Demonstration of Toyota Ecoful Town Hydrogen Refueling Station

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1.Introduction

Fuel Cell Vehicles (FCVs) have come to occupy an important place as a next-generation vehicle due to the facts that they do not generate carbon dioxide while they are moving, and they have the convenience similar to that of the now widely used gasoline automobiles in terms of mileage, refueling time, etc.
The Fuel Cell Commercialization Conference of Japan (FCCJ), which carries out activities toward more practical application and spread of fuel cells in Japan, determined milestones in time frame in 2010 such that the year 2015 would be a year when spreading FCVs to the general users started and the year 2025 would be a year when FCVs and the hydrogen refueling stations spread on their own, and proposed issues that would have to be resolved to achieve each milestone. In the wake of this move, 13 auto manufactures and energy supply companies, including our company, released in 2011 a joint statement related to the introduction of FCV into the domestic market and development of hydrogen refueling stations. The statement declared that the auto manufactures aimed to commence introducing mass-produced FCVs to the domestic markets centered on the four major urban conurbations (Kanto, Kansai, Chubu, and Kitakyushu) and launching them to the general users in 2015, and the energy supply companies aimed to develop approximately 100 hydrogen supply installations ahead of actual sales by 2015 according to the estimated number of mass-produced FCVs to be sold.

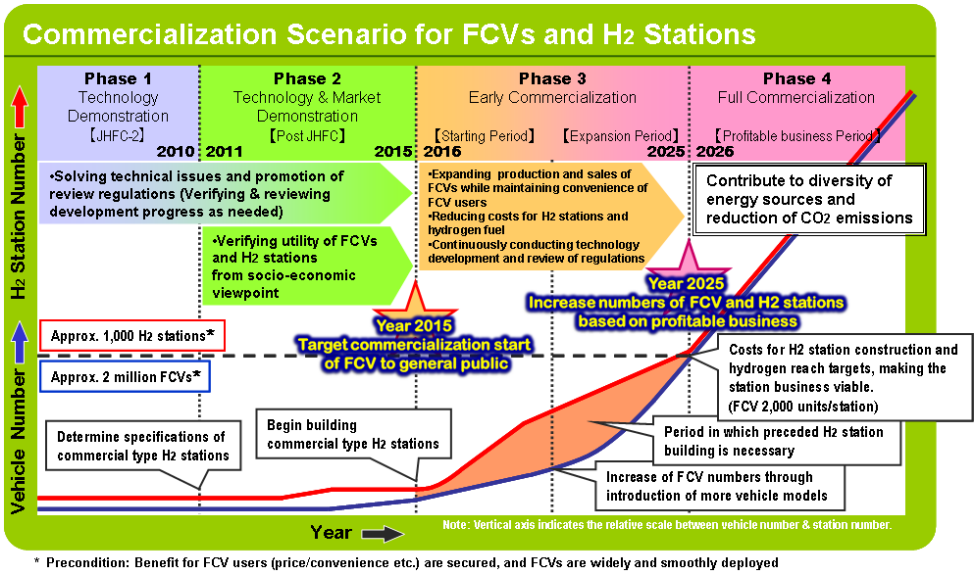

Figure 1. Scenario toward Spreading FCVs and Hydrogen Stations Created by FCCJ

On the other hand, in order to facilitate the development of commercial hydrogen stations, it is necessary to acquire the comprehensive knowledge related to site selection, design, construction, and operation to develop the hydrogen stations, in addition to taking a new approach that will develop technologies, etc. such as refueling FCVs with a refueling pressure of 70 MPa, the current mainstream FCVs, with hydrogen in a short period of time. Against these backgrounds, our company constructed the "Toyota Ecoful Town Hydrogen Refueling Station" as a demonstrative hydrogen station based on commercial specifications in the Toyota city of the Aichi prefecture jointly with Iwatani Corporation as a part of "Project for Local Hydrogen Supply Infrastructure technical and social Demonstration (joint research projectfrom 2011 to 2013)" and " Project for Research and Development of

Technology for Hydrogen Utilization (commissionedprojectfrom 2014)," which are the projects between the Research Association of Hydrogen Supply/Utilization Technology (HySUT)*, in which our company participates, and the New Energy and Industrial Technology Development Organization (NEDO).
This report is intended to inform the public about the overview of the Toyota Ecoful Town Hydrogen Refueling Station and the content of the technological development under way.

*HySUT: A research association consisting of 16 energy-related companies and 3 auto manufacturers tackles technical development efforts toward the realization of a hydrogen energy utilization society.

2.Overview of Toyota Ecoful Town Hydrogen Refueling Station

(1) Selecting a construction site for hydrogen station

We pursued consultations with the Toyota city or the competent municipal government about the construction site of Toyota Ecoful Town Hydrogen Refueling Station, and as we were successful in acquiring their understanding and cooperation about the awareness campaign of spread of hydrogen stations and FCVs. As a result, we agreed with them on constructing ahydrogen station within the site of "Toyota Ecoful Town," which was scheduled to open in the urban area of the city. The ToyotaEcofulTown is a facility into which the next-generation environmental technologies concentrate, such as ITS (Intelligent Transportation System), in which future transportation systems can be experienced, HEMS (Home Energy Management System), and EDMS (Energy Data Management System), in addition to the hydrogen station. As many visitors are expected to come to the facility, it is possible to conduct effective promotion activities of understanding on innovativeness and safety of hydrogen stations and FCVs. In addition, the ToyotaEcofulTown provides an access point to the FC bus service operated within the Toyota city, and is also good for demonstrating the refueling for FC buses, which is one of the features of the Toyota Ecoful Town Hydrogen Refueling Station, which is one of the reasons for selecting it as the construction site.

Source: Toyota City Home Page

Figure 2. Overview of Toyota Ecoful Town (the HydrogenStation Is Circled with a Dotted Line)

(2)Hydrogen station construction

The Toyota Ecoful Town Hydrogen Refueling Station is ahydrogen station intended to refuel FCVs with a refueling pressure of 70 MPa with hydrogen. The "High Pressure Gas Safety Law," or the law related to the manufacturing, storage, etc. of high pressure gases within Japan, allowed only hydrogen stations with a normal operation pressure of up to 40 MPa to be constructed in urban area such as commercial areas before, but a relevant

ministerial ordinance of the law, "Security Regulation for General High-Pressure Gas," was amended in November 2012, and it allowed hydrogen stations of a normal operation pressure of up to 82 MPa to be constructed in urban areas.In the wake of the amendment of the Regulation, we applied in December 2012 for permission to construct a high pressure gas manufacturing facility regarding the construction of Toyota Ecoful Town Hydrogen Refueling Station. The permission we applied for was granted in January 2013, and we commenced the installation work of the high pressure facility in February 2013 and completed the work in March of the same year. After that, we continued to confirm the performance of the hydrogen station such as the test run of the high-pressure gas facility and tests for refueling test FCV vehicles with hydrogen, and completed the construction of the entire facility at the end of March 2013.

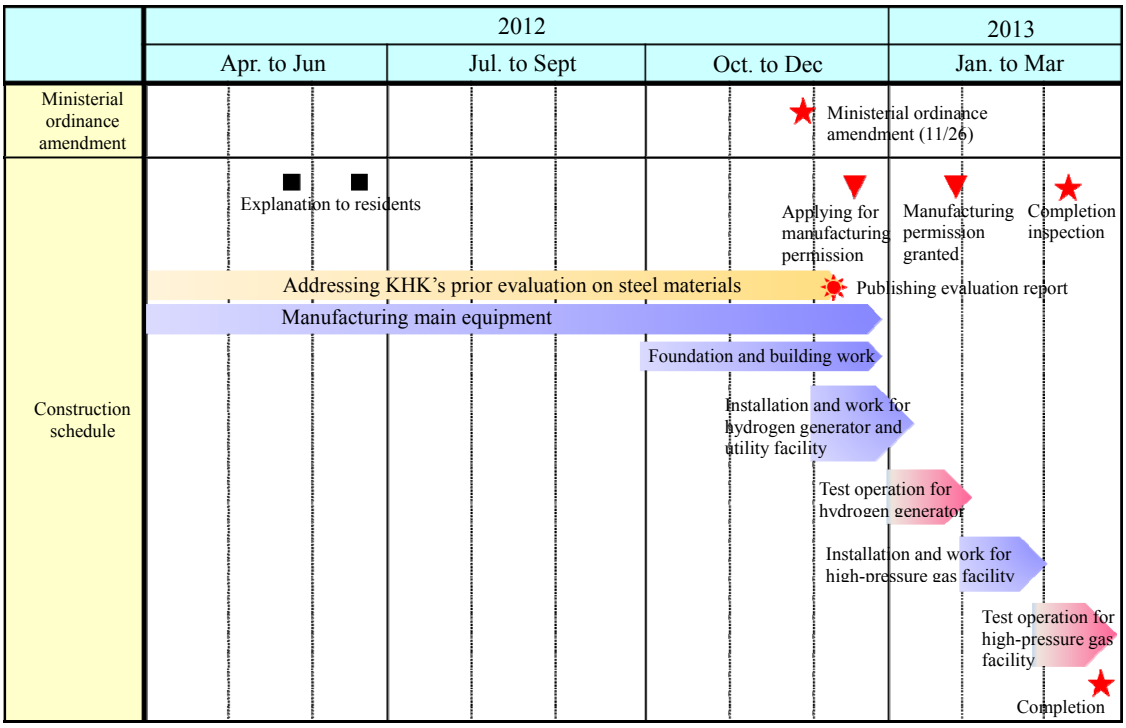

Figure 3. Construction Schedule of Toyota Ecoful Town Hydrogen Refueling Station

Figure 4. Outside Appearance of Toyota Ecoful Town Hydrogen Refueling Station

(3)Features of ToyotaEcofulTown Hydrogen Refueling Station

The hydrogen stations consist of those with an on-site method, which manufactures hydrogen on site from other fuels such as the natural gas or LP gas and supplies it, and those with an off-site method, which supplies hydrogen that is procured from the outside. The Toyota Ecoful Town Hydrogen Refueling Station adopts an on-site method that manufactures hydrogen on site from the city gas with a hydrogen generator. After increasing the pressure of the manufactured hydrogen to 40 MPa with a primary compressor, the station stores the hydrogen in a pressure accumulator with a normal operation pressure of 40 MPa. After that, the station increases the pressure of the hydrogen to 82 MPa with a large-flow compressor and refuels fuel cell vehicles with the compressed hydrogen with a dispenser. The refueling pressure to fuel cell vehicles can be selected from 35 MPa or 70 MPa, depending on the types of the vehicles. The following summarizes the features of the station:

1)Adopting one of the Japan's largest large-flow compressors with a direct refueling method

With the aim for the short-time refueling to FC buses with a refueling pressure of 70 MPa, we adopted the package type refueling equipment from Linde AG Germany, which embeds one of the Japan's largest large-flow compressors with a direct refueling method. As the FC buses have a larger capacity of a vehicular vessel than FCVs, the pressure difference refueling method (method to refuel a vehicle tank using the pressure difference between a pressure accumulator and the tank after storing hydrogen whose pressure is increased with a compressor into the pressure accumulator) or a current mainstream refueling method for hydrogen stations for FCVs, requires many pressure accumulators (with a normal operating pressure of 82 MPa) to fill up an FC bus in a short period of time, which results in higher cost. For this reason, we have adopted a direct refueling method (method to refuel a vehicle tank directly with hydrogen whose pressure was increased with a compressor) using a large-flow compressor. This adoption eliminates the need for 82 MPa pressure accumulators and at the same time enables the short-time refueling to FCVs and FC buses (the refueling will be completed for 3 to 5 minutes per FCV).

2)Adopting package type refueling equipment

The above large-capacity compressor is integrated vertically into a package with multiple pieces of equipment such as a hydrogen chiller, which enables an attempt to be made to reduce the installation area and as shorten the construction term for the work on site.

3)Safety and disaster prevention measures

The Toyota Ecoful Town Hydrogen Refueling Station takes quadruple safety measures of leakage prevention of hydrogen, accumulation prevention, ignition prevention, and prevention of influence on surroundings according to the High Pressure Gas Safety Act. In addition, as demand for energy supply in case of emergency has heightened since the Great East Japan Earthquake, it is equipped with a function that enables refueling to a fuel cell vehicle to be continued even during a power failure through installation of private power generating equipment or other means.

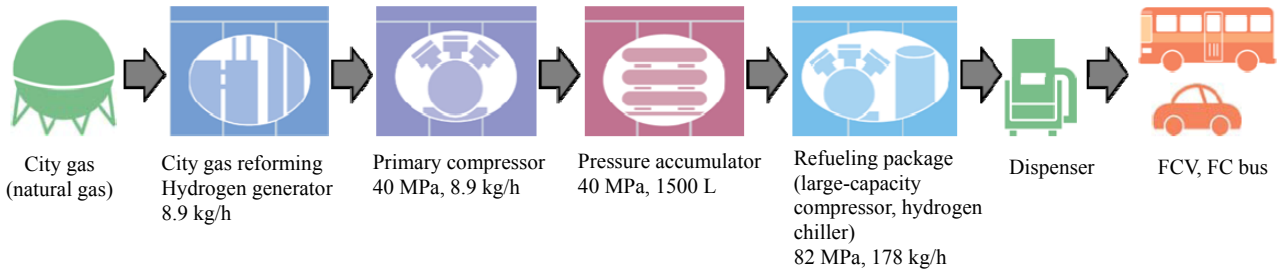

Figure 5. Equipment Configuration for Toyota Ecoful Town Hydrogen Refueling Station

Table 1: List of Equipment Specifications

Equipment name	Specification
Hydrogen generator	Material: City gas Manufacturing method: Steam reforming PSA method Manufacturing capability: 8.9 kg/h (100 Nm^3/h)

	Hydrogen purity: 99.999 vol % or more	
Primary compressor	Model: Reciprocating piston type, 4 step & 4 cylinders Compression capacity: 8.9 kg/h (100 Nm^3/h) Intake/delivery pressure: 0.4 MPa/40 MPa	
Pressure accumulator	Vessel type: Copper vessel (material: SCM435) Storage capacity: 1,500 L (300 L per vessel for 5 vessels), 40MPa Normal operation pressure: 40 MPa	
Refueling package	Secondary compressor (large-capacity compressor)	Model: Ionic type, 1 step & 4 cylinders Compression capacity: 178 kg/h (2,000 Nm^3/h) Intake/delivery pressure: 20 MPa/82 MPa
	Hydrogen chiller	Method: Refrigerating machine and brine heat exchange method Hydrogen temperature: -40 to -33°C
Refueling machine (Dispenser)	Refueling method: Direct refueling method Refueling pressure: 35 MPa/70 MPa	

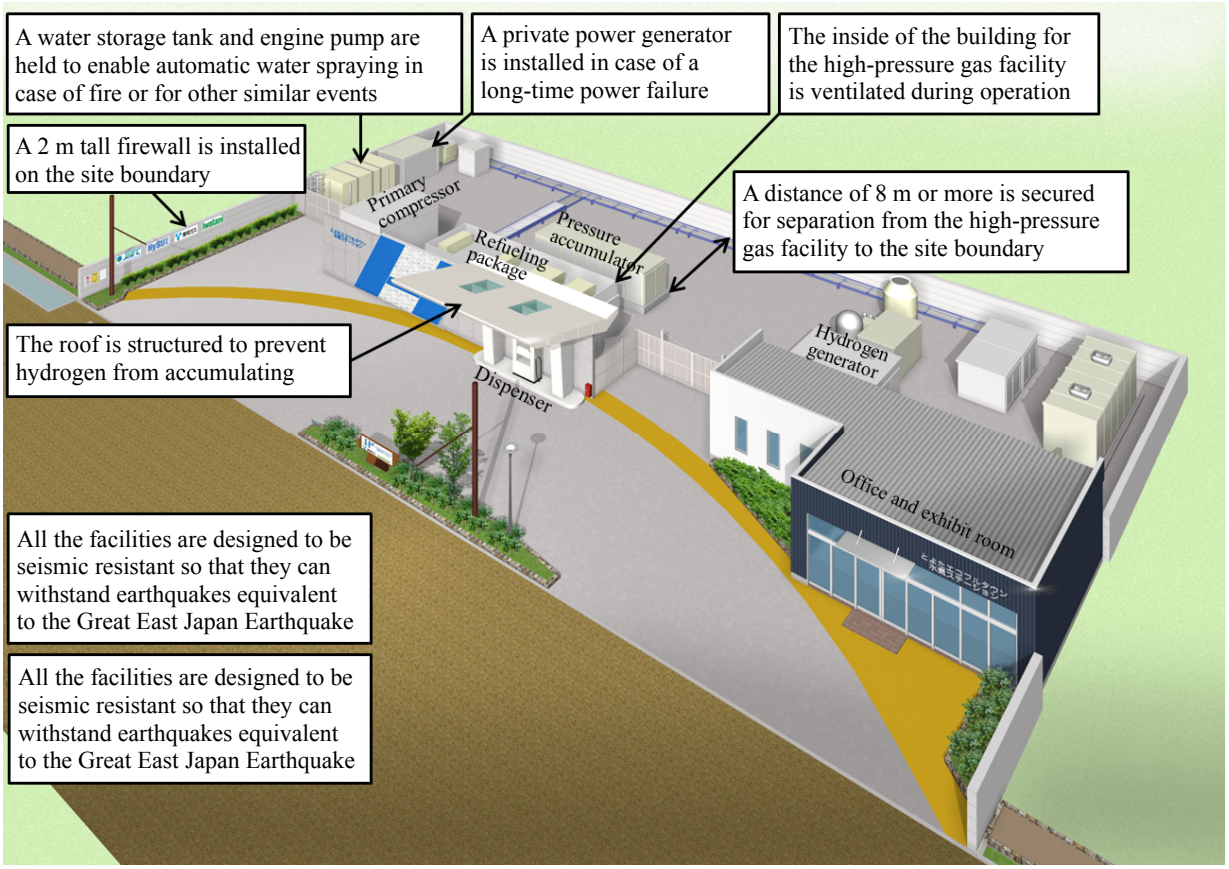

Figure 6. Main Safety Measures at Toyota Ecoful Town Hydrogen Refueling Station

3.Technical Demonstration at Toyota Ecoful Town Hydrogen Refueling Station

(1)Demonstration of technology of short-time refueling to FCV

Once refueling a vehicle vessel with compressed hydrogen, thework of compression brought with the hydrogen refueling will be converted to the internal energy, and it will increase the hydrogen temperature within the vessel. If rapidly refueling the vessel with hydrogen, the hydrogen temperature in it may exceed 85°C or the highest operating temperature of the CFRP vessel made of resin liner adopted as the vehicle vessel. For this reason, we

have adopted a technique to pre-cool hydrogen before it is used for refueling so that the filled hydrogen may not exceed 85°C even in the case of rapid refueling.In Japan, the Exemplified Standard Related to the Security Regulation for General High-Pressure Gas provides that the refueling of compressed hydrogen at any hydrogen station in urban areas must follow the "Compressed Hydrogen Refueling Technical Standard JPEC-S0003 (2012)" established by the Japan Petroleum Energy Center (general incorporated foundation). The standard determines the pressureramp rate (target value and upper limit value) and the end pressure when refueling a fuel cell vehicle based on the outside air temperature and the initial pressure of the vehicle when starting to refuel it, and the cooling hydrogen temperature (to be selected from -33 to -40°C or -17.5 to -22.5°C). When refueling a fuel cell vehicle under the determined conditions, it is confirmed from a simulation or other means that the filled hydrogen does not exceed 85°C.
The Toyota Ecoful Town Hydrogen Refueling Station is designed to follow the refueling technical standard when the cooling hydrogen temperature is -33 to -40°C. We verified with a refueling test using a real fuel cell vehicle whether the refueling following the standard was really viable. As a result of the verification, we confirmed that all the conditions specified in the standard were met.

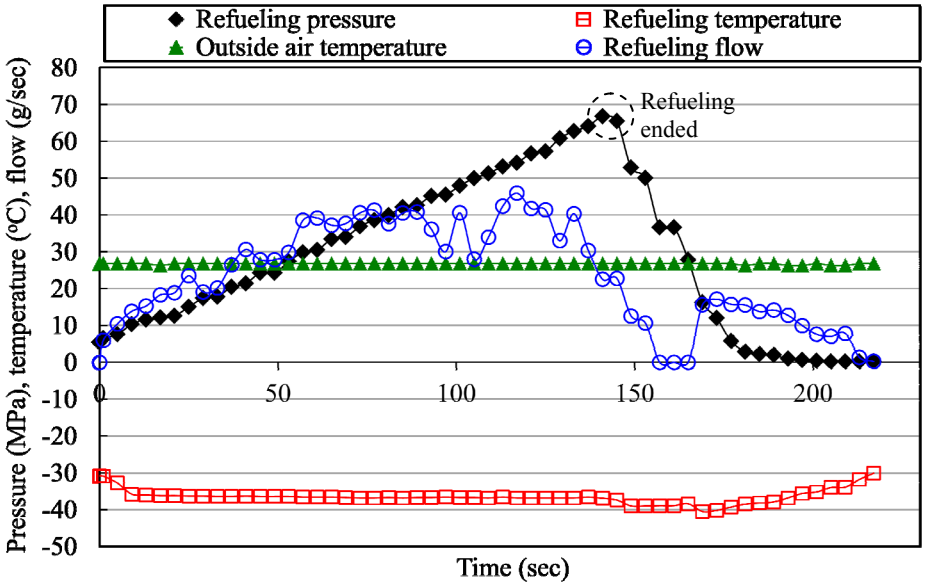

Figure 7. Refueling Test Results (in Compliance with JPEC-S0003 (2012))

Table 2: Results from Confirming Conformity to JPEC-S0003 (2012)

Evaluation item		Specified values according to JPEC-S0003 (2012)*	Resultsfrom refueling test	Performance determination
Pressure at completion of refueling		67.4 MPa or less	64.1 MPa	Pass
Pressure boosting rate	Target value	27.9 MPa/min	Average: 25.4 MPa/min	Pass
	Upper limit value	30.7 MPa/min		
Refueling temperature	Upper limit value	-33°C	-36.3°C	Pass
	Lower limit value	-40°C	-37.3°C	Pass

*Setting values according to the measured values
(outside air temperature: 26.8°C, initial pressure on the vehicle: 5.4 MPa) when refueling starts

(2)Refueling test under simulated power failure conditions

The Toyota Ecoful Town Hydrogen Refueling Station has been designed such that the pressure difference refueling from a pressure accumulator to a fuel cell vehicle is made viable by operating a private power generator (driven by a diesel engine) and supplying power to the control system, etc during a power failure. We verified by

conducting a refueling test on FCVs while the refueling station was put under the simulated power failure condition whether FCVs could be refueled during a real power failure. As a result of the test, we have confirmed that they can be refueled as intended with the design.

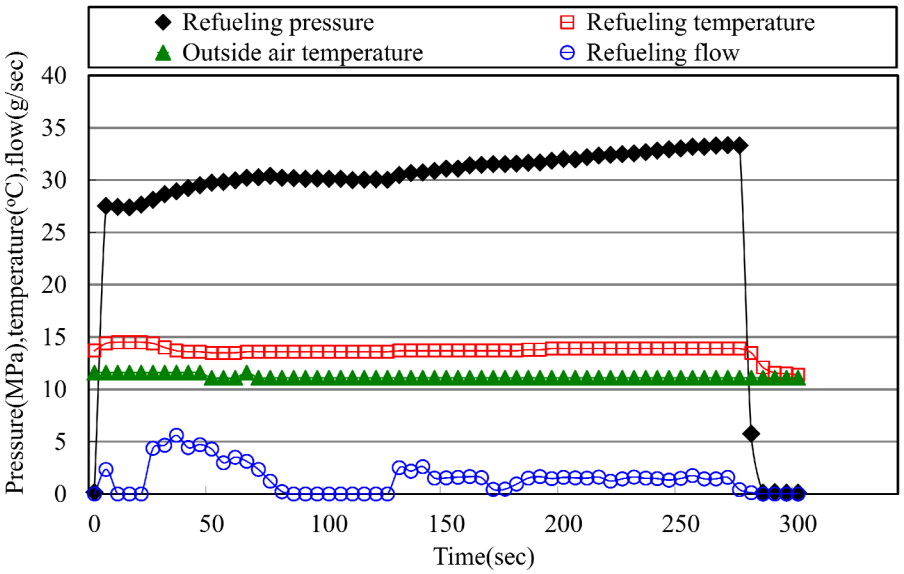

Figure 8. Refueling Test Results under Simulated Power Failure Conditions

4.Summary and Future Plan

- Our company constructed the "Toyota Ecoful Town Hydrogen Refueling Station" or a demonstrative hydrogen refueling station based on commercial specifications jointly with Iwatani Corporation in the Toyota city of the Aichi prefecture, ahead of any domestic pilot development of commercial hydrogen refueling stations.
- With the aim for the reduction of the size of a facility, the short-time refueling to FC buses, etc., we have adopted the package type refueling equipment from Linde AG Germany, which embeds one of the Japan's largest large-flow compressors with a direct refueling method.
- From a result of the refueling tests to FCVs, we have confirmed that FCVs can be refueled in compliance with JPEC-S0003 (2012) or a domestic hydrogen refueling technology standard in Japan. In addition, we have also confirmed by conducting the refueling test under the simulated refueling conditions that the vehicles can be refueled even during a power failure.
- We plan to add additional pressure accumulators in future to further improve convenience of operating the hydrogen refueling station toward the acceptance of 70-MPa FC buses planned to be introduced into the market. In addition, immediately after the 70-MPa FC buses are introduced, we will demonstrate the short-time refueling to FC buses.

5.Acknowledgement

This project was carried out as a part ofthe projects between NEDO and HySUT or "Project for Local Hydrogen Supply Infrastructure technical and social Demonstration (joint research projectfrom 2011 to 2013)" and "Project for Research and Development of Technology for Hydrogen Utilization (commissioned projectfrom 2014)," and we would like to express appreciation to those concerned.