Introduction of Sodium Fire Extinguishing System for STELLA-1

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1. Introduction

Sodium, which is the sixth abundant element on earth, exists in a liquid state under the temperature from 98℃ to 883℃. And also the heat transfer characteristic of sodium is 130 times better than that of water. This characteristic is a big advantage as a thermal transfer fluid. However, the high reactivity of sodium, especially with water and oxygen, and white aerosol in the event of fire can cause serious accidents. Thus, large sodium facility needs a specific-developed fire extinguishing system for a safe experiment. Korea Atomic Energy Research Institute (KAERI) has conducted sodium heat transfer experiments using the facility named the Sodium Integral Effect Test Loop for Safety Simulation and Assessment (STELLA-1). STELLA-1 fully equipped a sodium fire extinguishing system for the safe experiment and fire spread prevention.

In this paper, a preparation of the fire extinguishing system of STELLA-1 facility is introduced. This paper can provide an example of how to design a sodium fire extinguishing system for a large sodium experiment facility.

2. Fire Extinguishing Agent for Sodium Fire and Calculation of Demanded Quantity

2.1 Extinguishing Agent

A fluid experiment facility using sodium commonly runs under high temperature(from 100℃ to 600℃). At this condition, the event of sodium leakage causes consecutive fires with oxygen. The point to care is the high reactivity of sodium with water, oxygen and halogen. It is very important to select extinguishing agent to prevent fire spread. Extinguishment by smothering and cooling is the principle of sodium fire control.

The following are extinguishing agents for sodium fire among metal fires(classification of level D)

- Dry sand, Expanded vermiculite, Expanded pearlite
- Dry sodium carbonate powder
- Dry sodium chloride powder
- Dry graphite powder

In Korea, related law of hazardous material approves only Dry sand, expanded vermiculite and expanded pearlite. But dry sand has problems of density and moisture content. Vermiculite and pearlite have space possession problem. So these three agents are not suitable for sodium fire from a practical point of view. For this reason, STELLA-1 applied dry sodium chloride agent for extinguishing system.

2.2 Calculation of Demand Quantity

The calculation of demanded quantity of extinguishing agent follows Korea Fire Protection Laws, Korea Fire Equipment Inspection Corporation and Design Criteria for Fire Fighting System. Unfortunately, there is no rule for the extinguishing agent especially for sodium fire in Korea. Therefore, STELLA-1 had been given the approval of use from Korea Fire Institute or Ministry of Public Safety and Security by applying international certificate verification.

The following equation is to calculate quantity of dry chemical extinguishing agent by National Fire Safety Codes (NFSC 108). However, because there is no guideline for sodium fire(D-Class), we apply the highest value of $NaHCO_3$ agent unit quantity(A) as shown in Table 1.

$$Q = A \times V \times S$$

Q : Quantity of extinguishing agent (㎏)
A : Agent unit quantity (㎏/㎡)
V : Volume of protection target (㎥)
S : Safety factor (1.1)

Table 1: Agent unit quantity by kind

Kind of extinguishing agent	Agent unit quantity (A)
$NaHCO_3$	8.8
$KHCO_3$, $NH_4H_2PO_4$	5.2
$[NH_2]_2CO + KHCO_3$	3.6

3. Fire Extinguishing System for STELLA-1

3.1 The composition of system

STELLA-1 is a facility with 18 tons of sodium which is third-class of hazardous material. Thus, it is important to be specially equipped with sodium fire protection system. STELLA-1 has the dry chemical extinguishing system which has the capacity satisfying the demanded

quantity of extinguishing agent calculation result. To maximize extinguishing effect of sodium fire, it is a ground rule to spray dry chemical agent onto fire target after containing leakage sodium in catch pan or funneling. STELLA-1 installed local application system because of open type of catch pan and funneling floor. The extinguishing system is composed of smoke detection sensors, controller panel, catch pan, funneling floor, leak detection sensor, pipe lines and nozzles to release powder, solenoid box, nitrogen cylinder and dry chemical extinguishing agent storage tank.

Fig. 1. STELLA-1 facility and fire extinguishing pipe line(yellow line)

Fig. 2. Dry chemical extinguishing agent tank installed for STELLA-1

3.2 Process of operating fire control system

The dry chemical extinguishing system of STELLA-1 is automatic all the time to prevent sodium fire. But full knowledge of extinguishing process and operating manual is an essential for malfunction or power fail situation. Operators need to learn repeatedly the fire extinguishing system process and to respond emergency situation. The following three processes are flow charts for each case.

1. **Automatic Operating Process** (Selection Valve "AUTO")

Fire → Alarm → Controller → Solenoid V/V → N_2 Cylinder Gas(release)→ Extinguishing Agent Tank(14~16 kgf/cm^2) → Discharge V/V → Agent(release) → Extinguishment

2. **Manual Operating Process** (Selection Valve "MANUAL")

Fire → Alarm → Controller Start Button Switch → Solenoid V/V → N_2 Cylinder Gas(release)→ Extinguishing Agent Tank(14~16 kgf/cm^2) → Discharge V/V → Agent(release) → Extinguishment

3. **Manual at Power Fail State**

Fire → Alarm → Remove a Safety Clip at Solenoid V/V → N_2 Cylinder Gas(release)→ Extinguishing Agent Tank(14~16 kgf/cm^2) → Open Release Valve → Solenoid V/V Button → Open Discharge V/V → Agent Release → Extinguishment

4. Conclusions

In this paper, a preparation of the fire extinguishment system for STELLA-1 as a large sodium experiment facility was introduced and explained.

For safe operation of the liquid sodium utility, it is important to equip specific-developed fire extinguishing system because of the chemical characteristics of sodium. Operators should know the process and operating manual before conducting an experiment to prevent hazardous situation. Though the dry chemical extinguishing agent put out the fire target, removing agent at high temperature state can cause re-combustion. Thus, extinguishment confirmation work should be conducted after sufficient cooling time to stabilize the surface. And in case of fire at a sealed room, a method making the percentage of oxygen low(injecting nitrogen gas or argon gas) is effective.

It is suggested that experimental studies on finding more appropriate type of agent and calculation parameter value satisfying safety factor and economic efficiency need to be conducted as future work.

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