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A Methodology of Floor Protection during Sodium Fire in SFR

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1. Introduction

The SFR (Sodium cooled Fast Reactor) is a fast neutron reactor, i.e. it operates without a moderator. The core is cooled by molten metal, sodium (Na). Compared with thermal-spectrum neutrons, fast-spectrum neutrons more efficiently convert natural uranium(uranium-238), a fertile material, into plutonium, a fissile material, which means that the SFR could be operated in breeder mode, or conversely in burner mode for increased plutonium consumption. It can also transmute the very-long-lived actinides (americium, curium and neptunium).

Due to the use of the sodium coolant in SFR, we have to consider the potential sodium fires when sodium leak occurs in the rooms where the sodium is contained. Therefore it takes account of challenging the sodium fires to design the SFR Plant.

This paper presents the method of floor protection against high temperature during sodium fires which is classified as a design basis accident to be considered in accordance with the requirements of the SFR.

2. Sodium Fire Analysis and Results

This section provides information about the analyses performed that provide a design basis accident in the steam generator room in PGSFR (Fig. 1) due to sodium leaking, including computer code and methods, key assumptions, and the results of the analyses.

2.1 Computer Code

The CONTAIN LMR/1B-Mod. 1 is a special version of the CONTAIN computer code, is used for analysis. This code is intended for application to liquid metal reactor (LMR) using sodium coolant including sodium fire model, debris bed models and sodium concrete interaction models, etc. The code is produced by applying LMR-specific updates to an official light water reactor (LWR) version of the CONTAIN 1.11 [1,2,3].

2.2 Analysis Model

There are three (3) kinds of sodium fires as shown in Fig. 2 due to leaking of sodium system such as IHTS (Intermediate Heat Transfer System), DHRS (Decay Heat Removal System) and sodium transportation systems.

The sodium fire in the steam generator room (SG room) modeled as one node with heat structures of 4 walls, a roof and a floor in PSFGR [4].

The SG room geometry in Table I is a rectangular shape and the floor modeled a lower-cell as sodium burning area below in Fig. 3.

- Pool layer : sodium burning pool
- Intermediate layer : liner plate
- Intermediate layer : insulating material if needs
- Concrete layer : floor concrete with 40 nodes

It needs material properties as shown in Table II to analyze using CONTAIN-LMR.

The amount of sodium source for sodium fire is 3,625.1 kg which is leakage from crack of IHTS pipe in the SG room for 95 seconds considering the engineering safety features actuation but this was assumed to be temporary leakage at the beginning.

In case that the floor temperature can be higher than the requirement in Table III regarding as accident condition, we have to consider the protection method for floor concrete to inset the insulating material in Table II.

2.3 Analysis Results

From the analyses results, the peak pressure and temperature of SG room are 156.1 kPa and 301.7 ℃ as shown in Fig. 4 and Fig. 5 shows the floor concrete temperature profile with 376.0 ℃ of the peak temperature which is higher than the acceptable limit based on the requirement in ACI-349 in Table III [5]. Therefore, the floor concrete needs to be protected using insulation material as light weight insulating concrete which will be inserted between liner plate and structure floor concrete to reduce the top of floor temperature to meet the requirements.

3. Conclusions

The floor temperature of SG room due to the sodium fire is higher than the acceptable limit based on the requirement in ACI-349.

Therefore, the floor concrete needs to be protected using insulation material as light weight insulating concrete which will be inserted between liner plate and structure floor concrete. In this case, thickness of light weight insulating concrete is 3 cm as a minimum to meet the requirement as shown in Table IV and Fig. 6.

Based on the above analysis results, the floor concrete can be protected in accordance with the requirements by inserting insulation material, and the design improvement plan considering the drainage of leaked sodium in a way that can reduce the atmosphere temperature is discussed next time.

Table I: SG Room Geometry

Description	SG Room	Remark
Free Volume(m^3)	5,744.654	
Height(m)	25.988	
Floor Area(m^2)	221.050	
Wall Area(m^2)	428.4901 376.5141	North, South side East, West side
Pressure(Pa)	101,352.9	
Temperature(℃)	40.0	Floor, 4 walls, Roof and internal
	48.9	outside
Floor Concrete(m)	2	Ref. 4
Floor Liner Plate(m)	0.006	Ref. 4

Table II: Concrete Thermal Property

Description	Light Weight Insulating Concrete*	Structure Concrete
Density(kg/m^3)	1,041.2	2,242.6
Compressive strength (Mpa)	6.2	27.6 ~ 41.4
Thickness(cm)	3 ~	45.7 ~
Thermal Conductivity (W/mK)	0.692 (310.92 K) 0.363 (477.64 K)	1.5923
Specific Heat (J/Kg-K)	1,674.72 (310.92 K) 1,088.57 (477.64 K)	879.2

* Thermal Property of Light Weight Insulating Concrete from Clinch River PSAR (Table 15.6.1.4-2)

Table III: Concrete Temperature Requirement in ACI-349

Description	Temperature Limit	Remark
Normal Operation or any other long-term period	150˚F (65.5℃)	
During an accident or for any other short-term interruption	350˚F (176.6℃) 650˚F (343.3℃) for fluid jets local area	

Table IV: Floor Concrete Temperature

Description	Temperature	Remark
No Insulation	376.0℃	X
2 cm light weight concrete	200.0℃	X
3 cm light weight concrete	164.4℃	O
5 cm light weight concrete	125.5℃	O

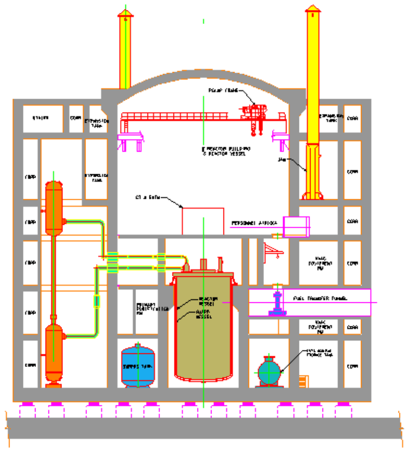
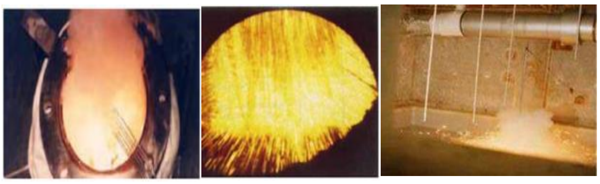


Fig. 1. PGSFR nuclear island



Pool Fire   Spray Fire   Mixed Fire

Fig. 2. Sodium fire types

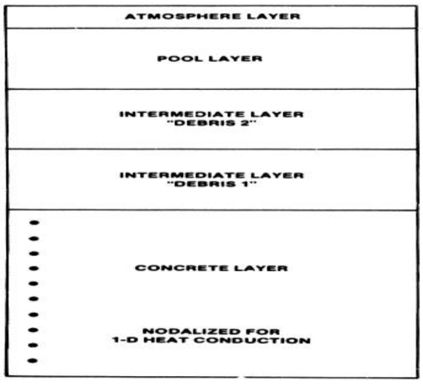


Fig. 3. CONTAIN-LMR lower-cell's model

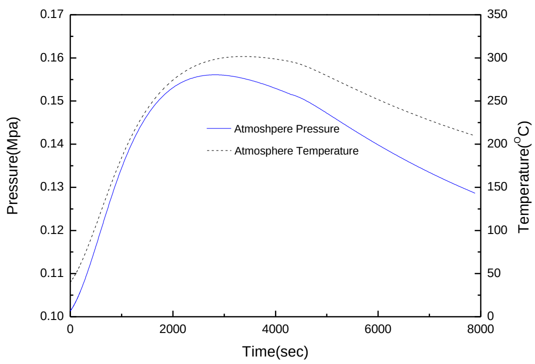


Fig. 4. SG room pressure and temperature

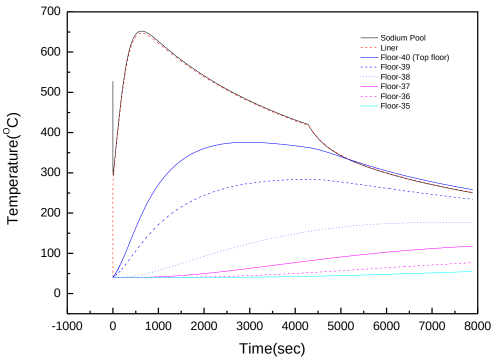


Fig. 5. Temperature of SG room floor concrete

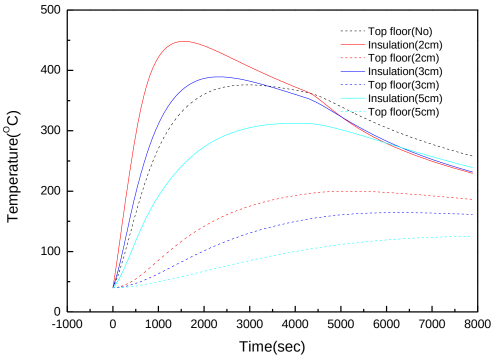


Fig. 6. SG room floor and light weight insulating concrete

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