Review of Sodium and Plutonium related Technical Standards in Trans-Uranium Fuel Fabrication Facilities

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1. Introduction

These days, many nuclear related researches focus on separating and reducing the long-lived radioactive transuranic (TRU) in the spent nuclear fuel. They are useful technology in reusing the potential energy of uranium fuel resources and in reducing the high level wastes.

The feasibility and conceptual designs are being examined on related facilities, for example, TRU Fuel Fabrication Facilities (TFFF), Korea Advanced Pyro-process Facility (KAPF), and Sodium Cooled Fast Reactor (SFR), in Korea.

However, the safety concerns of these facilities have been controversial in part because of the Sodium fire accident and Plutonium related radiation safety caused by transport and handling accident. Thus, many researches have been performed to ensure safety and various documents including safety requirements have been developed.

In this paper, we would introduce and review technical standards related to sodium fire and plutonium criticality safety.

This paper may be helpful to identify considerations in the development of equipment, standards, and etc., to meet the safety requirements in the design, construction and operating of TFFF, KAPF and SFR.

2. Review on Technical Standards

2.1 Sodium Fire

Sodium(Na, Natrium, atomic number 11) is soft, silver-white and highly reactive metal. It is extremely flammable and emits flammable but non-toxic gases in presence of moisture[1]. Moreover, it is highly flammable under open flames and sparks of heat[1]. Thus, DC 41 of the general design criteria for nuclear power reactors[2] is under consideration for addressing sodium related criteria, because Sodium chemical reactions may produce reaction products that impact the containment atmosphere and oxygen and hydrogen might not be present in Sodium-cooled Fast Reactor (SFR)[2].

Sodium and mixture containing at least 25% sodium are the substances that requires preparing for accident, which should prepare and submit Hazard Control Program and notify to local communities in accordance with "Chemical Control Act" of the Ministry of Environment (ME)[3]. Also, according to "Act on the Safety Control of Dangerous Substances" of the Ministry of Public Safety and Security (MPSS)[4], Sodium is the material which should obtain a permit from the licensing authorities through examination or inspection, cooperating closely together every process from start (installation planning) to finish(beginning to use).

Table 1 shows the regulatory Information of Sodium[1,3,4].

Because Sodium is a flammable solid and a moisture reactive material, water, CO_2 or halogenated extinguishing agents is inadequate for extinguishing media of Sodium fire. Dry chemical powders are generally recommended for small fires while water spray or fog except water jet are employed for large fires[6]. Another important consideration of Sodium fire is toxic fumes emitted by thermal decomposition or combustion. When exposed, workers must escape from the exposure, immediately move to fresh air zone and get appropriate medical aids.

2.2 Plutonium Criticality

Plutonium(Pu, Transuranic radioactive element, atomic number 94) is a grayish white, dense silvery and radioactive solid that is strongly electropositive. Critical mass of Plutonium is above 5.0 kg for Pu metal and above 500 kg for Pu in any form. Plutonium may form pyrophoric products on exposure to air and moisture which may cause a fire hazard with subsequent spread of radioactive material[7]. Plutonium in liquid solutions poses a greater criticality hazard than solid plutonium[7]. Thus, it is recommended to avoid the conditions of radiation hazard and do not allow material to spread or contaminate water resources[7]. NRC RG3.16 recommended that plant should be designed to assure the confinement of hazardous materials under both normal and abnormal conditions including fires and explosions and then flammable gas should not be introduced into[8]. Especially, structure shells surrounding any area handling plutonium should be designed with sufficient fire resistance assuming failures of any fire suppression system which is not designed as an essential item[8].

When a fire occurs, dust, power or fumes are flammable or explosive when exposed to heat and

flames. Thus undamaged containers should be moved out of fire zone in accordance with the emergency response guidebook(ERG)[9]. Metal-X(Class D) fire extinguisher is suitable for small fires.

Table 2 shows the regulatory Information of Plutonium[7, 8,10,11,12,13].

2.3 Other Standards

There are many technical standards for the safety evaluation for TFFF. Major technical standards are NUREG-1513, which is the guidance document for integrated safety analysis including radiological, nuclear criticality fire and chemical, and 10CFR70.62, which is the code for safety program and integrated safety analysis. And RG3.14 provides the guidance for the seismic design classification for plutonium processing and fuel fabrication plants.

3. Conclusions

In separating and reducing the long-lived radioactive transuranic(TRU) in the spent nuclear fuel, reusing as the potential energy of uranium fuel resources and reducing the high level wastes, TFFF would be receiving the attention of many people. Thus, people would wonder whether compliance with technical standards that ensures safety.

For new facility design, one of the important tasks is to review of technical standards, especially for sodium and Plutonium because of water related highly reactive characteristics and criticality hazard respectively.

We have introduced and reviewed two important technical standards for TFFF, which are sodium fire and plutonium criticality safety, in this paper. This paper would provide a brief guidance, about how to start and what is important, to people who are responsible for the initial design to operation of TFFF.

In the future, we will perform safety analysis reflecting the requirements and review which the requirements is necessary to enhance and revise or not.

REFERENCES

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[10] Nuclear Safety and Security Commission, Regulation for Radioactive Package and Transport, 2014.
[11] Nuclear Safety and Security Commission, Standards for Protection against Radiation, 2014.
[12] US NRC, 10CFR71, Packaging and Transportation of Radioactive Material, 2015.
[13] US NRC, 10CFR20, Standards for Protection Against Radiation, 2001.
[14] US NRC, RG3.47, Nuclear Criticality Control and Safety of Homogeneous Plutonium-Uranium Fuel Mixtures Outside Reactors, 1981.

Table 1. Regulatory information of Sodium

(a) Domestic[1,3,4]

Agency	Regulations
ME	○ Chemicals Control Act : - Toxic substances - Substances requiring preparing for accident(Sodium and Mixture containing at least 25% Sodium)
MPSS	○ Act on the Safety Control of Dangerous Substances : Class 3 Sodium
Applying abroad regulations	○ CERCLA : Reportable quantity of 10lb or 4.54kg ○ Based on NFPA : - Health : 2 - Flammability : 3 - Reactivity : 2 - Specific Hazard : \ (Incompatible with water)

(b) Foreign[2,5,6]

Agency	Regulations
US DOT	○ DOT classification : Class 4.3, Material that emits flammable gases on contact water
Federal and State (USA)	○ Pennsylvania RTK : Sodium ○ Massachusetts RTK : Sodium ○ TSCA 8(b) inventory : Sodium ○ CERCLA : Hazardous substances, Sodium ○ 10CFR50 : General Design Criteria(GDC) ○ 49CFR171~177 : Transportation
OSHA (USA)	○ Hazardous by definition of Hazard Communication Standard (29CFR1910.1200)
WHMIS (Canada)	- Class D-2B : material causing other toxic effects(TOXIC)
DSCL (EEC)	- R17 : Spontaneously flammable in air - R38 : Irritating to skin - R-41 : risk of serious damage to eyes
HMIS (USA)	- Health Hazard : 3 - Fire Hazard : 3 - Reactivity : 2 - Personal Protection : E
NFPA (USA)	- Health : 3 - Flammability : 3 - Reactivity : 2 - Specific Hazard : -W-
IATA	○ Resolution 618 Dangerous Goods Regulations ○ Resolution 619 Dangerous Goods Board

ME : Ministry of Environment
MPSS : Ministry of Public Safety and Security
CERCLA : Comprehensive Environmental Response, compensation and Liability Act
CFR : Code of Federal Regulation
DOT : Department of Transportation
DSCL : Dangerous Substances Classification and Labeling
EEC : European Economic Community
HMIS : Hazardous Material Information System
IATA : International Air Transport Association
NFPA : National Fire Protection Association
OSHA : Occupational Safety and Health Administration
RTK : Right-To-Know Law
TSCA : Toxic Substances Control Act
WHMIS : Workplace Hazardous Material Information System

Table 2. Regulatory information of Plutonium

(a) Domestic

Agency	Regulations
NSSC	○ Regulation for Radioactive Material Package and Transport[10] : Based on 10CFR71 - Un-irradiated uranium : uranium containing not more than 2kBq of plutonium per gram of urnium-235 - Technical Standards of Transport Cask : Article 22~29 - L-type cask : not exceed 5 mSv/h at the surface of the package i - IP-type cask : not exceed 10 mSv/h at a distance of 3m from the surface of the package - B(U) typed cask : not exceed 10 mSv/h at a distance of 1m from the surface of the package - C typed cask : not exceed 10 mSv/h at a distance of 1m from the surface of the package ○ Standards for Protection against Radiation[11] - Allowable Surface Contamination : 0.4Bq/cm^2 for alpha-emitting material and 4Bq/cm^2 for alpha non-emitting material - Annual Intake Limits : Pu-239(M) 6E+02Bq for inhalation / 8E+04Bq for intake Pu-239(S) 2E+03Bq for inhalation / 2E+06Bq for intake

(b) Foreign[7]

Agency	Regulations
US NRC (USA)	○ 10CFR71.63[12] : Shipments containing plutonium must be made with the contents in solid form, if the contents contain greater than 0.74 Ci) of plutonium ○ 10CFR71.64[12] : External radiation level would not exceed 10 mSv/h at a distance of 1m from the surface of the package in its post-tested condition in air ○ 10CFR20[13] : Storage and Radiation Standards - Occupational Dose Limits for Adults : total effective dose equivalent 50 mSv/yr ○ 20CFR1910.96 : Radiation Standards ○ NRC RG3.7 : Monitoring of combustible gas and vapors in plutonium processing and fuel fabrication plants ○ NRC RG3.12 : ventilation of plutonium processing and fuel fabrication plants ○ NRC RG3.16[8] : Fire protection guide for plutonium more than 0.71 processing and fuel fabrication plants ○ NRC RG3.47[14] : - Based on ANSI/ANS 8,12 - Nuclear Criticality Control and Safety of Homogeneous Plutonium-Uranium Fuel Mixtures (mixtures containing no more than 30 wt-% plutonium combined with uranium containing no wt-% U-235)

NSSC : Nuclea Safety and Security Commission
US NRC : United States Nuclear Regulatory Commission
RG: Regulatory Guide