Toyota Mirai Hydrogen Fuel Cell EV
- Repair Garage Design & Safety -

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Mirai Fuel Cell EV Operation & Service

Agenda

• Toyota Mirai Overview
• Toyota Dealer Hydrogen Repair Facility
• Hydrogen Vehicle Safety Train
• Feedback and Discussion
Mirai Fuel Cell EV Operation

FCEV Operation Video
Toyota Mirai Fuel Cell System Layout

- Inverter/Converter Assembly
- MG2/Transaxle
- NiMH Battery
- FC & EV Cooling
- Radiators
- FC Boost Converter
- Fuel Cell Stack
- Hydrogen Tanks
Toyota Mirai Fuel System

- Three pressure zones
- Closed fuel system
  - Pressurized H2 confined to tanks when “Ready-off”
- Volume of pressurized H2 fuel in lines < 300cc npt
  - Energy content of H2 in lines <40 btu, about same as one drop of gasoline
  - During service, lines are safely vented to atmosphere
Toyota Mirai Fuel Tanks

- Tank valves are normally closed (N/C), de-energize to off position
- Combined tank capacity = ~5.3 Kg at 10,000 psi
  - ~ 5 gallons gas equivalent
- Defueling is performed from mid-pressure line at pressure regulator
  - Defueling pressure ~175psi
Toyota Mirai Hydrogen Tanks

- **Hydrogen Tank Design:**
  - HGV Type IV Tank
  - Rated (22,500 psi) - 2.25X
  - Certified to GTR13 standards

- **Composite Tank Construction**
  - Polymer liner
  - Carbon fiber strength layer
  - Surface Protection Layer

- **Tank Valve Operation**
  - Inlet check valve
  - Outlet solenoid valve (normally closed)
  - Manual shut off
  - Thermal pressure relief device (110 C)
Toyota Mirai In-vehicle H2 Sensors

- Operational when vehicle is “ready-on” and during service (i.e. defueling)
- If hydrogen is sensed during vehicle operation or service, tank valves automatically close
Toyota Mirai Defueling

• Performed for certain hydrogen repair operations (i.e. tank replacement)
  ✓ Performed in “operational” H2 service bay only (or outdoors with AHJ approval)
  ✓ Defueling line discharges outside of H2 service bay and building; > 50’ from any intakes

• Defueling hose connects to mid-pressure port & defueling vent line

• Scan tool service utility used to energize tank valves for defueling

If hydrogen is sensed under the vehicle or hood during defueling, operation aborts & N/C tank solenoid valves automatically close.

Keep union connections out of this space to prevent possible leak source in non-ventilated space.
Dealer Hydrogen Repair Facility (codes)

- **Repair Garage Code Base**
  - ✓ Building Code – IBCs)
  - ✓ Fire Code – NFPA 1, 2 (2016) or IFC (NY)
  - ✓ Mechanical code – IMC
  - ✓ Electric code – NEC/NFPA 70

- **Repair garage code requirements for vehicles fueled by lighter than air fuels**
  - Exception – maintenance and non fuel system work (majority of repairs)
  - ✓ Mechanical ventilation
    - o >1 cfm/sf continuous / > 4 cfm/sf upon $H_2$ detection (2 minute air change) or as code requires
  - ✓ Gas detection/visual & audible alarms
    - o Hydrogen sensor and alarm control panel activating at 25% LFL
    - o Interface to NFPA 72 fire alarm panel (typically supervisory)
  - ✓ Deactivation of heating systems when triggered
    - o Alarm control panel will deactivate heaters where required or prudent
  - ✓ Classified electrical within 18” of ceiling
    - o Eliminate electrical within 18” of ceiling; Class 1, Div 2 if necessary or prudent
  - ✓ Fire Protection
    - o Add sprinkler heads to enclosure ceiling when building equipped or code requires
  - ✓ Installation of hydrogen tank defueling equipment
    - o Stainless steel hydrogen line to defuel tanks; vents hydrogen safely to atmosphere
Hydrogen Service Bay (H2SB)

- Designed to create a safe and compliant working environment for H2 repairs
- Essentially, an updraft paint booth

Hydrogen Code Compliant Repair Garage
- required for all hydrogen system repairs

Features

1. Enclosed space
   a) Freestanding hood / valence supported by 4 posts
   b) Retractable vinyl curtains (NFPA 701 fire retardant)

2. Ventilation system; exhaust at ceiling, make-up air at lower 4 corners

3. Hydrogen sensing with audible/visual alarms

4. Atmospheric hydrogen defueling pipe

5. Classified electrical (within 18” of ceiling)
   a) Above ground lift requires class 1, div 2 limit switch or switch must be located outside of upper 18” zone
   b) Overhead lights; sealed, tempered glass (class 1, div 2)

6. Fire sprinklers
Hydrogen Service Bay (H2SB) -ventilation-

- Continuous ventilation with H2SB “operational”
  - System is operational with System Switch “on” & curtains closed
  - ~500 - ~750 cfm continuous (~1 air change/8 minutes)
  - Increases to ~2K cfm under alarm conditions (~1 air change/2 minutes)

Exhaust >50’ from H2SB or other building intakes

Exhaust at top center of enclosure – aft of H2 sensor

Intake air from bottom of support posts at 4 corners
**Hydrogen Service Bay (H2SB)**

- **H2 Sensing**

  - RKI sensor – tested for reliability in automotive repair environment by KPA and NREL
    - Validated for accuracy, durability, stability
    - Recalibrated and logged quarterly

  - RKI control panel w/ emergency power backup
    - Wall mount outside of enclosure
    - Contains visual & audible alarms
      - Level 1 alarm 10% LFL (strobe alert & ventilation increase to ~ 2K cfm)
      - Level 2 alarm at 25% LFL, alarm sounds & red strobe flashes

  H2 sensing is always operational when Main Disconnect switch is “on”
Hydrogen Service Bay (H2SB) - sequence of operation -

- Dealer personnel trained at time of installation
  - Follow-on training by KPA
- **Main Disconnect** switch is always ON when shop is occupied – system is in “standby”
  - H2 sensing operational, fans standby
- When H2 repairs are to be performed
  - **System Switch** turned ON
  - Curtains closed within 3 minutes
  - Remote beacon turns from red to green
  - If curtains not closed, red strobe flashes and alarm sounds
Hydrogen Service Bay (H2SB) - sequence of operation

- Alarm conditions are posted in close proximity to control panel

### Alarm Conditions Table

<table>
<thead>
<tr>
<th>Condition</th>
<th>Indicator</th>
<th>Action</th>
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</thead>
<tbody>
<tr>
<td>System, Intake Fan or Exhaust Fan in “OFF”</td>
<td>1) Red panel light, red flashing remote light &amp; siren</td>
<td>Turn System, Intake Fan and Exhaust Fan to “ON”</td>
</tr>
<tr>
<td>Curtain is Open</td>
<td>1) Solid Red remote panel light</td>
<td>Close Curtain</td>
</tr>
<tr>
<td>Curtain is Open for &gt; 3 min</td>
<td>1) Flashing Red remote Light &amp; siren</td>
<td>Close Curtain</td>
</tr>
<tr>
<td>10% LEL Hydrogen reached</td>
<td>1) Fan speed increases to 2,000+ cfm</td>
<td>Warning Only upon exit do not re-enter until yellow light turns off.</td>
</tr>
<tr>
<td>25% LEL Hydrogen reached</td>
<td>1) Alarm horn</td>
<td>Stop Work, Evacuate Hydrogen Service Bay and surrounding area. Do not re-enter until alarms are silenced and yellow light turns off.</td>
</tr>
<tr>
<td>2) Red flashing light &amp; siren</td>
<td>3) Remote solid red light</td>
<td></td>
</tr>
<tr>
<td>LEL System Failure (Hydrogen Detection System Failure)</td>
<td>1) Alarm bell</td>
<td>Stop work, cease use of Hydrogen Service Bay until repairs can be made.</td>
</tr>
<tr>
<td>2) Amber light top of panel</td>
<td>3) Remote solid red light</td>
<td></td>
</tr>
<tr>
<td>3) Remote solid red light</td>
<td>4) Fans activate at 2000+ cfm</td>
<td></td>
</tr>
</tbody>
</table>

Silencing Alarms:
Depressing the LEL Failure Silence Bell button, the LEL Alarm #1 Silence Horn button or the button on the bottom of the RKI Sensor Panel silences each alarm after activation.

Manual Mode:
TO BE USED FOR TESTING ONLY: Intake Fan or Exhaust Fan may be placed in manual mode when the Hydrogen Service Bay is not in an Alarm State by use of the key switches. In manual mode the fan speed can be controlled by the Pot Intake Fan and the Pot Exhaust Fan respectively.

Emergency Stop:
Depressing the Emergency Stop button shuts down the entire system. This button is for emergency use only.
Hydrogen Service Bay (H2SB) - defueling to atmosphere -

- Defueling always performed in an “operational” H2SB