INTRODUCTION TO FUEL CELL VEHICLES

Student Guide

Student Guide
January, 2018

LOS ANGELES TRADE-TECH
LATTC
A Community College

TWI
Transportation
Workforce
Institute

INTRODUCTION TO FUEL CELL VEHICLES

Course Outline
January, 2018

LOS ANGELES TRADE-TECH
LATTC
A Community College

TWI
Transportation
Workforce
Institute

Course Outline

Introduction to Fuel Cell Vehicles

Table of Contents

Course Overview

This 24-hour course covers Hydrogen Fuel Cell Vehicle Technology at the introductory level. It includes the history of using hydrogen gas as a fuel, the properties of hydrogen, considerations of safety and hazards, hydrogen vehicle fuel systems, and fuel cell vehicle diagnostics and troubleshooting. This course is aimed at hydrogen fuel cell technicians and first responders.

I. Learning Outcomes and Objectives

Course Learning Outcomes

- Participants will understand the design, operation, maintenance, diagnosis and repair of fuel cell vehicles
- Participants will be able to service and maintain fuel cell vehicles
- Participants will be able to safely work in an environment where hydrogen is used as a fuel

Learning Objectives

Upon completion of the course, participants will be able to:

1. Identify historical and current uses for hydrogen as a fuel
2. Discuss advantages of hydrogen as a fuel source
3. Name at least three properties of hydrogen
4. Select appropriate safety attire for working in an environment with hydrogen fuel
5. List two ways to detect a hydrogen leak
6. List several hydrogen combustion methods
7. Follow proper procedures in case of a hydrogen emergencies and first responder procedures
8. First responders will be able to safely and effectively deal with hydrogen fuel cell vehicle emergencies
9. Identify the parts of a fuel cell system
10. Name at least two major pieces of hardware one might find in a hydrogen fuel cell system
11. Diagnose a fuel cell problem using the TIS system

II. Course Agenda

Day 1

Module 00: Introduction	

10 Min	• Recommended Course Materials
	• Lab Requirements
	  ○ Personal Equipment and Attire
	  ○ Personal Protective Equipment (PPE)
	  ○ Tattoo and Health Disclosure

Module 01: History of Hydrogen Gas as a Fuel	
1.25 Hours	• Discovery and Use • Why Consider Hydrogen as Fuel? • Infrastructure and Demand • Production
Module 02: Hydrogen Gas Safety & Service Procedures	
1.25 Hours	• First Responder Procedures • Properties of Hydrogen • Safe Work Practices • Hydrogen Leaks Module continues…
Lunch	

Lab 01: Hands-on Activities	
1.5 Hours	**Safety Concerns, Emergency Precautions, & Special Equipment** • High voltage rescue and tooling – Intro & demonstration • HV measuring and testing equipment and tooling – Procedure demo

Lab 01: Hands-on Activities	

2 Hours	**Hydrogen Fuel Cell Introduction and Familiarization**
	• Dash Board and Cluster
	  ○ Lamps, symbols and alarms
	  ○ Dashboard control and management
	  ○ Center consul and controls
	• FCV Safety areas and points of concern - HV circuits & high-pressure gas
	• High voltage power and hydrogen systems identification, distribution & layout
	• Turning ON/OFF vehicle
	• Vehicle familiarization and system operation modes

1.5 Hours	**Vehicle Compartments and Access Panels** • Front, passenger cabin and trunk • Undercarriage design, deflection panels and streamlining

Day 2

Module 02: Hydrogen Gas Safety & Service Procedures (continued)	
1.25 Hours	• Hydrogen Flames • Hydrogen Explosions • Electrostatic Discharge
Module 03: Fuel System	
1.75 Hours	• Fuel System Layout • Fuel Cell Stack
Lunch	

Lab 02: Hands-on Activities	
1.5 Hours	**Vehicle Operation** • Noise and feel • Forward, neutral, reverse and park operation • Acceleration and regenerative braking
1.5 Hours	**Onboard Diagnostics** • Software identification • Toyota TIS System intro and demonstration – Connection and access • Positive communication and pairing
1.5 Hours	**TIS Operation** • TIS main menu and contents • System selection • Real-time data monitoring

Day 3

Module 04: Toyota Mirai Fuel Cell	
1.5 Hours	• Fuel Cell Technological Innovations • Toyota's New FC Stack Structure • Fuel Storage and Safety
Module 05: Diagnostics and Troubleshooting	
1.5 Hours	• Techstream
Lunch	

Lab 02: Hands-on Activities	
5 Hours	**Advanced Testing Diagnostics** • Using TIS efficiently along with Smartborad technology • System wiring read and schematic understanding • Diagnostic trouble code and faults – DTCs • TIS navigation and module selection • System testing and output logic comprehension – demonstration • Using wiring diagrams together with TIS for correct diagnosis

III. Course Information

COURSE NAME: Introduction to Fuel Cell Vehicles

APPROVED: TBD

CLASS TIME: 24 Hours

PREREQUISITES: None

TRAINING LOCATION: TBD
TARGET CLASS SIZE: 20-25

TARGET AUDIENCE: Fuel Cell Vehicle Technicians and Emergency Personnel

CERTIFICATE(S): None

TRAINING AIDS AND EQUIPMENT:

- ☑ Smartphone, Tablet, or Laptop
- ☑ PowerPoint Presentations
- ☑ Personal safety equipment
- ☑ Maintenance reference documentation
- ☑ Vehicle Keys (Crew, operating, and maintenance keys)
- ☑ Set of maintenance tools
- ☑ Compact flashlight
- ☑ Laboratory/shop equipment as determined by activity

HANDOUTS:

- ☑ Exercise Handouts
- ☑ Participant Handouts

PARTICIPANT EVALUATION METHODS:

- Written Final Assessment TBD
- Practical Skill Assessment TBD

RESOURCES & LAB EXERCISES

Introduction to Fuel Cell Vehicles
January, 2018

LOS ANGELES TRADE-TECH
LATTC
A Community College

Resources &
Lab Exercises

Introduction to Fuel Cell Vehicles – Lab Exercises

Table of Contents

Instructions for Hands-on Exercises

Use the activities in this section to guide your hands-on practice with the instructor. Your instructor may modify the duration or content of the exercises to fit the circumstances of your class. This document also includes links to useful resources.

Links for Resources

1. **Online**
   a) **U.S. Department of Energy**
      - http://bit.ly/2EfKqdb - USDOE Hydrogen Quiz; "How much do you know about hydrogen?

   b) **Videos**
      - http://rsc.li/2DSUoRC - Visual hydrogen atom (1:21)
      - http://rsc.li/2Dufkkp - Hydrogen properties (7:15)
      - http://bit.ly/2DnALAg - Toyota Fuel Cell System (3:23)

   c) **Toyota Motor Corporation**
      - http://toyota.us/2npcIKy - Toyota Information System TIS (Requires Acct & login setup)
      - http://toyota.us/2EkBK5C - Mirai FCV Mayor Tech Specs (Req Acct Login)

2. **Text Resources**
      - http://bit.ly/2roGEvk -Hydrogen fuel cell Toyota Mirai cruises 300 miles
      - http://bit.ly/2ru0CVE -Toyota Mirai - A Preview of future propulsion
      - http://bit.ly/2nqYXuO - Toyota Mirai could run your home in an emergency

Lab 1 Exercises

Complete the following exercises according to the directions given by your instructor.

1. **Safety Concerns, Emergency Precautions and Special Equipment**
   a. High voltage rescue and tooling – Intro & demonstration
   b. HV measuring and testing equipment and tooling – Procedure demo

2. **Hydrogen Fuel Cell Vehicle introduction and familiarization**
   a. Dash Board and Cluster
      - Lamps, symbols and alarms
      - Dashboard control and management
      - Center consul and controls
   b. FCV Safety areas and points of concern - HV circuits & high-pressure gas
   c. High voltage power and hydrogen systems identification, distribution & layout
   d. Turning ON/OFF vehicle
   e. Vehicle familiarization and system operation modes

3. **Vehicle Compartments and Access Panels**
   a. Front, passenger cabin and trunk
   b. Undercarriage design, defection panels and streamlining

Lab 2 Exercises

Complete the following exercises according to the directions given by your instructor.

1. **Vehicle Operation**
   a. Noise and feel
   b. Forward, neutral, reverse and park operation
   c. Acceleration and regenerative braking

2. **Onboard Diagnostics**
   a. Software identification
   b. Toyota TIS System intro and demonstration – Connection and access
   c. Positive communication and pairing

3. **TIS Operation**
   a. TIS main menu and contents
   b. System selection
   c. Real-time data monitoring

Lab 3 Exercises

1. **Advance Testing – Diagnosis**
   a. Using TIS efficiently along with Smartborad technology
   b. System wiring read and schematic understanding
   c. Diagnostic trouble code and faults – DTCs
   d. TIS navigation and module selection
   e. System testing and output logic comprehension – demonstration
   f. Using wiring diagrams together with TIS for correct diagnosis

STUDENT SLIDES

Introduction to Fuel Cell Vehicles
January, 2018

LOS ANGELES TRADE-TECH
LATTC
A Community College

Student Slides

Introduction to Fuel Cell Vehicles

SPRING 2018

1

Recommended Course Materials

- Notebook, pen/pencil, highlighter to take notes
- An electronic device to follow lecture, share course material, access resources and retrieve specifications
  - (Smartphone is essential but a Laptop or a tablet desired)
- 2GB USB memory stick is highly recommended to save course handouts

2

Lab Requirements

Personal Protective Equipment (PPE), Attire, & Equipment

- OSHA-approved **safety glasses** MUST be worn in the lab/shop area
- **Short-sleeve shirt** and regular shop **workpants** along with **oil slip-resistant work shoes**
- **Flashlight**: Compact, working flashlight (recommended)
  - (Phone / tablet / key-chain lights are cumbersome & inefficient)
- No jewelry is allowed to be worn while in lab
  - Gold is the best conductor of electricity and loose chains are potential connections to high voltage (shock hazards)

3

Lab Requirements

Health Conditions

- **Pace Maker** or **any similar implants**: MUST be reported to the instructor and noted at the beginning of the class
  - We will be in close proximity to strong direct and alternating currents, magnetic fields, and high voltages which can directly alter their operation
- **WARNING**: *Any* health concerns or conditions that could be affected by exposure to strong electrical / electronic or magnetic fields, or high voltages, **MUST** be reported to instructor at the beginning of class

4

Lab Requirements

Body Art

- **Tattoo ink (Body Art):** Conducts electricity more easily than plain skin. If you have tattoos, especially on your hands and arms, please notify the instructor at the start of the class
  - Ink typically made with Iron Oxides (FeO_2) – the same as car paint!

Source: Muffet

5

HISTORY OF HYDROGEN GAS AS A FUEL

ORIGIN AND APPLICATION

U.S. DEPARTMENT OF ENERGY: HOW MUCH DO YOU KNOW ABOUT HYDROGEN?

URL: HTTPS://ENERGY.GOV/MAPS/QUIZ-HOW-MUCH-DO-YOU-KNOW-ABOUT-HYDROGEN-AND-FUEL-CELLS

6

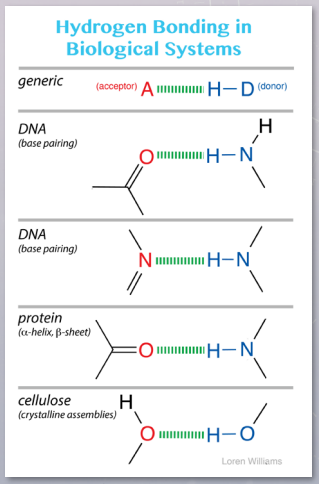
DISCOVERY & USE

NATURE, HUMAN CURIOSITY AND INGENUITY

7

Biological Role

- Hydrogen is an essential element for life
- Present in most living things
- Exists mainly in molecules bonded to Carbon and Oxygen atoms

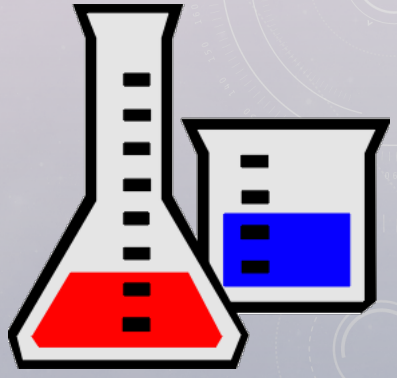


Source: Georgia Tech

8

Artificial Production

- Hydrogen gas first artificially produced in the early 16th century by the reaction of acids on metals
- In 1766–81, Henry Cavendish first to recognize hydrogen gas was a discrete substance and that it produced water when burned
  - Property for which it was later named in Greek, *"hudro-genè";* means "water-former"



9

Hydrogen Gas as an Energy Source

- Studied since 1838 by Swiss Scientist Friedrich Schoenbein, who named the device a **fuel cell**
- Welsh scientist Sir William Robert Grove is credited for inventing fuel cells in 1839
- In 1889, Ludwig Mond and Charles Langer attempted to build the first fuel cell device using air and industrial coal gas

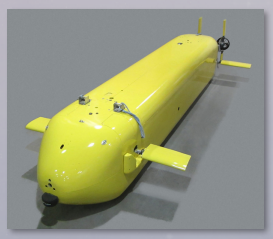
Friedrich Schönbein

Sir William Robert Grove

10

Hydrogen Gas as an Energy Source

- Not used commercially until the 1960s
- Used for flight as with the Hindenburg
- NASA's Gemini Project (1965) & later as rocket propulsion
- Toyota's Sports 800 GT HYBD Car (1977)
- Currently being adapted into powering submarines



Source: Alex Brogan

11

WHY CONSIDER HYDROGEN AS A FUEL?

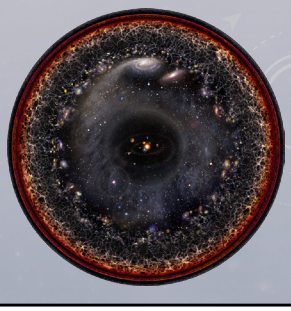
VITALITY AND FEASIBILITY

12

Why Hydrogen?

- Most abundant element in the universe (75% of all matter)
  - Helium is second, Oxygen is third
  - Jupiter almost all H_2!
  - All of the other elements are relatively rare

Artist's Conceptions of Observable Universe
Source: Unmismoobjetivo



LATTC

13

Why Hydrogen?

- On earth, hydrogen is found mostly as water compound (H_2O)
- Can energize water to get Hydrogen and Oxygen (Electrolysis)
- 20% of our atmosphere is Oxygen (Sea-level)
- Closed Power Cycle - Regeneration
  - More responsible method to get energy than current (Fossil fuels)

Earth
(surface mostly covered in water)
Source: NASA Crew of Apollo 17

LATTC

14

LOS ANGELES TRADE-TECH LATTC A Community College

Why Hydrogen?

- Some speculate that water will replace fossil fuels in the future as the primary resource for power
- Hydrogen will be distributed via national networks of hydrogen transport pipelines and fueling stations
- Hydrogen energy and fuel cell power plants will be clean, abundant, reliable and affordable

Hydrogen Fuel Station
Source:

15

Why Hydrogen?

Energy Density:

How does Hydrogen compare to other current fuel sources?:

Fuel	Density
Gasoline	18,095 BTU/Lb.
Diesel	19,857 BTU/Lb.
Hydrogen	61,084 BTU/Lb.

Hydrogen surpasses even diesel fuel by three-fold in energy content

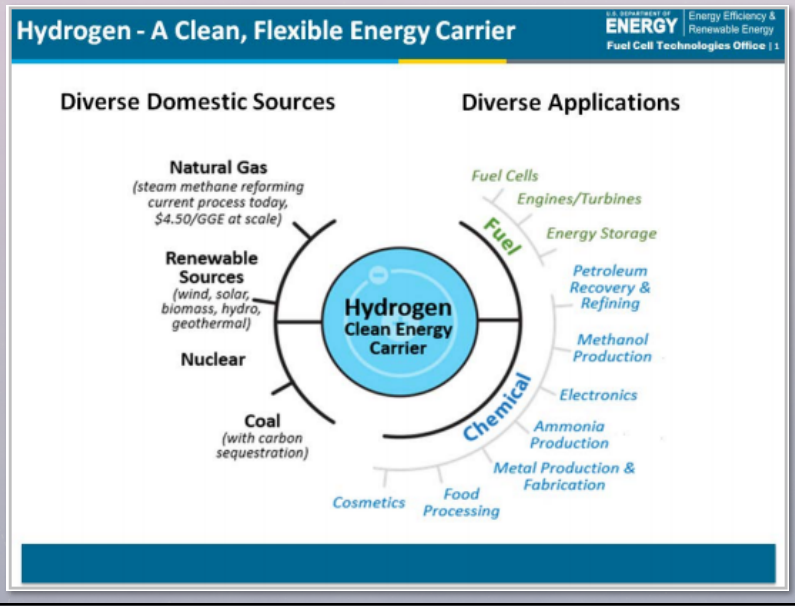
16

HYDROGEN DEMAND AND INFRASTRUCTURE

ENERGY SECTOR OUTLOOK

17

Clean, Flexible, Carrier Chart



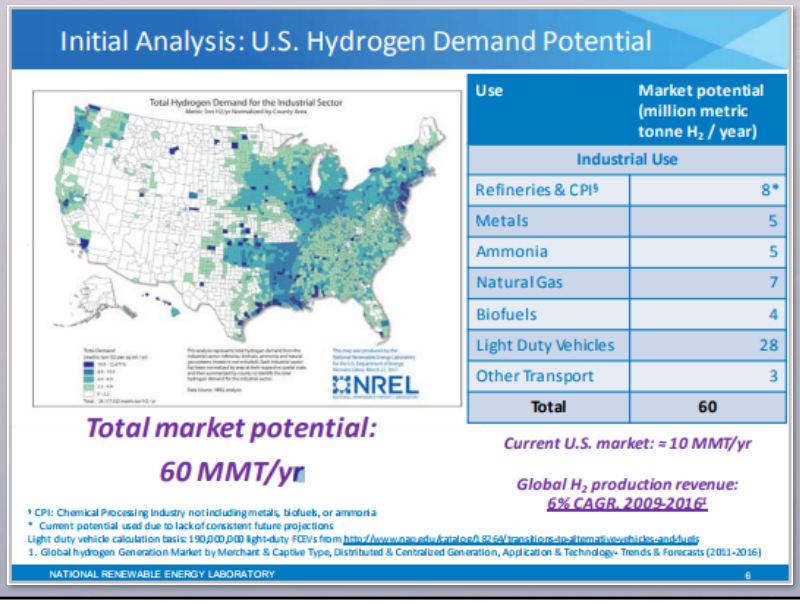
H2@Scale

- hydrogen enables diverse feedstocks and applications

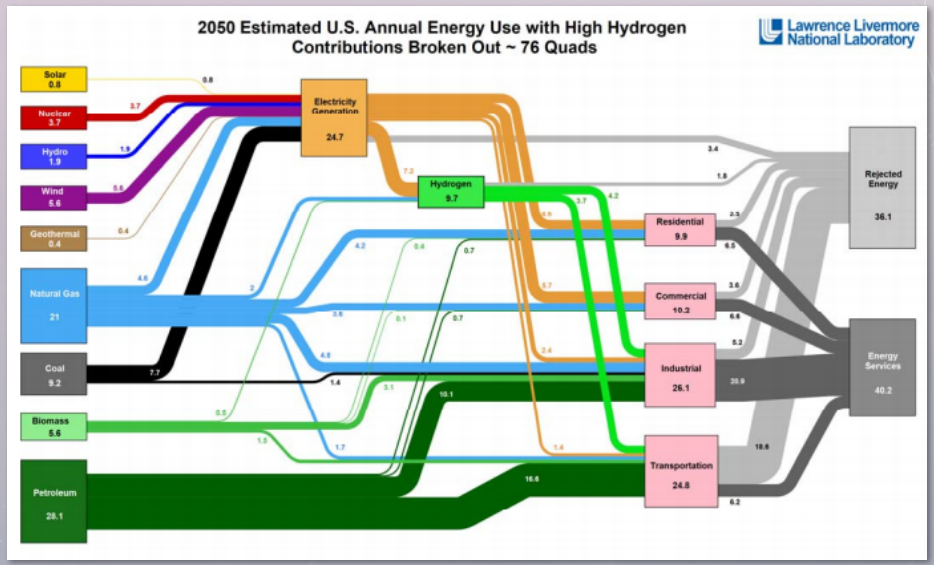
Source: U.S. Department of Energy

18

U.S. Hydrogen Demand Potential



2050 Estimated U.S. Energy Use with Hydrogen

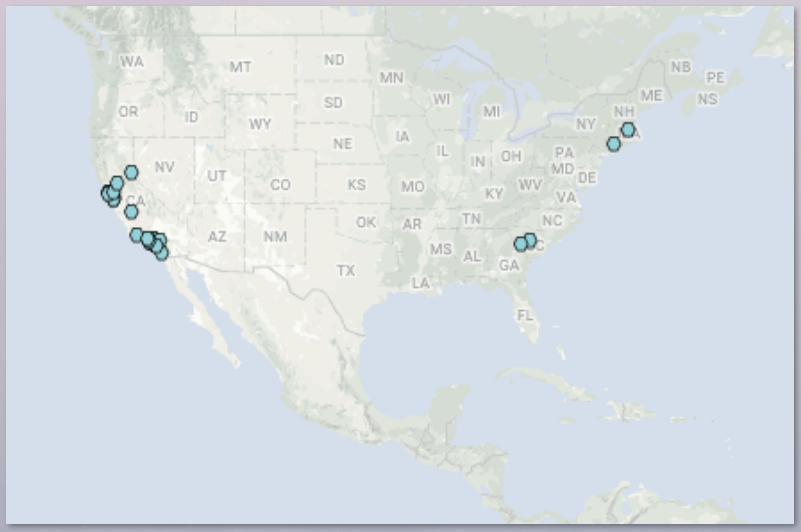


H2@Scale

- hydrogen enables diverse feedstocks and applications

Source: U.S. Department of Energy

Hydrogen Fueling Stations in the United States



21

PRODUCTION

ATTAINMENT AND ALLOCATION

22

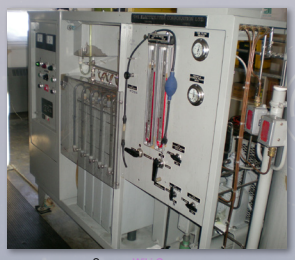
Hydrogen Production

- Hydrogen gas does not exist naturally on Earth
  - Must be separated from other elements
- Industrial production mainly from **steam reforming natural gas**
- Less often from electrolysis of water

Gasification

Source: Wiki Commons (Public Domain)

Electrolyser



Source: Wiki Commons

23

Hydrogen Production

- Hydrogen is a standard industrial chemical commodity today
- 10 million metric tons produced per year in the U.S.
  - Most used near the site of its production
- Largest uses:
  - Fossil fuel processing (e.g., hydrocracking)
  - Ammonia production, mostly for fertilizer market

Fluid Catalytic Cracker

Source: Valero Energy Corporation/TX

24

HYDROGEN GAS SAFETY AND SERVICE PROCEDURES

FIRST RESPONDER PROCEDURES, PROPERTIES, SAFE WORK PRACTICES & HAZARDS

25

FIRST RESPONDER PROCEDURES

DISABLING THE VEHICLE

26

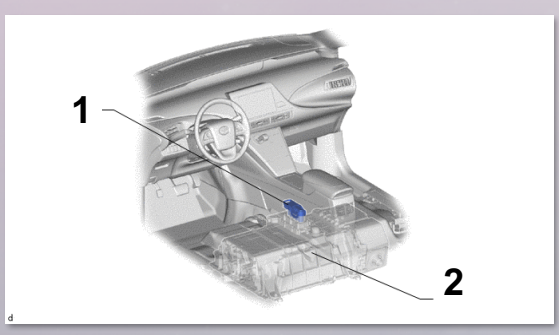
Toyota Emergency Response Guide

- Open Document – 2017

27

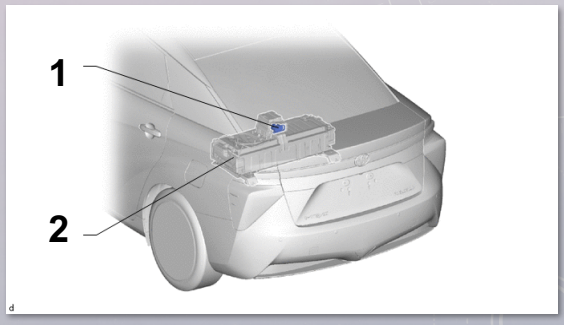
High Voltage Disconnect and/or Service Plugs

FC Stack **SAFETY** Disconnect



1. FC Service Plug Grip
2. FC Stack Assembly

HV Battery **SAFETY** Disconnect



1. Service Plug Grip
2. EV Battery Assembly

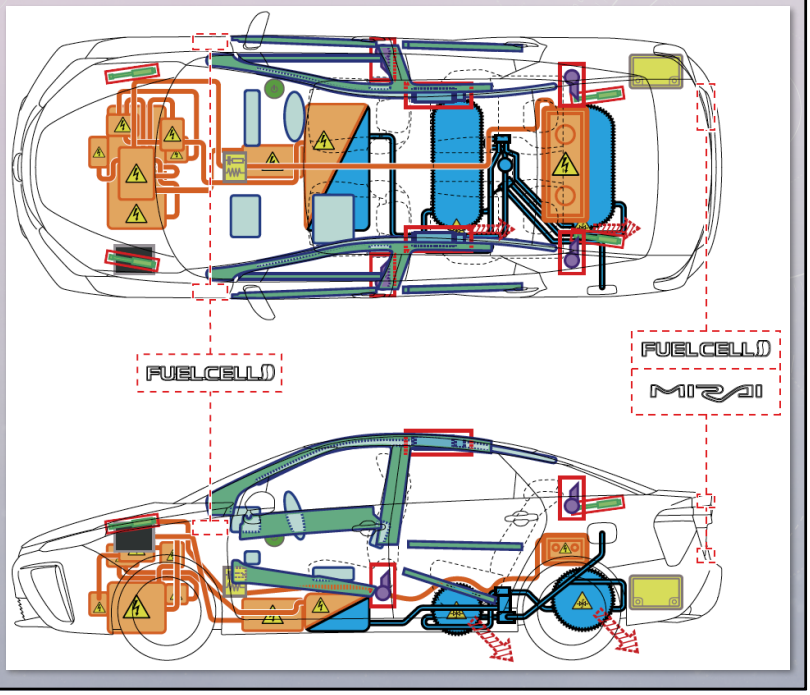
28

Components

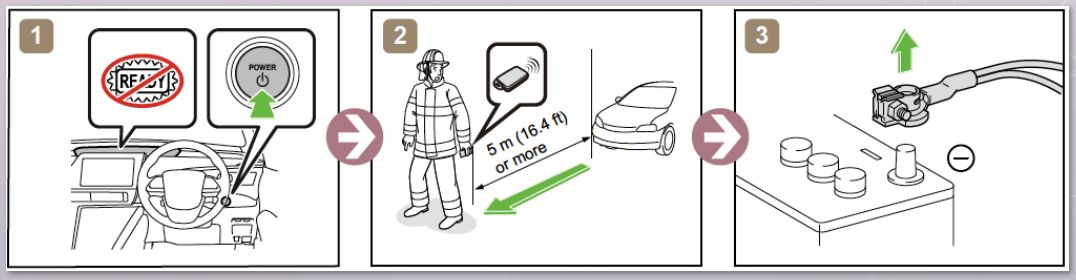
	POWER SW		Structural Reinforcements
	Airbag (incl. Inflator)		Fuse Box
	High Voltage Components		Inflator
	Pressure relief device (PRD) (Hydrogen release direction)		Hydrogen Tank
			Gas-filled Damper

	Airbag Computer
	12V Battery
	High Voltage Battery
	Hydrogen Components
	Seat Belt Pretensioner (Gas Generator)

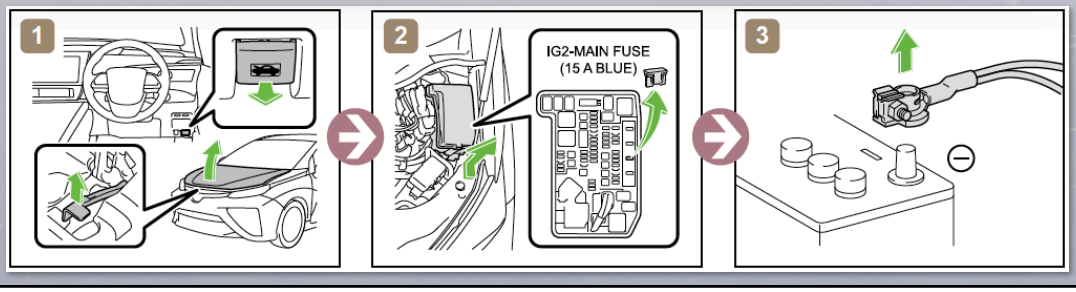
Open Document



Disable the Vehicle

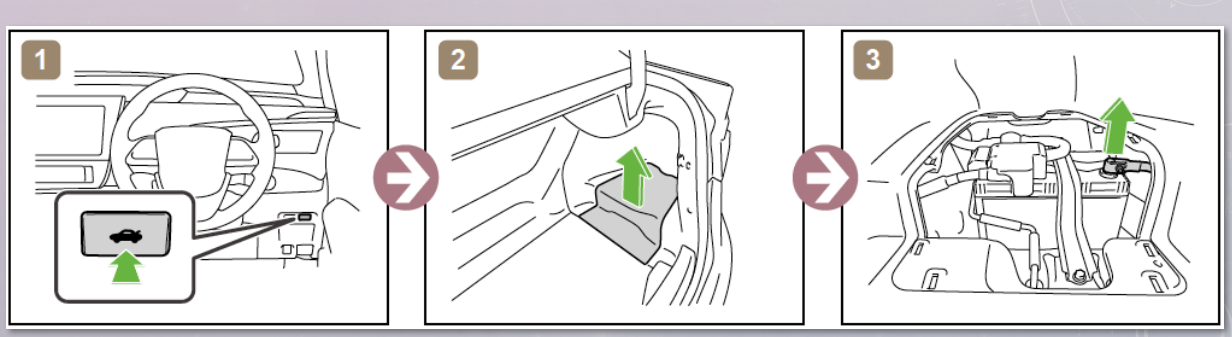


or



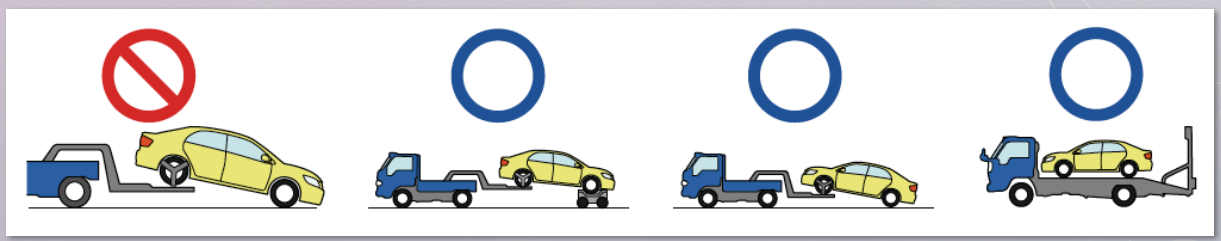
30

Access to 12V Battery



31

Towing Information



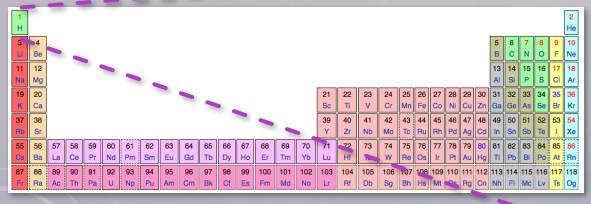
32

PROPERTIES OF HYDROGEN

WHAT WE NEED TO KNOW

Gaseous Hydrogen Properties & Behaviors

- **Lightest** molecule in the universe
  - 14 times lighter than air
  - Rises at almost 20 meters per second (44 mph) and disperses rapidly
  - This buoyancy is a safety advantage in outside environment



1

H

1.00794 u ± 0.00001 u

No balloon soars as well as a hydrogen balloon

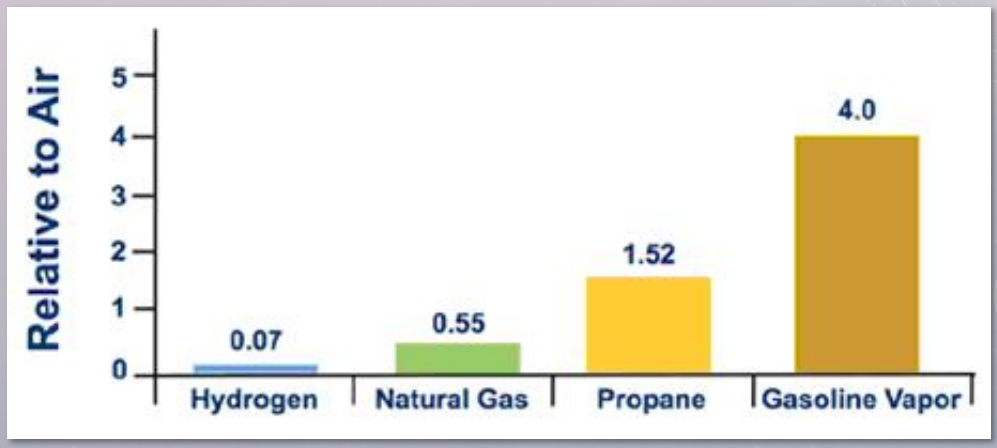
Gaseous Hydrogen Properties & Behaviors

- **Undetectable by human senses:** Colorless, odorless, & tasteless
- **Non-toxic & non-poisonous** but can be an *asphyxiant*
- **Flammable & explosive**: Store safely and used in an area that is free of heat, flames, and sparks
- **Non-corrosive**, but it *can embrittle some metals*
  - i.e. cause significant deterioration of the metal's mechanical properties

35

Gaseous Hydrogen Properties & Behaviors

Relative Vapor Density:



36

SAFE WORK PRACTICES

WORKING WITH HYDROGEN

37

Good Safety Practices for Working with Hydrogen

- **Protective Equipment:** Always wear appropriate personal protective equipment (PPE) for the specific hazards of your job:
  - **Gaseous:** No specific PPE requirements, other than safety glasses or goggles when working with a compressed gas
  - **Liquid:** Insulated gloves & protective shoes in addition to eye protection
- Basic hydrogen safety training & familiarization with properties
- **New hydrogen users** should have clear guidance and instructions from supervisor or mentor
- Access to OSHA P-4604 Safety Data Sheet (US 29CFR)

38

Good Safety Practices for Working with Hydrogen

- Use a **graded approach** to safety planning and **risk assessment** based on the quantities of hydrogen involved
- **First time** you work with hydrogen, **ask someone** with hydrogen experience **to assist you**
- Never take chances or shortcuts. Mirai's hydrogen tanks are rated up to 70MPa (10,150 psi)!
- Always **plan for the worst-case scenario**, but **give some thought to the most probable scenario** and be ready for that as well

39

HYDROGEN LEAKS

40

Hydrogen Leaks

- Because hydrogen is a small molecule, leaks are common
- Gaseous hydrogen leaks are **impossible to detect** by senses
- Can be an asphyxiant if it accumulates in a confined space
- **Liquid hydrogen leaks** characterized by **frost or ice crystals near the leak** and usually **a vapor cloud indicating moisture condensation** from the surrounding air
- In the event of a **cryogenic fuel spill**, **immediately evacuate the area** and notify the authorities

41

Hydrogen Leaks

Leak Detection:

- Listen for high-pressure gas leaking (loud hissing sound)
- Use portable hydrogen detectors
- Gas detectors may be installed in storage facilities and fueling stations. Listen and watch for audible or visual alarms
- Handle, turn off, and neutralize any equipment which may be a ignition source for the hydrogen leak

42

HYDROGEN FLAMES

ALMOST INVISIBLE

Flammability is the Main Concern

- NFPA 704's highest rating of 4 on flammability scale

Hydrogen Flames

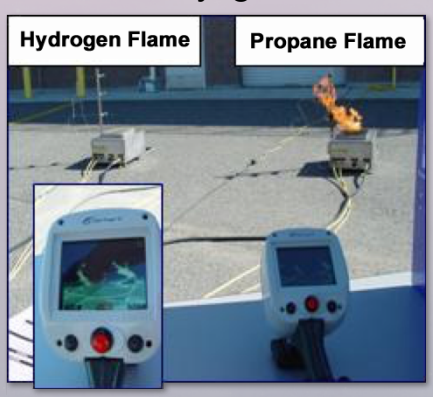
Potential Ignition Sources:

- **Electrical**
  - Static electricity (Electrostatic Discharge)
  - Electric charge from equipment operation
- **Mechanical**
  - Impact
  - Friction (Rubbing surfaces)
  - Metal fracture (Spark)
- **Thermal**
  - Open flame
  - High-velocity jet heating
  - Hot surfaces (e.g., an exhaust manifold)
  - Vehicle exhaust
- **Chemical**
  - Catalysts
  - Reactants

45

Hydrogen Flames

Daylight



Night

46

Hydrogen Flames

- Hydrogen flammable at concentrations of 4% to 75% in air (wide range compared to other common fuels)
  - Easily reach the lower limit (4%) if a leak in a confined space with no ventilation (outdoor leak would simply rise quickly and diffuse)
- Almost impossible to see in daylight with naked eye
  - (Burns with a pale blue flame almost invisible during daylight hours)
- Low radiant heat
  - Can't sense the flame until you are close to it (or even in it)
- Oxygen (or air) and ignition source are required for combustion
  - (Combustion can't occur in a tank containing only hydrogen)

47

Hydrogen Flames

Hydrogen Flame Detection

A pure hydrogen flame will not produce smoke, has low radiant heat, nearly invisible in daylight, but may appear yell of impurities in the are (e.g. dust or sodium). Because of these properties:

- Use a **portable flame detector**, such as a thermal imaging camera, when possible
  - If flame detection equipment is not available, listen for venting hydrogen and watch for thermal waves (See bellow)
  - Vent stacks standard in storage facilities, and the ignition of venting gaseous hydrogen is common. Systems are designed to do this safely
  - Fame detectors may be installed in storage facilities and fueling stations. Listen and watch for audible or visual alarms

48

Hydrogen Flames

Thermal Imaging Camera in Use:

49

HYDROGEN EXPLOSIONS

50

Explosions

Overpressures:

- Hydrogen in sufficient concentrations and quantities can create a harmful overpressure which may result in direct hazards from the overpressure and indirect hazards from building damage or flying debris
- Can occur as a result of unignited releases of pressurized gas or as a result of ignition of a cloud of released flammable gas

51

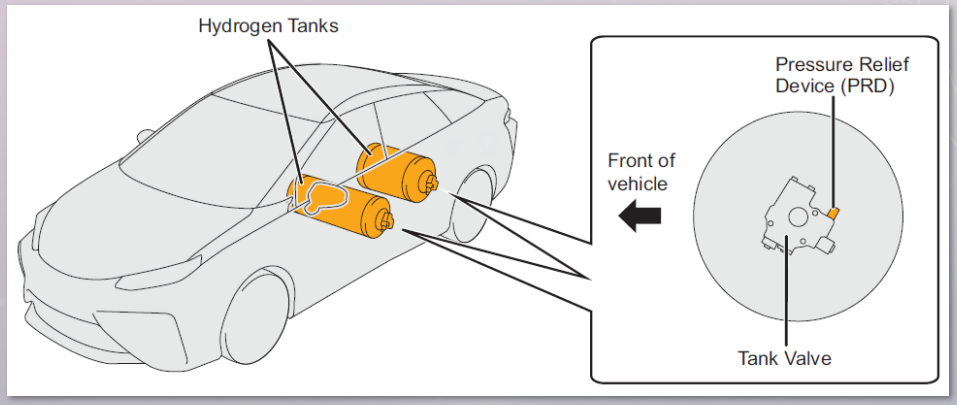
Explosions

Overpressure from Unignited Releases:

- If liquid H_2 warms up and vaporizes into gas, it occupies more space
  - Liquid hydrogen expands 850 times from liquid to gas
  - A confining vessel, pipeline or sealed space could easily become over pressurized
  - Gas will expand creating an unsafe condition when pressure exceeds the container design & a mechanical failure occurs
- Pressure-relief devices (PRDs) such as rupture disks or relief valves should be installed to prevent overpressure
  - PRD should be vented to a safe location

52

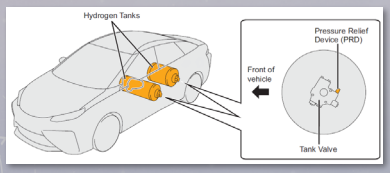
Compressed Hydrogen Gas Automatic Safety Release



- Each tank has a pressure relief device (PRD)
- PRD prevents a hydrogen tank explosion in the event of a vehicle fire
- PRD opens at approx. 110ºC (230ºF) to release the hydrogen gas from the tank to the outside

53

Compressed Hydrogen Gas Tank Expiration



- After tanks experience a **thermal event** (fire) which set-off the PRDs to release, tanks **MUST be condemned and destroyed**
- Hydrogen tanks also have an expiration date
  - Listed inside the fuel fill cover on the Mirai

54

Explosions

Overpressure from Ignited Releases:

- Hydrogen can burn or combust
  - If a cloud of gas is ignited, rapid combustion can create an overpressure. This is the common perception of an "explosion"
- Limit the amount of ignition sources (e.g. lit cigarettes or unclassified electrical equipment) from areas where a release of hydrogen could form a cloud with sufficient concentration to create an ignited overpressure
  - These areas are called "exclusion zones" or "separation distances"

55

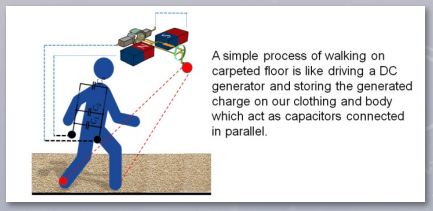
ELECTROSTATIC DISCHARGE

THE HIDDEN ENERGY

56

Dangers of Electrostatic Discharge (ESD)

- Can set off **explosions** (battery gasses) or **fires** in flammable environments
- Occurs when a non-conducting surface is rubbed against another and the surfaces are then parted
  - "ZAP" or shock received when touching a conductive object after walking or picking up an electronic



57

Dangers of Electrostatic Discharge (ESD)

Basic work habits for electronic components:

- Disconnect the accessory battery at the negative terminal and wait for capacitors to discharge (5-10 minutes)
- Keep new components in their protective packaging until you are directly in position to service/install
- Ground yourself before removing the component
- ***NEVER*** touch the terminals of the component

58

Dangers of Electrostatic Discharge (ESD)

Discharging ESD Safely:

- A ground strap while handling the parts
- Equalize your body to the vehicle. Simply touch an unpainted metal surface while sitting in the vehicle
- Grounding lowers the charge in your body by providing a harmless path for the static electricity to escape
- If you get out of the vehicle you will need to repeat this process. If you are working with several components you may have to repeat this when switching the various parts

59

FUEL SYSTEM

LAYOUT, FUEL CELL STACK, DIAGRAMS, & FUEL STORAGE

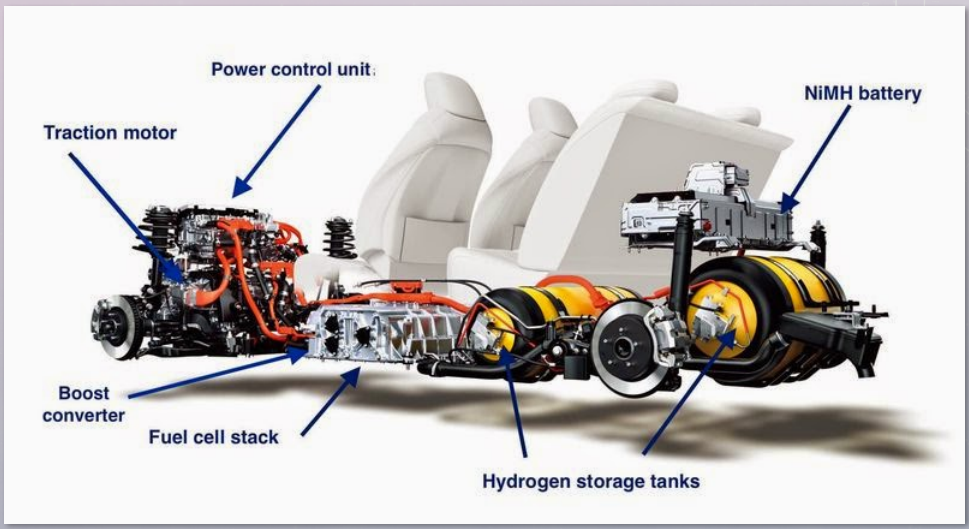
60

FUEL SYSTEM LAYOUT

SYSTEM OVERVIEW – MIRAI VEHICLE

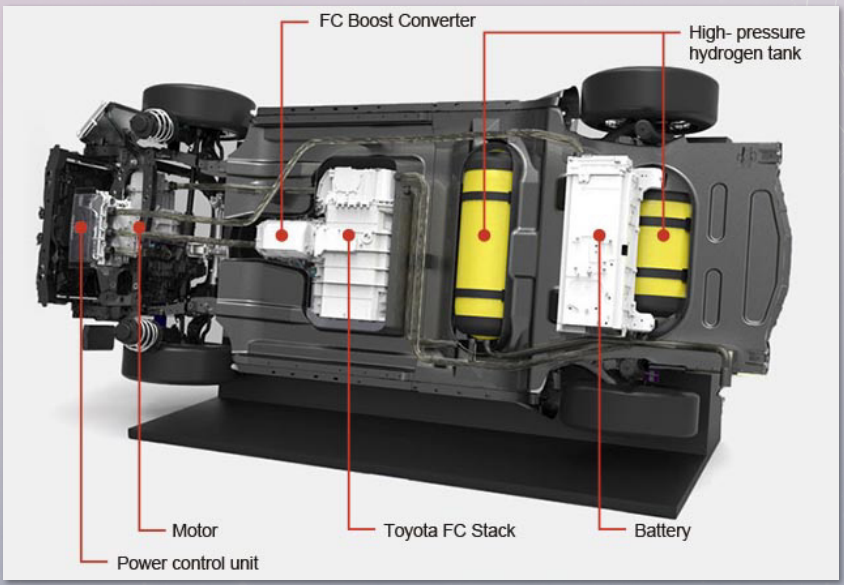
61

Side View



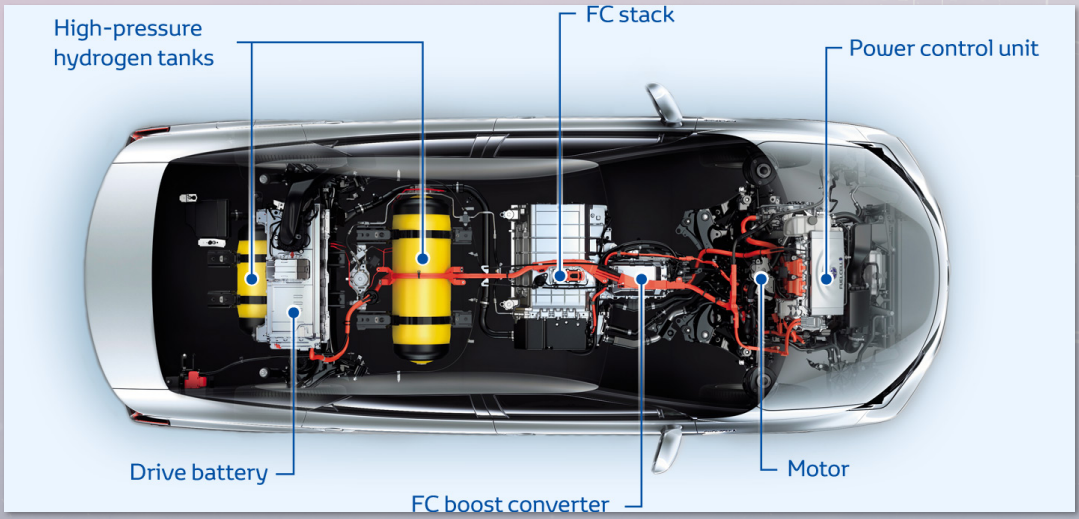
62

Passenger Cabin Floor View



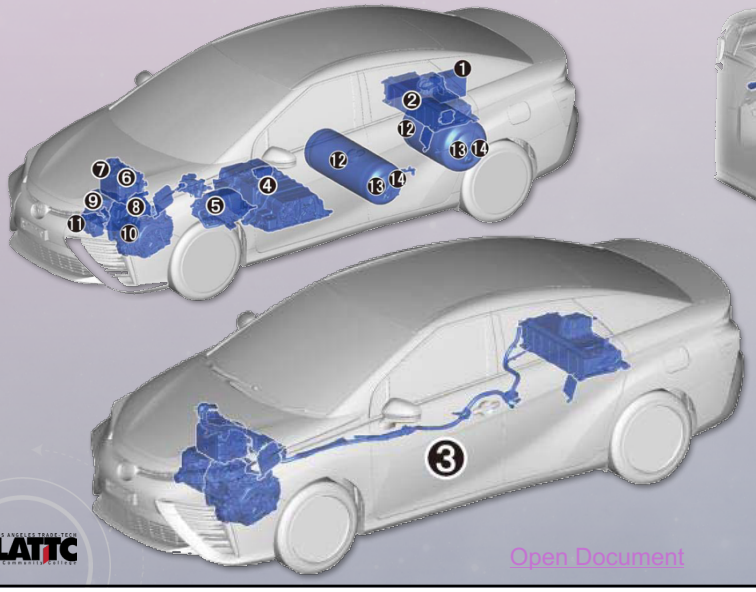
63

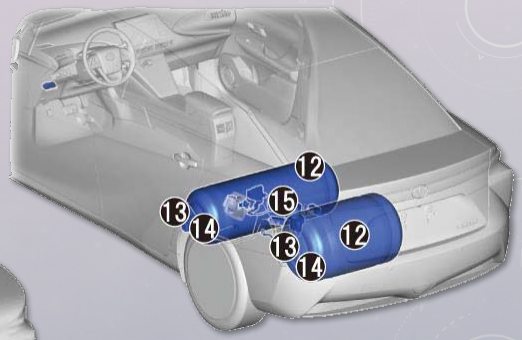
Top View



64

Component Location & Identification



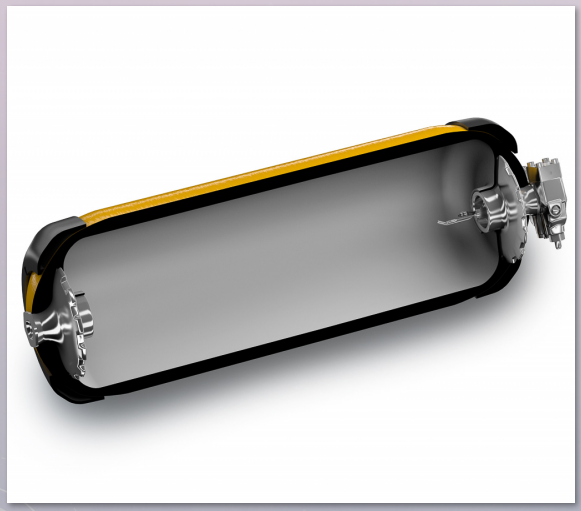


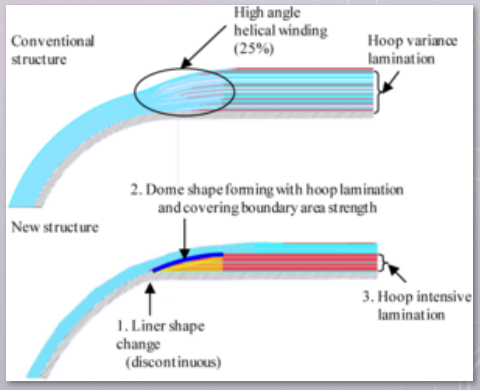
Mirai FC Vehicle Specifications	
Electric Motors:	123 kW
EV Battery:	244.8 Volt Sealed NiMH Battery
Curb Weight:	1,850 kg / 4078 lb
Fame Material	Steel Unibody
Body Material:	Steel Panels except Aluminum Hood
Seating Capacity:	4 passenger

Open Document

65

Mirai Hydrogen Gas Tank - New design

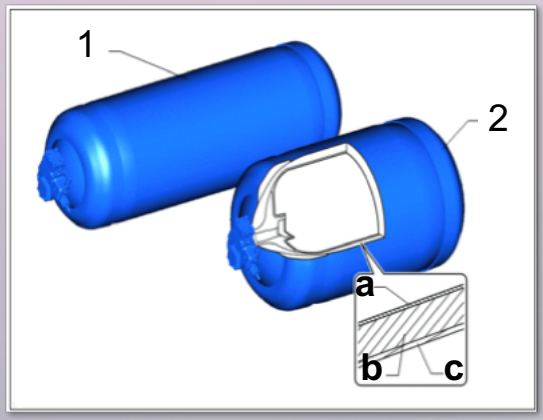




Comparison of conventional and new lamination methods. Toyota made three critical changes to the lamination method, resulting in a thinner tank wall and reduced weight.

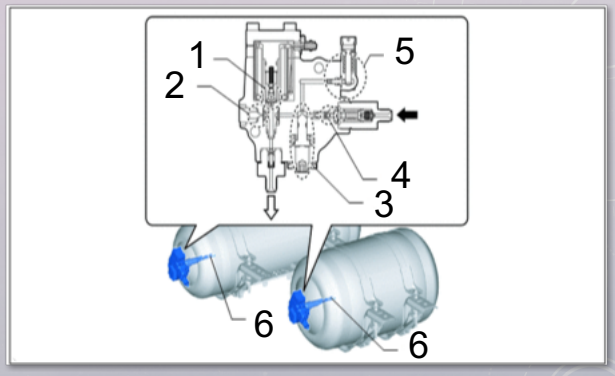
66

Hydrogen Tank Assemblies (Cylinders)



1. No.1 Hydrogen Tank Assembly
2. 2 No. 2 Hydrogen Tank Assembly

a. Plastic Liner
b. Carbon Fiber Reinforced Plastic Layer
c. Glass Fiber Reinforced Plastic Layer

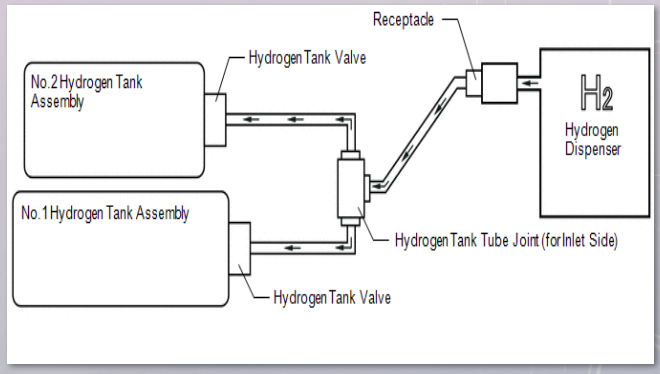


1. Tank Shut Valve
2. Defueling Valve
3. Pressure Relief Device
4. Check Valve
5. Pressure Relief Device
6. Hydrogen Tank Temperature Sensor

➡ From Receptacle ⇨ To Regulator

67

Hydrogen Filling/Fueling Control

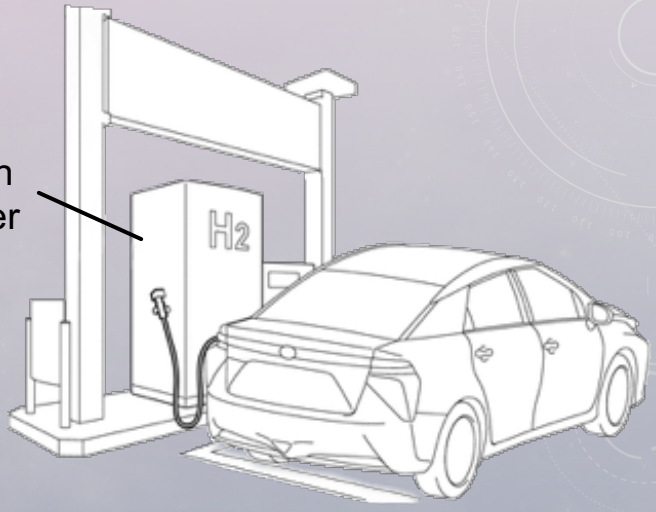


- The hydrogen fuel passes from the receptacle through the hydrogen tank tube assembly, branches at the hydrogen tank tube joint (for Inlet side), presses open the check valves of the hydrogen tank valves on the No. 1 and No. 2 hydrogen tanks, and fills the tanks

68

Hydrogen Dispenser

Hydrogen Dispenser



- When filling hydrogen fuel from a hydrogen dispenser supporting infrared communication, hydrogen fuel filling is performed according to vehicle conditions

69

Fuel Fill Receptacle

Fuel Fill Receptacle Cover in Place

Fuel Fill Receptacle Cover Removed

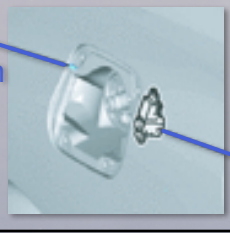
70

Fuel Lid Open/Closed Position Control

Infrared Communication Sensor:

- When fuel lid is open, the system cannot be set to READY ON
  - Prevents vehicle from moving suddenly during hydrogen fuel filling
- When the system is in READY ON, the fuel lid will not open even if the fuel lid opening is pressed

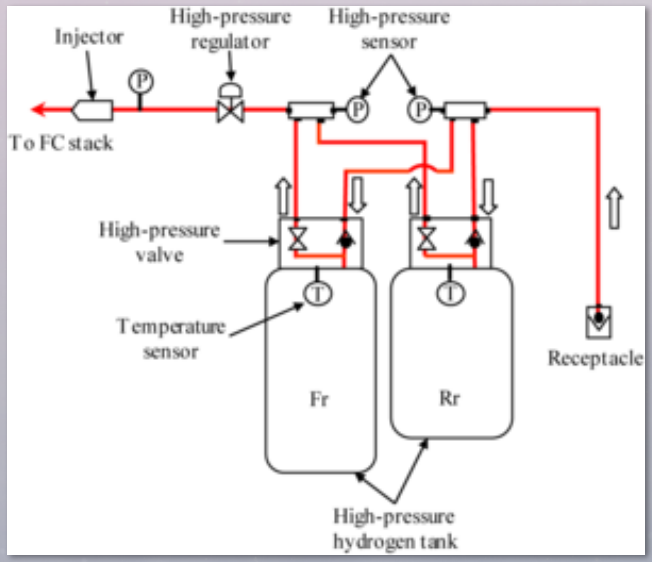
OPEN / CLOSED Lid Switches:



HINT: If the lid is not fully closed, the system will not enter READY ON.

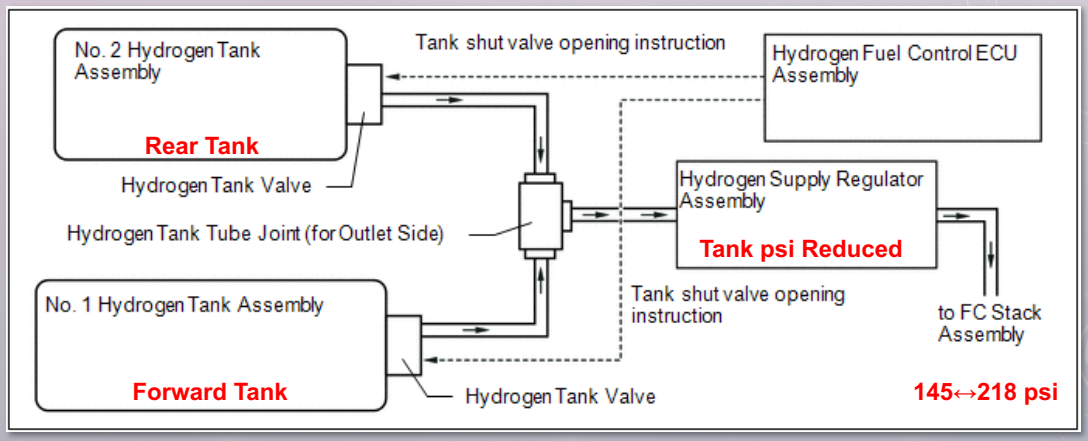
71

Hydrogen Gas System Diagram



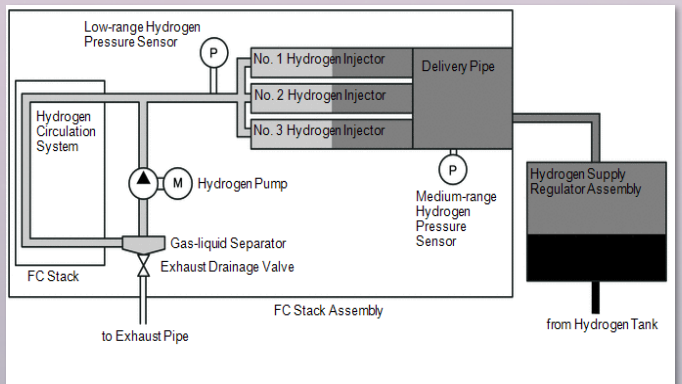
72

Hydrogen Gas Supply Flow

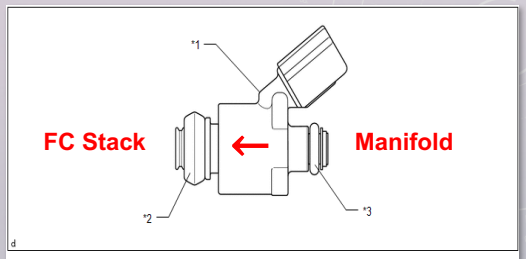


73

Fuel Cell Stack Hydrogen Gas Flow



	40 kPa to 300 kPa (0.4 kgf/cm2 to 3.1 kgf/cm2, 5.8 psi to 43.5 psi)		1.0 MPa to 1.5 MPa (10.2 kg/cm2 to 15.3 kg/cm2, 145 psi to 218 psi)
	70 MPa (713.8 kgf/cm2, 10150 psi)	-	-



*1	Hydrogen Injector	*2	Insulator
*3	O-ring	-	-

H_2 Injector Specifications	
No. 1 Injector:	Starting, Stopped, Idling to Low Load, High Load
No. 2 Injector:	Starting, Stopped, Idling to Low Load, High Load
No. 3 Injector:	High Load

74

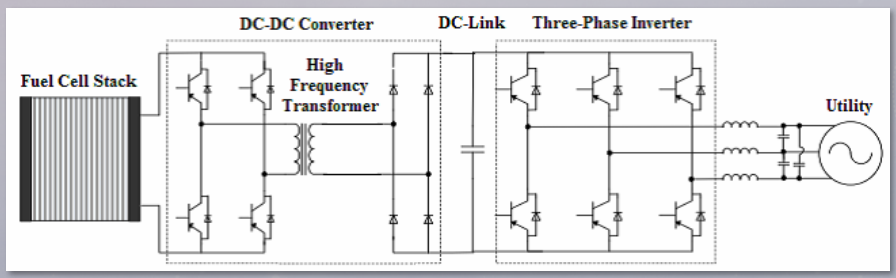
FUEL CELL STACK

OPEN DOCUMENT

Types of Fuel Cells

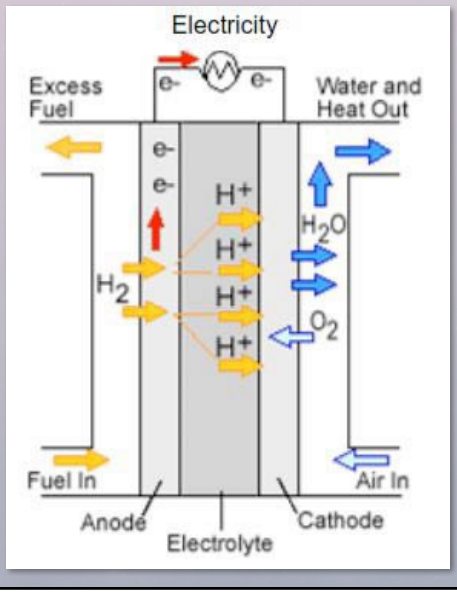
- **Proton Exchange Membrane (PEM):** Hydrogen Gas, oxygen and platinum
- **Direct methanol:** Use pure Methanol as fuel
- **Alkaline:** Similar to PEMs, use alkaline membrane instead of acid membrane
- **Phosphoric Acid:** Use liquid phosphoric acid as an electrolyte
- **Molten Carbonate:** Operate at high temperatures of 650°C (≅1,200°F)
- **Solid Oxide:** Non-porous ceramic compound as the electrolyte
- **Reversible:** Produce electricity from hydrogen and oxygen and generate heat and water as byproducts

Fuel Cell Stack Assembly & Circuitry Sample



77

Fuel Cell System Diagram of a PEM



78

How a Fuel Cell Works

Think of a **fuel cell** as a different kind of **battery fed with reactants** and that **produces electricity**.

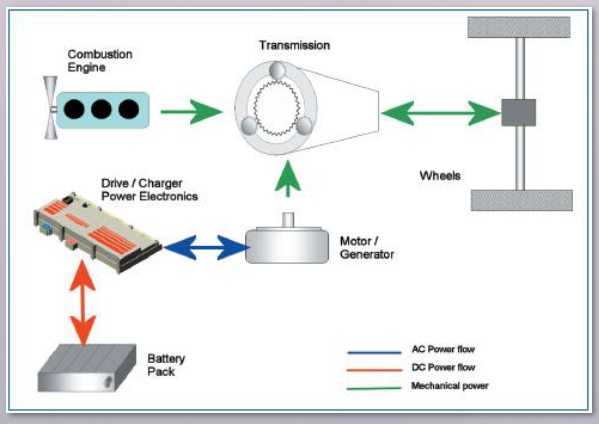
Internal combustion engines are also fed with fuel, but **with fuel cells, nothing is burned**. There are **no combustion losses**. Instead, **chemical energy** (hydrogen & oxygen) **transforms into electrical energy**.

Hydrogen gas travels from a storage tank through the fuel cell's channel (or plates) to a **membrane coated with a platinum catalyst**. It then **splits into protons and electrons**.

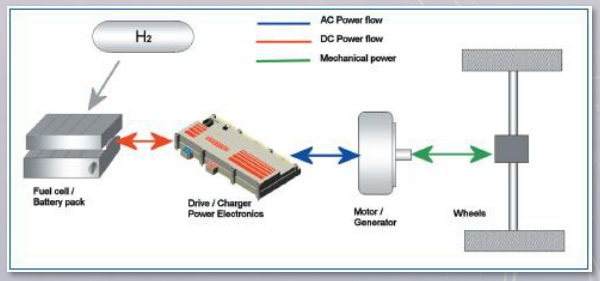
The **protons** (positive charge) **pass through**, but the **catalyst prevents the electrons** (negative charge) from advancing from the **anode** (hydrogen side) to the **cathode** (plate on the side containing oxygen).

79

Hybrid vs. Fuel Cell Setup



Hybrid

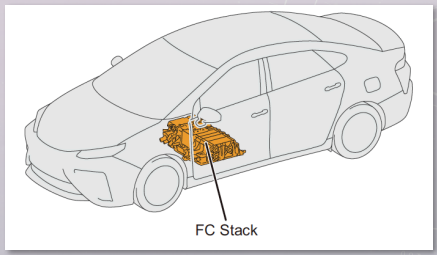


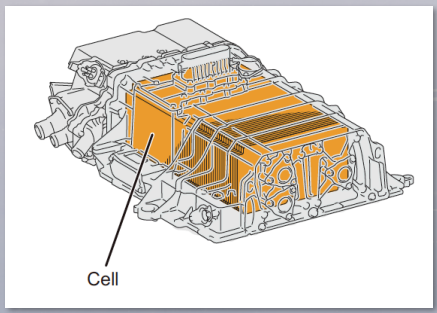
Fuel Cell

80

Fuel Cell Stack

- Heart of a fuel cell power system
- Generates direct current (DC) from electro-chemical reactions in fuel cell
- Single fuel cell produces less than 1V
  - Insufficient for most applications
- Cells combined in series into a fuel cell stack
  - May consist of hundreds of fuel cells
- Power depends on cell type, size, temperature, and pressure of gases





81

Parts of a Fuel Cell

Proton Exchange Membrane

- AKA Polymer electrolyte membrane or “PEM” fuel cells
  - Current focus of research for fuel cell vehicle applications
  - Made from several layers of different materials
- The Membrane electrode assembly or “MEA”, is the heart of the fuel cell
  - Membrane
  - Catalyst layers, and
  - Gas diffusion layers (GDLs)

82

Parts of a Fuel Cell

Proton Exchange Membrane

- Hardware used to incorporate an MEA into a fuel cell:
- Gaskets
  - Provide a seal around the MEA to prevent leakage of gases
- Bipolar plates
  - Used to assemble individual PEM fuel cells into a fuel cell stack
  - Provide channels for the gaseous fuel and air

83

Hardware

The Membrane Electrode Assembly (MEA) is where power is produced, but hardware components are required to enable effective MEA operation.

Major Hardware include:

- Power Conditioners
- Air Compressors
- Humidifiers

84

Power Conditioner

- Both AC and DC power must be conditioned.
- Current inverters and conditioners adapt the electrical current from the fuel cell to suit the needs of the application
  - E.g. Simple electrical motor v. Complex utility power grid
- Conversion and conditioning reduce system efficiency slightly (2%–6%)

85

Air Compressors

- Fuel cell performance improves as the pressure of the reactant gases increases
- Air compressor raises the pressure of the inlet air to 2–4 times the ambient atmospheric pressure
- For transportation applications, air compressors should have an efficiency of at least 75%.
- In some cases, an expander is also included to recover power from the high pressure exhaust gases. Expander efficiency should be at least 80%.

86

Humidifiers

- Polymer electrolyte membrane does not work well when dry
- Many fuel cell systems include a humidifier for the inlet air
- Usually a thin membrane
  - Sometimes the same material as the PEM
- Mode of action:
  - Flow dry inlet air on one side of the humidifier and wet exhaust air on the other side
  - Water produced may be recycled to keep the PEM hydrated

87

TOYOTA MIRAI FUEL CELL

TECHNICAL ADVANCE AND INNOVATION

88

FUEL CELL TECHNOLOGICAL INNOVATIONS

89

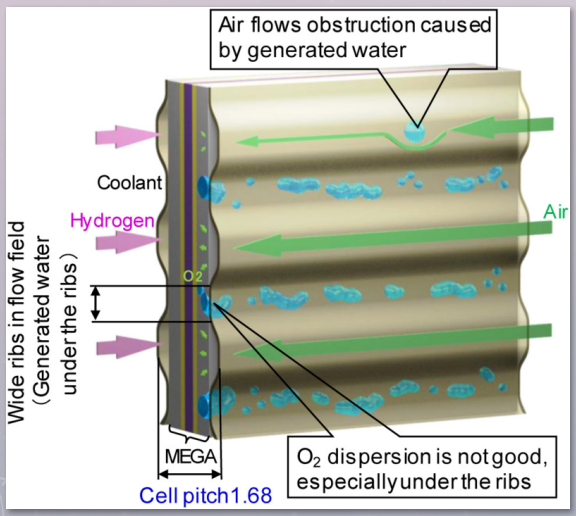
Toyota Mirai Fuel Cell Operating New Parameters

Maximum Output	114KW (PS155)
Output Density	3.1KW/L

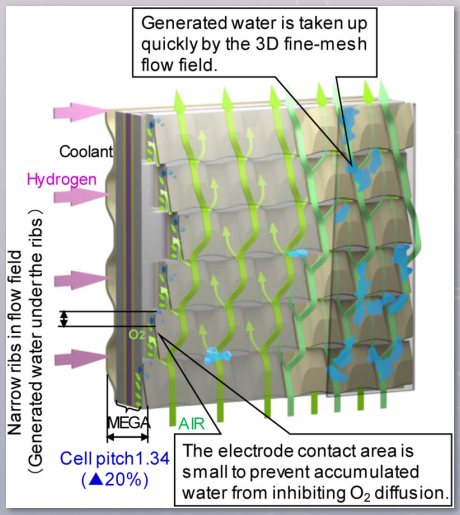
90

Conventional vs. 3D Fine Mesh (New FC)

Conventional Flow



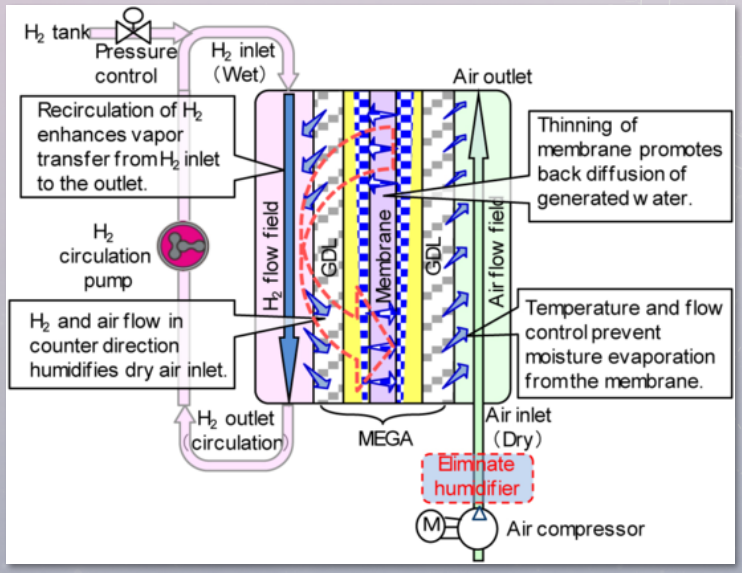
New 3D Fine Mesh Flow



91

New Toyota Fuel Cell System (TCFS) - Details

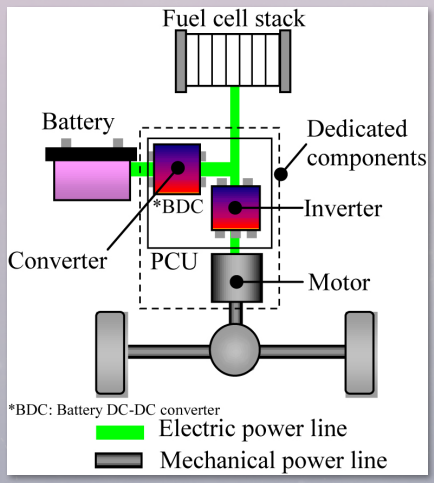
Outline of self-humidification within cell surface



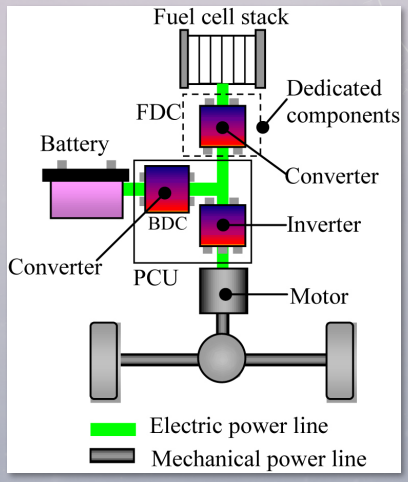
92

Adding a Boost Converter (Higher FC Output)

FCHV Hybrid System:

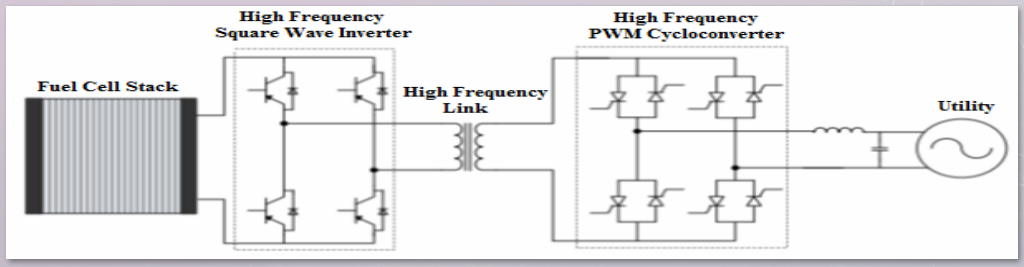


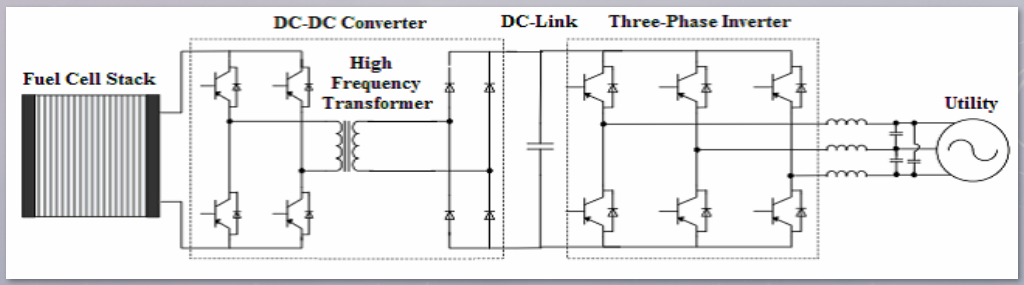
Mirai Hybrid System



93

DC-DC Converter Innovations (FC Booster)

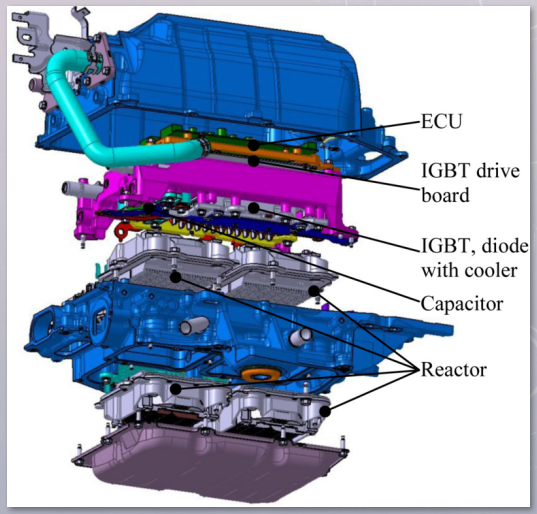




94

Adding a Boost Converter (Higher FC Output)

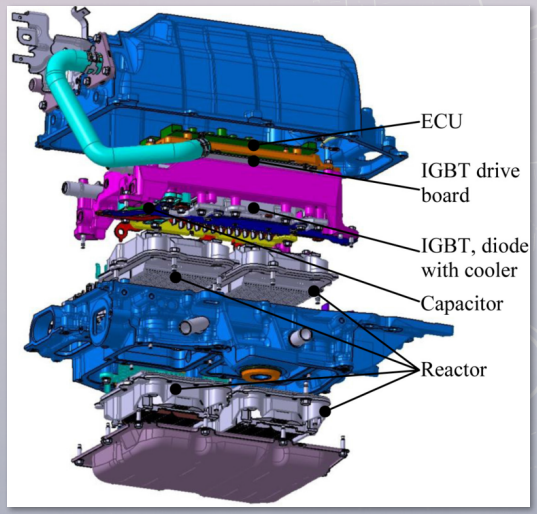
- Phase drive control using optimum number of phases in accordance with the power passing through FDC allows the FCV to be driven highly efficiently
- Improved loss by approx 10% at 15kW
- TMC reduced thermal resistance by approx 50%
  - compared with HEV reactors through the use of a new structure for reactor cooling and dedicated filler



95

Adding a Boost Converter (Higher FC Output)

- Rubber in the body mounting structure helps prevent the transmission of vibration directly to the body
  - Resulting in a reduction of 30 dB
- Nosie and vibration are also reduced by a carrier control that changes the switching frequency at random over time



96

Power-Out Port for Power outs & Emergencies

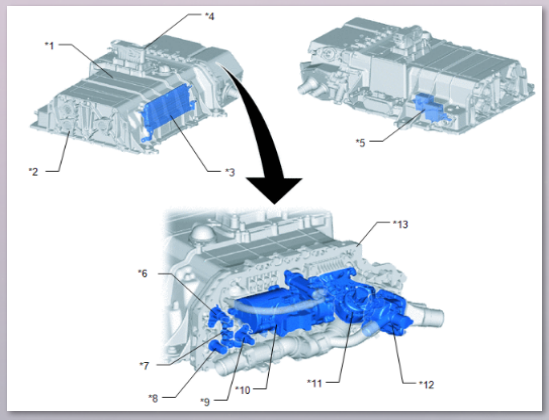
97

TOYOTA'S NEW FC STACK STRUCTURE

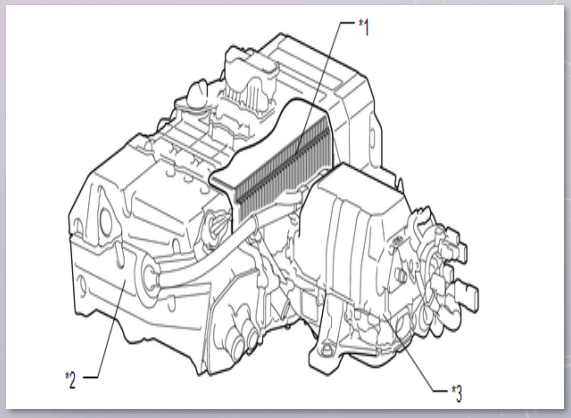
TOYOTA INFORMATION SYSTEM - TIS

98

2017 Mirai Fuel Cell Stack



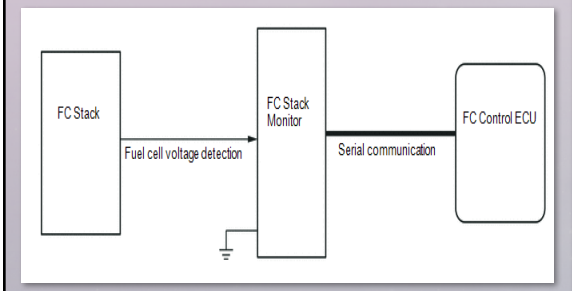
*1	FC Stack Assembly	*2	FC Stack Ventilation Cover
*3	FC Stack Monitor	*4	FC Service Plug Grip
*5	FC Main Relay	*6	Low-range Hydrogen Pressure Sensor
*7	Hydrogen Injector	*8	Pressure Relief Valve
*9	Medium-range Hydrogen Pressure Sensor	*10	Hydrogen Pump
*11	Air Pressure Regulating Valve	*12	Air Shunt Valve
*13	Stack manifold	-	-

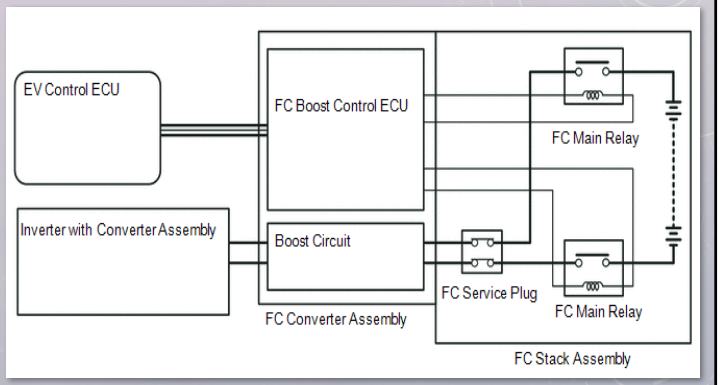


*1	FC Stack	*2	FC Stack Assembly
*3	FC Converter Assembly	-	-

99

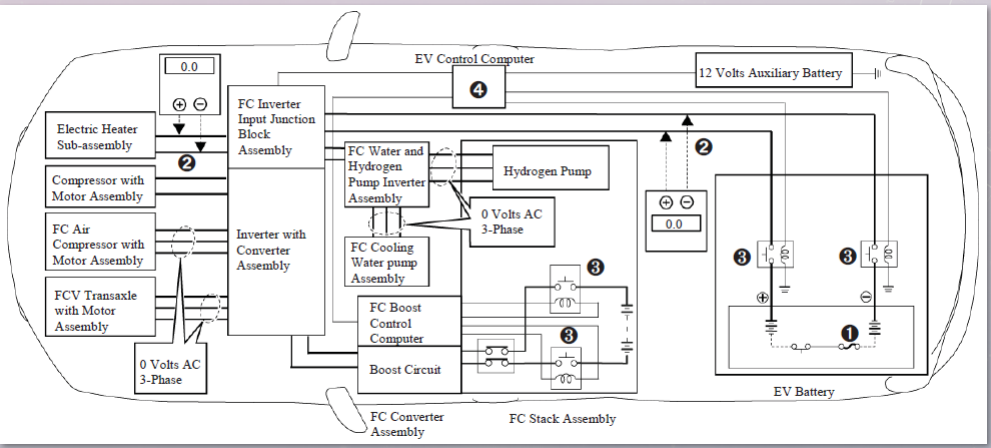
Fuel Cell Stack Control





100

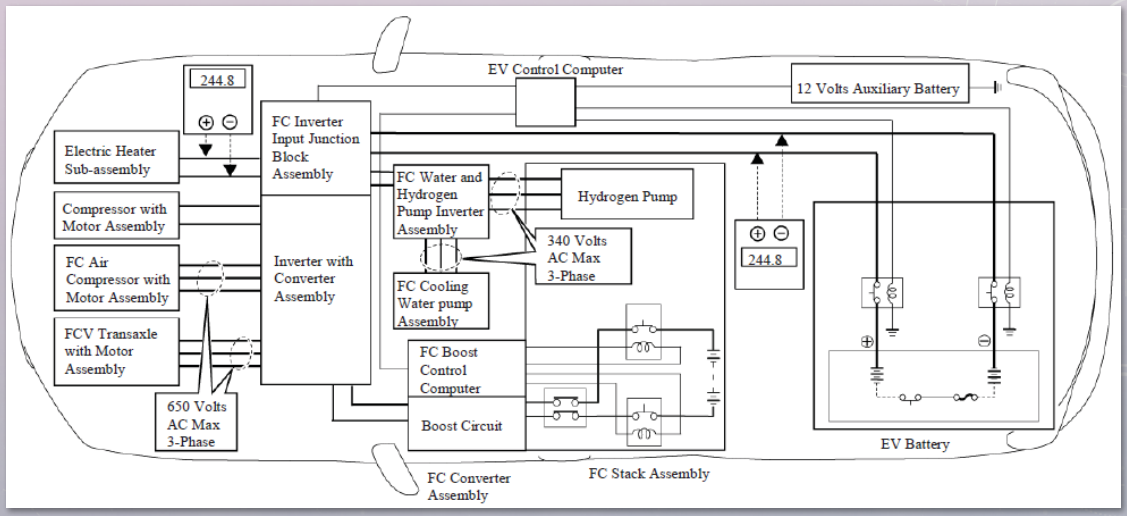
High Voltage System OFF (No READY light)



1. High Voltage Fuse provides protection for the EV Battery
2. HV Cables insulated from chassis
3. SMRs Relays (NO)
4. A ground fault monitor continuously monitors for high voltage leakage to the metal chassis while the vehicle is running

101

High Voltage System ON (READY light ON)



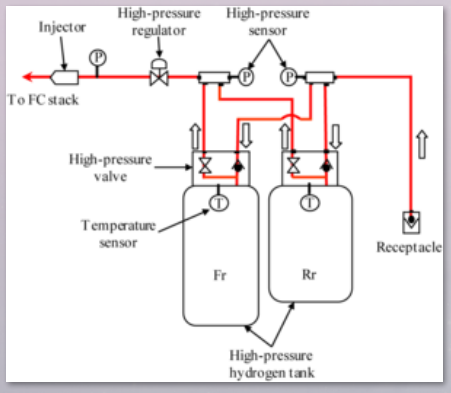
102

FUEL STORAGE AND SAFETY

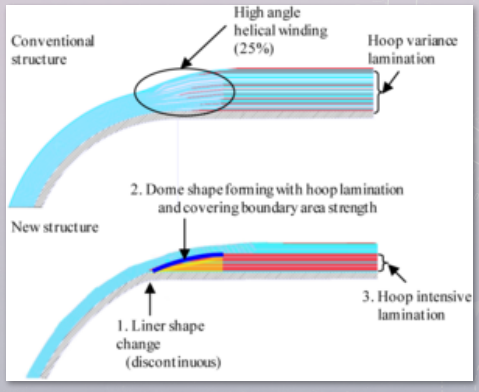
TOYOTA MOTOR CORPORATION

103

Storage



Basic configuration of high-pressure storage system. The high pressure from the two hydrogen tanks is reduced in two stages by the high-pressure regulator and injector before reaching the fuel cell (FC) stack.



Comparison of conventional and new lamination methods. Toyota made three critical changes to the lamination method, resulting in a thinner tank wall and reduced weight.

104

Safety and Control

Purging

- Assume hydrogen present and verify the system is purged to the appropriate level when performing maintenance
- Assume air is present and verify the system has been purged to the appropriate level when reintroducing hydrogen into a system

Pressure Relief System

- Pressure equipment should be fitted with a pressure relief device (PRD), such as a rupture disc or a relief valve
- The PRD should be vented to a safe outside location

105

Safety and Control

Venting

- Hydrogen storage facilities should have adequate ventilation for both normal operation and emergencies
- Vent lines for hydrogen (including pressure relief lines and boil-off from cryogenic systems) should be vented to an appropriate exhaust system or a safe outside location

Pressure Relief System

- The vent should be designed to prevent moisture or ice from accumulating in the line
- Unused hydrogen should be disposed of by venting or possibly flaring

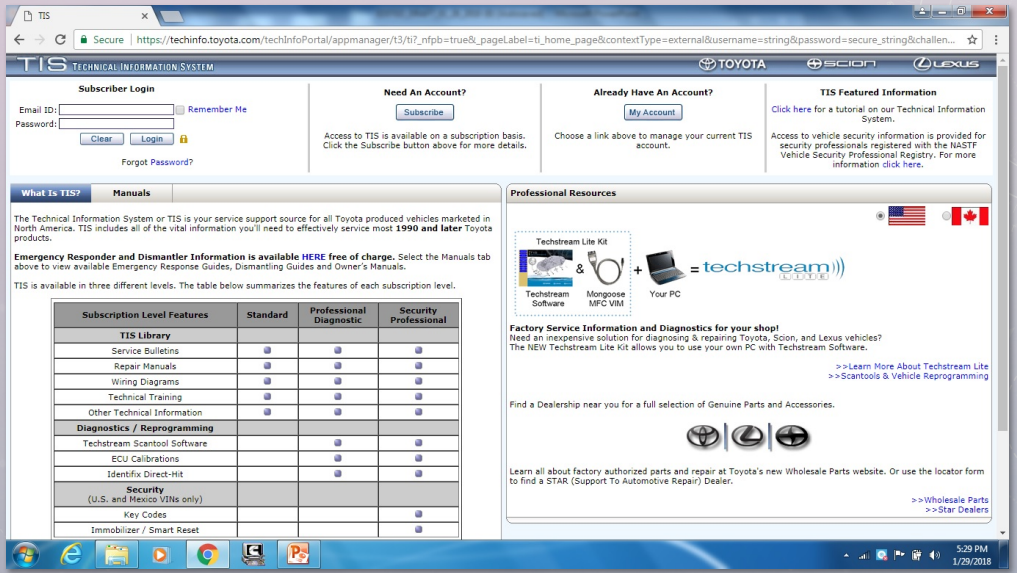
106

DIAGNOSTICS & TROUBLESHOOTING

SCANNERS AND SOFTWARE

107

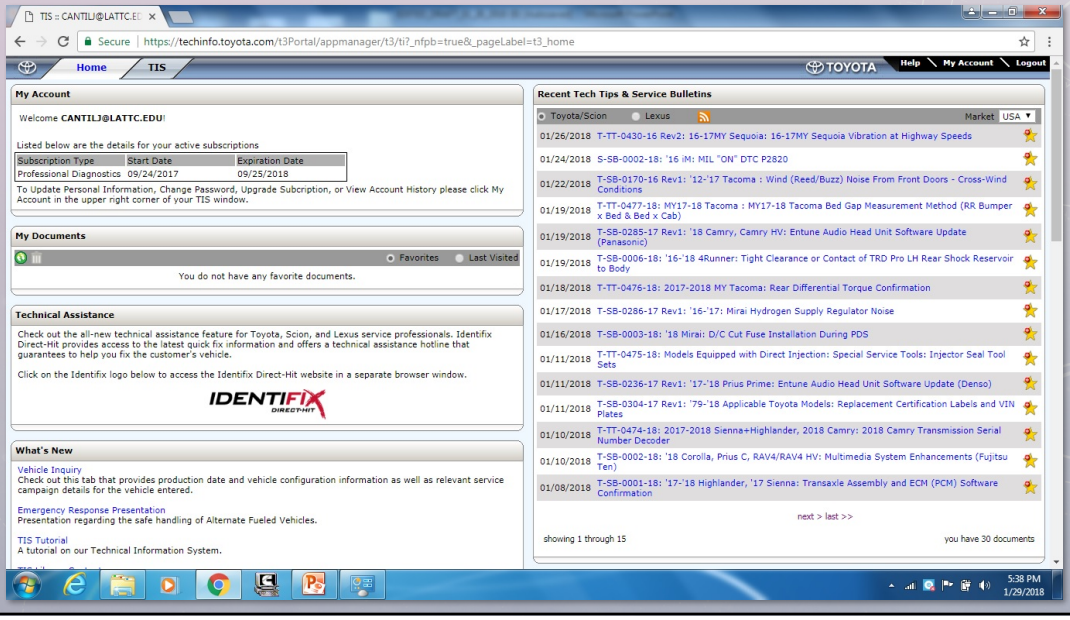
Toyota Information System – TIS website



- **URL:** http://techinfo.toyota.com

108

TIS website (logged-in)



109

TIS techstream

ONBOARD DIAGNOSTICS

TECHSTREAM

110

Techstream Overview

- The Technical Information System (TIS) is the service support source for Toyota vehicles marketed in North America
  - Includes all vital information needed to effectively service most 1990 and later Toyota products
  - Perform tests & monitor data on most systems
    - Fuel system (High pressure hydrogen monitoring & control)
    - Leak detection
    - Fuel cell stack system
    - High voltage power monitoring and control
    - Automatic safety disconnect
      - ➢To neutralize systems in the event of accidents, fires and electrical discharges/shorts

LATTC

111

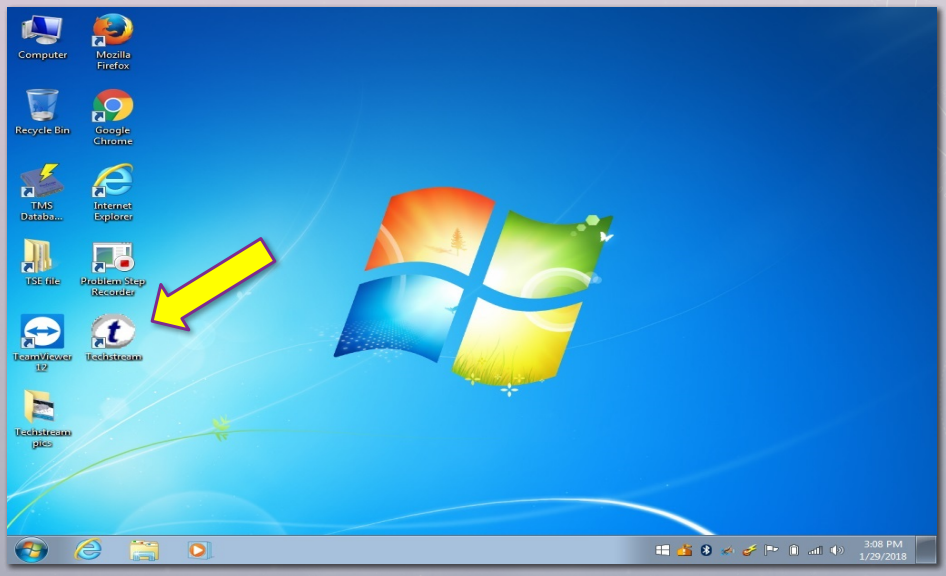
Parameters and Real-time Data (Caution)

- Access to all systems to give the technician as much information possible about how systems operate
- Because of amount of information available, proceed with caution:
  - Understand how systems designed to function under normal circumstances and therefore comprehend their behavior
  - This allows you to verify repairs by comparing the pre and post operation states

LATTC

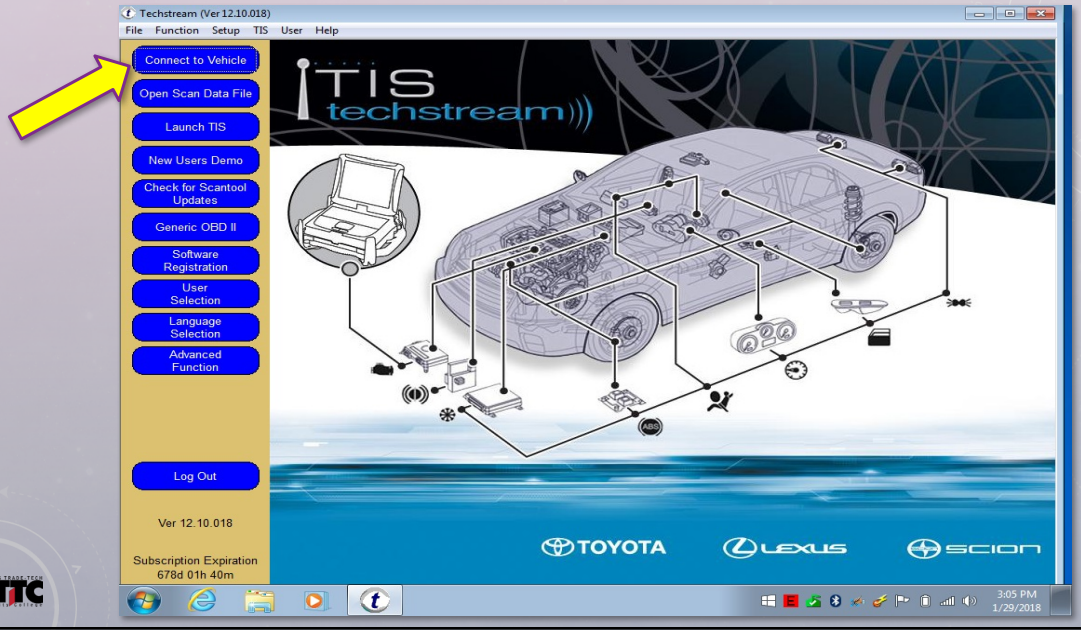
112

Desktop/Home Screen for most Computers



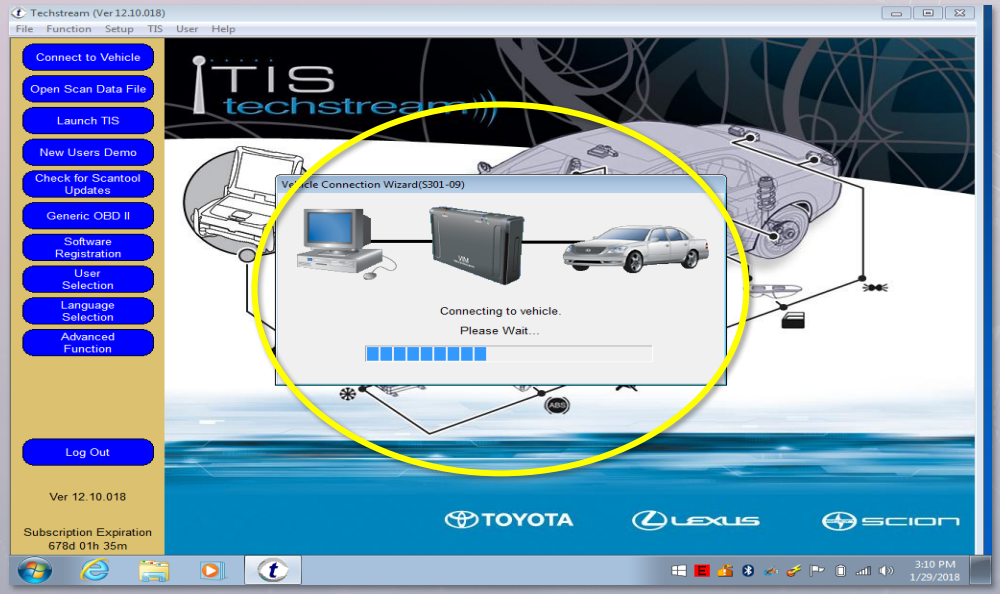
113

Teachstream Opening Screen - Choices



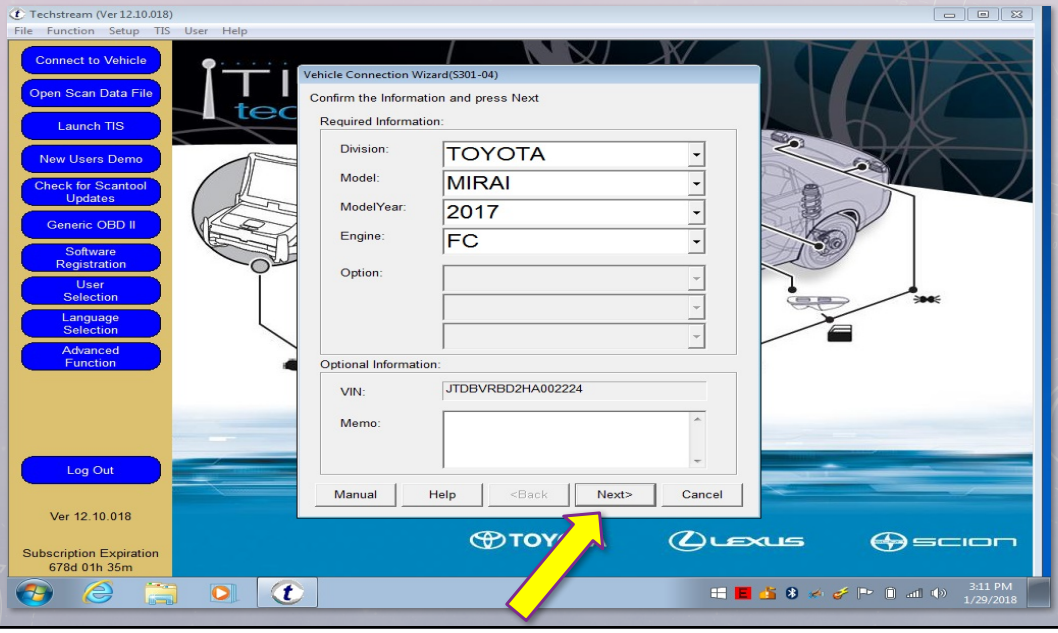
114

Connecting…



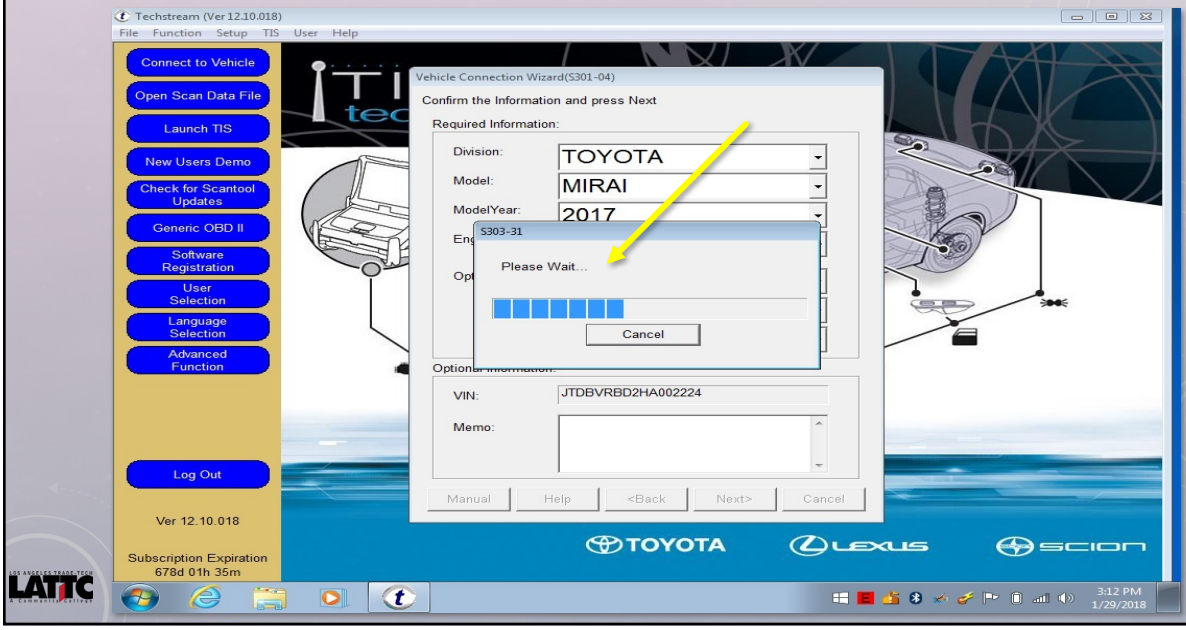
115

Further Information May be Needed…, "Next"



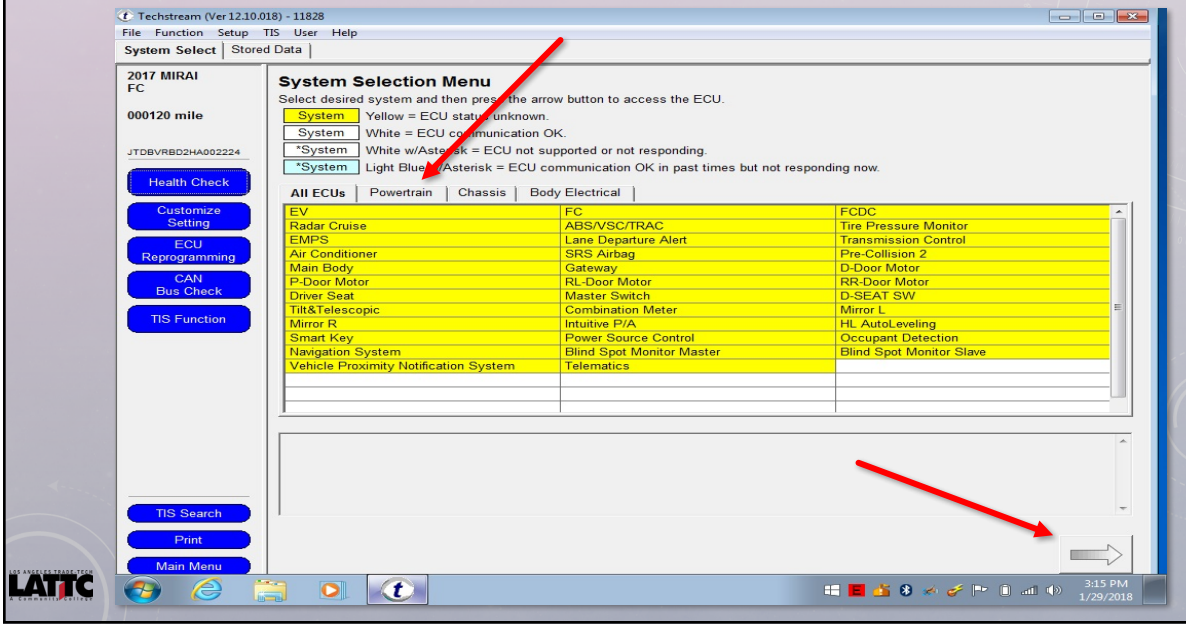
116

Please Wait…



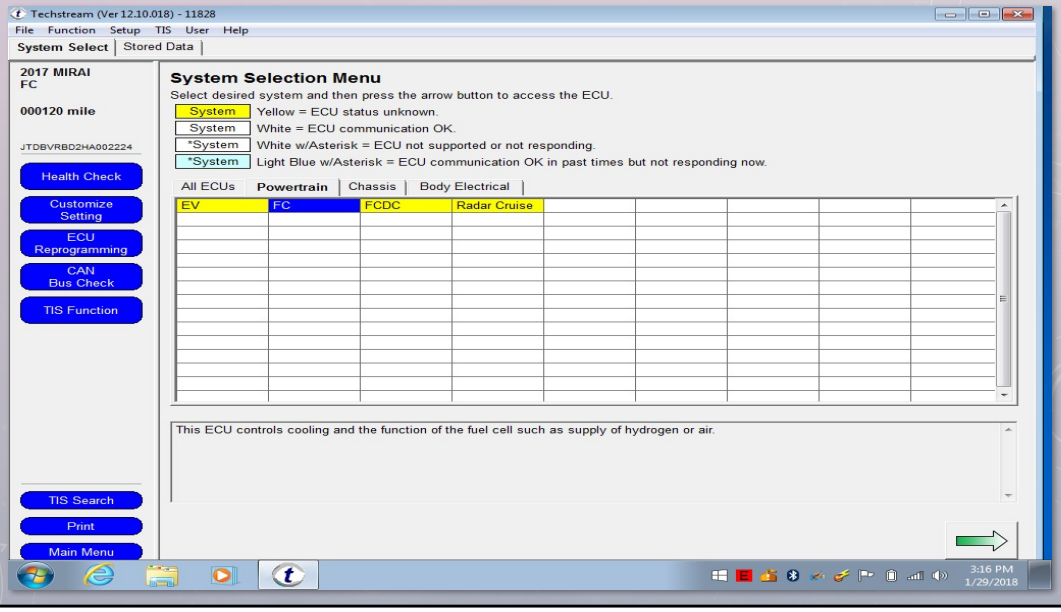
117

Accessing the Fuel Cell Stack Data…



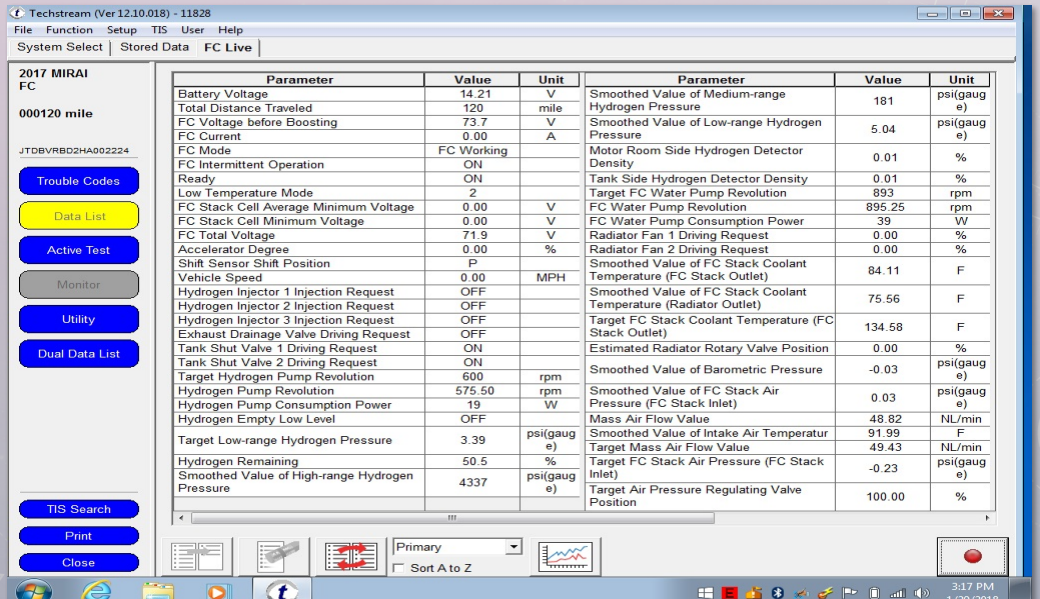
118

Accessing FC Data…, Click Green Arrow



119

All Info on the FC Stack is Displayed… Success!



Parameter	Value	Unit
Battery Voltage	14.21	V
Total Distance Traveled	120	mile
FC Voltage before Boosting	73.7	V
FC Current	0.00	A
FC Mode	FC Working	
FC Intermittent Operation	ON	
Ready	ON	
Low Temperature Mode	2	
FC Stack Cell Average Minimum Voltage	0.00	V
FC Stack Cell Minimum Voltage	0.00	V
FC Total Voltage	71.9	V
Accelerator Degree	0.00	%
Shift Sensor Shift Position	P	
Vehicle Speed	0.00	MPH
Hydrogen Injector 1 Injection Request	OFF	
Hydrogen Injector 2 Injection Request	OFF	
Hydrogen Injector 3 Injection Request	OFF	
Exhaust Drainage Valve Driving Request	OFF	
Tank Shut Valve 1 Driving Request	ON	
Tank Shut Valve 2 Driving Request	ON	
Target Hydrogen Pump Revolution	600	rpm
Hydrogen Pump Revolution	575.50	rpm
Hydrogen Pump Consumption Power	19	W
Hydrogen Empty Low Level	OFF	
Target Low-range Hydrogen Pressure	3.39	psi(gauge)
Hydrogen Remaining	50.5	%
Smoothed Value of High-range Hydrogen Pressure	4337	psi(gauge)

Parameter	Value	Unit
Smoothed Value of Medium-range Hydrogen Pressure	181	psi(gauge)
Smoothed Value of Low-range Hydrogen Pressure	5.04	psi(gauge)
Motor Room Side Hydrogen Detector Density	0.01	%
Tank Side Hydrogen Detector Density	0.01	%
Target FC Water Pump Revolution	893	rpm
FC Water Pump Revolution	895.25	rpm
FC Water Pump Consumption Power	39	W
Radiator Fan 1 Driving Request	0.00	%
Radiator Fan 2 Driving Request	0.00	%
Smoothed Value of FC Stack Coolant Temperature (FC Stack Outlet)	84.11	F
Smoothed Value of FC Stack Coolant Temperature (Radiator Outlet)	75.56	F
Target FC Stack Coolant Temperature (FC Stack Outlet)	134.58	F
Estimated Radiator Rotary Valve Position	0.00	%
Smoothed Value of Barometric Pressure	-0.03	psi(gauge)
Smoothed Value of FC Stack Air Pressure (FC Stack Inlet)	0.03	psi(gauge)
Mass Air Flow Value	48.82	NL/min
Smoothed Value of Intake Air Temperatur	91.99	F
Target Mass Air Flow Value	49.43	NL/min
Target FC Stack Air Pressure (FC Stack Inlet)	-0.23	psi(gauge)
Target Air Pressure Regulating Valve Position	100.00	%

120

Questions?

Thank you.

121

RESOURCES AND LINKS

122

Links for Resources

Online Documents	Web Address
Toyota Mirai:	
Cruises 300 miles	http://bit.ly/2roGEvk
A Preview of future propulsion	http://bit.ly/2ru0CVE
Run your home in an emergency	http://bit.ly/2nqYXuO

Videos	Web Address
Visual hydrogen atom (1:21)	http://rsc.li/2DSUoRC
Hydrogen properties (7:15)	http://rsc.li/2Dufkkp
Toyota Fuel Cell System (3:23)	http://bit.ly/2DnALAg
Toyota Motor Corporation (Requires Account Login)	
Toyota Information System TIS	http://toyota.us/2npcIKy
Mirai FCV Mayor Tech Specs	http://toyota.us/2EkBK5C

Websites	Web Address
U.S. Department of Energy Quiz: How much do you know about hydrogen?	http://bit.ly/2EfKqdb

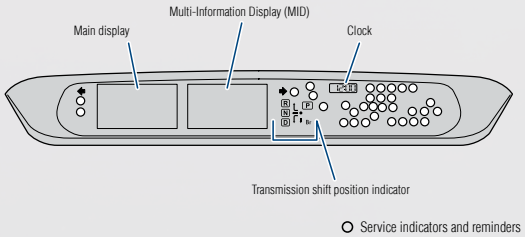
LATTC

123

17 Mirai Instrument Cluster Symbols

OVERVIEW

Instrument cluster



○ Service indicators and reminders

Instrument symbols

For details, refer to "Indicators and warning lights," Section 3-3, 2017 Owner's Manual.

- H_2 Hydrogen leak warning
- High coolant temperature warning
- Low fuel level warning
- Master warning[1]
- Low tire pressure warning[1]
- READY indicator
- Security indicator
- Airbag ON/OFF
- Driver seat belt reminder (alarm will sound if speed is over 12 mph)
- Supplemental Restraint System warning
- Open door warning

[1] *If indicator does not turn off within a few seconds of starting Hydrogen Fuel Cell System, there may be malfunction. Have vehicle inspected by your Toyota dealer.*

LATTC

124

LOS ANGELES TRADE-TECH LATTC A Community College

PHOTOS, ILLUSTRATIONS, & CHARTS

USEFUL INFORMATION FOR LAB EXERCISES

125

Fueling a Hydrogen Vehicle

126

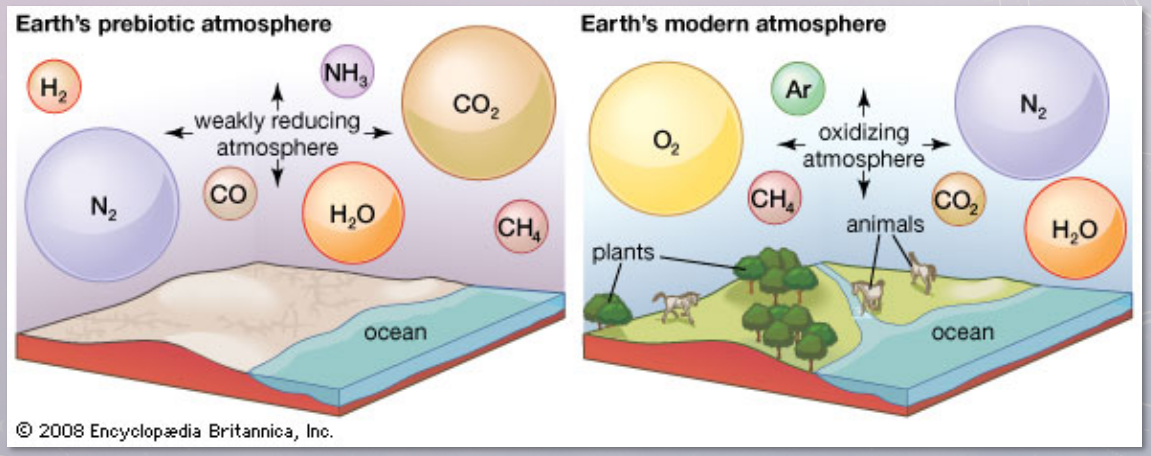
Dashboard Instruments

127

Dashboard Buttons

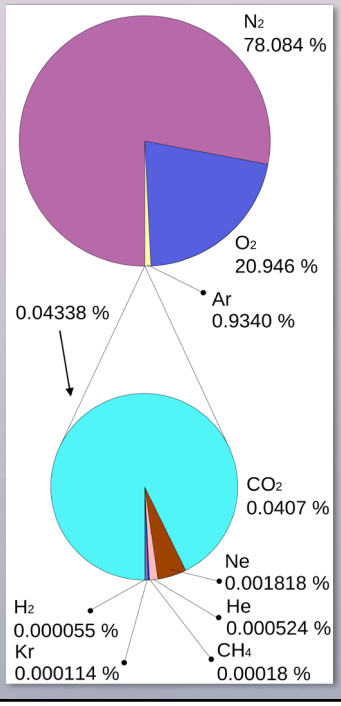
128

Prebiotic v. Modern Atmospheric Gas



129

Atmospheric Gas Proportions

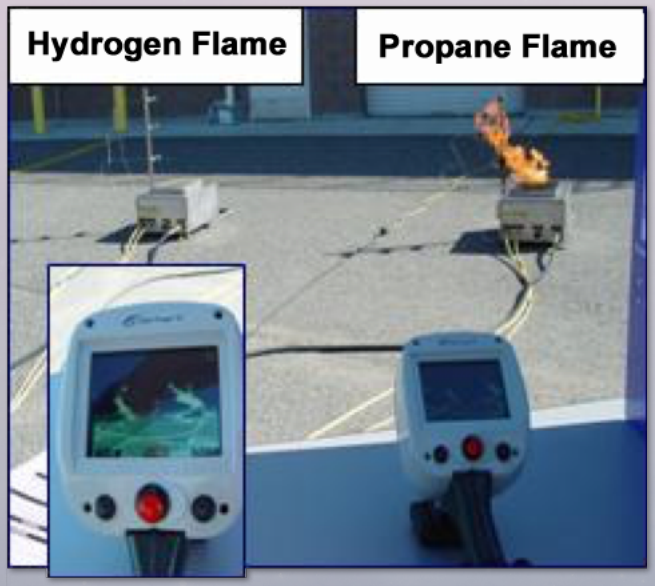


130

Propane Flame v. Hydrogen Flame - Night

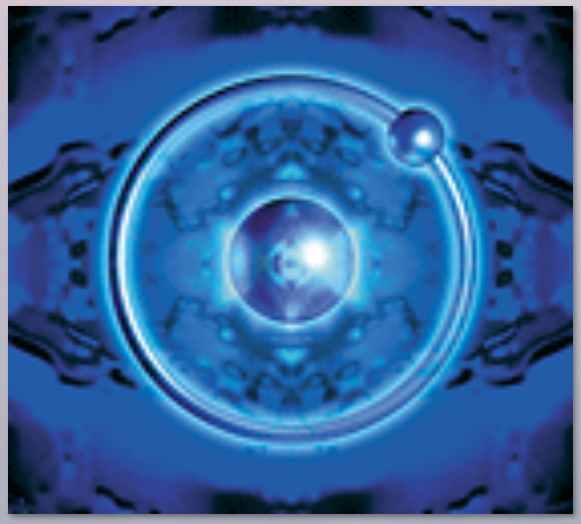
131

Hydrogen Flame v. Propane Flame (infrared) - Day



132

Hydrogen Atom

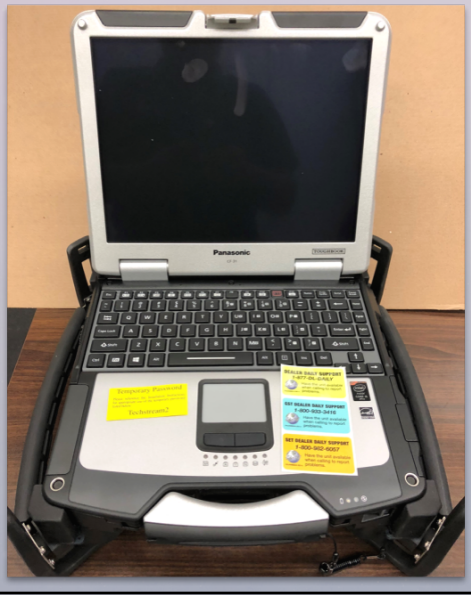


133

TIS-techstream (closed)

134

TIS-techstream (open & off)

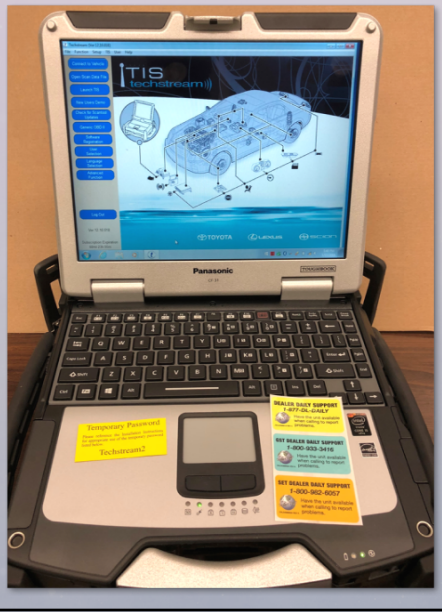


135

TIS-techstream (screen)

136

TIS-techstream (open & on)



137