A Study on Hazard Types Occurring in Hydrogen Facilities

Nam-Chul Cho a, Moosung Jae[1] a, Yang Joon-Eon b
a Department of Nuclear Engineering Hanyang University 17 Haengdang, Sungdong, Seoul, Korea
b Korea Atomic Energy Research Institute 150, Dukjin, yuseong, Daejeon, Korea

[1]To whom correspondence should be addressed. jae@hanyang.ac.kr

1. Introduction

Hydrogen has ideal characteristics as an energy carrier. Hydrogen can be used as a clean fuel in a variety of energy end-use sectors including the conversion to electricity. After combustion, it produces only water. Therefore, the concept of hydrogen energy system has attracted much interest worldwide. [1]

But hydrogen has a defect that the explosion risk is high to an inflammable gas of a colorless, tasteless and odorless. Therefore, to use the hydrogen to the source of energy, hydrogen accident sequences and causes analysis must be needed. For this, hazard types occurring in hydrogen facilities have been considered through the case of domestic and foreign hydrogen accident in this study and hazard types to be considered are ignition, leaks, hydrogen dispersion, fire an explosion, storage vessel failure, vent and exhaust system, purging, condensation of air, hydrogen embrittlement, physiological hazard, and collisions during transportation.

2. Methods and Result

2.1 Hydrogen accident distribution

The French and U.S accident causes implying hydrogen are distributed as follows (Fig.1 and Fig.2): [2,3]

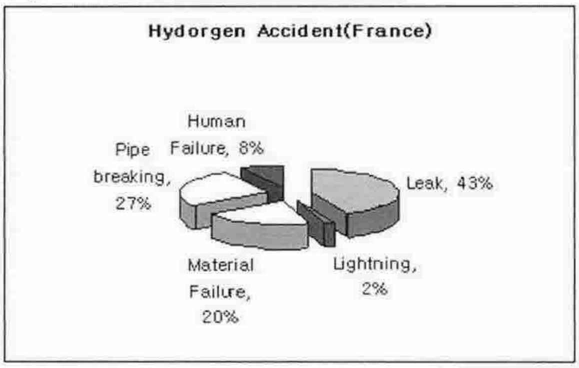

Fig.1 Accident number percentages in France

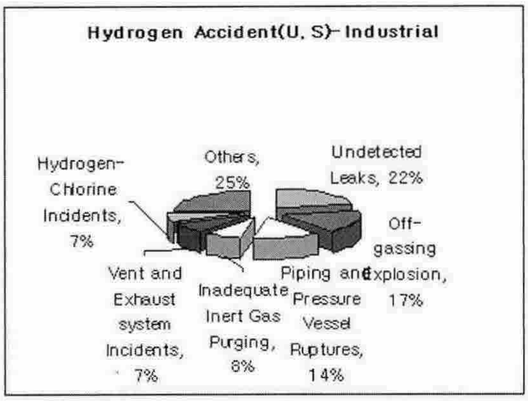

Fig.2 Accident number percentages in U.S

Through accident in U.S and France, leak and rupture including pipe breaking must be paid attention among the hydrogen accidents.

The Korean accident causes implying hydrogen are distributed as follows (Fig.1): [4]

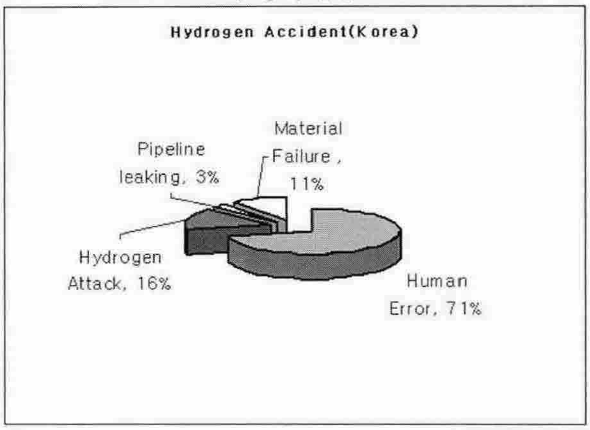

Fig.3 Accident number percentages in Korea

In case of domestic, most of accidents are human error and accident was not enough due to a legal regulation.

Analyses of these accidents indicate the following factors are of primary importance in causing system failures:

- Mechanical failure of the containment vessel, piping, or auxiliary components (brittle failure, hydrogen embrittlement, or freeze-up)
- Reaction of the fluid with a contaminant
- Failure of a safety device to operate properly
- Operational error

2.2 Types of Hazards

The hazards associated with the use of hydrogen can be characterized as physiological (frostbite, respiratory ailment, and asphyxiation), physical (phase changes, component failures, and embrittlement), and chemical (ignition and burning). A combination of hazards occurs in most instances. The primary hazard associated with any form of hydrogen is inadvertently producing a flammable or detonable mixture, leading to a fire or detonation. Hazards of hydrogen use are discussed below. [3]

- Ignition: Ignition sources have included mechanical sparks from rapidly closing valves, electrostatic discharges in ungrounded particulate filters, sparks from electrical equipment, welding and cutting operations, catalyst particles, and lightning strikes near the vent stack.
- Fire and Explosion: H_2 diffuses rapidly with air turbulence increasing the rate of H_2 dispersion. Although ignition sources may not be present at the leak or spill location, fire could occur if the movement of the flammable mixture causes it to reach an ignition source.
- Leaks: Leaks can occur within a system or to the surroundings. Leaks are usually caused by deformed seals of gaskets, valve misalignment, failures of flanges / equipments. Undetected hydrogen leaks can lead to fires and explosions.
- Hydrogen Dispersion: The dispersion of the cloud is affected by wind speed and wind direction and can be influenced by atmospheric turbulence and nearby structures.
- Storage Vessel Failure: Vessel failure may be started by material failure, excessive pressure caused by heat leak, or failure of the pressure-relief system.
- Vent and Exhaust System: Vent and exhaust system accidents are attributed to inadequate ventilation and the inadvertent entry of air into the vent.
- Purging: Pipes and vessels should be purged with an inert gas before and after using hydrogen in the equipment. It is difficult in purging hydrogen from large systems.
- Vaporization System Failure: Pipe valving in vaporization systems may fail, causing injury from low-temperature exposures.
- Condensation of Air: An uninsulated line containing LH_2 or cold hydrogen gas, such as a vent line, can be sufficiently cold (less than 90 K (-298 °F) at 101.3 kPa (14.7 psia)) to condense air on the outside of the pipe. Materials not suitable for low temperatures, such as carbon steel, can become embrittled and fail. Moving parts and electronic equipment can be adversely affected.
- Hydrogen Embrittlement: Containment systems may fail and the subsequent spills and leaks will create hazards when the mechanical properties of metallic and nonmetallic materials degrade from hydrogen embrittlement.
- Physiological hazards: Physiological Hazards are Asphyxiation, Blast waves from explosions, the radiant heat, Cryogenic burns, and Exposure to large LH_2 spills could result in hypothermia.
- Collision during Transportation: Damage to hydrogen transportation systems (road, rail, air, and water) can cause spills and leaks that may result in fires and explosions.

3. Conclusion

The types of hazards from accidents occurring in hydrogen facility have been classified. Domestic and international hydrogen accidents data have been analyzed. One of dominant causes turns out to be human errors. For accidents being occurred in other countries, hydrogen accidents were caused by material failure, hydrogen leak by pipe breaking, deformed seals or gaskets, valve misalignment, or failures of flanges or equipment in order of importance.

Considering types of hazards for hydrogen accident sequence, consequence analysis will be performed with respect to the distance and mass using the TNT equivalency formula as a further study.

REFERENCES

[1] Shinji KUBO, Hayato NAKAJIMA, Shunichi HIGASHI, Tomoo MASAKI, Seiji KASAHARA, Mikihiro NOMURA, Shintaro ISHIYAMA, Kaoru ONUKI, Saburo SHIMIZU, R&D Program on Thermochemical Water-Splitting Iodine-Sulfur Process at JAERI, GENES4/ANP2003, Sep. 15-19, 2003, Kyoto, JAPAN, Paper 1072

[2] Isabelle. Sochet, Anne-Laure Viossat, Jean-Loup Rouyer Philippe Hemmerich, Safe Hydrogen Generation By Nuclear HTR, Poceedings of ICAPP'04, Pittsburgh, PA USA, June 13-17, 2004

[3] NATIONAL AERONAUTICS and SPACE ADMINISTRATION, Safety standard for hydrogen and hydrogen systems, Guidelines for hydrogen system design, materials selection, operations, storage, and transportation, Office of safety and mission assurance, Washington, DC 20546, NSS 1740.16 (1997)

[4] Youn-Do Jo, Song-Su Tak, Kyoung-Suhk Choi, Jong Rark Lee, and Kyo-Shik Park, Analysis of Hydrogen Accident in Korea, Trans. Of the Hydrogen and New Energy Society, 2004, Vol. 15, No. 1, pp. 82~87