Transactions of the Korean Nuclear Society Fall Meeting
Pyeongchang, Korea, October 30-31, 2014

Sodium Fire Demonstration Facility Design and Operation

Youngil Cho*, Jong-Man Kim, Jewhan Lee, Jonggan Hong, Sujin Yeom, Chungho Cho, Min-Hwan Jung, Da-Young Gam, Ji-Young Jeong
Korea Atomic Energy Research Institute, Daedeok-Daero989-111, Yuseong-gu, Daejeon, Rep. of KOREA
**Corresponding author:yicho@kaeri.re.kr*

1. Introduction

Although sodium has good characteristics such as high heat transfer rate and stable nuclear property, it is difficult to manage because of high reactivity. Sodium is solid at the room temperature and it easily reacts with oxygen resulting in fire due to the reaction heat. Thus, sodium must be stored in a chemically stable place, i.e., an inert gas-sealed or oil filled vessel. When a sodium fire occurs, the Na_2O of white fume is formed. It is mainly composed of Na_2O_2, NaOH, and Na_2CO_3, ranging from 0.1 to several tens of micrometers in size [1]. It is known that the particle size increases by aggregation during floating in air. The skin contact of molten sodium causes burns and the inhalation of sodium fume results in oral mucositis as well as dyspnea. Thus, the protection method is important and should be considered in the design and operation of a sodium system. In this paper, sodium fire characteristics are described, and the demonstration utility of outbreak of sodium fire and its extinguishing is introduced.

2. Sodium fire characteristics and classification of sodium combustion

2.1 Sodium fire characteristics

The solid sodium is usually covered by an oxide film. The solid sodium dose not ignites until the temperature of the film does not reach its melting point. It is slightly changed depending on the composition of the film; however, it is nearly 300℃ when the contents of sodium carbonate are less than 30%. This temperature is considered to be the practical point of ignition. When the film is peeled off by heating or scratching, the sodium vapor is generated at the exposed surface. This sodium vapor reacts with the oxygen in air, and finally the sodium ignites by reaction heat [2].

Thus, when liquid sodium is formed at a sodium surface, it soon ignites because the sodium vapor that directly reacts with oxygen is concentrated near the liquid sodium surface.

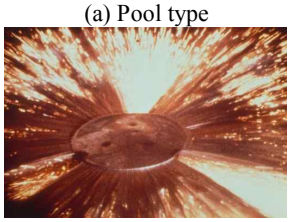
2.2 Classification of sodium fire

According to the combustion process, a sodium fire is classified into three types: a pool type, a spray type, and a column type [3]. When a pool type sodium fire occurs, sodium spreads like a pool on the floor and reacts with the oxygen and moisture on the pool surface. Although its combustion is calmer than the spray type combustion, mentioned below, it continues to burn even after the sodium leakage is stopped as shown in Fig. 1 (a). In this type, the designers have to pay attention to the structural strength of the sodium contacting surface.

Second, a spray type sodium fire occurs when sodium leaks from a pipe as shown in Fig. 1(b). The leaked sodium is scattered and becomes droplets. At the same time, the sodium droplets react with the oxygen and the moisture in atmosphere with a large surface-to-volume ratio. Usually, this type of fire occurs at the pressurized sealed compartment. It gets hotter because of burning heat and becomes more pressurized, resulting in an explosion.

Last, a column type sodium fire is shown in Fig. 1 (c). In this case, the leaked sodium from a pipe falls like a waterfall. It impacts the floor, becomes droplets, and reacts with the oxygen and moisture. The column type is milder than the spray combustion and most real accidents occur through this type.

(a) Pool type



(b) Spray type

(c) Column type

Fig.1.Classification of sodium combustion

3. Design and operation of the sodium fire demonstration facility

3.1 System design

The purpose of a sodium fire demonstration facility is to experience a sodium fire and fire extinguishing process. This utility consists of a training cell, a sodium fire pot, and scrubbers as shown in Fig. 2.

The training cell area is 4000×4000×3000 mm^3 and the sodium fire and extinguishing demonstration occur inside this structure. Thus, a protection system is

installed in the training cell. A scrubber and 10mm thick fireproof glasses are installed to prevent the leakage of poisonous gas (i.e. sodium fume) to the outside and exposing the shocks, respectively.

A sodium fire pot consists of a base, a sodium storage tank, a sodium supply tank, a sodium melting pot, and a top cover of melting pot. The capacity of the sodium storage tank and supply tank is 9L and 1L, respectively, and the operating temperature is 200℃. The sodium fire pot demonstrates pool-type ignition about sodium with 17L. At the top of the tank, a level sensor and an Ar supply line are installed. Also, the sheath heater is installed to supply heat. The maximum operating temperature of sodium melting pot is 300℃. This pot uses a ceramic heater for easy maintenance.

The scrubber is designed by 10kg/h of gas treatment. It consists of a watering part and charging part and operates during a sodium fire. Three spiral type nozzles are installed in the watering part with an interval of 65° for a uniform distribution of water.

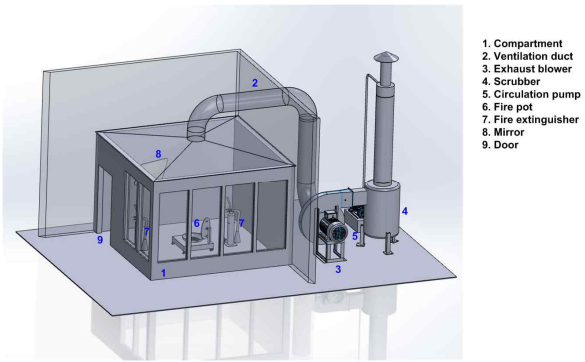


Fig.2. Schematic view of sodium fire demonstration facility

3.2 System operation

The sodium fire demonstration facility is operated as follows. First, the operator checks the power and operating status of the sodium fire demonstration facility. Then, operator supplies power to the device and sets the target temperature at 200℃ for easy ignition. The scrubber is turned on to remove the sodium fire fume. When the temperature reaches its target, the operator opens the valve to induce liquid sodium to the sodium fire pot. The liquid sodium in a sodium fire pot is ignited by an oxygen reaction. For the case of a sodium fire, the height of the flame is lower than in a general fire. However, when sodium is combusted, poisonous aerosol is generated at a large amount. During sodium fire extinguishing, the operator and trainees should wear firefighting equipment without any clearance, from which sodium gas can leak. The sleeves of the outer wear and the skirt of the pants must be worn on long leather glove and half long boots. In Fig. 3, the operator and trainees are extinguishing a sodium fire using protection equipment. For sodium firefighting, water or general extinguishing media including CO_2 are strictly forbidden because they explosively react with sodium. Class D extinguishing agent should be used to suppress a sodium fire. Since the extinguishing of sodium combustion is carried out based on the principle of extinguishment by smothering, the most important point is to cover up the firing area completely with a fire extinguisher to prevent a re-ignition.

Fig.3. Extinguishment of sodium fire in training cell

3. Conclusions

In this paper, sodium fire characteristics and a demonstration facility are described. The introduced sodium fire demonstration facility is the only training device used to observe a sodium fire and extinguish it domestically. Furthermore, the type of sodium fire will be diversified with the enhancement of the utility. It is expected that this utility will contribute to experience in the safe treatment of sodium by the handlers.

Acknowledgement

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP). (No. 2012M2A8A2025635)

REFERENCES

[1] JAEA, “Sodium Technology Handbook”, JNC TN9410 2005-011 (2005).
[2] J.L. Ballif et al., “Liquid Metals Fire Control Engineering Handbook”, HEDL-TME-79-17(1979).
[3] J. Y. Jeong et al., “Safety management of coolant in SFR”, KAERI/TR-4374/2011(2011).