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Quantitative risk assessment on a gaseous hydrogen refueling station in Shanghai

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ABSTRACT

The potential risk exposure of people for hydrogen refueling stations is often a critical factor to gain authority approval and public acceptance. Quantitative risk assessment (QRA) is often used to quantify the risk around hydrogen facilities and support the communication with authorities during the permitting process. This paper shows a case study on a gaseous hydrogen refueling station using QRA methodology. Risks to station personnel, to refueling customers and to third parties are evaluated respectively. Both individual risk measure and societal risk measure are used in risk assessment. Results show that the compressor leak is the main contributor to risks of all three parties. Elevating compressors can be considered as an effective mitigation measure to reduce occupational risks while setting enclosure around compressors cannot. Both measures are effective to reduce risks to customers. As for third parties, societal risks can be reduced to ALARP region by either elevating compressors or setting enclosure around compressors. External safety distance of compressors cannot be considerably reduced by elevation of compressors, but can significantly be reduced by setting compressor enclosure. However, safety distances of the station are not very sensitive to both mitigation measures.

1. Introduction

With the rapid development of hydrogen vehicle technology and large scale fuel cell vehicle (FCV) demonstration project worldwide, more hydrogen refueling stations need to be built. As a new energy infrastructure for public use, the potential risk exposure of people is often a critical factor to gain authority approval and public acceptance for the development of a project. Quantitative risk assessment (QRA) methodology is often used to quantify the risk around hydrogen facilities and is considered as a valuable tool to support the communication with authorities and other stakeholders during the permitting process. This paper shows a case study on a gaseous hydrogen refueling station using QRA methodology.

In risk assessment studies there are generally three main types of risk to be considered [1]: (1) Occupational risks – risks to the workforce of the plant; (2) Community risks – risks to people nearby and environment; and (3) Economic risks – the financial penalties arising from loss of capital assets, production and compensation. The economic risks are usually covered by insurance and are not our concern. The main attention to the introduction of hydrogen refueling station to public is its risks to people, including occupational risks and

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especially community risks. For hydrogen refueling station there are two kinds of community: customers inside the station and people outside the station (nearby residents or pass-by persons). If occupational risks are defined as first party risks, then risks to customers and people outside the station can be perceived as second party risks and third party risks, respectively. European Integrated Hydrogen Project Phase 2 (EIHP2) has suggested different risk acceptance criteria for the three kinds of parties. These criteria are expressed in the form of individual risk (IR) or societal risk (SR). The IR is usually displayed as a risk contour around hydrogen facilities and thus also called geographical risk. The SR represents the probability (F) of several deaths (N) at a time as a consequence of an accident (F–N curve). IR and SR are two different ways of characterization of risk and both will be used in our risk assessment in this paper.

The term "Safety distance" will be used in our discussion. Here, the safety distance is related to a risk-based approach rather than deterministic concept of the maximum consequences likely to occur. At distances superior to the safety distance it is assumed that the risk is acceptably low by an accidental event related to the hazardous installation [2].

2. Station description

In this paper, Shanghai Anting Hydrogen Refueling Station is used as a case study. Anting Hydrogen Refueling Station is co-built by Tongji University, Shanghai Aerospace Energy Company and Shanghai Sunwise Energy System Company. Shell Hydrogen cooperates with Tongji University as technical consultant and funds part of the station demonstration. Linde and Shanghai Gas Engineering Design Institute provide engineering services for the construction of the station. This station is the first hydrogen refueling station in Shanghai and has successfully served FCV fleet developed by Tongji University for 2008 Olympic Games. A plot plan of the station is shown in Fig. 1.

This station is a 35 MPa station. Hydrogen is brought to the station by road trailer, which consists of eight tubes with a volume of approximately 2.3 m^3 each and contains compressed hydrogen pressure no more than 200 bar (200 bar is the upper limit restricted by transportation law in China). The trailer is connected by flexible hose, which is connected to 17 m pipe work to compressor. The compressor draws hydrogen from the trailer to fill the buffer storage up to maximum pressure 414 bar. The buffer storage is nine interconnected cylindrical pressure vessels with a volume of approximately 0.77 m^3 each. When refueling, hydrogen will be drawn from buffer storage through 16 m pipe work to the dispenser, and fill cars to a maximum pressure of 350 bar.

3. Modeling

Releases of hydrogen can be either instantaneous or continuous. Ignition of an instantaneous release will result in a vapor cloud explosion. In the case of a catastrophic rupture of a cylinder, the contents of only one cylinder will be instantly released. It is not expected that several cylinders will rupture simultaneously. The rupture of a cylinder can cause a domino effect. As the peak overpressures are not likely to coincide, the effects of the domino event will not be considerably larger than the effects of a single event [3]. The consequences of continuous release will depend on the time of ignition. Direct ignition results in a jet fire, while delayed ignition results in a flash fire or results in an explosion if the released hydrogen piles up in a confined area or if there is a considerable amount of pipe work in the cloud envelope. For reasons of conservatism, all continuous releases are assumed to be horizontal and a probability of 40% is assigned to an explosion event, and a probability of 60% to a flash fire [4].

The scenarios and input data showed in Table 1 are used for the risk calculations for the refueling station. The scenarios are chosen based on previous HAZOP studies. The scenarios studied for risks to station personnel, customers and third parties are exactly the same: all scenarios in Table 1 will be considered in calculation. The station is assumed to work 365 days per year. The initial frequencies of failure are

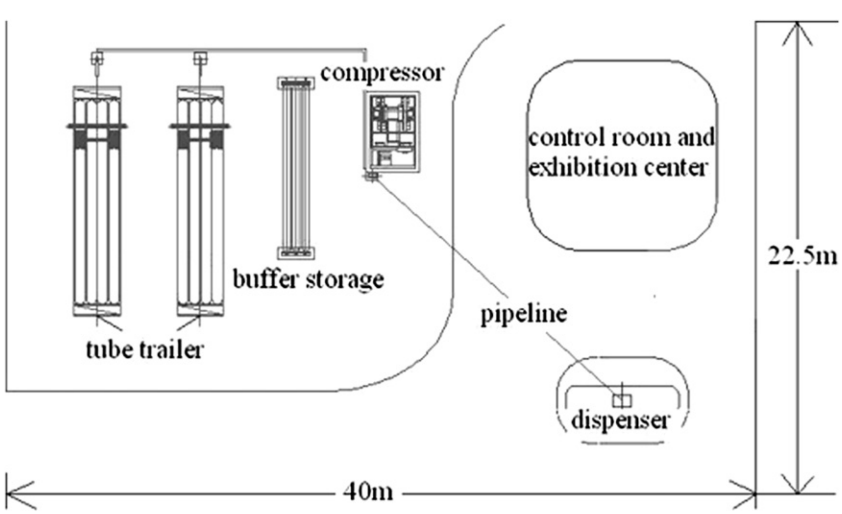

Fig. 1 – Plot plan of Anting Hydrogen Refueling Station.