Kawasaki is Committed to Contributing to the Realization of a "Hydrogen Energy Society" that is Friendly to the Environment

When fired (oxidized), hydrogen produces just water, making it one of the most friendly energy sources for humankind and nature. A great dream for the 21st century is to realize a clean "hydrogen energy society" that uses hydrogen instead of fossil fuels that unavoidably lead to emissions of substances that are harmful to the environment.

Our cryogenic technology, which has helped achieve successes in various projects including a liquid hydrogen storage-supply station for Japan's H-II rockets, will help us provide infrastructure for the hydrogen energy society. In this section, our efforts to develop hydrogen-related technologies are described.

Liquid hydrogen storage-supply station for Japan's H-Ⅱ rockets

Development of Japan's First Liquid Hydrogen Container

In a liquid state, the volume of hydrogen is 1/800 as small as when in a gaseous state, meaning that liquid hydrogen can be more easily stored and transported. With an increasing number of fuel cell cars being used, a network of hydrogen stations will be needed so that hydrogen can be made available throughout Japan like gasoline. As a means of supplying hydrogen to these stations, the liquid hydrogen container we have developed will come into the spotlight.

In January 2005, we successfully completed a long-distance public road test with this liquid hydrogen container, transporting it from Amagasaki City to the Tokyo Metropolis. We will continue to study how to improve the performance of liquid hydrogen containers so that they can be used commercially in the near future.

Utilization of Experience with Cryogenic Technology Accumulated Through Space Development and Other Efforts

A liquid hydrogen container can be defined as a transportation and storage container that is specifically designed for handling liquid hydrogen and satisfies the unique requirements to do so. Currently, mainly tanker trucks are used for transporting liquid hydrogen. Use of liquid hydrogen containers, however, will increase the range of flexibility for transportation methods and result in decreased transportation expenses. The higher insulation performance of liquid hydrogen containers will also allow transportation for longer times and distances. A liquid hydrogen container will also serve for liquid hydrogen storage. We have been committed to the development of a liquid hydrogen container and have been commissioned to do this by the New Energy and Industrial Technology Development Organization (NEDO). NEDO is committed to research on advanced elements for liquid hydrogen containers as part of Japan's National Development for Safe Utilization and Infrastructure of Hydrogen project.

The volume of hydrogen when liquefied is as small as 1/800 that of hydrogen in a gaseous state, so, hydrogen in a liquid state can be conveniently stored or transported. However, since the temperature of liquid hydrogen is as low as -253°C, design and fabrication of a container requires much advanced technology. We have so far gained experience in developing and fabricating storage tanks for LPG (-45°C), LNG (-162°C) and liquid helium (-269°C). The fuel for Japan's H-series space rockets is liquid hydrogen, and we had the responsibility for construction and maintenance of the liquid hydrogen storage tanks at the rocket launch facility. Our liquid hydrogen container design reflects the accumulation of knowledge and expertise that we gained from experience with cryogenic technologies.

Preparing for the commercial use of hydrogen fuel cells

Hydrogen is sometimes referred to as a "post-LNG" energy source. However, hydrogen manufacture, storage, transportation and utilization on a large scale have still not been achieved, making it an underdeveloped energy source. Manufacturing costs, efficiency and costs associated with transportation of hydrogen need to be improved greatly. Ten or more years of effort will be necessary before hydrogen can be utilized like petroleum or LNG. However, considering ever worsening environmental problems and the rapid depletion of oil resources, overcoming the various obstacles to realize the commercial utilization of hydrogen is imperative.

A gradual increase in the utilization of hydrogen will help accelerate research and development, possibly leading to an earlier-than-expected commercialization of hydrogen energy. The scheme, which consists of use of surplus electricity for manufacture and liquefaction, storage and transportation in the form of liquid hydrogen that features higher volume efficiency, and utilization in stationary fuel cells, may be commercialized in the near future. Liquid hydrogen containers are a key technology for realizing this possibility.

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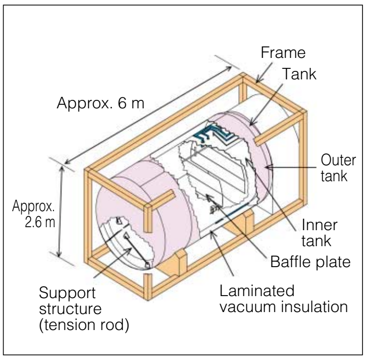
Devising Arrangements for Support and Insulation Materials in Limited Vacuum Space

The structure of a liquid hydrogen container is shown schematically below. The container itself is a double-cylinder vacuum structure like a thermos bottle designed to maintain a cryogenic temperature. The major challenge in realizing this container was assuring the ability to transport a much larger amount of liquid hydrogen while achieving heat insulation efficiency that is better than that of existing liquid hydrogen vessels such as tanker trucks in spite of the size limitations of the container. To address these challenges, we designed the inner tank to be as large as possible and kept the vacuum space between the inner tank and outer tank as small as possible. This vacuum space includes aluminum-deposited film for preventing radiant heat, pipes for transferring liquid hydrogen and supports for retaining the inner tank. In order to arrange these components in the limited space while ensuring heat insulation efficiency, we adopted novel arrangements in addition to conventional techniques. For example, though the inner tank is supported with a suspension structure similar to the one used for the liquid hydrogen storage tanks situated at Japan's H-II rocket launch site, we have incorporated measures to prevent the inner tank from shaking during transport and to allow shrinkage of the inner tank when it is subjected to very low temperatures.

Incidentally, a law stipulates that baffle plates must be incorporated to minimize the vibration of liquid hydrogen during transport. Through a fluid vibration simulation, we have optimized the size and locations of the baffle plates and the intervals between them.



Structure of liquid hydrogen container


Installation of insulation

Demonstrating High Performance in Amagasaki-Tokyo Public Road Test

We subjected a liquid hydrogen container to various tests. In August 2003, a liquid nitrogen (–196°C) filling test was performed with the container in a stationary state. In January 2004, a liquid hydrogen filling test was conducted and then the container filled with liquid hydrogen was subjected to a traveling test on the site of the works to investigate the amount of hydrogen lost by evaporation. Since January 2005, several public road tests have also been performed.

The first public road test took place in January 2005 with a container carrying approximately 6 kL of liquid hydrogen – only half of the container's capacity. The liquid hydrogen container was transported along a 600-km route from the hydrogen liquefaction station in Amagasaki City, Hyogo Prefecture, to the hydrogen station for fuel cell cars in Koto-ku, Tokyo. The amount of liquid hydrogen lost to evaporation was limited to only 0.7% per day, demonstrating the container's high performance.

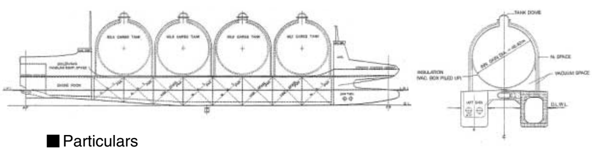
We will further pursue lighter weight, higher insulation efficiency and lower costs and also hope to develop a large-sized liquid hydrogen container for rolling stock and ships.

Liquid hydrogen container

Identifying Technological Challenges for Liquid Hydrogen Tankers

Manufacture and liquefaction of hydrogen requires an enormous amount of electricity. Possible sources for providing such electricity are hydroelectric power in Canada, which has abundant water resources, solar power in deserts and wind power. To transport hydrogen to consumer locations, liquid hydrogen tankers need to be realized. Since taking an active role in WE-NET, we have been pursuing technological development to overcome the obstacles to the realization of liquid hydrogen tankers.

WE-NET: World Energy Network



■Particulars

Tank type	Double skin spherical tank
Ship type	Wave piercing semi-SWATH
Cargo capacity	200,000 m^3 (−253℃, 0.071 t/m^3)
Length (o.a.)	About 345.00 m
Breadth (mld.)	64.00 m
Depth (mld.)	26.00 m
Draft (mld.)	14.00 m
Main engine	Hydrogen burning boiler + Steam turbine
MCR	2 × About 40,000 PS (29,400 kW)
Propulsion system	4 × About 20,000 PS (14,700 kW) Waterjet pump
Service speed	About 25 knots
Boil-off rate	About 0.4 %/day

Technically Feasible

WE-NET was a Japanese national project for development and verification of hydrogen-related technology at all phases from manufacture to utilization, and included construction of a liquid hydrogen tanker. We executed technical studies for liquid hydrogen tankers from 1993 to 1998.

A great challenge for the realization of a liquid hydrogen tanker is the provision of an insulation method capable of keeping the liquid hydrogen below its boiling point of –253°C. According to calculations, when using the same insulation materials as those for LNG tankers, the thickness needed will be approximately 1,000 mm. Currently, no technique exists that can either produce or install insulation of such thickness. One possibility is to design a double-shell tank, with a vacuum maintained in the space between the inner and outer shells. However, to provide sufficient strength for a double-shell tank to withstand pitching and rolling on the ocean, it is impossible to adopt the conventional "suspension structure" that supports the tank with thin supports of lower heat conduction. New tank support methods and materials that satisfy both strength and heat conduction requirements need to be developed.

Furthermore, hydrogen molecules are very small and can pass through very fine pores that would block LNG molecules. Therefore, extremely cautious welding work, which has hitherto been unnecessary, must be performed when assembling the liquid hydrogen tank.

Notwithstanding, through concentrated studies, we have learned that construction of a liquid hydrogen tanker is technically feasible.

At Least 10 Years of Development Is Necessary before Commercialization

Having designed and constructed the liquid hydrogen storage tanks for Japan's H-Ⅱ rockets as an application on land and built Japan's first LNG tanker as an application at sea, we have learned that the realization of a liquid hydrogen tanker will take a considerable development period. Since hydrogen molecules are very small, it is very light, and the temperature of liquid hydrogen is extremely low, time consuming efforts and very advanced technologies will be needed to optimize the tank, heat insulation, cargo outfitting, propulsion system and ship type and structure. The next challenge is to develop design and implementation techniques that can reduce construction costs while ensuring safety.

I believe Japan should lead international cooperation projects for research and development of liquid hydrogen tankers as well as other hydrogen-related technologies. Our comprehensive experience with cryogenic technology and large-scale high-speed ship technology will greatly contribute to the realization of a hydrogen energy society.

Recently, hydrogen utilization technologies, including fuel cells, have been developing rapidly while the price of petroleum has been soaring. For these reasons, I believe that in the near future, liquid hydrogen tankers will be traveling the oceans between hydrogen production sites and the locations of hydrogen consumption.

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