# Development of Objective Provision Trees for Sodium-Cooled Fast Reactor Defense-in-Depth Evaluation

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## 1. Introduction

Based on the safety functions and the schematic for the development of Objective Provision Trees (OPTs) suggested in reference [1], an OPT for KALIMER which is one of sodium-cooled fast reactor and being developed by Korea Atomic Energy Research Institute (KAERI), was developed and suggested in this paper. Developed OPT is for the defense-in-depth level 3, core heat removal safety function.

## 2. OPT Structure

Generally, OPT has leveled structure as following;

- Level of defense-in-depth,
- objective,
- safety function,
- challenges,
- mechanisms, and
- provisions

Detailed definitions for each level were provided in the reference [2].

### *2.1 Level of Defense-in-Depth and Objective*

Among 5 levels of defense-in-depth levels in the reference [5], level 3 was chosen as an example defense-in-depth level because this level can cover the Design Basis Accidents (DBAs) which are the very first step to evaluate the defense-in-depth concept implemented to the new reactor design. The objective of level 3 defense-in-depth is “control of accident within the design basis.”

### *2.2 Safety Functions*

Safety functions for KALIMER were defined as following in the reference [1];

- control of the reactivity,
- removal of heat from the core, and
- confinement of radioactive materials and control of operational discharges, as well as limitation of accidental releases.

“Removal of heat from the core” was selected as an example safety function for OPT development.

### *2.3 Challenges*

Challenges defined in this study were selected by categorizing them along with the system boundaries to identify mechanisms and provisions much comprehensively. This approach was possible because KALIMER design have been progress to the level of detail relatively. The categorization of challenges was as following;

- Degradation of heat removal through primary heat transfer system,
- degradation of heat removal through intermediate heat transfer system,
- degradation of heat removal through steam generator system, and
- degradation of heat removal for spent fuel pool.

### *2.4 Mechanisms*

Mechanisms for the challenge, “degradation of heat removal through PHTS” were selected as following;

- Long-term loss of forced convection,
- loss of coolant inventory,
- loss of ultimate heat sink,
- loss of vital powers (short-term and long-term), and
- loss of instrumentation and control

Mechanisms for the challenge, “degradation of heat removal through IHTS” were selected as following;

- Long-term loss of forced convection,
- loss of coolant inventory,
- loss of vital powers (short-term and long-term), and
- loss of instrumentation and control

Mechanisms for the challenge, “degradation of heat removal through SGS” were selected as following;

- Degraded or disrupted flow paths in SGs,
- loss of inventory (tube rupture),
- loss of vital powers (short-term and long-term),
- loss of instrumentation and control, and
- Sodium-Water reactions

These mechanisms were selected obviously considering the lessons from Fukushima accident.

*2.5 Provisions*

Provisions to each mechanism were suggested in fig. 1 to fig. 3. Representative provisions are as following;

- Redundancy and diversity of steam and pressure relief systems,
- Redundancy and diversity of feedwater system,
- Sodium leak detection system,
- Steam and pressure relief system,
- Isolation of affected SG, and
- Sodium-water reaction pressure relief system

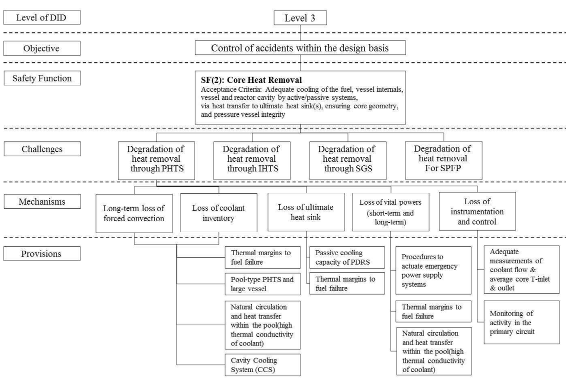


Fig. 1 KALIMER OPT for level 3, core heat removal safety function (1/3)

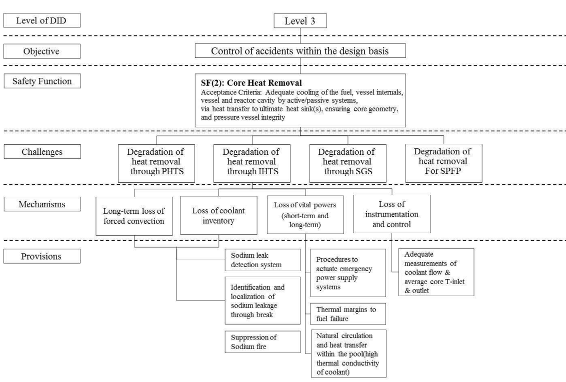


Fig. 2 KALIMER OPT for level 3, core heat removal safety function (2/3)

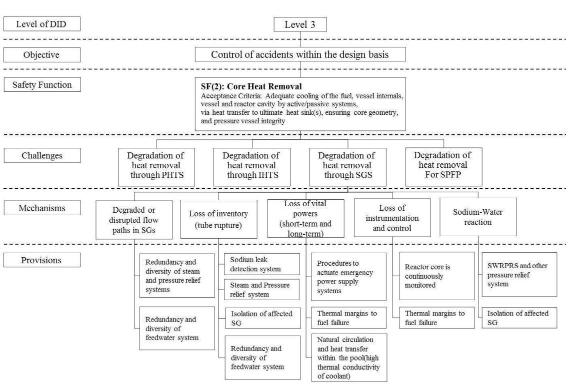


Fig. 3 KALIMER OPT for level 3, core heat removal safety function (3/3)

## 3. Conclusions

Using OPT method, the evaluation of defense-in-depth implementation for the design features of KALIMER reactors were tried in this study. To utilize the design information of KALIMER, challenges in OPTs which are under development in this study, were identified based on the system physical boundaries. This approach make the identification of possible and postulated challenges much clear and this will be a benefit to further identification of provisions in KALIMER design. OPTs for other levels of defense-in-depth and other safety functions are under development.

## REFERENCES

[1] H. Yang and N. Suh, Safety Functions and Objective Provision Tree Application to Sodium-Cooled Fast Reactor, Transactions of the Korean Nuclear Society Autumn Meeting, Gyeongju, Korea, 2012

[2] GEN-IV International Forum, Risk and Safety Working Group (RSWG), "An Integrated Safety Assessment Methodology (ISAM) for Generation IV Nuclear System, Ver. 1.1, p.15, 2011.

[3] International Atomic Energy Agency, "Considerations in the Development of Safety Requirements for Innovative Reactors: Application to Modular High Temperature Gas Cooled Reactors," IAEA-TECDOC-1366, pp.35-46, 2003.

[4] G. L. Fiorini and T. Leahy, "Safety Approach of Gen-IV Systems: Application to SFR," presentation slides, IAEA Workshop on Safety Aspects of Sodium Cooled Fast Reactors, p.14, Vienna, 2010.

[5] International Nuclear Safety Advisory Group, "Defence in Depth in Nuclear Safety," INSAG-10, p.6, 1996 .

[6] International Atomic Energy Agency, "Safety of Nuclear Power Plants: Design," NS-R-1, p.11, 2000.