INTERNATIONAL JOURNAL OF HYDROGEN ENERGY XXX (2016) 1–9

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/he

HAZID for CO_2-Free Hydrogen Supply Chain FEED (Front End Engineering Design)

S. Oyama*, S. Satoh, S. Sakanaka

Kawasaki Heavy Industries, Ltd., Akashi City, 673-8666, Japan

ARTICLE INFO

Article history:
Received 8 April 2016
Received in revised form
5 July 2016
Accepted 5 July 2016
Available online xxx

Keywords:
HAZID
Safety management
IPL
Safety measures

ABSTRACT

We at Kawasaki have proposed a "CO_2 free H_2 chain" using the abundant brown coal of Australia as a hydrogen source. We developed the basic design package and finished the Front End Engineering Design (FEED) in 2014. There are not only the hazards of the processing plant system, but also the characteristic hazards of a hydrogen plant system. We considered and carried out Hazard Identification (HAZID) as the most appropriate approach for safety design in this stage. This paper describes the safety design and HAZID which we practiced for the CO_2-Free Hydrogen Supply Chain FEED.

Introduction

Coal deposits are plentiful when compared with availability of other fossil fuels, and coal is excellent from the point of view of supply stability and economic efficiency. However, certain issues have become obvious in relation to the recent increase in demand in developing countries, as well as the steep rise in price linked with other energy prices, etc. Moreover, from the viewpoint of preventing global warming, "Fossil fuel + Carbon Capture and Storage (CCS)" and exploration of new energy including renewable energy, have become formidable challenges. In order to solve these problems, we at Kawasaki Heavy Industries, Ltd., focused on the inexpensive Australian brown coal which boasts tremendous reserves, and we are now proposing the concept of the "CO_2-Free Hydrogen Chain," in which a large amount of hydrogen would be transported to Japan by liquefied-hydrogen carriers after gasifying and refining the brown coal to produce hydrogen [1]. In addition, CO_2 generated in the process is separately captured for storage pursuant to the "Carbon Net" promoted by the Australian government. Therefore, no carbon dioxide is emitted when we use imported hydrogen. At Kawasaki, we aim to realize the commercialization of the "CO_2-Free Hydrogen Chain" in 2030, and are therefore keenly pursuing the technical development, to enable us to start in 2025 the operation of a demonstration chain equivalent to that for commercial use, following the start in 2020 of a small-scale pilot chain, aimed at providing technological demonstration. Fig. 1 shows the main components. In this paper, we explain a small-scale pilot chain for the "CO_2-Free Hydrogen Chain," and comment on the outline of the basic design (FEED) implemented since 2012, with Hazard Identification (HAZID) implemented in the context of FEED as safety management.

* Corresponding author.
E-mail addresses: oyama_suguru@khi.co.jp (S. Oyama), satoh_shuichi@khi.co.jp (S. Satoh), sakanaka_satoru@khi.co.jp (S. Sakanaka).
http://dx.doi.org/10.1016/j.ijhydene.2016.07.023

Fig. 1 – Small-scale pilot CO_2-Free Hydrogen Supply Chain (production plant, loading base and small-sized liquefied hydrogen carrier).

Pilot scale hydrogen supply chain plant FEED

The small-scale pilot supply chain plant which we plan to construct consists of a hydrogen production plant and hydrogen transport/storage. The hydrogen production plant has a gasification and gas purification plant for producing hydrogen made from brown coal, water electrolysis plants for back-up of hydrogen production and supplying gasification oxygen, hydrogen liquefaction plants, a hydrogen gas turbine for power generation, liquefied hydrogen storage tanks, and a truck & rotary station. The hydrogen transport/storage has a truck unloading station, a storage tank and a loading system for liquefied hydrogen carriers. We have also proposed the supply chain, which includes CCS in Australia and hydrogen gas turbine plants for power generation in Japan, as a "CO_2-Free Hydrogen Chain". However, although the pilot-scale project includes hydrogen utilization components, it does not include a CCS system, because CCS is outside our scope for technological demonstration in 2017.

We have spent two years since 2012 in the implementation of the basic design (FEED) covering a pilot chain, in order to calculate the precise cost of facilities and operating costs, in parallel with the preparation/organization of literature for the basic design, forming the basis for detailed design. The main points of the implementation are shown below:

1) Determination of hydrogen production process and plant capacity
2) Determination of postulated conditions for operation
3) Determination of design conditions, e.g. weather condition, degree of leeway, backup perception
4) Implementation of basic design
5) Preparation of basic design literature
6) Safety review/evaluation (HAZID)
7) Preparation of installation specifications
8) Acquisition of equipment vendor quotation and installation work estimates, calculation of approval/license cost and owner expenditure including insurance costs
9) Calculation of total plant costs
10) Calculation of operating costs

We assumed 10 ton/day hydrogen production with integrated assumption that a gasification and gas purification plant, an electrolysis plant and a liquefaction plant could be established in 2017, and we also balanced the investment in them and their costs, in order to determine the hydrogen production process and plant capacity shown as step 1). Then we assumed the rate of operation for hydrogen production as 89%, and calculated annual hydrogen production amount as 3250 ton/year.

10 (ton) * 365 (day) * 89 (%) = 3250 (ton/year)

We also assumed production loss, the capacity of liquefaction hydrogen carrier, 2500 m^3, and the imported hydrogen volume from Australia to Japan, and from this we calculated the annual hydrogen production volume: 2660 ton/year.

[Specification for Liquefaction Hydrogen Carrier]

Distance between Australia and Japan: 9000 km
Liquefaction Hydrogen Carrier Geometric Volume: 2500 m^3
Ship Speed: 13 knots (24 km/h)
Rate of Operation for Ship: 330 days/year
Loading/Unloading time (Total): 4 days
Net Loading (Ship Filling): 85%
Liquefaction Hydrogen Stock Required for Cooling: 3%

[Calculation]

Trip Days/Round: 9000 (km) * 2 (ways)/(24 (km/hour) * 24 (hour/day)) = 31.2 (days)
Additional time Loading/Unloading: 31.2 (days) + 4 (days) = 36 (days)
Round Trip: 330 (days/year)/36 (days/round trip) = 9.2 (round trip/year)
Liquefaction Hydrogen density: 0.0708 (ton/m^3)

Please cite this article in press as: Oyama S, et al., HAZID for CO_2-Free Hydrogen Supply Chain FEED (Front End Engineering Design), International Journal of Hydrogen Energy (2016), http://dx.doi.org/10.1016/j.ijhydene.2016.07.023