

Safety Guidance for FCV



Toyota Motor Corporation

Introduction

The Fuel Cell Vehicle, or FCV, is a clean energy vehicle equipped with a fuel cell stack that generates electricity through the chemical reaction between hydrogen and oxygen. Unlike conventional vehicles, the fuel cell vehicle utilizes hydrogen as a fuel, and some may feel uneasy about servicing the vehicle. However, like other fuels such as gasoline, CNG (Compressed Natural Gas) and LPG (Liquefied Petroleum Gas), hydrogen is a safe fuel when the user has an understanding of its properties and handles it correctly. This guidance will help you to better understand the fuel cell vehicles and hydrogen, as well as help you to ensure safety during work.

For detailed maintenance and repair procedures, refer to the respective repair manuals and make sure to perform operations in accordance with the instructions provided in the manuals.

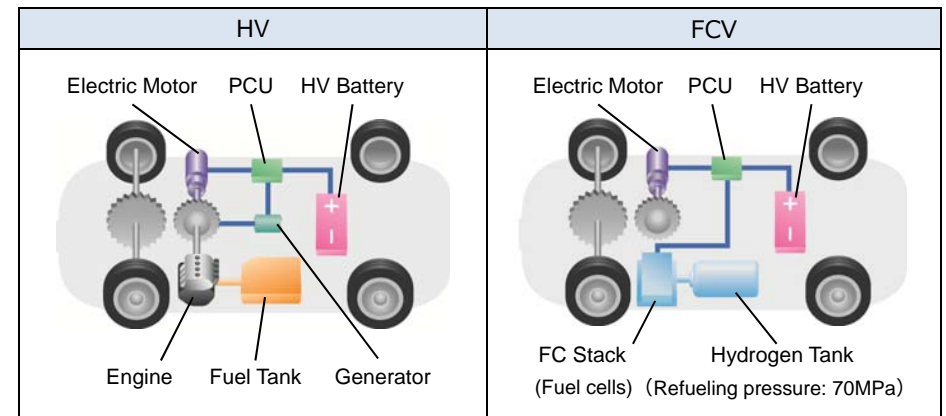
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What is a Fuel Cell Vehicle?

Toyota's hybrid technology is used as a core technology in the development of the fuel cell vehicle.

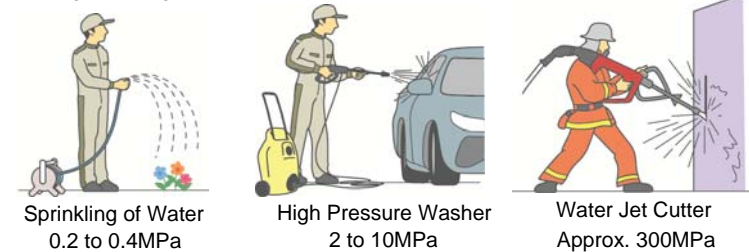
Hybrid vehicles combine an engine and electric motor, fusing the advantage of these two power sources depending on the driving conditions. However, the fuel cell vehicle is not equipped with an internal combustion engine, but generates electricity through chemical reaction between the hydrogen stored as a fuel and oxygen in air, and supplies this electricity to electric motors to produce driving power.



- ⦿ The refueling pressure to the hydrogen tanks is 70MPa, or approximately 700 bars. However, this pressure is lowered when the hydrogen is supplied to the FC stack.
- ⦿ The FC stack is not a device for storing electricity but is a generator that generates electricity through chemical reaction between hydrogen and oxygen.

💡 Tips

The refueling pressure to the hydrogen tanks is 70MPa, or approximately 700 bars. This means that a force of approximately 700 kg is being applied per square centimeter. (9954 psi)



Properties of Hydrogen

Hydrogen is the lightest element on the earth. It is colorless and odorless, and when used as a fuel for the fuel cells, there are no harmful emissions and the only by-product is water. In addition, hydrogen is non-toxic, so it does not present a health hazard to humans by inhalation, skin contact, etc. Hydrogen can be obtained from petroleum or natural gas, or even from water through electrolysis. By harnessing natural energy such as solar, wind and water power to produce the electricity for the electrolysis of water, hydrogen can be produced with extremely low CO₂ emissions.



- Compared to CNG and LPG, hydrogen gas is easy to leak and difficult to detect because its molecular mass is small. In addition, hydrogen is extremely flammable over a wide concentration range. However, it is easy to diffuse and if a small amount of hydrogen leaks, it will quickly dissipate to below the flammable concentration range.

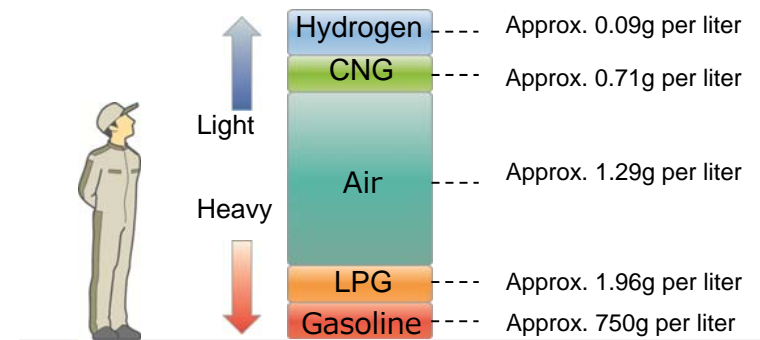
- Hydrogen has been used over 200 years for gas lamps, town gas etc. Hydrogen is not a dangerous fuel when the user has an understanding of the properties and handles it correctly.



Tips

If ignited, pure hydrogen flame is nearly colorless, making it almost invisible. However, if hydrogen flame ignites other materials, flame may become visible.

Comparison of Vehicle Fuel Weight

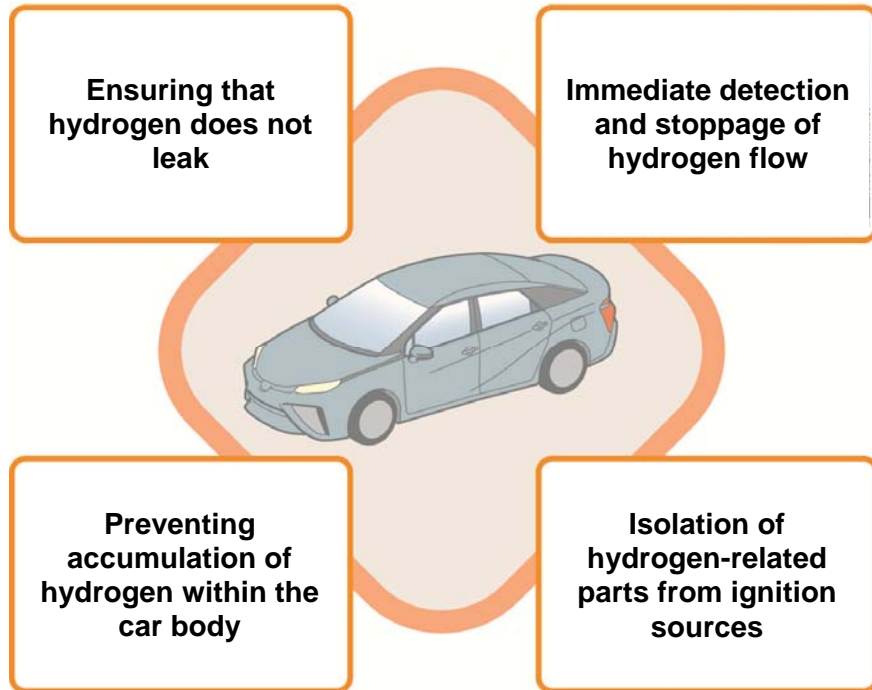


Comparison of Vehicle Fuel Properties

Property	Hydrogen	CNG	LPG	Gasoline
Molecular mass	2	16	44	Approx. 106
Color	Colorless	Colorless	Colorless	Colored
Odor	Odorless	Odorless (Can be odorized)	Odorless (Can be odorized)	Odorized
Minimum ignition energy (mJ)	0.02	0.29	0.26	0.24
Flammable concentration range (vol / %)	4.0 to 74.5	5.3 to 15.0	2.4 to 9.5	1.0 to 7.6
Detonation concentration range (vol / %)	18.3 to 59	6.3 to 13.5	2.6~7.4	1.1 to 3.3
Diffusion coefficient (m ² /s)	6.1×10 ⁻⁵	1.6×10 ⁻⁵	1.2×10 ⁻⁵	5×10 ⁻⁶
Specific gravity (air = 1)	0.07	0.55	1.52	3.4 to 4.0
Ignition temperature (Celsius)	527	540	457	228
Diffusability	Diffuses quickly due to being lighter than air	Diffuses due to being lighter than air	Flows along floor or ground due to being heavier than air	<ul style="list-style-type: none"> Flows along floor or ground due to being liquid. Adheres to clothes due to being liquid.
	◎	○	△	△
Detectability	Detectable by noise (hissing noise)	Detectable by odor and noise	Detectable by odor and noise	Detectable by eyes and odor
	△	○	○	●

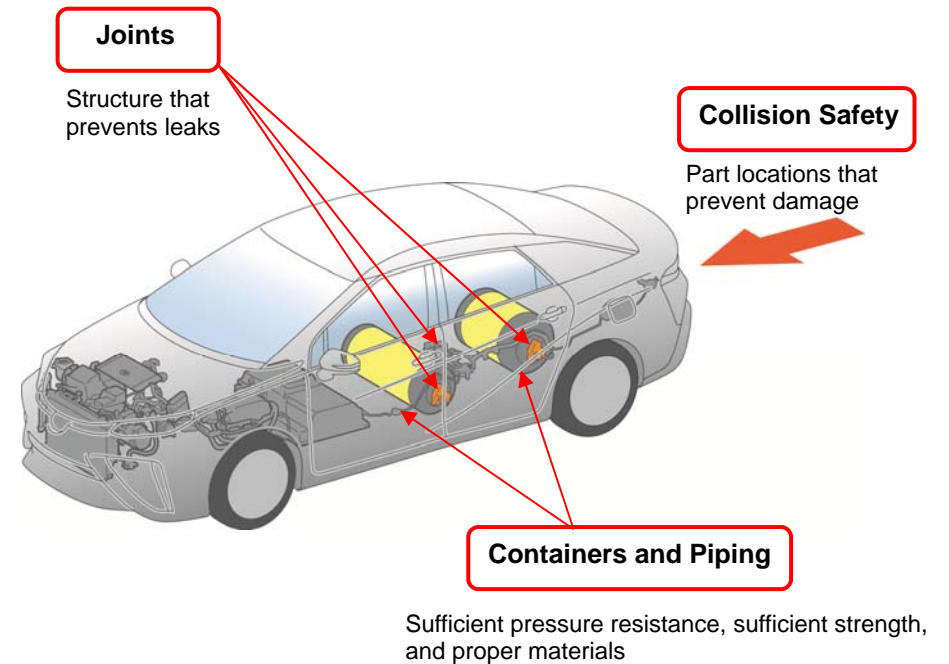
Safety Measures for the Hydrogen in an FCV

Fuel cell vehicles were developed based on the following “Four Basic Concepts for the Hydrogen in an FCV” so as to ensure that the FCVs are as safe as the conventional vehicles such as gasoline, CNG, and LPG vehicles.



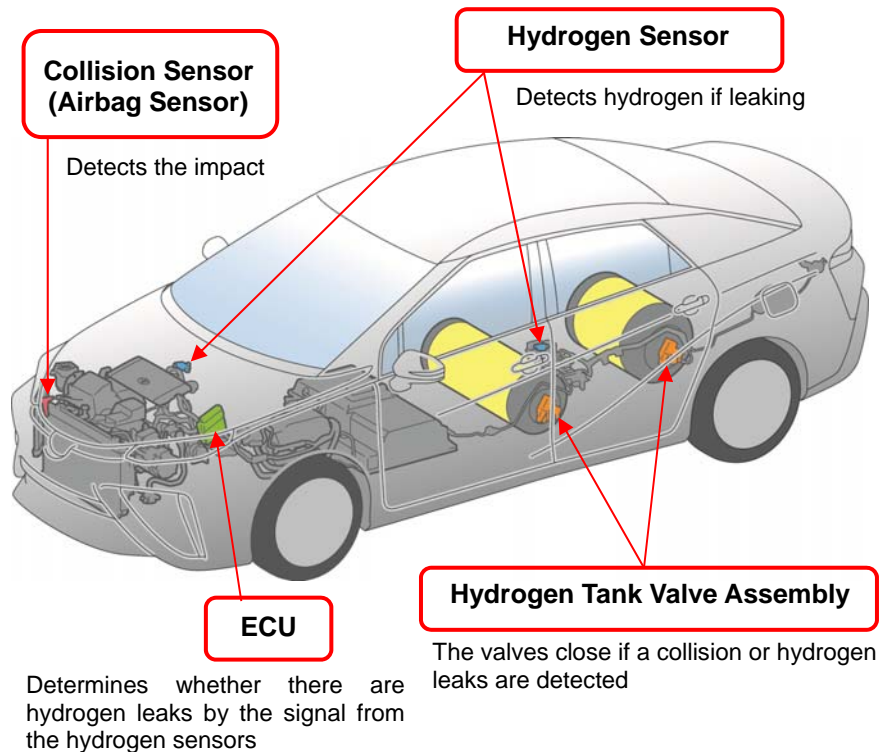
Ensuring that hydrogen does not leak

- ① The hydrogen tanks comply with the standards set forth in the High Pressure Gas Safety Act of Japan and have undergone extreme testing, including repetitive refueling durability tests, to ensure their durability and reliability.
- ② Mechanical joints of the hydrogen pipes are specially designed to prevent hydrogen leaks. The joints of the hydrogen pipes must be checked at every periodic inspection.



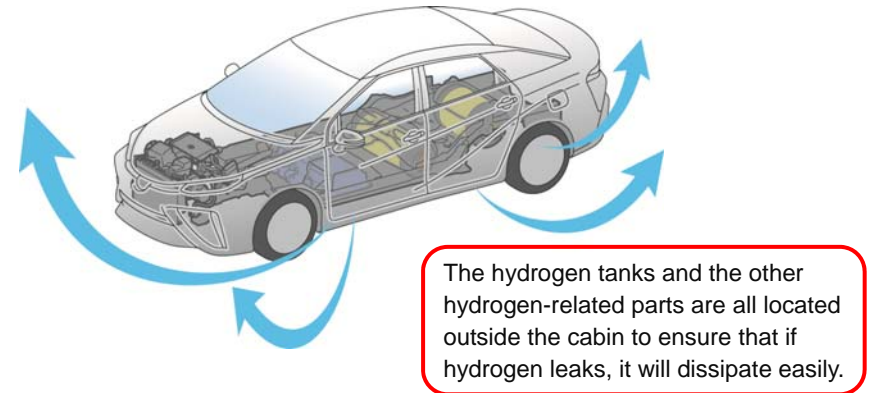
Immediate detection and stoppage of hydrogen flow

- ⦿ In the unlikely event that the hydrogen sensors detect hydrogen at concentration levels higher than the specific target values, the electromagnetic valves of the hydrogen tank valve assemblies close to shut off flow of the hydrogen gas.
- ⦿ If the collision sensor (airbag sensor) detects an impact larger than the pre-set level, the electromagnetic valves of the hydrogen tank valve assemblies close to shut off the hydrogen gas flow.



Preventing accumulation of hydrogen within the car body

- ⦿ The locations of the hydrogen tanks and hydrogen pipes are designed to prevent accumulation of hydrogen.



Isolation of hydrogen-related parts from ignition sources

- ⦿ The vehicle is designed so that no ignition sources are located near the hydrogen-related parts.

Safety Requirements for Maintenance and Repair

Observe the following procedure to ensure safety when performing maintenance or repair on the hydrogen-related parts or high voltage parts.

Maintenance/Repair Workflow

(1) Ensure enough ventilation



(2) Wear protective gear and eliminate static electricity



(3) Ensure safety when working on high voltage parts



(4) Ensure sealing of the hydrogen tanks



Maintenance and/or Repair

(5) Ensure safety when performing body repair and painting



(6) Check for leaks after working on hydrogen-related parts

(1) Ensure enough ventilation

- ◎ The light-weight hydrogen gas will dissipate very rapidly into the atmosphere. Ensure enough ventilation before starting maintenance or repair, and work in an area where the released hydrogen gas will not concentrate.

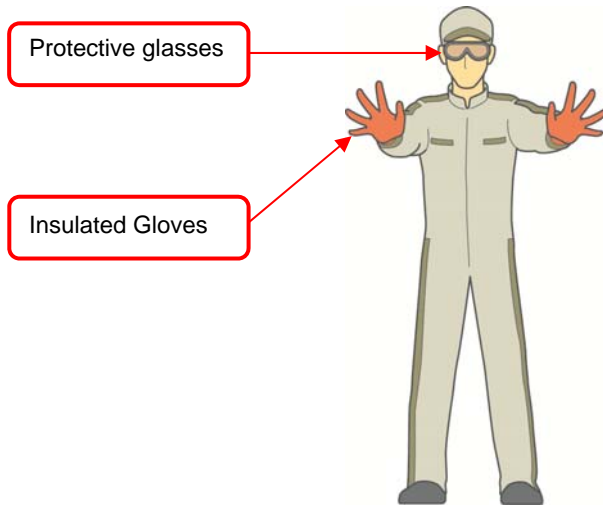


! Caution

When performing repairs on any hydrogen-related parts, all operations shall be performed in full compliance with Japan's High Pressure Gas Safety Act.

(2) Wear protective gear and eliminate static electricity

- Wear insulated gloves to avoid electrical shock, prior to performing maintenance or repair of the high voltage system parts.
- Wear protective glasses to protect your eyes, prior to performing maintenance or repair of the hydrogen-related parts.

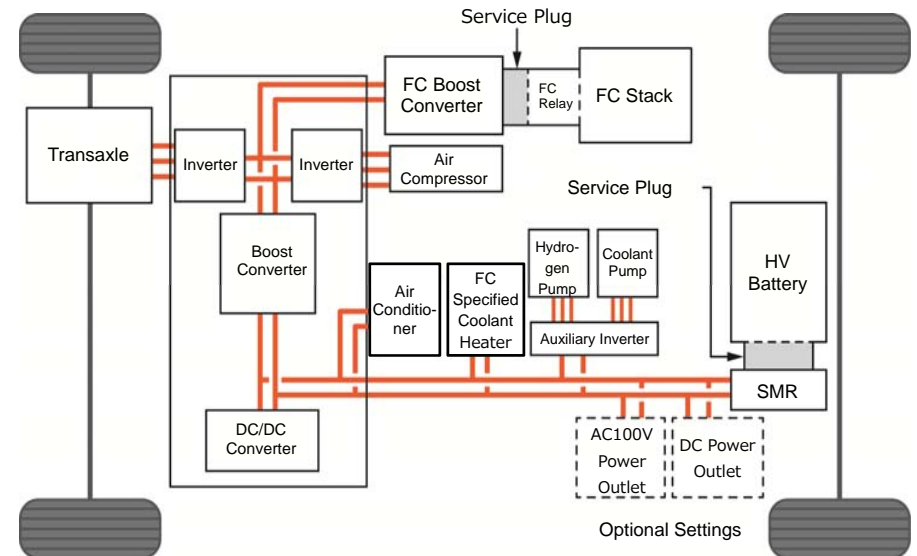


Caution

Eliminate static electricity before removing or installing any hydrogen-related part which may result in release of hydrogen.

(3) Ensure safety when working on high voltage parts

High Voltage System Overview



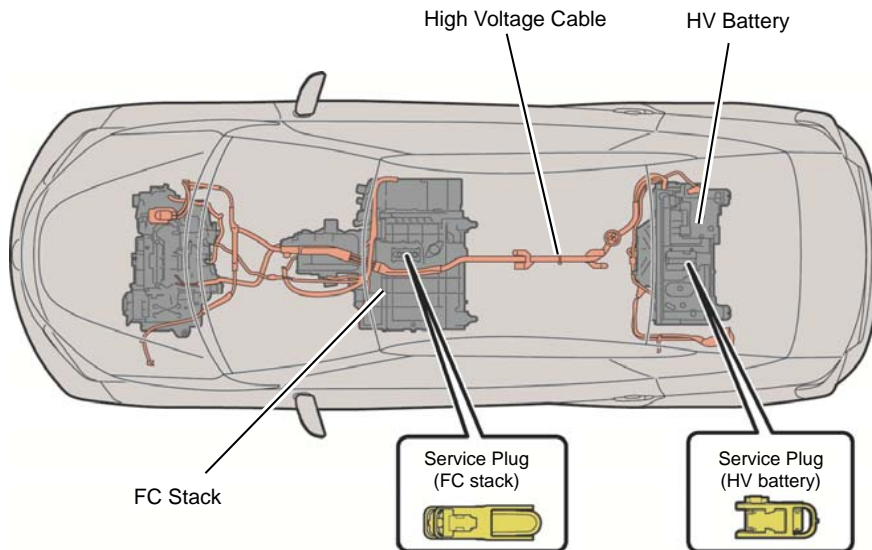
Label

- High voltage parts that are connected by high voltage cables (indicated in orange) are used in the fuel cell vehicles. Do not touch the high voltage cables (indicated in orange) or the connectors without wearing adequate protective gear, including insulated gloves, as it can be extremely dangerous. In addition, observe the handling precautions on the labels that are attached to the high voltage parts.

Attention

When performing inspection, repair, or maintenance of the high voltage parts, refer to the relevant repair manual and observe the precautions in the manual.

Service Plug Layout



- ⦿ The service plugs are provided at 2 locations; one on the FC stack and the other on the HV battery. For safety reasons, remove the 2 service plugs, in no particular order, to shut off the high voltage circuits prior to starting the inspection, maintenance or repair procedure.
 - ⦿ Before removing the service plugs, make sure to turn the ignition switch off and then disconnect the cable from the negative terminal of the auxiliary battery*1.
- *1: Refer to the relevant repair manual and read the caution notice for the disconnection of the cable from the negative auxiliary battery terminal, before turning the ignition switch off. It may be necessary to wait for a certain amount of time before disconnecting the cable.
- ⦿ Do not start the system (READY ON) before reinstalling the 2 service plugs as this may cause a malfunction.
 - ⦿ Make sure to wear adequate protective gear, including insulated gloves, to avoid electrical shock.
 - ⦿ Do not touch the high voltage connectors or the terminals for at least 10 minutes after removing the service plugs. In addition, always wear insulated gloves and check that no voltage remains in the high voltage system components before working on them.

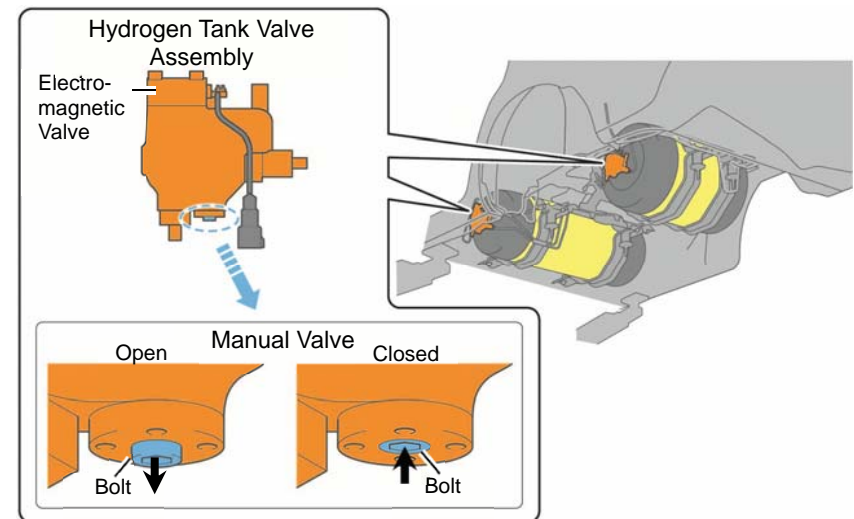


Attention

When performing inspection, repair, or maintenance of the high voltage parts, refer to the relevant repair manual and observe the precautions in the manual.

(4) Ensure sealing of the hydrogen tanks

- ⦿ Make sure that the electro-magnetic valves and manual valves of the hydrogen tank valve assemblies are completely closed to ensure double sealing of the hydrogen tanks. Otherwise, a large amount of hydrogen may be released during work. (The electro-magnetic valves are closed automatically when the ignition switch is turned off.)
- ⦿ Depressurize the hydrogen pipes before removing or installing any hydrogen-related components.

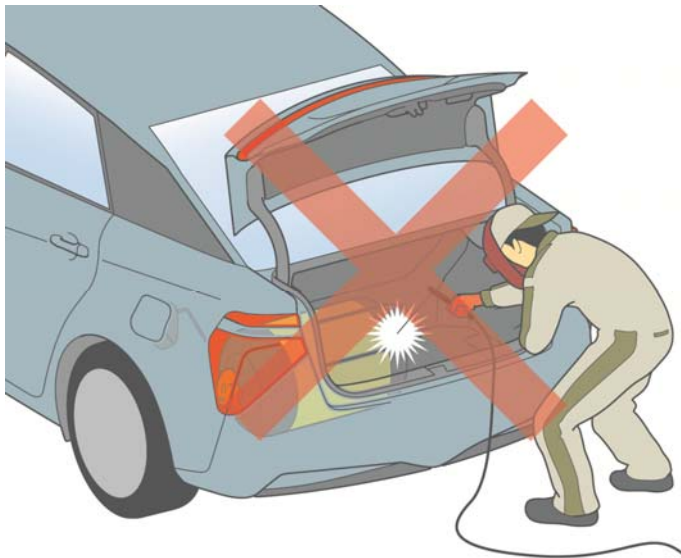


Attention

When ensuring the sealing of the hydrogen tanks or depressurizing the hydrogen pipes, refer to the relevant repair manual and perform the operations in accordance with the instructions in the manual.

(5) Ensure safety when performing body repair and painting

- ◎ Make sure that the electro-magnetic valves and manual valves of the hydrogen tank valve assemblies are completely closed to ensure double sealing of the tanks before starting the work. Otherwise, a large amount of hydrogen may be released during work. (The electro-magnetic valves are closed automatically when the ignition switch is turned off.)
- ◎ Do not expose the hydrogen sensors to solvent.
- ◎ Remove the hydrogen tank before welding any parts in the periphery.
- ◎ Do not expose the hydrogen tanks to flames, sparks or solvents as they are made of layers of plastic, woven CFRP (carbon-fiber-reinforced-plastic), etc.
- ◎ Do not expose the hydrogen tanks to extreme temperatures of 85 degrees Celsius or higher.
- ◎ Do not use an infrared heating panel near the hydrogen pipes, as temperatures cannot be controlled.
- ◎ The fuel cell vehicles are allowed to be placed in a paint booth after making sure that there are no gas leaks, just like the CNG vehicles and LPG vehicles.



Attention

When performing body repair and/or painting, refer to the relevant repair manual and observe the precautions in the manual.

(6) Check for leaks after working on hydrogen-related parts

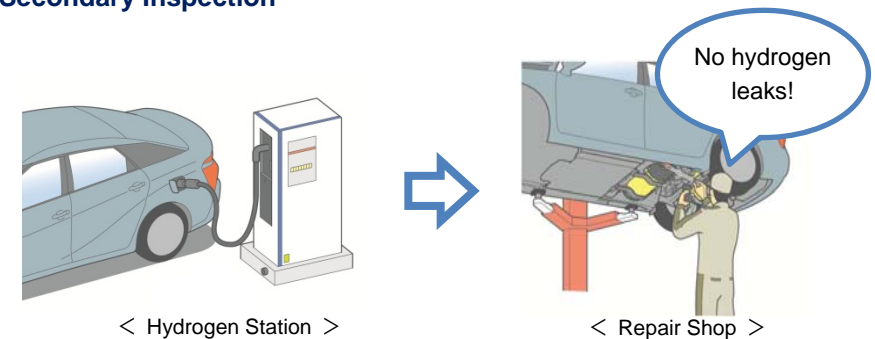
- ◎ Whenever conducting any maintenance or repair on the hydrogen-related components, 2 step leakage inspections must be performed after the work is completed. When conducting the secondary inspection, do not drive the vehicle to and from the hydrogen station but transfer it with a vehicle carrier trailer.

Inspection	Primary inspection using nitrogen gas	Secondary inspection using hydrogen gas
Outlines	<ul style="list-style-type: none"> • Inspect after installation to the vehicle. • Use inert nitrogen gas and pressure gauge. 	Use highly pressurized hydrogen and a hydrogen gas detector.
Purpose	Inspect the hydrogen-related components to confirm that there are no leaks by applying pressure with inert nitrogen gas.	Perform the final inspection of the hydrogen-related components to confirm that there are no leaks by simulating the actual vehicle usage condition by applying pressure with highly pressurized hydrogen.

Primary Inspection



Secondary Inspection



Attention

When performing the leakage inspections, refer to the relevant repair manual and perform the operations in accordance with the instructions provided in the manual.

Note

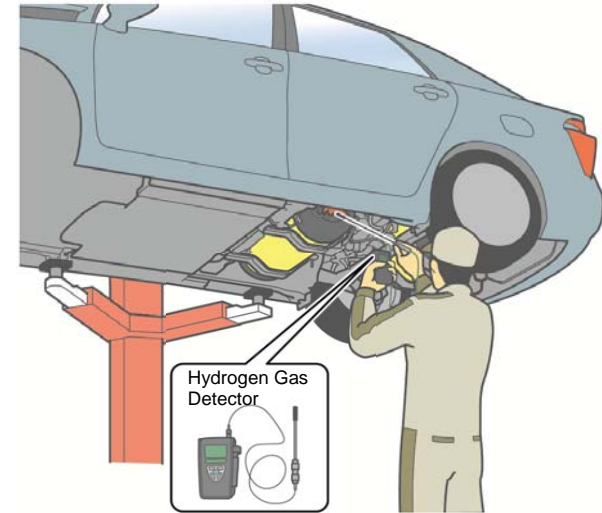
Precautions for Hydrogen-related Parts Repair

Prepare the items as indicated below prior to starting the repair of the hydrogen-related components.

Items to Prepare

[Hydrogen Gas Detector]

Used when inspecting for hydrogen gas leaks during repair and maintenance.

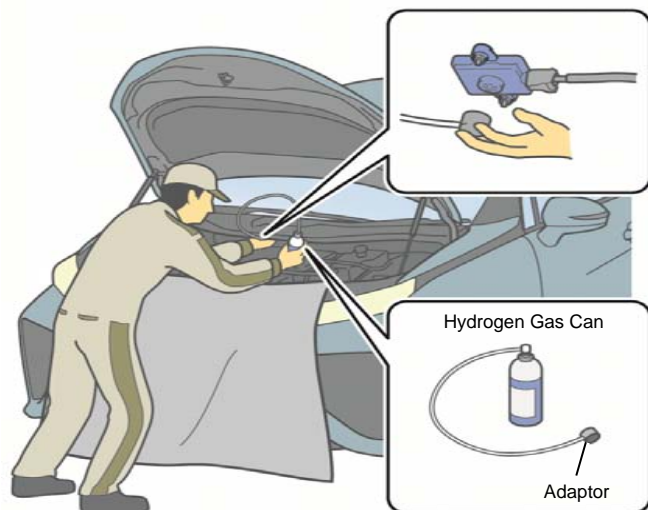


Attention

The hydrogen gas detectors must be calibrated periodically. For handling of the hydrogen gas detectors, refer to the user's manual that came with the device.

[The Test Hydrogen Gas]

Used when testing the functionality of the hydrogen sensors to expose a certain concentration of the test hydrogen gas to the sensors via an adaptor.



Caution

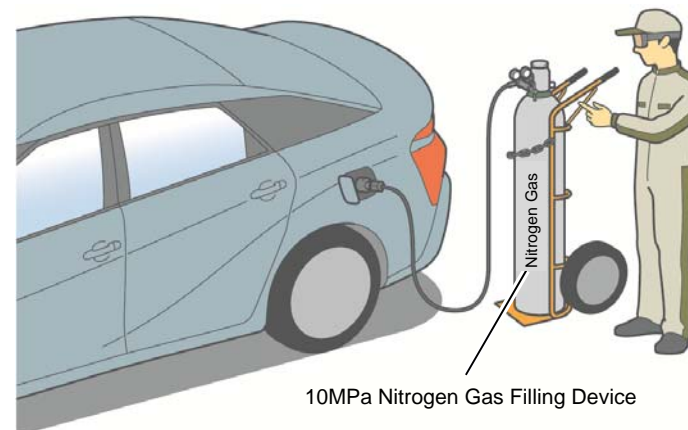
Do not use hydrogen gas in a higher concentration than the specified value, as this may cause malfunctioning of the hydrogen sensors.

Attention

Refer to the relevant repair manual and inspect the hydrogen sensors in accordance with the instructions in the manual.

[10MPa Nitrogen Gas Filling Device]

Used when performing primary inspection for hydrogen leaks after installation of the hydrogen-related parts to the vehicle. Hydrogen leaks can be found by checking for a decrease in pressure.

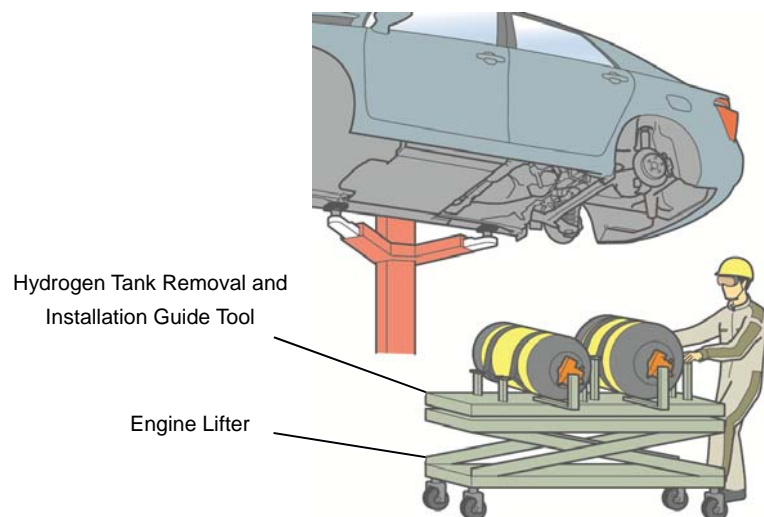


Attention

Refer to the relevant repair manual and inspect for leaks in accordance with the instructions in the manual.

[Hydrogen Tank Removal and Installation Guide Tool]

Used in conjunction with the engine lifter when removing or reinstalling the hydrogen tanks or replacing the high pressure hydrogen pipes indicated in red, so as to prevent load from being applied to the pipes.

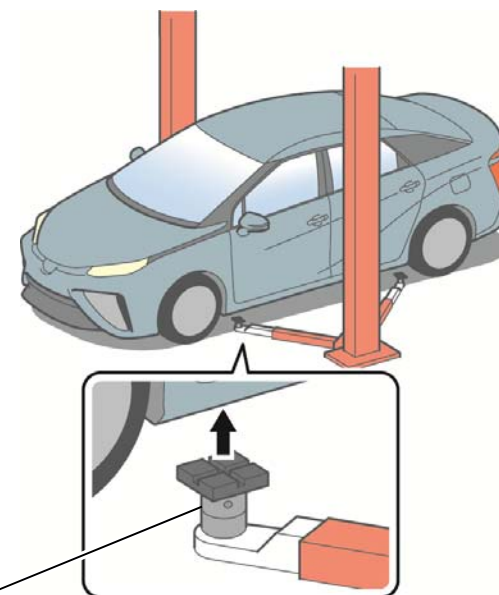


Attention

When performing removal or installation of the hydrogen tanks, refer to the relevant repair manual and perform the operations in accordance with the instructions in the manual.

[Vehicle Lift Adapter Pads]

Used when lifting the vehicle for prevention of interferences between the vehicle and the swing arm or the plate of the lift.

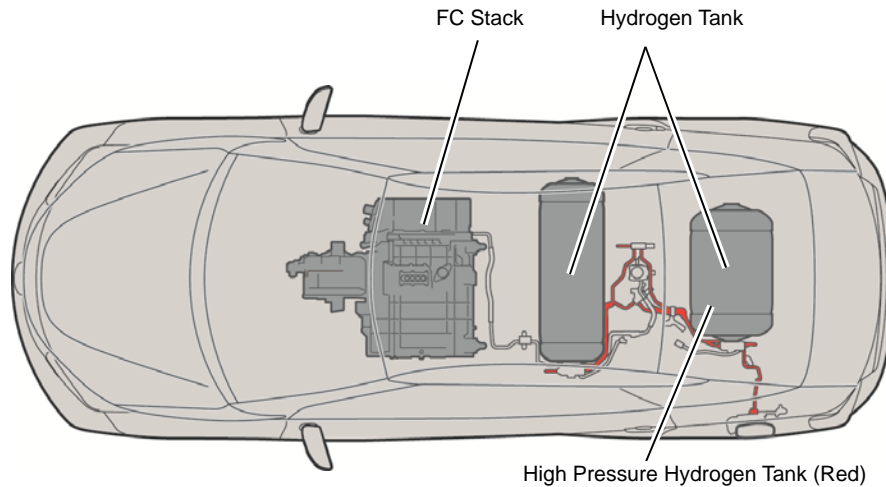


Caution

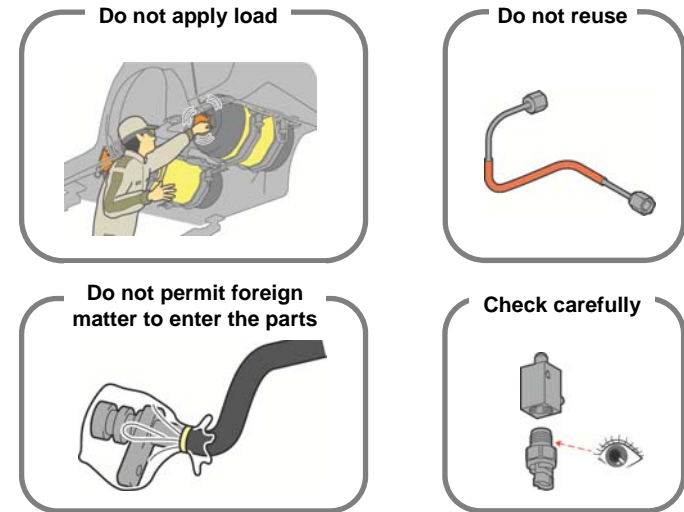
A swing type arm style lift must always be used when removing or installing the hydrogen tanks or the FC stack.

Handling of the Hydrogen Pipes

The refueling pressure to the hydrogen tanks is 70MPa, or approximately 700 bars. However, this pressure is lowered when the hydrogen is supplied to the FC stack (fuel cells). For distinction, the high pressure hydrogen pipes are indicated in red.



- ⦿ **Extreme care must be used when handling the high pressure hydrogen pipes, which are indicated in red.** Not just during removal and installation, but the pipes should never be subjected to any load or stress, for example by pulling.
- ⦿ **Do not reinstall any high pressure hydrogen pipes, which are indicated in red, if once removed.** Reusing the pipes will result in poor sealing of the joints and may cause hydrogen leaks.
- ⦿ **When replacing the high pressure hydrogen pipes indicated in red,** be sure to replace them after removing the hydrogen tanks from the vehicle using the hydrogen tank removal and installation guide tool. **The replacement of the high pressure hydrogen pipes must be performed with the removed hydrogen tanks placed on the guide tool** as the pipes must not be subjected to any strain or load.
- ⦿ Be sure to **protect the disconnected portions** of the components that can be reused **from entry of any foreign material such as dust and metal chips.** Entry of foreign material can significantly affect the sealing quality and the power generating performance of the FC stack (fuel cells).
- ⦿ **Do not use cloth gloves** when removing or installing the high pressure hydrogen pipes, **as doing so may allow pieces of thread to enter into the pipes.**
- ⦿ For components that can be reused, **carefully check the installation surfaces for any foreign material that can impair sealing performance before reinstallation.**

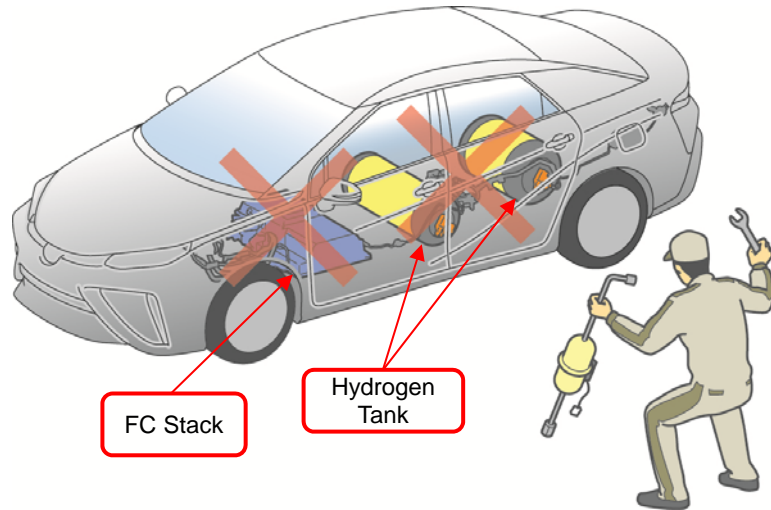


Attention

For prevention of foreign matter from entering into the parts, refer to the relevant repair manual and observe the instructions in the manual.

Do Not Disassemble the FC Stack or the Hydrogen Tanks

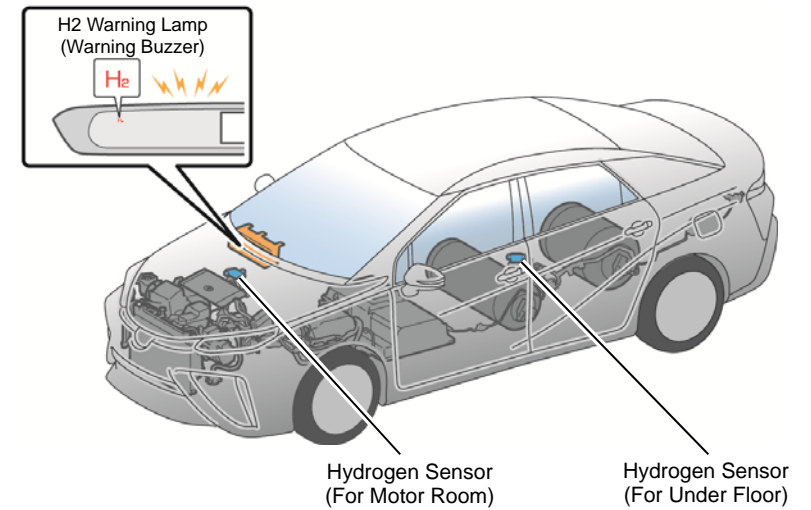
Do not modify or disassemble any components unless otherwise specified to do so in the relevant repair manual. Improper handling of the fuel cell-specific components such as the FC stack and hydrogen tanks may cause hydrogen leaks.



Perform Inspections

[Periodic Inspections of the Hydrogen Sensors]

The fuel cell vehicle is provided with the hydrogen sensors which are located outside the cabin at 2 locations to monitor for hydrogen leaks. Use the test hydrogen gas to inspect the functionality of the hydrogen sensors.

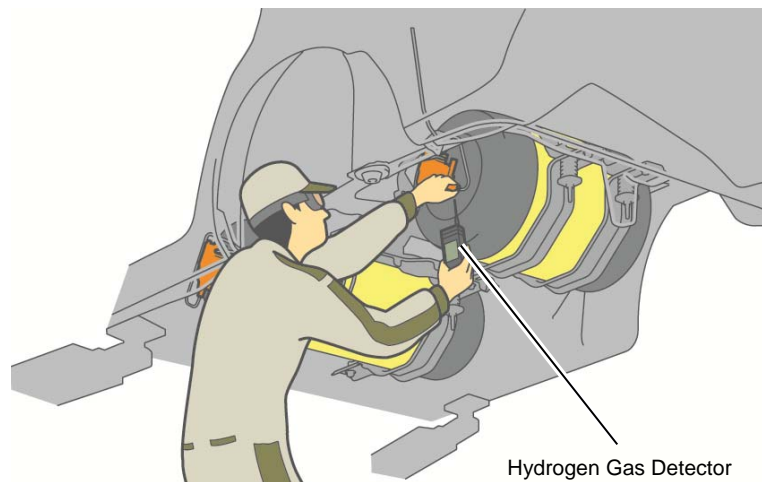


Attention

Refer to the relevant repair manual and inspect the hydrogen sensors in accordance with the instructions in the manual.

[Periodic Inspection for Hydrogen Leaks]

- ⦿ Inspections for hydrogen leaks from the hydrogen tanks, hydrogen pipes or other hydrogen-related components that are connected to the hydrogen pipes must be performed using the hydrogen gas detector.
- ⦿ The maximum duration (15 years) of hydrogen storage is set for hydrogen tanks by law. Check and observe the expiration date indicated on the hydrogen tank at the rear of the fuel lid.



Attention

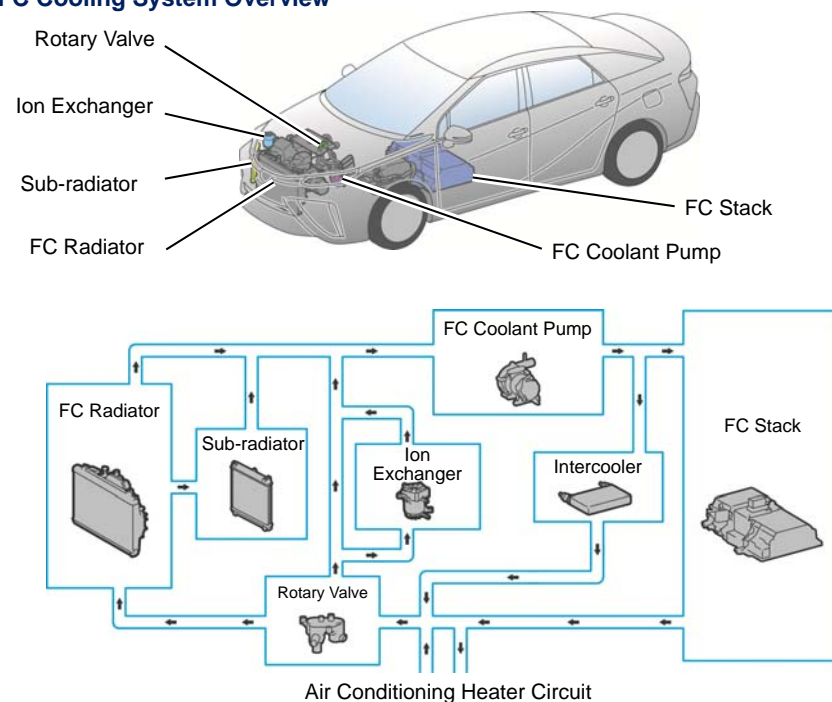
Refer to the relevant repair manual and perform periodic inspections for hydrogen leakage in accordance with the instructions in the manual.

FCV Specific Precautions

FC Cooling System Specified Coolant

A specific transparent coolant is used for the FC cooling system of the fuel cell vehicles. The specified coolant for the FC cooling system is a coolant with extremely low electrical conductivity which ensures insulation of the fuel cells and fuel cell related components. Unlike conventional LLCs, the FC specified coolant does not need to be replaced. Only the filter of the ion exchanger needs to be replaced every 60,000 kilometers of driving.

FC Cooling System Overview



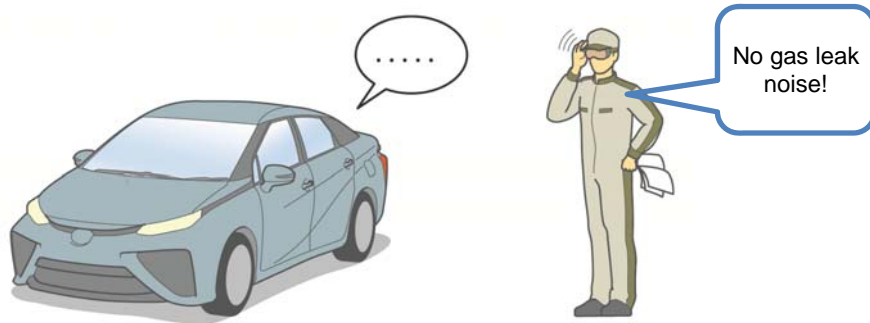
Caution

- Be sure to fill the FC cooling system with the specified coolant.
- Do not use engine inverter coolant or anything other than the specified coolant for the FC cooling system, as this could cause malfunctions.
- Do not reuse the specified coolant which has been drained from the radiator.

(1) In Case of Hydrogen Leaks During Work

The sealing of the hydrogen tanks is ensured to prevent hydrogen leaks (See page 13). However, in the unlikely event of hydrogen leaks, give priority to observing the following procedure to ensure safety.

- 1: If a gas leak noise (hissing noise) is heard, stay at least 10 meters away from the vehicle and the problem components until the noise stops.
- 2: Wear appropriate protective gear and eliminate static electricity.



- 3: Using the hydrogen gas detector, confirm that the hydrogen concentration is lower than 4%.



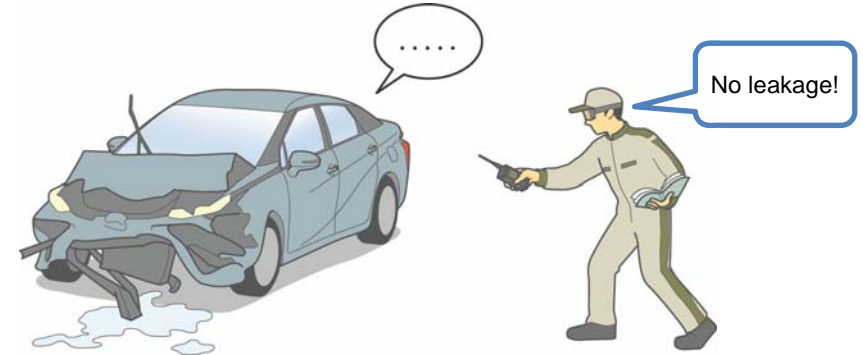
- 4: Conduct diagnostic examinations.

Refer to the relevant repair manual and work properly in accordance with the instructions in the manual.

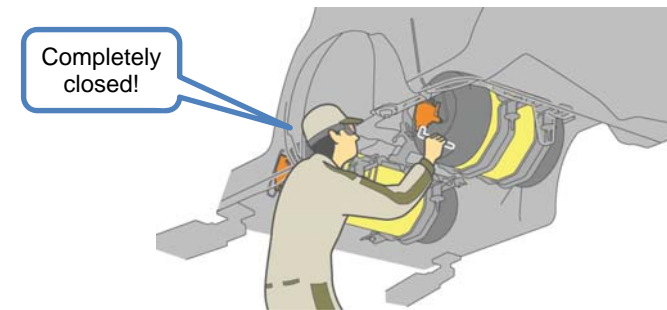
(2) When a Vehicle Involved in an Accident is Brought in

Give priority to observing the following procedure and work while ensuring safety.

- 1: Wear appropriate protective gear and eliminate static electricity.
- 2: Confirm that no gas leak noise (hissing noise) is heard and then using the hydrogen gas detector, check that the hydrogen concentration is lower than 4%.



- 3: Make sure that the manual valves of the hydrogen tank valve assemblies are completely closed.



- 4: Conduct diagnostic examinations of the damaged components.

Refer to the relevant repair manual and work properly in accordance with the instructions in the manual.

Caution

Whenever a fuel cell vehicle involved in an accident is brought in, make sure to confirm that there are no hydrogen leaks and ensure that the manual valves of the hydrogen tanks are completely closed as specified above, before storing the vehicle.

Note

Handwriting practice area with 12 horizontal dashed lines.

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