Fire Analysis for Compartment of ITER Tritium SDS

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1. Introduction

The objective of the fire accident analysis for the compartment where the ITER tritium storage and delivery system (hereafter SDS) glove boxes are installed is to estimate the integrity of the glove box.

Fires in grouped electrical cable trays pose distinct fire hazards within the compartment where the SDS glove boxes are installed.

The nuclear industry has defined two general types of electrical cables, referred to as IEEE-383 qualified and unqualified. According to NUREG/CR-4679[3.7.1-1] and DOT-TSC-UMAT-83-4-1[3.7.1-2], a damage threshold temperature of 370 ℃ and a critical heat flux of 10 kW/m^2 have been selected for IEEE-383 qualified cable. A damage threshold temperature of 218 ℃ and a critical heat flux of 5 kW/m^2 have been selected for IEEE-383 unqualified cable.

Cable tray fires can occur from various sources. The scenarios of concern include a fire within a cable tray and as exposure fire. However, fire within the compartment where the SDS glove boxes are installed could be happened due to over-currents. Therefore, it is common practice to consider only self-ignited cable fires to occur in power cable trays since they carry enough electrical energy for ignition. In general, electrical cables typically do not carry enough electrical energy for self ignition. According to NUREG/CR-5384[3.7.1-3], it was concluded that electrical cables which passed the IEEE-383-74 flame test were less likely to propagate electrically initiated fires. However, the scenario in this fire accident analysis assumed that the IEEE-383 qualified cable is burned completely.

2. Load Specifications for SDS

The Fire Dynamics Simulator (FDS) computer code is used to simulate the cable tray fire accident due to over-currents. The FDS computer code was developed at National Institute of Standards and Technology (NIST). And it is a computational fluid dynamics (CFD) model of fire-driven fluid flow.

SDS includes the long-term storage system (LTS) and the short-term storage system (STS). The LTS has several special glove boxes for unpacking the primary shipping containers of tritium, for accurately measuring the tritium inventory, for off-loading T2 gas from the shipping containers to the SDS, and for packing solid waste. In the compartment, 4 glove boxes are installed.

A description of the compartment is provided in Table I. The outer length of the compartment is 19.1 m, its width is 8.7 m and its height is 4.75 m. The compartment has 6 openings in the 4 walls for the ventilation.

The electrical cable tray consists of the 20 power cables and the 40 power & control cables. Figure 1 shows the power cable and the power and control cable. The power cable diameter and jacket thickness are 1.4 cm, and 0.18 cm, respectively. The power and control cable diameter and jacket thickness are 2.2 cm, and 0.18 cm, respectively.

Table I: Description of the compartment

Item	Description
Compartment	19.1 m(L) x 8.7 m(W) x 4.75 m(H)
Glove box	6.0 m(L) x 1.6 m(W) x 2.6 m(H) : 2 ea
	4.5 m(L) x 1.6 m(W) x 2.6 m(H) : 1 ea
	3.0 m(L) x 1.6 m(W) x 2.6 m(H) : 1 ea
	0.2 m(W) x 0.8 m(H) : 1 ea
Ventilation openings	
- East wall	0.8 m(W) x 0.2 m(H) : 1 ea
- West wall	0.3 m(W) x 0.2 m(H) : 1 ea
- South wall	0.5 m(W) x 0.2 m(H) : 1 ea
	0.5 m(W) x 0.45 m(H) : 1 ea
- North wall	0.5 m(W) x 0.2 m(H) : 1 ea
	0.5 m(W) x 0.45 m(H) : 1 ea

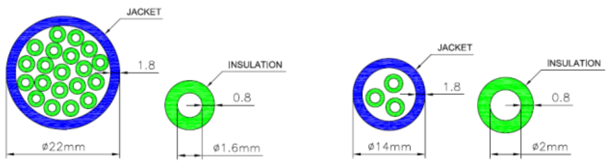

Fig. 1. Power cable and the power and control cable

The fire accident analysis was performed under the assumption that fire happens due to over-currents of the electrical cable tray located below a 70 cm from the ceiling of the compartment. The diameter of the electrical cable is small about 14 mm ~ 18 mm. If the fire accident analysis is carried out by applying as the same size, there is lots of the number of the element in the analysis model. Accordingly, the fire accident analysis will take a long time. Therefore, the fire accident analysis was performed by applying the element with the equivalent area.

In the boundary conditions, the copper wires within the insulation of the electrical cable were assumed to be adiabatic. An ambient temperature of 20 ℃ was applied.

The material of the glove box was applied to the glass with a low thermal conductivity. Heat flux of 150

kW/m^2 was applied to the electrical cables in order to perform the conservative fire accident analysis. Heat of combustion of 43,400 kJ/kg was applied to the electrical cables. Figure 2 shows three-dimensional model of the compartment. This model was created using the PyroSim.

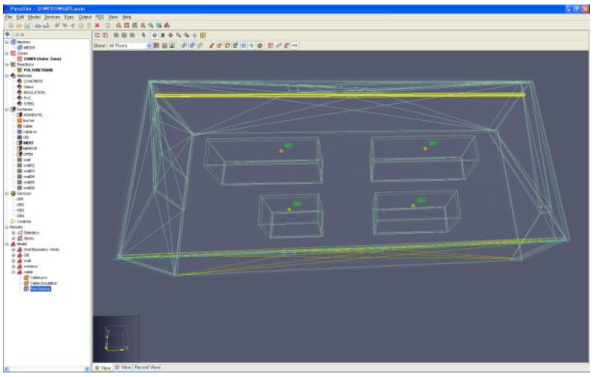

Fig. 2. Three-dimensional compartment FDS model

3. Analysis Results

The temperature and heat release rate data of the fire accident analysis are summarized in Table II. The maximum temperature of the glove box is 22 ℃. This temperature is a slightly higher than ambient temperature. The maximum heat release rate is estimated as 258.7 kW. The heat release rate profile for the fire accident analysis is shown in Figure 3.

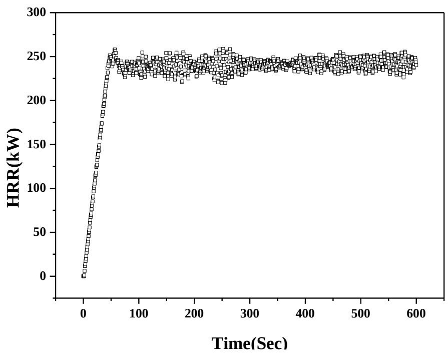

Fig. 3. Heat release rate profile according to transient

Table II: Heat release rate of the electrical cable and temperatures of the glove box calculated in FDS simulation

Items		Time(sec)					
		0	120	240	360	480	600
HRR(kW)		0	204	217	200	208	205
Temp(°C)	GB1	20	21	21	21	21	21
	GB2	20	21	21	22	22	22
	GB3	20	21	21	21	21	22
	GB4	20	20	21	21	22	22

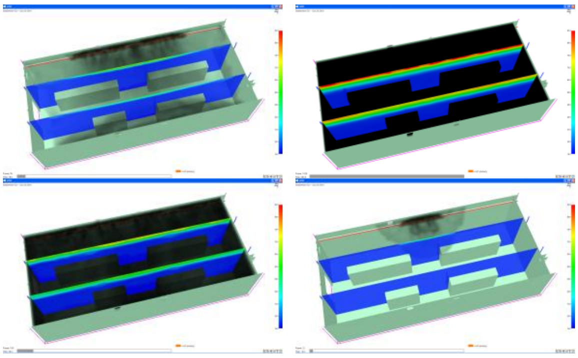

Fig. 3. Computed flame propagation process (12 sec, 30 sec, 60 sec, and 600 sec).

Figure 3 shows the computed flame propagation process represented by heat release rate of unit area at 150 kW/m^2.

The glove boxes will be received heat by radiation and natural convection from the flame of the electrical cable in the fire accident. However, the temperatures of the glove boxes were not so high as to affect thermal integrity. It is evaluated that the glove box does not affect by radioactive and convective heat transfer, because heat release rate from the electrical cable is smaller than the space of the compartment. Therefore, the influence that the cable tray fire in the compartment reaches to the glove box was estimated to be minimal.

4. Conclusions

The fire accident analysis for the compartment where the SDS glove boxes are installed is performed to estimate the integrity of the glove box. The temperatures of the glove boxes were not so high as to affect thermal integrity. Therefore, the influence of the cable tray fire in the compartment on the glove box was estimated to be very small.

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