfillment of the provisions in SRS-46 to evaluate the robustness of each level of DiD of Japanese plants. In JANSI assessment, two kinds of checkmark are assigned to each provision, that is, if the provision has been implemented checkmark "Y" is assigned, and if there is no measure then checkmark "N" is assigned to the provision.
If redundant systems have been implemented to the provision, also the same checkmark "Y" is assigned.

(2) Sufficiency Ratio

Then JANSI defined to express the implementation situation of SRS-46 as "Sufficiency Ratio, SR" as following equation :

$$SR = N_{ap}/(N_{pp}-N_{na}) \quad \ldots\ldots (1)$$

Where,

N_{ap}: Number of provisions marked "Y"

N_{pp}: Total number of provisions in the specific objective tree

N_{na}: Number of provisions which are not applicable to the subject plant (Ex. SG related provisions to BWR plant)

The Sufficiency Ratio (SR) is an indicator of areas for safety enhancement on the target plant. By comparing the SR value between the target plant and other plant, areas for safety improvement can be identified easily, and also addition of new upgrades of equipment and measures for these improvements can be visually shown to the related parties.

The evaluated results are graphed in SR value regarding the provisions of SA measures. Figure 4 shows the comparison for the representative domestic PWR and European PWR plant. The vertical axis shows SR value and the horizontal axis shows 18 objective trees. The striped bars show SR value for the representative Japanese plant before Fukushima Daiichi accident and the blank bars show SR value including the additional safety measures after the accident. And black line shows SR value of a representative European plant.

In Europe, SA studies were initiated after TMI-2 accident, and have been conducted continuously. Furthermore, they have reflected the study results to their plants, so implementation of SA measures have progressed significantly compared to Japan.

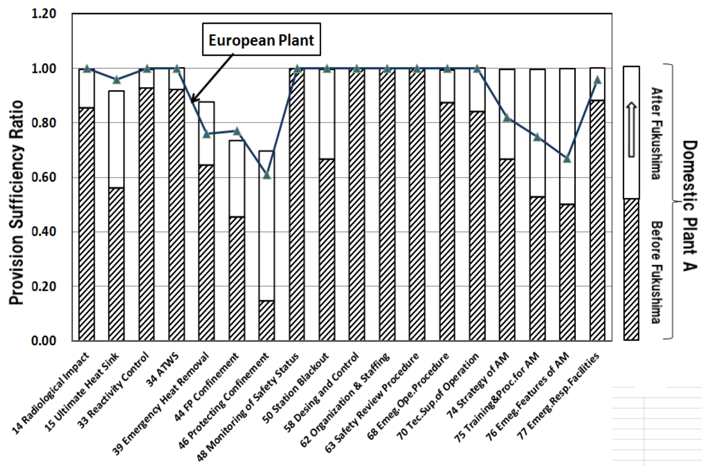

Figure 4 DiD Evaluation Results by SR Graph

Before Fukushima Daiichi accident, it can be identified that SA measures installation situation of Japanese plants were behind the European plants as shown in Figure 4. Today SA installation situation of Japanese plants have attained to an equivalent level of the European plants, because many SA measures have been implemented in accordance with Japanese new regulatory requirement. Therefore, SR value has increased with newly installed measures such as "FCVS", " PAR and Igniter", "alternative water injection to RPV/CV", "enhanced electrical power", "SA instrumentation", " SAMG, education and training" .

SR value of OT-34 "ATWS", OT-39"Emergency Heat Removal", OT-44 "FP Confinement" and OT-46 "Protecting Confinement" show lower value for both domestic and European plant. The reasons are too many conceivable measures are listed in SRS-46, some of these provisions are difficult to realize, and some are just ideas. For example, missing provisions of OT-46 are IVR (corium cooling from outside reactor vessel), core catcher, etc. These safety features are under developing for the planning and/or construction plants, but have not been installed to the operating plants.

Also, SR value of OT-74, 75, 76 for European plant are lower than 1.0, because of insufficient open information on the management (Human Related) measures. JANSI supposes that the management measures might be implemented in European plant, so JANSI will continue further plant survey(4).

(3) Mechanism analysis

There are some objective trees having low SR value. Although It may seem to be low in safety, it is not necessary to pursuit SR=1.0 as far as other provisions prevent the mechanisms. JANSI introduces "Mechanism Analysis" to examine the need for additional provisions. Mechanism analysis has been conducted based on the Safety Analysis Report, information obtained by site visiting, and so on.

The analysis is performed with the following considerations.

・Judgment whether a mechanism can be prevented to occur

・Judgment whether a challenge can be prevented to occur

The conclusion of mechanism analysis,

・Necessity of missing provision is considered to be low when other provision prevents the occurrence of mechanism

・If not, necessity of missing provision is considered to be high.

An example of the mechanism analysis is shown in Table 1 for OT-39. According to the Table 1, six provisions are proposed to prevent "Slow Overpressure due to Steam Generation", and the missing provision "External Spray System" can be covered by other provisions. Based on such mechanism analysis, JANSI concludes the missing provision is not necessary to install to the plant, because the target plant keeps its safety.

Table 1 Example of Mechanism Analysis to OT-39

Mechanism	Provision	Function	Status
(OT-39) Slow Overpressure due to Steam Generation	Internal Spray	Gas Phase Cooling	Y
	External Spray	Gas Phase Cooling	N
	Filtered Venting	Gas Venting	Y
	S/ P Cooling System	Liq.Phase Cooling (BWR plant only)	NA
	Sump Cooling System	Liq.Phase Cooling (PWR plant only)	Y
	Fan Coolers	Gas Phase Cooling	Y

(Note)

Note : Missing provision "External Spray" is covered by other provisions.

(4) Area for Safety Improvement

Based on the mechanism analysis mentioned above, JANSI is going to extract the area for safety improvement, and will propose and/or recommend to utilities to take proper actions.

5. Conclusion

JANSI has used SRS-46 as a tool to evaluate how Japanese plants improve their safety. Our evaluated result shows that Japanese plants have attained comparable levels of European plants after Fukushima Daiichi accident.

JANSI confirms the effectiveness of SRS-46 as follows:

・Comprehensive safety evaluation or review based on DiD with the limited resources,

・Identify improvement area for prevention and mitigation against severe accident,

・Confirm the degree of safety enhancement between before and after the improvement.

Finally, JANSI will pursue the further safety improvement of Japanese plants with SRS-46.

6. Acknowledgement

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7. References

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(4) K.Tominaga, M.Ohtani, “Some Considerations on Severe Accident Countermeasures” ICONE23-1097,2015,Chiba,Japan