A Preliminary Evaluation of the Initiating Events of a Hydrogen Conversion Reactor

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1. Introduction

This paper proposes a preliminary evaluation of the initiating events of a HCR for an early stage PSA. A main concern of this approach is to identify the possible initiating events of a HCR. The identification of initiating events provides a basis of the accident sequence analysis of the PSA and a selection of the design basis events (DBE) (including the anticipated operational occurrences (AOO) or the beyond design basis events (BDBE)). A primary candidate for a reactor system layout for a hydrogen conversion would have no power conversion system as shown in Fig. 1[1]. This unique type of reactor system does not exist in the world, so that we believe that the initiating events for this system are very different to the current nuclear reactors including high temperature gas cooled reactors. By using Fig. 1's system layout, we tried to identify the unique features of the initiating events of this system. For the identification, we considered the physical or technical facts disturbing the heat or reactivity balance.

2. Identification Methods

There are several approaches to identify the initiating events for a nuclear reactor. These approaches are in pursuit of (1) logical structure of an identification and (2) completeness of the events set. These approaches are classified as two groups: top-down approach group and bottom-up approach group. The other approaches are used as supporting methods for a completeness.

In LWR PSA, the master logic diagram is adopted as the identification of the initiating events because an essential issue in the identification is a completeness problem of the initiating events set. The master logic diagram provides a completeness by using a logical consideration of the initiating causes. For a HCR, there is less experience of a PSA so it is important to know about the unique features of the initiating events in this system to distinguish it from other systems.

For this reason, this study applied a method to consider the physical or technical facts disturbing the heat or reactivity balance because we expect that this general approach could be useful to search for the unique features of a HCR. This approach was generally adopted in the framework of the safety analysis report of the LWRs.

3. An Application Example

To identify the initiating events, the considered system layout should be fixed. This study assumed an example system layout as shown in Fig.1. There is a candidate system layout for developing the current hydrogen conversion reactor, so an arbitrary system layout has been assumed as shown in Fig. 1. We tried to consider the current proposed design features for this layout if possible. Our assumed system layout approximately consists of three parts:

1. Reactor system layout (primary and secondary coolant loops)
2. Confinement system layout
3. Engineered system layout

The major components in the reactor system basically include a reactor core, related structure, intermediate heat exchangers, coolant blowers (circulators), etc. The confinement system is expected to be a radiation material purge & filtering system and a pressure control system (like a PSV), etc. Engineered systems include the supporting and engineered safety systems. Supporting system has a coolant makeup & supply system and a pressure control system (like a safety & relief valves).

It is noted that the related structure, systems & components (SSC) are assumed to work well. Several necessary systems such as instrument & control systems, support systems, balance of plan (BOP), & electric power supply systems are not considered at this time. Other options are also not considered. There are many candidates for each system or component. Although each systems' candidates have a similar function, adopted systems affect the type of the initiating events. Under this assumed system layout, initiating event analysis should be prepared to focus on an identification of them. In the current example, a simplified crude initiating event has been used.

The primary identification list is shown in Table 2. This work started from an inference of disturbing the heat balance between the heat source and the heat sink. Secondly, identified disturbing factors were compared with installed functions. More precise list of the initiators was obtained after several decompositions of the crude initiators, but this list does not reflects the direct initiators, which could be obtained after finishing a detailed design layout. These logical identifiers were considered as a primary initiating events list. The master logic diagram was used as a second tool for an identification as shown in Fig. 2. This list was screened and grouped by considering a sequential impact on the accidents. Table 3 shows a list of the screening and grouping of the initiators by a similar accident sequence. These preliminary events were binned as 11 accident groups.

4. Concluding Remark

This study evaluated the preliminary identification of the initiating events of a HCR based on a hypothetical system layout. The identification results will not be used as a direct list of the initiating events for a HCR, but serve to provide an insight into the identification process and to understand a new system and its characteristics. We expect that the identification approach and results will be useful tools as basic information for the HCR PSA.

ACKNOWLEDGEMENT

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REFERENCES

[1] Seok-Jung Han & Joon-Eon Yang, "A Preliminary Neutral Framework for the Accident Sequence Evaluation for a Hydrogen Conversion Reactor," 2005 KNS Autumn Conference, 2005.

Table 1. Several approaches for the identification of the initiating events

Classification		*Technique*	*Advantage*	*Disadvantage*	Remark
Main	Top-down	Systematic Deductive Identification of Events	• Simple & easy	• Non fixed format for logical approach • Non completeness	
		Master Logic Diagram (MLD)	**• Simple & easy**	**•Hard to identify the concrete initiators**	**Full power PSA**
		Fault Trees (FT)	• Medium	• Should be identified event category • Non completeness	Easy to imitator frequency
		Technical or Physical Considerations Disturbing the Heat or Reactivity Balance	• Understandable • Identification of specific features	• Non Completeness • No generalized method	Adequately reactor systems
	Bottom-up	Hazard and Operability Analysis (HAZOP)	• Consider various facts	• Hard to apply complex system • Large work • Not easy to identify consequential impact	Applied on the chemical process system
Support		Failure Mode and Effects Analysis (FMEA)	• Easy identification of support systems	• Complex • Time consuming	Induced initiator from support system
		Procedure Trees (PT)	• Trace procedure errors	•No generalized method	Procedural errors
		Human Reliability in Isolation/Mitigation	• Trace human errors	•No generalized method	Human errors

Table 2. A list of the identified initiating events

Index	Event Category			Related Event	Initiators	Class
1.	Heat Balance Disturbance					
1.1		Increase in Heat Removal by Secondary System		3.1		
1.1.1			Increase Secondary Coolant Flow		Secondary Blower Miss-Acceleration	
1.1.2			Decrease Secondary Flow Inlet Temperature		Increase Third-side Cooling	
1.2		Decrease in Heat Removal by Secondary System				
1.2.1			Decrease Secondary Coolant Flow		Secondary Safety/Relief Valve Accidental Open Secondary-Side Boundary Failure (Break or Leak) Secondary IHX Blocking Secondary Blower Blocking	
1.2.2			Increase Secondary Flow Inlet Temperature		Decrease Third-side cooling	
1.3		Increase in coolant flow		3.1 4.2.2	Primary Blower Miss-Acceleration	
1.4		Decrease in coolant flow		4.2.2	Primary Blower Blocking Primary IHX Blocking	
2.	Boundary Failure except Reactor Components					
2.1*		Increase in Boundary Pressure		*	*	
2.1.1			Unbalanced Coolant Makeup	4.3.2	* Helium Makeup System Over Charging	
2.1.2			Anomalies of Blower	1.3, 4.2.2	* Primary Blower Miss-Acceleration	
2.2		Decrease in Boundary Pressure		4.1.1, 4.2.1, 4.3.1		
2.2.1			Leak Boundary	4.3	Leak in Boundary Interface System Break Safety/Relief Valve Accidental Open	Chemical Reaction
2.2.2			Break Boundary	2.3	Catastrophic Failure of Coolant Piping Catastrophic Failure of Reactor Structure	
2.3		Chemical Reaction				
2.3.1			Air Ingression (O_2)		+ Break Boundary	
2.3.2			Water Ingression (H_2O)		- N/A	Primary + 2ndary IHXs Boundary Failure
3.	Physical Disturbance					
3.1		Reactivity and Power Distribution Anomalies				
3.1.1			With Power Operation		Control Rods Withdraw Shutdown Rods Withdraw	
3.1.2			With Startup Operation		Control Rods Withdraw Shutdown Rods Withdraw	
4.	Failure of Reactor Components except Affiliated Systems					
4.1		Intermediate Heat Exchanger				
4.1.1			Boundary Failure	2.3	IHX Interface Failure	
4.1.2			Heat Transfer Degradation		- N/A	
4.1.3			Flow Blocking		Internal Dust, Debris, Structure Failure	
4.2		Blower				
4.2.1			Boundary Failure	2.2		
4.2.2			Unbalanced Rotor Speed	1.3 & 1.4	Blower Miss-acceleration Blower Locked	
4.2.3			Mechanical Threaten		* Turbine Missile	
4.3		Helium Makeup & Purification System				
4.3.1			Boundary Failure	2.2		
4.3.2			Unbalanced Coolant Makeup	2.1		
5.	Radioactive Material Released from a System of Component				Exception	
5.1		...				

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Table 3. A list of screening and grouping of the initiators by a similar accident sequence

1. General Transient (Transient)
   - General Transient (Transient)
   - Increase Third-side Cooling (Transient)
   - Decrease Third-side Cooling (Transient)
2. Loss of Off-site Power (Transient)
3. Primary Blower Miss-Acceleration (Transient)
4. Loss of Coolant Flow (Transient)
   - Primary Blower Failure (Transient)
   - Primary Blower Locked (Transient)
   - Primary IHX Blocking (Transient)
5. Secondary Blower Miss-Acceleration (Transient)
6. Loss of Secondary Cooling (Transient)
   - Secondary Safety/Relief Valve Accidental Open (Transient)
   - Secondary-side Boundary Failure (Transient)
   - Secondary IHX Blocking (Transient)
   - Secondary Blower Blocking (Transient)
   - Secondary Blower Failure (Transient)
7. Helium Makeup System Over Charging (Transient)
8. Primary Boundary Failure without Chemical Reaction (LOCA)→ Depressurization Accident (HTTR)
   - Primary IHX Interface Failure (LOCA)→ Depressurization Accident (HTTR)
   - Primary Leak in Boundary (LOCA)
   - Primary Interface System Break (LOCA)
   - Primary Safety/Relief Valve Accidental Open (LOCA)
9. Large Boundary Failure with Chemical Reaction (LOCA)
   - Catastrophic Failure of Coolant Piping (LOCA)
   - Catastrophic Failure of Reactor Structure (LOCA)
10. Catastrophic failure of Blower (LOCA)
11. Control Rods Withdraw with/without Power Operation (CRWD)
    - Control Rods Withdraw with/without Power Operation (ATWS)
    - Shutdown Rods Withdraw with/without Power Operation (ATWS)

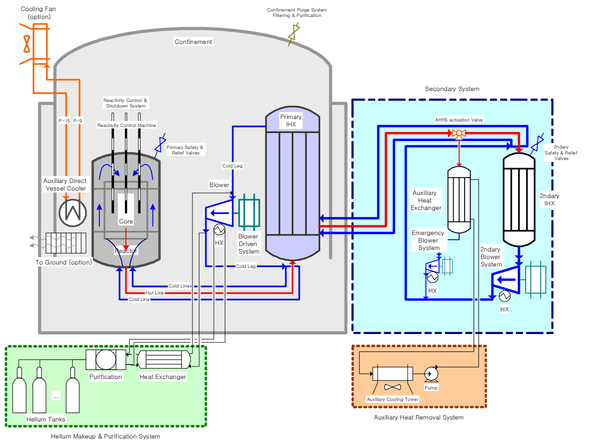

Fig. 1. An arbitrary system layout of a HCR for the PSA

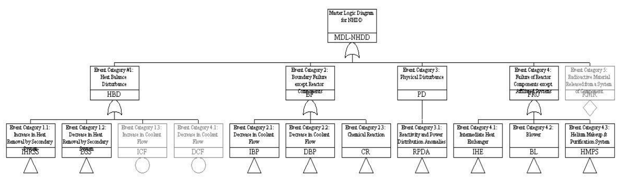

Fig. 2. A master logic diagram for the identification of the initiating events (including the level 3 decomposition)