ENGINEERING INVESTIGATION OF HYDROGEN STORAGE IN THE FORM OF CLATHRATE HYDRATES: CONCEPTUAL DESIGNS OF HYDRATE STORAGE SILOS

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ABSTRACT

This paper describes conceptual designs of the facility for storing, in the form of a clathrate hydrate, hydrogen produced in an industrial complex area. In a companion paper (Nakayama et al., Energy & Fuels 2010;24: 2576-2588), we reported the first engineering investigation of hydrate-based hydrogen storage, focusing on the conceptual design of hydrate production plants applicable for the large-scale stationary storage in urban or industrial complex areas. This paper complements the above companion paper by presenting the conceptual designs of underground hydrogen-hydrate storage silos to be coupled with such production plants. A few different types of underground silos each having a 35000 m³ capacity were planned and designed on a construction-engineering basis, which included (a) a tunnel-type silo consisting of several levels radially arranged around an access shaft, (b) a tunnel-type silo consisting of several levels that branch off from a single access level connected to an access shaft, and (c) a vertically-oriented cylindrical tank-type silo. A simple hydrogen hydrate provided by a production plant adjacent to each silo would be depressurized to the atmospheric level and conveyed to the silo to be stored at ~140 K and ~0.1 MPa. For each type of silo, we have specified the hydrate loading and unloading equipment as well as the cooling system, and have estimated the construction cost. The possible utility of clathrate hydrates for storing hydrogen has been the focus of hydrate researchers to develop the means of decreasing the hydrate-forming pressure and increasing the hydrogen storage capacity of the hydrates. However, the current hydrogen storage capacity levels are not sufficient to warrant the on-board use of hydrogen hydrates. We believe that hydrogen hydrates are more suitable for storing hydrogen in large-scale stationary stations in urban or industrial complex areas than for on-board use. This is because, for such stationary stations, the weight- or volume-based storage capacity requirement may be easier, and the potential safety of hydrogen hydrates compared to, for example, highly compressed hydrogen gas, will be of great benefit. In a recent paper (Nakayama et al., Energy & Fuels 2010; 24, 2576-2588), we reported the first engineering investigation of hydrate-based hydrogen storage, focusing on the conceptual design of hydrate production plants applicable for the large-scale stationary storage. The present paper complements this paper by presenting the conceptual designs of underground hydrogen-hydrate storage silos to be coupled with such production plants. A few different types of underground silos each having a 35000 m³ capacity were planned and designed on a construction-engineering basis, which included (a) a tunnel-type silo consisting of several levels radially arranged around an access shaft, (b) a tunnel-type silo consisting of several levels that branch off from a single access level connected to an access shaft, and (c) a vertically-oriented cylindrical tank-type silo. A simple hydrogen hydrate provided by a production plant adjacent to each silo would be depressurized to the atmospheric level and conveyed to the silo to be stored at ~140 K and ~0.1 MPa.