Discussion on the Safety Analysis Approach in Fuel Cycle Facility and Nuclear Power Plant

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1. Introduction

Domestic in-service light water reactors of 16 units generate spent fuel of around 320 ton/year and the heavy water reactors of 4 units around 380 tons/year, and 10,761 ton of spent fuel are deposited in plant sites. Electricity portion of nuclear power plants is planned to increase up to 59% share by 2030. So more spent fuel is expected to be produced. However, spent fuel in itself is also a very useful energy source. Thus, the safe management of spent fuel is very important confronting job in domestic nuclear industry. Advanced fuel cycle (AFC) using pyro-process is an innovative technology, by which environmental load is drastically relieved because the extracted long-lived fission products are burn in fast breeder reactors [1].

Domestic nuclear industry also has a perspective road map for the construction of AFC facilities. However, there is not a sufficiently detailed licensing regulatory system yet. Moreover, there is no systematic frame for the safety evaluation. For the advancement toward the development of safety this paper reviewed the feature of conventional safety approaches in nuclear power plants and non-reactor nuclear facilities, in particular fuel cycle facilities.

2. Difference of Fuel Cycle Facility from Nuclear Power Plant and Chemical Processes

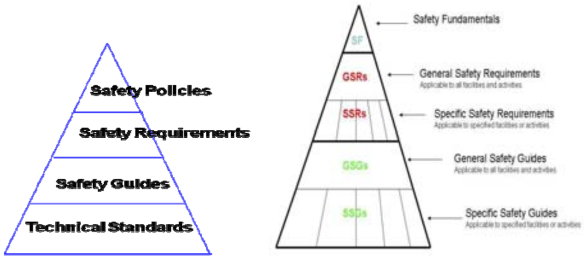
IAEA TECDOC-1575 [2] provides kind comparison of typical differences between nuclear power plants (NPPs), chemical processes, and fuel cycle facilities (FCFs). Some noticeable differences are;

- The hazardous sources and inventories in FCFs spread throughout the process equipments in the facility.
- The type of hazardous materials in FCFs is widely various.
- The typical causes and consequences in FCFs are not only related with the radiological ones but also variety of chemical toxics.
- It is necessary to provide correspondingly a wide range of specific safety measures as inherent parts of these activities FCFs.
- Radiation protection requirement of the personnel in FCFs is more demanding especially in view of the many human interventions required for the operation and maintenance of FCFs.

3. Comparison of Safety Approaches

3.1 Hierarchy of safety

IAEA safety standard has clear hierarchy of safety concept. In the contrary the U.S. safety framework does not seem to have definite hierarchy, and only DOE standards [3] propose conceptual formulation such as Fig. 1



(a) DOE (b) IAEA
Fig. 1 Safety Hierarchy DOE and IAEA

The safety hierarchy of DOE is mentioned in safety standards for nonreactor nuclear facilities, not for NPPs, whereas the one in IAEA is applied to both of them. Such a perspicuous hierarch is expected to help lead the substantial guidance not to confuse the core kernel and make clear the more important and less important.

3.2 Identification of hazards

Hazard in NPPs is very simple. The radiological consequence is the most important one, and it has been the unique target against achieving safety. So the job of hazard identification has not been important. However, in FCFs the processes themselves are various and the related hazards addresses broad band; solid, liquid, gas, slurry, powder; fissile materials, nitric acid, hydrogen fluoride, solvents, process and radiolytic hydrogen, etc. So the identification of hazard is the starting line to safety analysis and very important job.

DOE provide standards for the completeness of hazard identification [4], and NRC also requires the licensee to identify all possible hazards to be addressed in NUREG-1520[5].

3.3 Selection and categorization of postulated initial events

Categorization of event is to impose graded acceptance criteria according to the occurrence frequencies. The references of frequency categorization are the life time of a facility and the frequency of an occurrence during life time of many facilities. The life time is converted to the numeric value 100 years and an occurrence during life time of many facilities is converted to once during 100 X100 operational years. Such a numeric value is very conceptual and seems practical because such a categorization has been accepted in long history of NPPs. The same categorization is introduced in FCFs.

Identification of postulated initial events (PIEs) in conventional NPPs has depended on the experiences, and is not so much systematic, especially compared to the methodology of barrier performance analysis. Of course recent advanced reactor adopted systematic approaches using probabilistic safety analysis (PSA). Some standards suggested examples of PIEs.

In FCFs the PIEs are derived from the assessment of the process, related hazards, and experiences.

Both of NPPs and FCFs have the intent of grouping the events according to type. NPPs group the event according to the processes affecting the core; decrease in heat removal in secondary system, increase in heat removal in secondary system, and so on. In FCFs broader concept of process is involved. Table I is the PIEs in IAEA NS-R-5 according to the type[6].

Table I. PIEs in IAEA NS-R-5

Group	Subgroup	PIE
External Event	Natural Phenomena	(a) Extreme weather conditions
		(b) Flooding
		…
	Human Induced Phenomena	(a) Fires, explosions or releases of corrosive or hazardous substances
		(b) Aircraft crashes
		…
Internal Event	-	(a) Loss of energy and fluids
		(b) Failures in use of electricity
		…

3.4 Identification of event sequences

In NPPs event sequences are identified with consideration of system operation and all required operator actions together with the effect of single failures. Recent approaches also use the PSA for the convincement of the most severity. FCFs consider IROFS (items relied on for safety), and fault tree may be developed.

3.5 Analysis of system and barriers performances

Safety analysis in NPPs has used a rigorous mathematical model for the prediction of system and barrier performance in transient. There is no outstanding difference of strictness in its mathematical model according to the frequency categories or severity of the event. However, safety analysis in FCFs permits the graded approach according to the frequency and the severity of the consequences.

The basic philosophy in safety analysis in FCFs is to cover broad range of event and to analyze profoundly the important events.

3.6 Acceptance criteria

The fundamental principle for acceptance criteria is that the consequence of high frequency event should be mild and the event of severe consequence should have a low frequency. Such a principle is common in NPPs and FCFs. It is very similar to the concept of frequency-consequence curve (F-C curve). In NPPs the dose criteria are given according to the event categorization (frequency). And the physical limitations are imposed in barriers, such as peak cladding temperature less than 2200˚F. In the contrary in FCFs the acceptance criteria for the final consequences are more complicated. The radiological dose and chemical dose are given for worker, off-site public, and environment, respectively. Such acceptance criteria are for the protection of people and environments from various hazards.

4. Conclusions

Brief comparison of nuclear power plants and fuel cycle facilities is discussed. NPPs seem to focus on the radiological material in core and the effect of radiological hazard. In contrary FCFs tried to cover all the spectrum of hazard in various processes.

More details will be presented in conference.

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