Transactions of the Korean Nuclear Society Spring Meeting
Chuncheon, Korea, May 25-26 2006

Safety Assessments for the IS Process in a Hydrogen Production Facility

Gunhyo Jung, Nam-Chul Cho, Moosung Jae
Department of Nuclear Engineering, Hanyang University, 17 Haengdang, Sungdong, Seoul, Korea
jae@hanyang.ac.kr

1. Introduction

The thermochemical water decomposition cycle is one of the methods for the hydrogen production process from water [1]. The successful continuous operation of the IS-process was demonstrated and this process is one of the thermochemical processes, which is the closest to be industrialized [2]. Currently, Korea has also started a research about the IS process and the construction of the IS process system is planned. In this study, for risk analysis of the IS process, initiating events of the IS process are identified by using the Master Logic Diagram (MLD) which is the method for initiating the event identification. Also, 6 events were identified among 9 initiating events above and performed quantification of events using event tree analysis.

2. Methods and Results

2.1 Initiating events identification using Master Logic Diagram in IS process

The Master Logic Diagram technique is a basic approach for initiating event identification. The starting point of MLD development starts by defining the top event. In this study, the top event is defined as containment failure that can induce to stop the system and can cause risk. And then, the deductive decomposition is carried out through the following step

2.1.1 Identification of critical areas

The critical area of the plant contains different chemical material as follows:

(1) Bunsen Reaction Step
(2) H_2SO_4 Decomposition Step
(3) HI Decomposition Step
(4) H_2 Step

These four sections have been identified as possible sites of chemical material release. A schematic representation of the division of the IS process plant in the four sections is given in Figure 1.

The first level of decomposition was along the four possible sites of chemical material release as shown Figure 2.

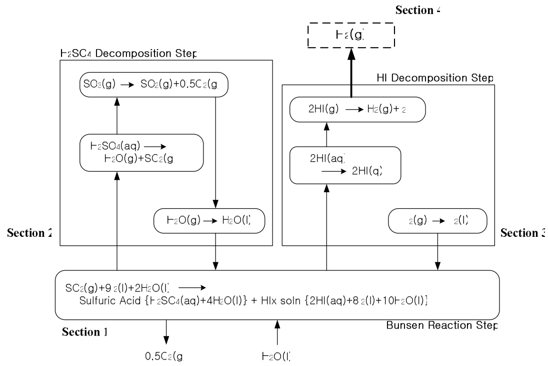

Figure 1. Schematic diagram of the IS process

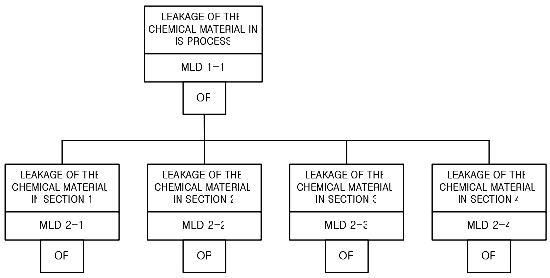

Figure 2. MLD of the IS Process

2.1.2 MLD of the Bunsen reaction section as an example

Figure 3 gives MLD of the Bunsen reaction section.

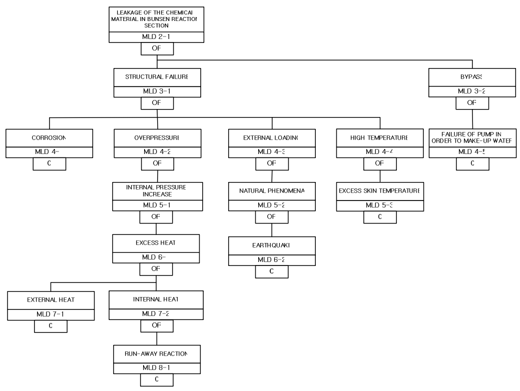

Figure 3. MLD of the Bunsen reaction section

The reasons that Bunsen reaction section may fail could be the structure failure and bypass some of the structure. Structure failures occur in corrosion by H_2SO_4, overpressure, external loading and high temperature. Overpressure in Bunsen reaction may occur in fire and run-away reaction. An earthquake is the only natural phenomenon considered which might cause loss of containment. All other natural phenomenon such as flooding and high wind has been neglected, because this particular system is surrounded in the outside building. High temperature may occur in external fire. Bypass in the Bunsen reaction happens due to the failure of the pump to provide the water.

2.1.3 Initiating Events Identification

The most important initiating events that were identified with the application of the Master Logic Diagram to the IS process are the following:

(1) Pipe-break owing to corrosion, thermal stress, hydrogen embrittlement and hydrogen induced cracking
(2) Overpressure owing to run-away reaction in the Bunsen reaction
(3) Vapor pressure increase from a temperature control failure
(4) Direct pressure increase from evaporated gas
(5) Clogged pipe by I_2 concentration control failure
(6) Overfilling in storing hydrogen
(7) Failure of check valves and molecular seals
(8) Bypass accident of a water supply pump
(9) Earthquakes
(10) Fire

2.2 Quantitative analysis of accidents

2.2.1Iidentification of accidents

In this study, the following 6 types of accidents were chosen among 10 initiating events according to the probability of occurrence and whether there is a concrete concept of design.

(1) Pipe-break owing to corrosion and thermal stress
(2) Break of a pipe that contains an inflammable gas
(3) Vapor pressure increase from a temperature control failure
(4) Bypass accident of a water supply pump
(5) Earthquakes
(6) Fire

2.2.2 Quantitative analysis of pipe-break owing to corrosion and thermal stress as an example

Event tree of pipe-break owing to corrosion and thermal stress is shown below Figure 4 that is shows outlines of accident scenario and accident frequency.

Frequency of pipe-break is fixed by accident risk data from U.S. hazardous chemical facilities [3]. Data of failure rate is composed of a database for general chemical plant.

As a result, Leakage probability of pipe-break was 1.75 x 10^{-5} that is lower than the value of CDF of nuclear power plant (1.0 x 10^{-4}).

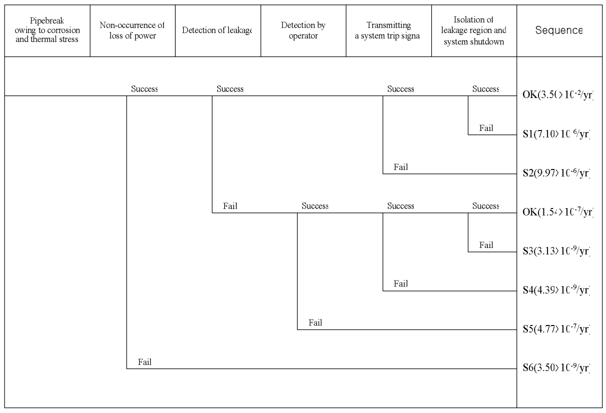

Figure 4. Event tree of the pipe-break accident

3. Conclusion

Initiating event identification uses both formed techniques which are based on systematic and logical method and experienced techniques which used the former data [4]. In this paper, initiating event identification of the IS process is carried out by using MLD. Also, 6 events were chosen and event tree method that is broadly used in order to evaluate safety of nuclear power plant is carried out for quantification. As a result, a sum of each event was 1.22 x 10^{-4} that is similar to the value of CDF of nuclear power plant (1 x 10^{-4}). But, plant that will be built later on requires much higher safety since it is operated in the condition of high pressure. Therefore, for the safety enhancement of hydrogen production facility, early detection after leakage and studies that enables to limit amount of leakage by block and removal are required. More over, studies of safety device and consideration are needed in the aspect of system design.

Finally, the result of this study is considered to contribute to the improvement of safety in pre-conceptual design and also to the safety management.

REFERENCES

[1] M. Sakurai, H. Nakajima, K. Onuki, K. Ikenoya, S. Shimizu, "Preliminary process analysis for the closed cycle operation of the iodine-sulfur thermochemical hydrogen production process", International Journal of Hydrogen Energy 24, p. 603-612, 1999.
[2] Makoto Sakurai, Hayato Nakajima, Rusli Amir, Kaoru Onuki, Saburo Shimizu, "Experimental study on side-reaction occurrence condition in the iodine-sulfur thermochemical hydrogen production process", International Journal of Hydrogen Energy 25, p. 613-619, 2000.
[3] James C. Belke, "Chemical accident risks in U.S. industry-A Preliminary analysis of accident risk data from U.S. hazardous chemical facilities", United Stats Envrionmental Protection Agency, 2000.
[4] Seok-Jung Han, "Identification of Initiating Events Using the Master Logic Diagram in Low-Power and Shutdown PSA for Nuclear Power Plant", KAERI, p.35, March, 2003.