BATCH-SYSTEMS OF HYDROGEN TRANSPORTATION

Kunihiro Takahashi
Director, Center for Supply Control and Disaster Management, Tokyo Gas Co. Ltd., Tokyo, Japan

Keywords: hydrogen storage, pressurized hydrogen, pressure container (vessel), atmospheric hydrogen storage tank, spherical hydrogen storage tank, underground storage, liquefaction of hydrogen, liquid hydrogen storage, ortho-para conversion, heat insulation, slush hydrogen, metal hydride

Contents

Summary

Systems for batch transportation of relatively small quantities of hydrogen in the gaseous phase or liquid phase or using other substances to store hydrogen, are presently in use or being studied. The density of hydrogen is very low and its volume is great; therefore, considering transportation efficiency, methods of lessening the apparent volume of hydrogen by pressurizing or liquefying it are used.

These methods include the transporting of pressure vessels filled with pressurized hydrogen and the transporting of insulated vessels filled with liquefied hydrogen. In addition to these methods, new methods are being studied recently, in which hydrogen is adsorbed onto metals and alloys and other substances for transport.

Generally, hydrogen batch transportation system includes shipping a large quantity of hydrogen as liquid hydrogen, ammonia, or methanol by tanker. The ocean transportation of hydrogen will be discussed in other articles. Here described are the systems for intermittent transporting of relatively small quantities of hydrogen.

1. Introduction

This section deals with systems—in use or under study—that employ methods of intermittently transporting hydrogen in gaseous or liquid state and in the form of other compounds such as metal hydride.

The density of hydrogen is very low and its volume is large, therefore in consideration of transport efficiency, the method of making the apparent volume of hydrogen smaller by pressurizing or liquefying it, is adopted.

There are various hydrogen batch transportation systems, such as the method of transporting pressure vessels filled with pressurized hydrogen, the method of transporting liquid hydrogen in insulated vessels, or the method of transporting hydrogen adsorbed onto metals and alloys concerning which various types of research have recently been done.

Generally, a hydrogen batch transportation system includes shipping a large quantity of liquid hydrogen or compounds containing hydrogen (e.g., ammonia, methanol, etc.) by tanker. The ocean transportation of liquid hydrogen, etc., will be discussed in other articles. Here we cover the systems for transporting relatively small quantities of hydrogen intermittently.

2. Pressurized Hydrogen Gas Batch Transportation System

The pressurized hydrogen gas batch transportation system has been widely used since the beginning of the twentieth century. This system is adopted in many cases where the quantity of hydrogen to be used is relatively small. When hydrogen is to be used continuously, a storage facility is needed in the location of use; in some cases, hydrogen transport vessels also function as storage facilities.

The concrete processes in this system can be divided into:

(i) refining processes to remove from hydrogen gas the impurities, which will interfere with the compression and transportation of hydrogen;
(ii) processes of compressing hydrogen and filling transport vessels;
(iii) the process of transporting hydrogen in the vessels.

2.1 Refining Processes

These processes remove impurities contained in raw hydrogen gas so that the hydrogen purity matches the purpose of its use, simultaneously achieving improved transportation efficiency and preventing corrosion and blockage of equipment, etc.

At present, coal gas produced in the iron industry, hydrogen from the electrolysis of salt water, partial oxidation gas and steam reforming gas from the oil refining industry and the petro-chemical industry, are the major raw materials for hydrogen gas. The composition of raw material gas is about 50-60% hydrogen; it also contains carbon dioxide gas, methane, other hydrocarbons and water, etc., as impurities.

There are various refining methods for removing the impurities from these raw material gases, such as the cooling removal method, gas absorption method and adsorption removal method, etc. Which of the various methods are selected depends on the varieties of impurities and on the hydrogen purity required.

The cooling removal method removes impurities, water, etc., by cooling the raw material gas to below the dew point, the gas absorption method removes carbon dioxide and other acidic gases by absorbing them using an alkaline cleaning solution, the adsorption removal method, represented by the PSA method, removes impurities including water, carbon dioxide, hydrocarbons, and other substances, utilizing the differences of the adsorption characteristics between hydrogen and those impurities for adsorbents such as zeolite and activated carbon.

Various refining methods are combined depending on the composition of the raw material gas, to refine the raw hydrogen gas to the required hydrogen purity.

Also, it is dangerous when hydrogen gas coexists under high pressure with oxidizers such as oxygen or chlorine, because hydrogen can be very easily ignited; therefore a refining method to remove these oxidizers as water and hydrogen chloride by making them react with hydrogen using a catalyst such as palladium, is also used.

The actual hydrogen purity required varies depending on the hydrogen utilization method, but hydrogen has been refined to roughly around 99.99–99.9999% by the above-mentioned refining processes.

2.2 Compression Process

The compression process means the process of increasing the pressure of refined hydrogen to high pressure condition using a compressor, etc.

It is effective for increasing transportation efficiency to pressurize hydrogen to high pressure to decrease its volume. Although depending on the boosted pressure level, this can result in restriction of the material quality and shape of pressure vessels, in increase of the boosting of pressure energy and vessel weight; therefore, with consideration of final use conditions, etc., when hydrogen is compressed, its pressure is usually heightened to around 15–30 MPa.

At this pressure level, the difference between the volume of hydrogen gas in the ideal gas state and that in the real gas state becomes remarkable. When hydrogen in the ideal gas state is boosted to 10 MPa, the volume of compressed gas is estimated to be 1/100 of the volume of hydrogen gas at 0.1 MPa, and when hydrogen in the ideal gas state is boosted to 20 MPa, the volume of compressed gas is estimated to be 1/200 of the volume of hydrogen gas at 0.1 MPa; but the volume of compressed hydrogen in the real gas state at 10 MPa, is only 1/94 of the volume of hydrogen gas at 0.1 MPa, and the volume of compressed hydrogen in the real gas state at 20 MPa is only 1/177 of the volume of hydrogen gas at 0.1 MPa, so it is necessary to pay thorough attention to these matters when considering transportation efficiency.

-
-
-

Bibliography

Fuziwara H., Yatabe M., Tamura H., Takahashi M., Miyazaki J., and Tsuruta Y. (1994). Experiment on slush hydrogen production with the auger method, *Hydrogen Energy Progress X*, International Association for Hydrogen Energy, Vol. 2, pp. 1079–1087. [This paper describes the properties and production method of slush hydrogen.]

New Energy and Industrial Technology Development Organization, (1998). *International Clean Energy Network Using Hydrogen Conversion (WE-NET): 1997 Annual Summary Reports NEDO-WE-NET-97*. [The report outlines the plan and results of the first period (1994 to 1998) of the World Energy Network (WE-NET) stressing the technical side at each stage from production to consumption in utilization of hydrogen produced utilizing renewable energy.

Biographical Sketch

Kunihiro Takahashi: born 28 January 1942 in Japan; graduated from Chemical System Engineering Department, Faculty of Engineering, the University of Tokyo; completed master course with major in engineering, the University of Tokyo; joined Tokyo Gas Co., Ltd.; presently general manager of the Center for Supply Control and Disaster Management, Tokyo Gas Co., Ltd. Previous positions: appointed as a member of General Research Laboratory of Tokyo Gas Co., Ltd. (1967–1977); appointed as general manager of Technical Development Department, general manager of Engineering Department, and general manager of System Energy Department of The Japan Gas Association (1994–1997); appointed as a member of Sub-task-1-committee of WE-NET committee of New Energy and Industrial Technology Development Organization (1994–1997); has held present position since June 1997; studied research themes: research on production processes and catalysts for hydrogen-rich gas and methane-rich gas.