# Level-1 Fire Probabilistic Safety Assessment for HANARO Research Reactor at Power

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## 1. Introduction

HANARO is the 30MW pool-type research reactor for utilizing neutrons rather than thermal energy, which features core cooling by natural convection with no external power. The objective of this study is to comprehensively and quantitatively assess the fire safety or fire-induced risk of the research reactor HANARO, and provide a technical basis for decision-making related to the safe operation and fire protection of the HANARO. This study conducts an At-Power Level-1 Fire Probabilistic Safety Assessment (PSA) for the HANARO to assess a fire-induced Core Damage Frequency (CDF) during the power operation of the HANARO.

The fire-induced CDF is assessed on a fire scenario as follows:

$$CDF_F = \sum(FIF_i \times SF_i \times NSP_i \times CCDP_{F,i})$$

Where
$CDF_F$ : Fire-induced Conditional Core Damage Frequency
$FIF_i$ : Fire Ignition Frequency
$SF_i$ : Fire Severity Factor
$NSP_i$ : Fire Non-Suppression Probability
$CCDP_{F,i}$ : Fire-induced Conditional Core Damage Probability
$i$ : Fire Scenario

Note that this study only covers the FIF and CCDP, not crediting SF nor NSP (i.e., assumed to be 1.0).

The fire damage states (FDSs) are generally classified and defined as follows:

- [FDS0]: Only ignition sources are damaged by the fire. The ignition source can also be a target by itself, such as an electrical enclosure, damage of which results in a CCDP greater than zero.
- [FDS1]: Components or cables near the fire ignition source (within the zone of influence) are damaged by the fire due to the vertical convective and/or radial radiative heat transferred from the fire.
- [FDS2]: All components or cables within the compartment of fire origin are extensively damaged by the fire due the development of a damaging hot gas layer.
- [FDS3]: All components or cables within the compartment of fire origin and an adjacent compartment are extensively damaged by the fire due to the development of a damaging hot gas layer and postulated fire propagated through a failed fire barrier element between two compartments.

Note that this study only covers the cases where fires initiated by ignition sources may lead to the FDS2, 3 and each FDS constitutes a single scenario. For instance, the fire scenario “%F-AUX” represents a full room burnout of the area “F-AUX(Auxiliary Area)” caused by fires occurred from any ignition sources in the “F-AUX” (FDS2). On the other hand, the fire scenario “%F-AUX_%F-GA” represents a full room burnout of both areas “F-AUX” and “F-GA(General Area)” caused by fires occurred from any ignition sources in the “F-AUX” and propagated to “F-GA” through any failed fire barrier elements between those two areas (FDS3).

## 2. Methods

The fire PSA procedure employed in this study is summarized in Fig. 1 and as follows: Step(1) Plant Boundary Definition and Partitioning; Step(2) Component & Cable Selection and Analysis; Step(3) Qualitative Screening Analysis; Step(4) Fire Ignition Analysis; Step(5) Development of Fire Risk Quantification Model; Step(6) Fire Risk Quantification; Step(7) Fire PSA Documentation.

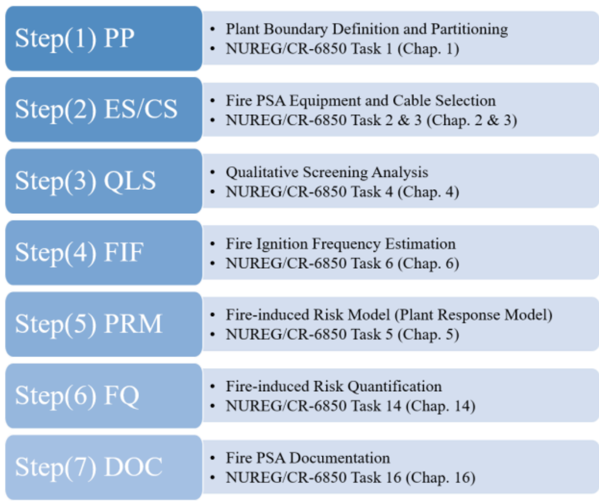


Fig. 1. An Overview of the HANARO Fire PSA Process.

## 3. Results

Fig. 2 show a pie chart of the CDF by fire scenario. A total fire-induced CDF of X.XXE-XX/yr was obtained by summing frequencies of all core damage accident sequences induced by 55 fire scenarios. Top five(5) fire scenarios or two(2) accident sequences account for most of the total CDF (98.8% or 99.9%, respectively).

The five(5) most risk-significant fire scenarios:

1. %F-AUX: F-AUX(Auxiliary Area) FDS2 Scenario
2. %F-6B13: F-6B13(Electrical Distribution Room) FDS2 Scenario
3. %F-6212: F-6212(MCC Room) FDS2 Scenario
4. %F-CR: F-CR(Control Room) FDS2 Scenario
5. %F-GA: F-GA(General Area) FDS2 Scenario

The two(2) most risk-significant accident sequences:

1. LOPCS-2: (Fire-induced Loss-Of-Primary-Cooling-System) AND (Failure of Residual Heat Removal by Natural Convection)
2. LOEP-2: (Fire-induced Loss-Of-Electric-Power) AND (Failure of Residual Heat Removal by Natural Convection)

The main reason for such dominant contribution is that, in those scenarios and sequences, a fire causes a function loss of both primary cooling pumps, i.e., a loss of forced convection flow through one of two primary cooling pumps, and therefore, residual heat removal is entirely dependent on natural convection by a gravity-driven recirculating flow via flap valves inside the reactor pool. For the same reason, the natural convection flow via flap valves plays the most significant role in preventing fire-induced core damage.

It is expected that an application of countermeasures to prevent damage of cables related to primary cooling pumps by fires, or fires themselves that have potential for such damage from occurring will significantly reduce the fire-induced risk.

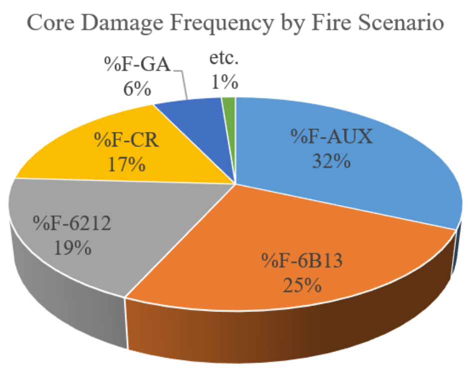


Fig. 2. Core Damage Frequency by Fire Scenario.

## 4. Conclusions

This study conducted the At-Power Level-1 Fire PSA for the research reactor HANARO. The main results of this study will be used as a technical basis for decision-making related to the safe operation and fire protection of the HANARO. An application of countermeasures for dominant risk contributors identified from this study would ultimately contribute to enhancing the fire safety of the HANARO.

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