



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

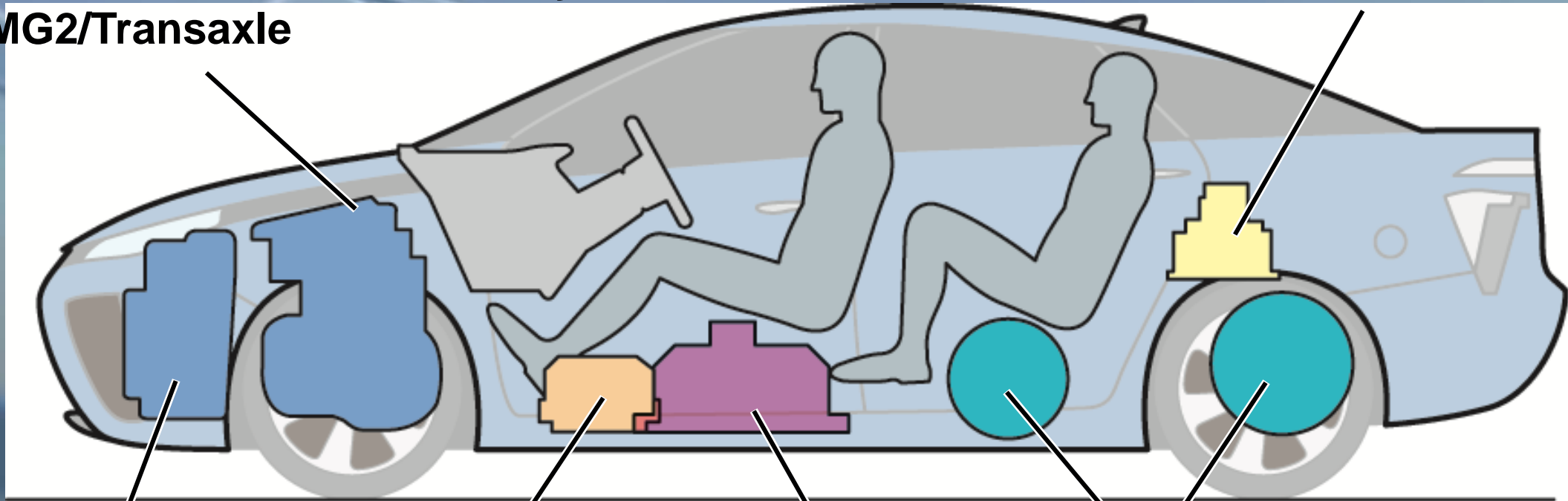


FCEV Operation Video

Toyota Mirai Fuel Cell System Layout

- Inverter/Converter Assembly
- MG2/Transaxle

- NiMH Battery



- FC & EV Cooling Radiators

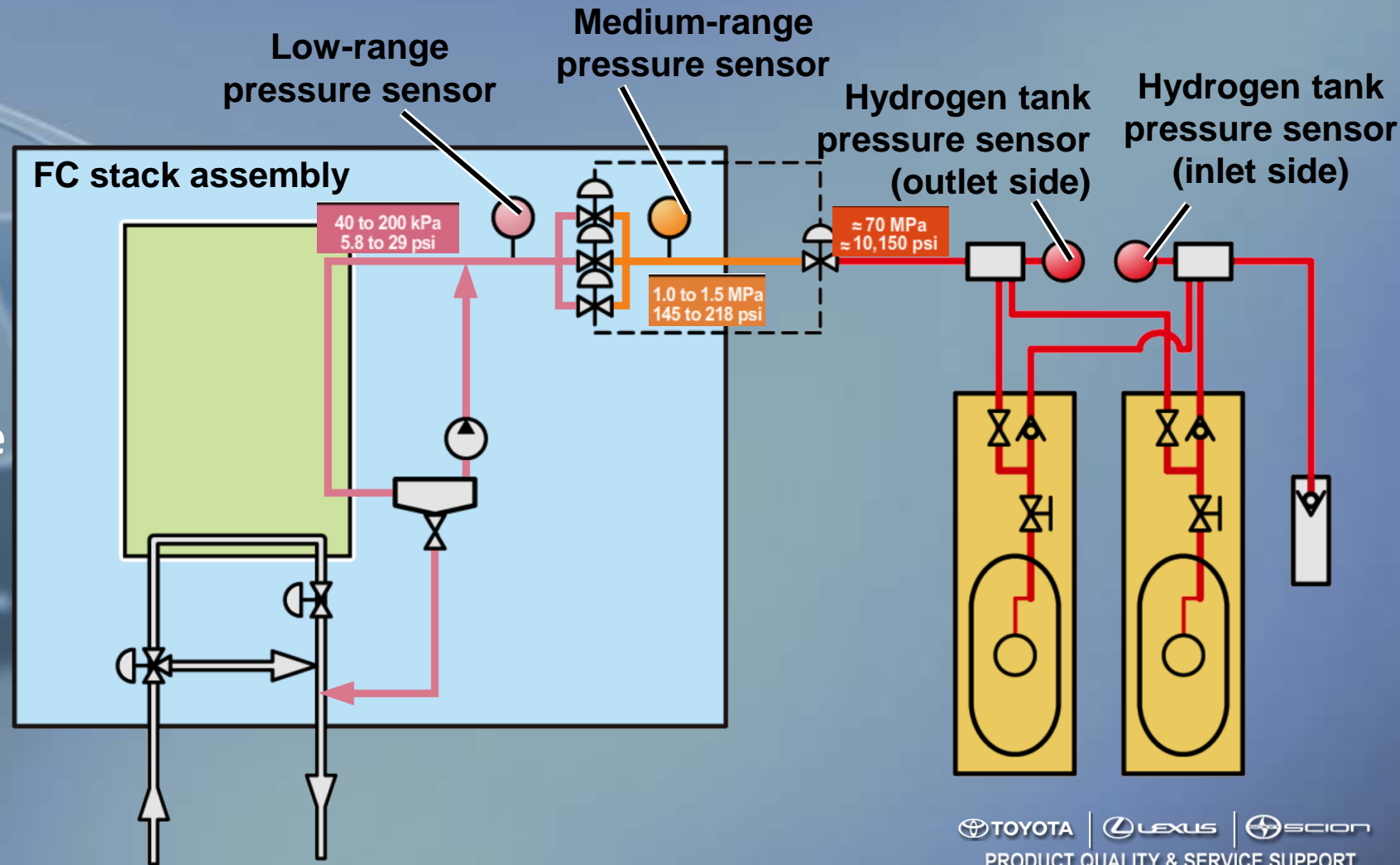
- FC Boost Converter

- Fuel Cell Stack

- Hydrogen Tanks

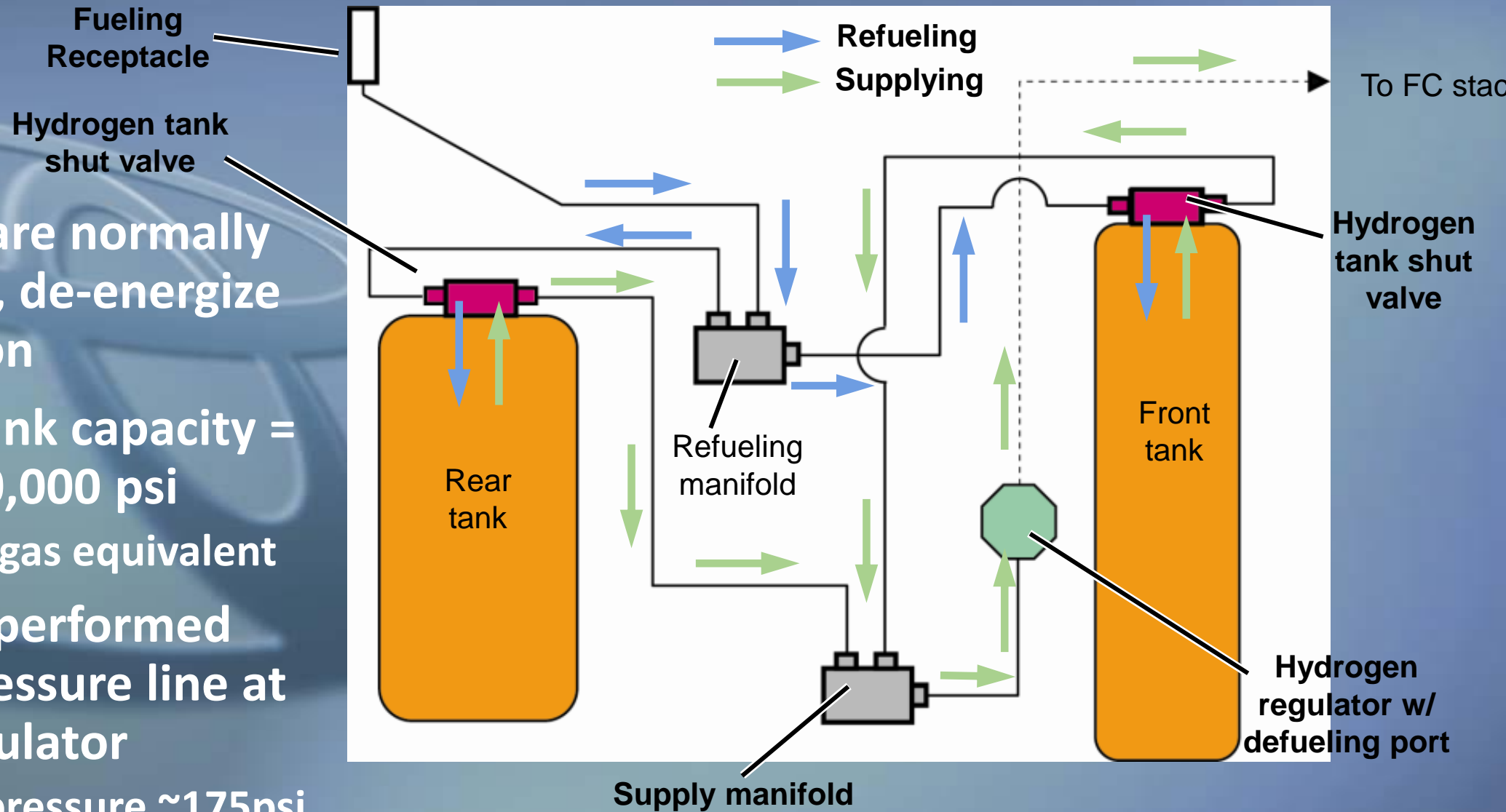
Toyota Mirai Fuel System

- 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

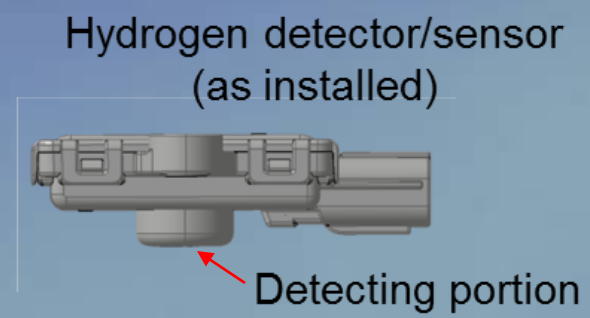
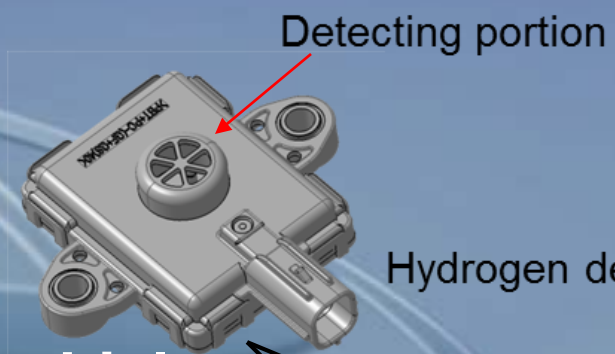


• Tank Valve Operation

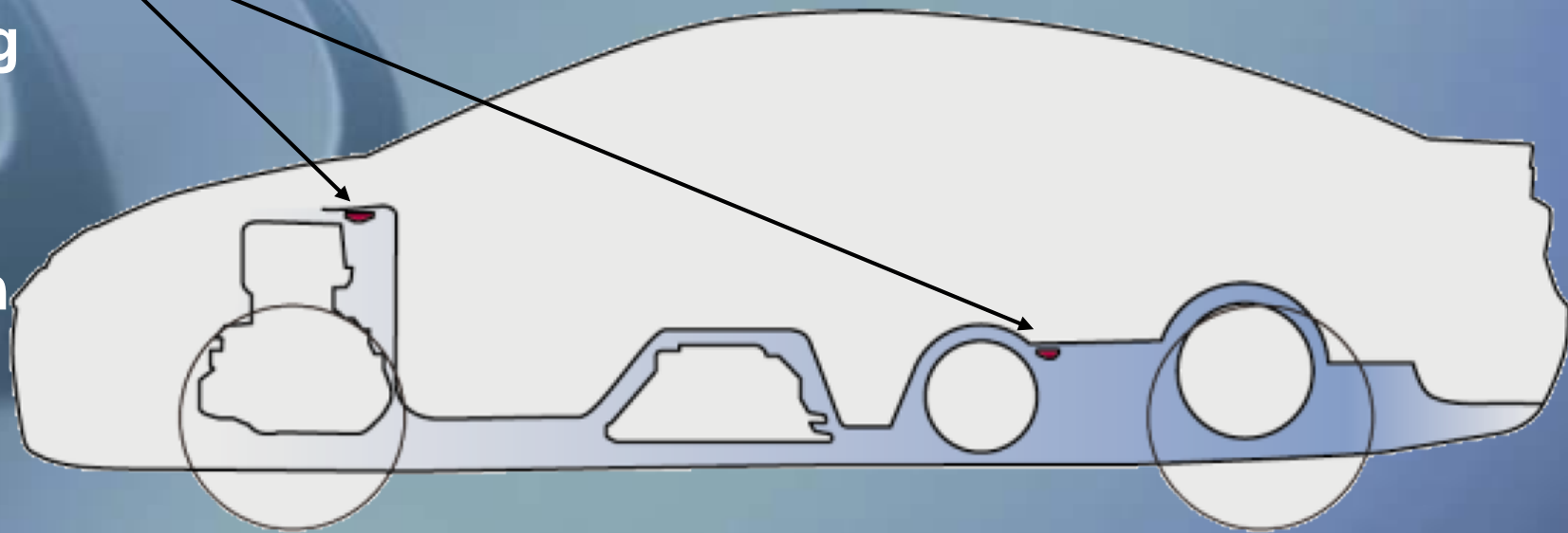
- ✓ - Inlet check valve
- ✓ Outlet solenoid valve (normally closed)
- ✓ Manual shut off
- ✓ Thermal pressure relief device (110 C)



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

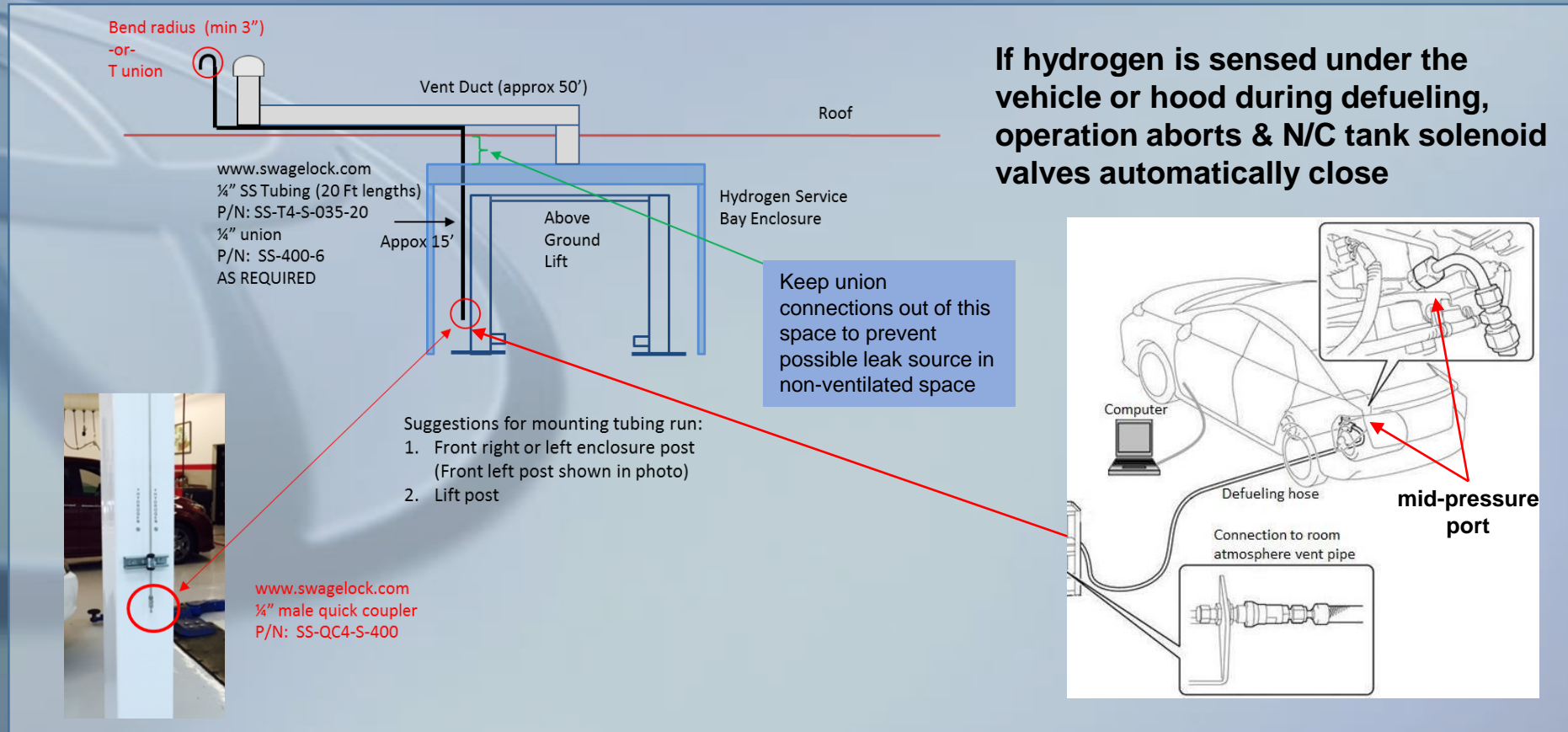


Areas where hydrogen can collect

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

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**

- *>1 cfm/sf continuous / >4 cfm/sf upon H₂ detection (2 minute air change) or as code requires*

- ✓ **Gas detection/visual & audible alarms**

- *Hydrogen sensor and alarm control panel activating at 25% LFL*
- *Interface to NFPA 72 fire alarm panel (typically supervisory)*

- ✓ **Deactivation of heating systems when triggered**

- *Alarm control panel will deactivate heaters where required or prudent*

- ✓ **Classified electrical within 18” of ceiling**

- *Eliminate electrical within 18” of ceiling; Class 1, Div 2 if necessary or prudent*

- ✓ **Fire Protection**

- *Add sprinkler heads to enclosure ceiling when building equipped or code requires*

- ✓ **Installation of hydrogen tank defueling equipment**

- *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

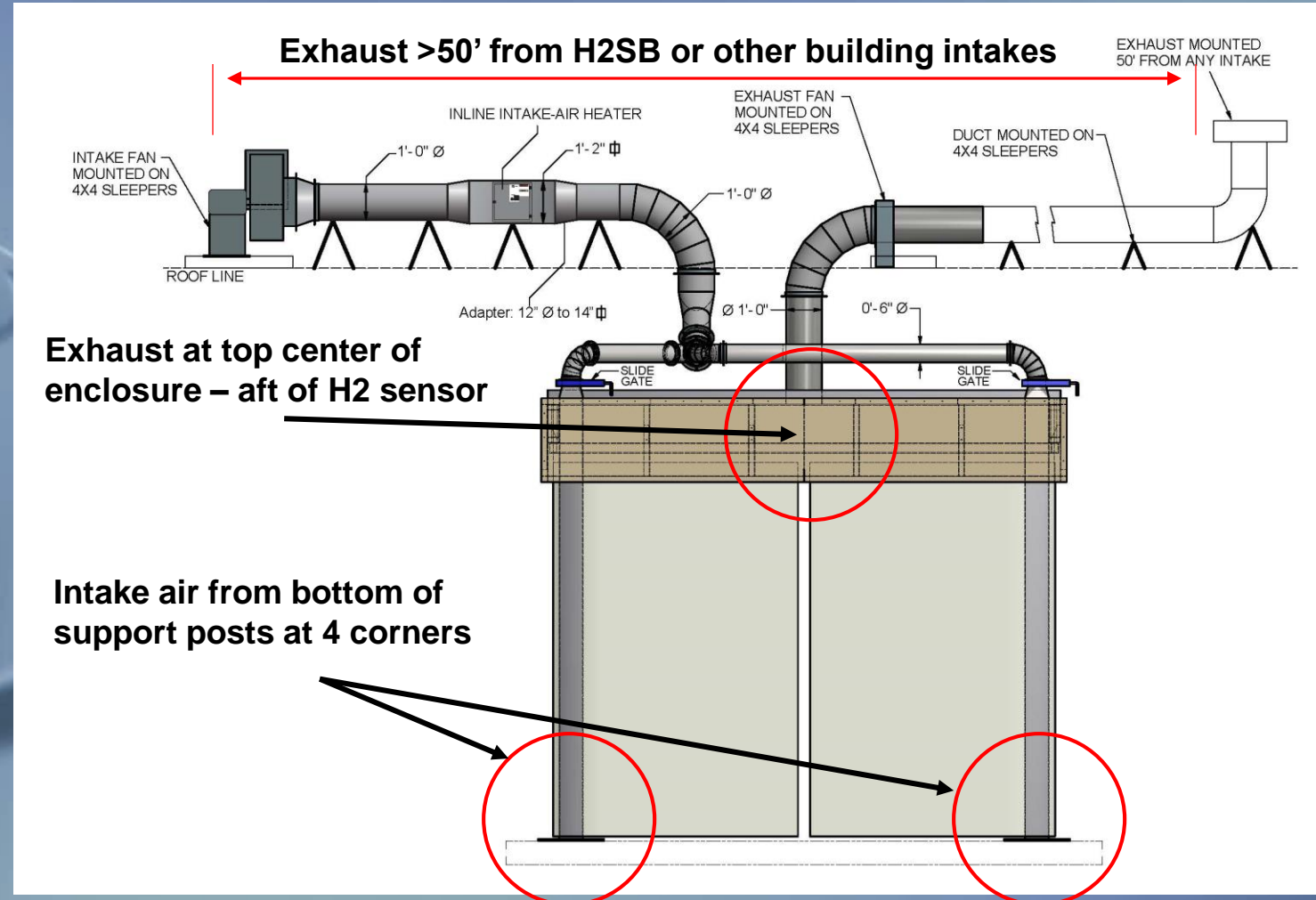
Features

- 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-

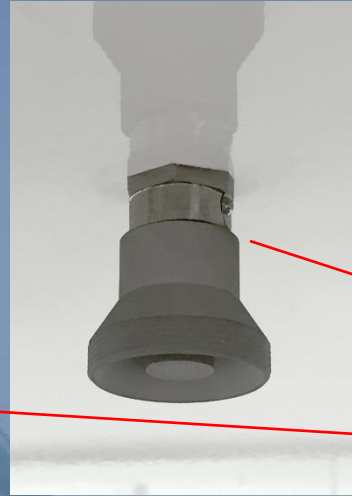
- Continuous ventilation with H2SB “operational”
 - System is operational with System Switch “on” & curtains closed
 - ~500 - ~750 cfm continuous (~1 air change/8 minutes)
 - Increases to ~2K cfm under alarm conditions (~1 air change/2 minutes)



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



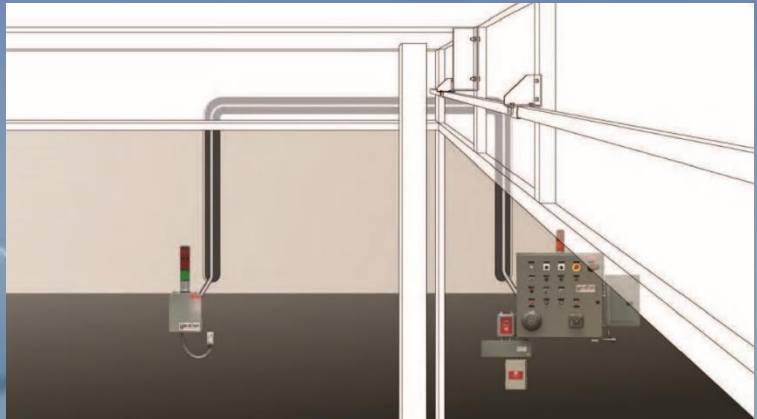
H2 sensing is always operational when Main Disconnect switch is “on”

A photograph of a "Quarterly Calibration & Performance Log" form. The form is titled "Quarterly Calibration & Performance Log" and contains several sections: "Calibration Data Used", "CALIBRATION", "AIRFLOW - NORMAL OPERATIONS", "AIRFLOW - ABNORM CONDITIONS", "PERFORMANCE EXPECTATIONS MET?", and "MANAGEMENT RESPONSIBILITY". The form is filled out with handwritten data and has a red circle around the "AIRFLOW - NORMAL OPERATIONS" section. A red arrow points from the sensor head to the form.

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 INDICATOR STATUS			
LIGHT	HORN	CONDITION	REMEDY
RED	OFF	NOT SAFE FOR HYDROGEN REPAIR	TURN MASTER SWITCH ON CLOSE CURTAINS
RED - FLASHING	ON	NOT SAFE FOR HYDROGEN REPAIR	CLOSE CURTAINS
GREEN	OFF	SAFE FOR HYDROGEN REPAIR	

IN CASE OF HYDROGEN RELEASE ACTIVATE FIRE PULL

NORMAL OPERATIONS		
Operation Step	Indicator	Action
1) Ensure Main Disconnect switch is “ON”	1) Beacon 110 Monitor Powers “ON” 2) Control panel cooling fan audible	H2 sensor and fans on standby
2) Ensure System Switch is “ON”	1) System On – white light 2) Intake Fan On – green light 3) Exhaust Fan On – green light 4) Fans operate at 500+ cfm	
3) Close curtains	1) System Operable – green light 2) Curtain interlock made – green panel light & green remote light	Normal Operations

ALARM CONDITIONS		
Condition	Indicator	Action
System, Intake Fan or Exhaust Fan in “OFF”	1) Red panel light, red flashing remote light & siren	Turn System, Intake Fan and Exhaust Fan to “ON”
Curtain is Open	1) Solid Red remote panel light	Close Curtain
Curtain is Open for > 3 min	1) Flashing Red remote Light & siren	Close Curtain
10% LEL Hydrogen reached	1) Fan speed increases to 2,000+ cfm 2) LEL alarm # 1 – Yellow light & buzzer on Beacon H2 Sensor	Warning Only upon exit do not re-enter until yellow light turns off.
25% LEL Hydrogen reached	1) Alarm horn 2) Red flashing light & siren	Stop Work, Evacuate Hydrogen Service Bay and surrounding area. Do not re-enter until alarms are silenced and yellow light turns off.
LEL System Failure (Hydrogen Detection System Failure)	1) Alarm bell 2) Amber light top of panel 3) Remote solid red light 4) Fans activate at 2000+ cfm	Stop work, cease use of Hydrogen Service Bay until repairs can be made.

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.

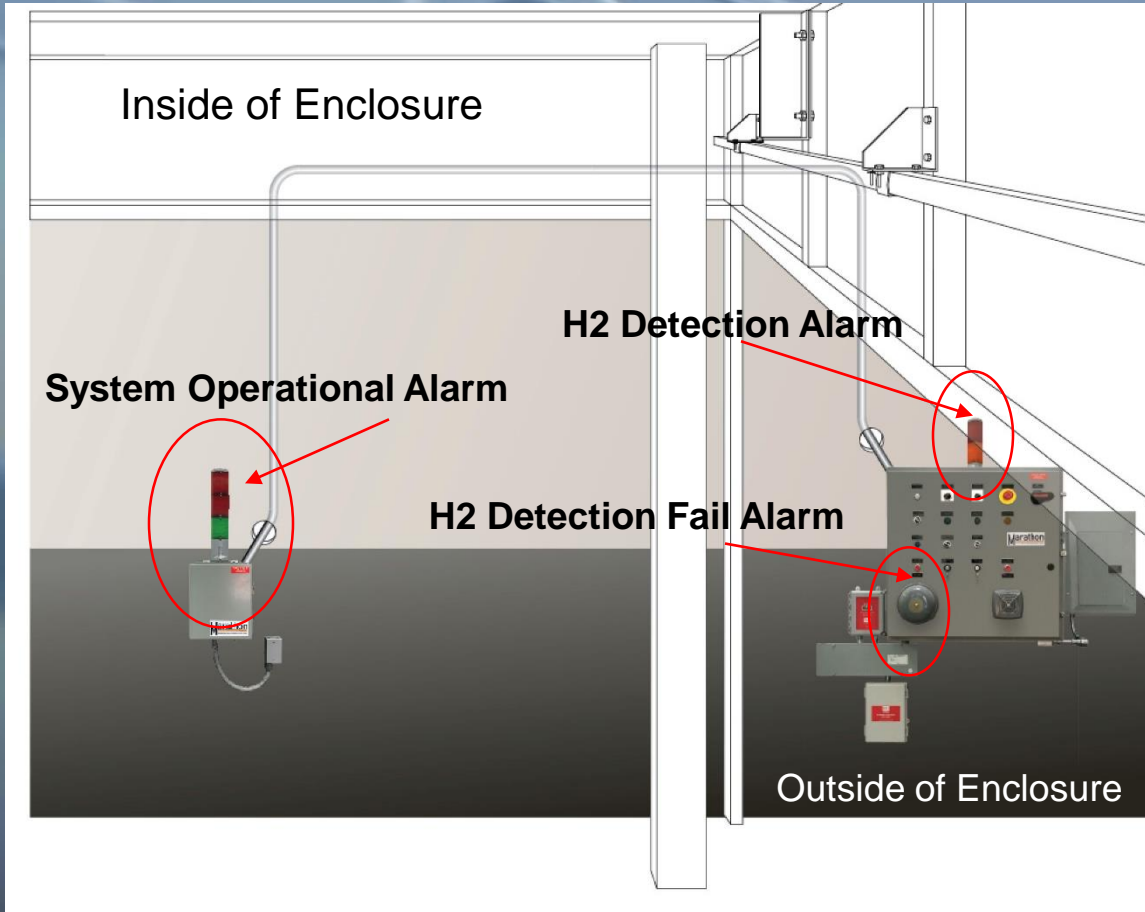
Emergency Stop:
Depressing the Emergency Stop button shuts down the entire system. This button is for emergency use only.

KPA
1-800-486-0400

Hydrogen Service Bay (H2SB)

-sequence of operation-

- Alarm conditions are posted in close proximity to control panel



System Operational Alarm
H2 Leak Detection Alarm
System Operational Alarm

ALARM CONDITIONS		
Condition	Indicator	Action
System, Intake Fan or Exhaust Fan in "OFF"	1) Red panel light, red flashing remote light & siren	Turn System, Intake Fan and Exhaust Fan to "ON"
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KPA
1-800-486-0400

Hydrogen Service Bay (H2SB) -defueling to atmosphere-

- Defueling always performed in an “operational” H2SB

