4th ICHS 2011

Assessment of Safety for HFCV

Sep. 12 ~ 14, 2011

Korea Transportation Safety Authority

Korea Automobile Testing and Research Institute (KATRI)

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- **Vehicle Electric Safety**
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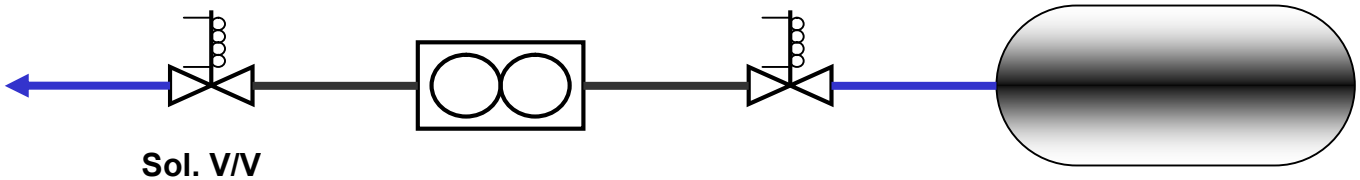
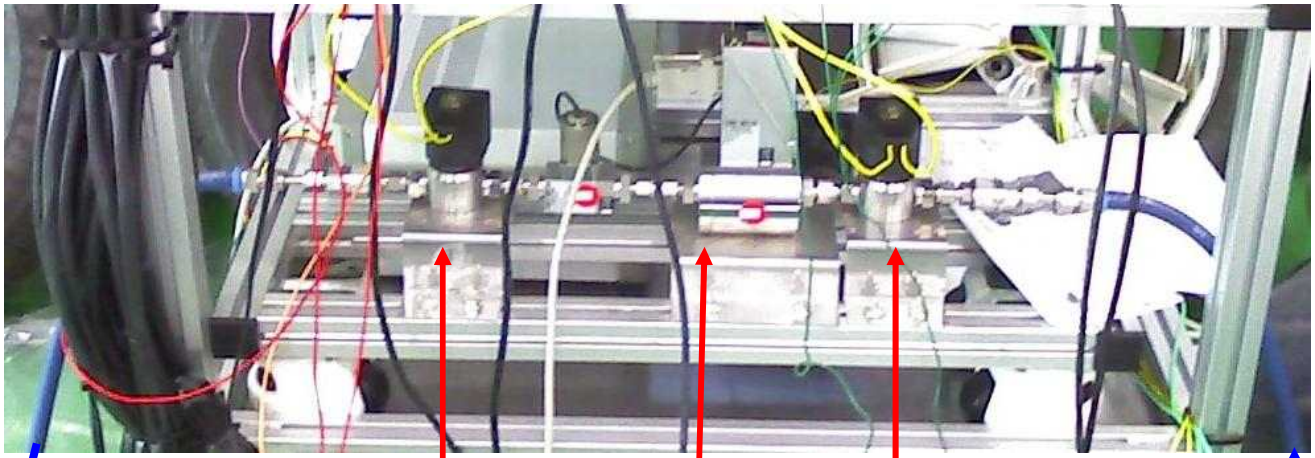
Hydrogen Safety

Hydrogen leakage Simulation System



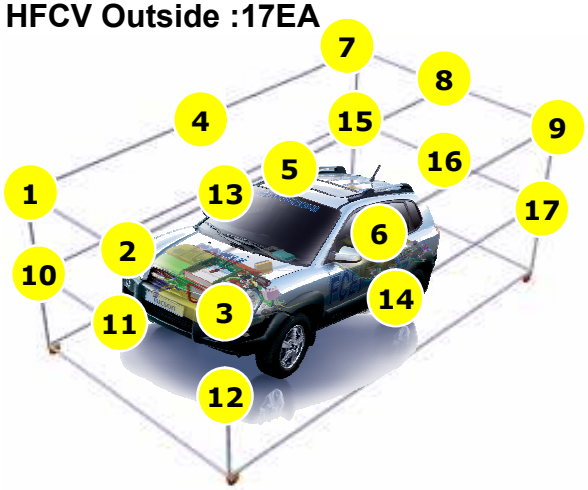


Hydrogen Safety

Hydrogen Sensors and Hydrogen Leakage Location

- **Hydrogen Sensors (34EA)**

HFCV Outside :17EA



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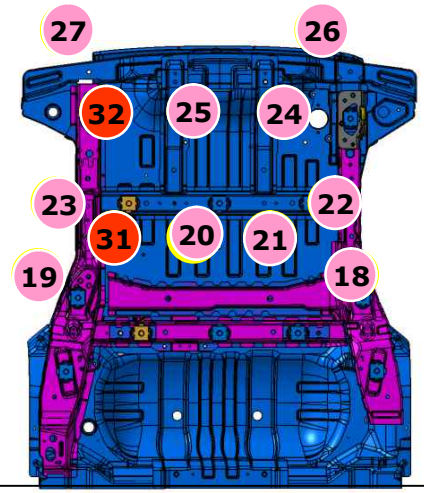
RR COMPLETE ASSY : 12EA



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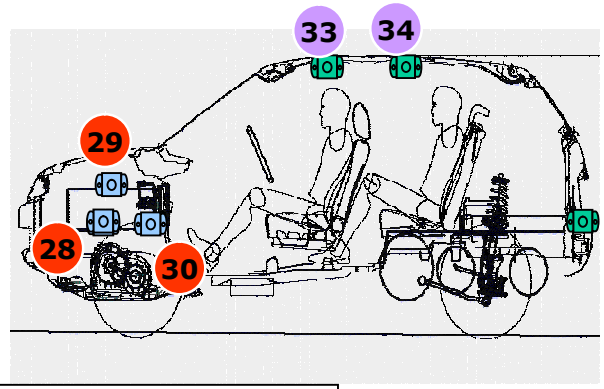
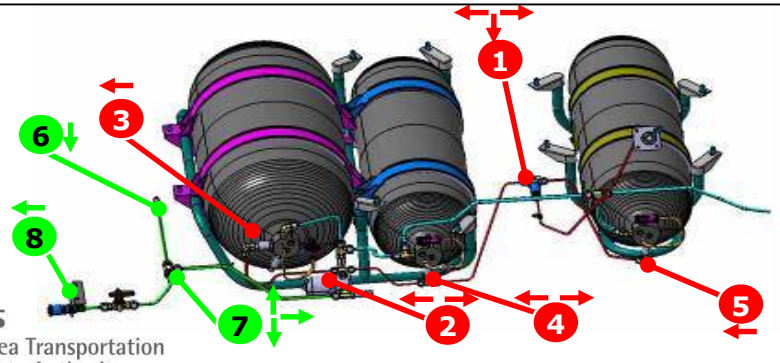
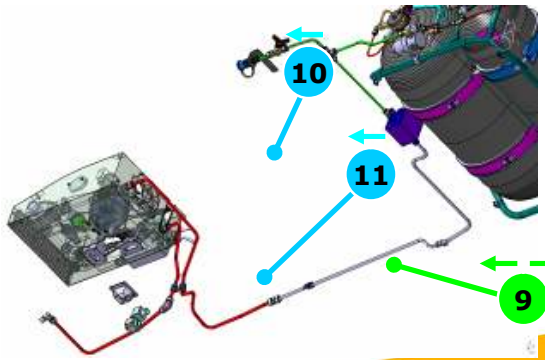
Engine Room : 3EA,
Inside : 2EA



- **Hydrogen Leakage Point** (High line 5 Points + Low line 4 Points + Engine room 2 Points)





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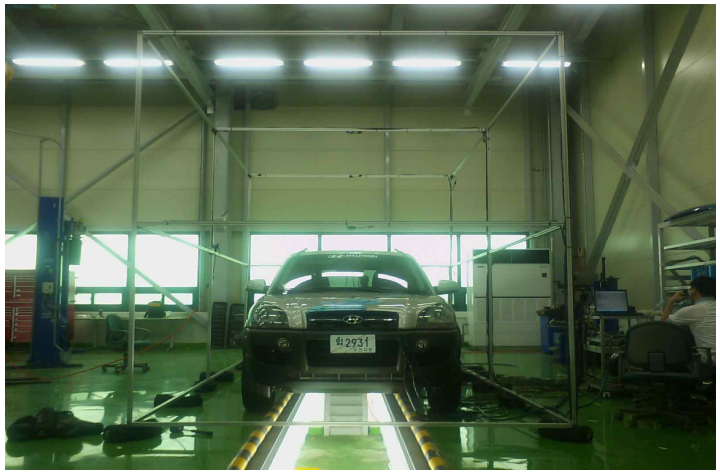
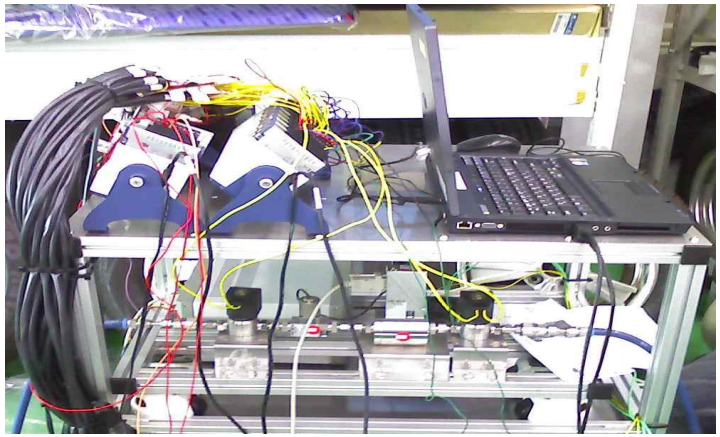
Hydrogen Safety

Hydrogen leakage Test

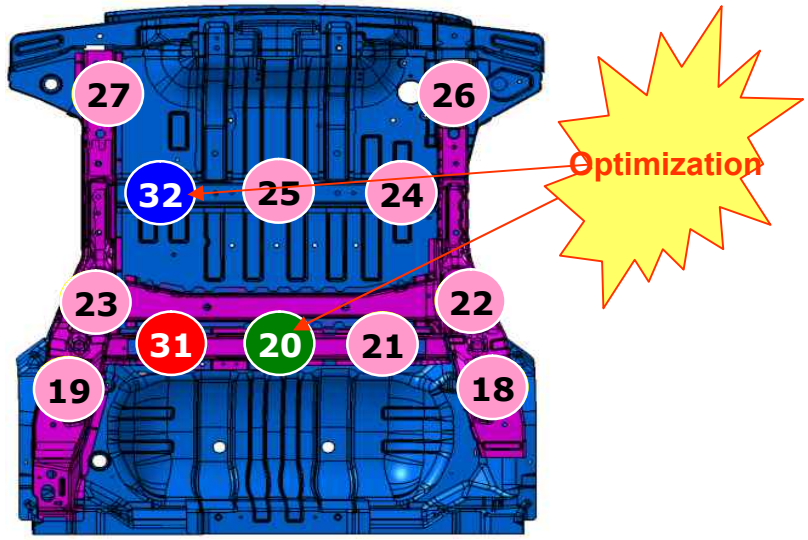




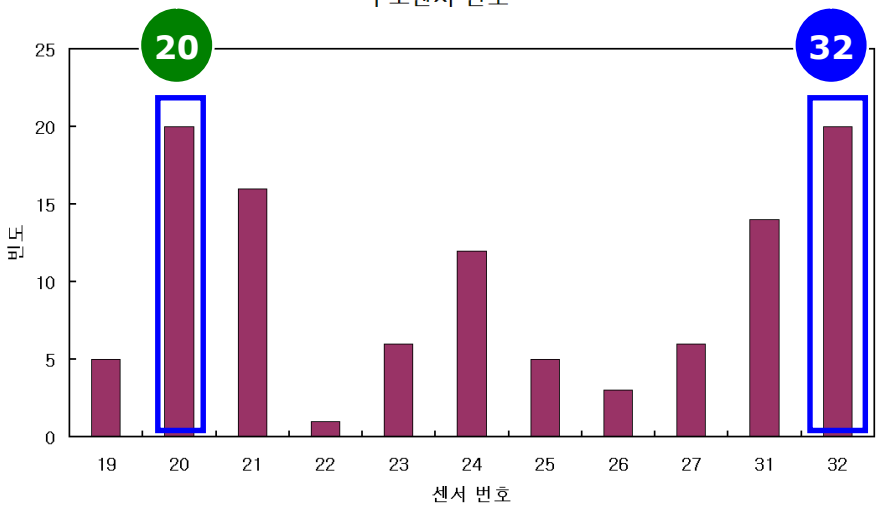
Hydrogen Safety

Test Result at rest (underbody)

누출위치		유량	1 센서		2 센서		3 센서	
누출 위치 번호	방향		센서	시간(초)	센서	시간(초)	센서	시간(초)
1	FR	10	24	11	25	15	32	16
		40	31	2	23	3	20	12
		131	31	2	19	4	23	5
	RR	10	27	6	32	7	25	23
		40	27	3	25	8	26	11
		131	27	2	26	5	25	5
	LH	10	24	12	32	30	26	41
		40	23	2	20	4	24	7
		131	23	2	20	3	31	4
2	FR	10	31	8	20	8	21	10
		40	31	12	20	13	21	17
		131	18	12	21	14	30	14
	RR	10	24	9	32	17	25	17
		40	23	2	32	4	25	5
		131	23	2	25	3	32	3
3	FR	10	21	11	20	19	24	22
		40	21	8	20	10	31	14
		131	20	5	31	5	24	10
4	FR	10	23	11	24	39	32	48
		40	19	1	31	2	20	8
		131	31	2	19	2	20	4
	RR	10	23	5				
		40	32	3	27	4		
		131	27	3	32	3	25	4
5	FR	10	32	3	27	10	24	15
		40	32	2	25	2	24	4
		131	25	2	32	3	22	3
6	RH	10	20	13	21	18	31	19
		40	18	5	21	6	20	6
		131	18	3	21	3	20	4
7	LH	10	20	13	31	21	32	23
		40	20	19	31	21	19	24
		131	19	7	20	41	31	47
	RH	10	21	15	20	17	31	17
		40	31	6	20	7	22	8
		131	20	3	31	4	21	4
	RR	10	21	10	20	12	32	19
		40	19	2	31	2	20	3
		131	19	2	31	2	23	2
8	FR	10	19	4	31	15	20	17
		40	19	2	31	8	20	10
		131	19	2	23	4	31	5



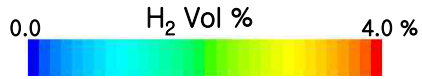
수소센서 빈도

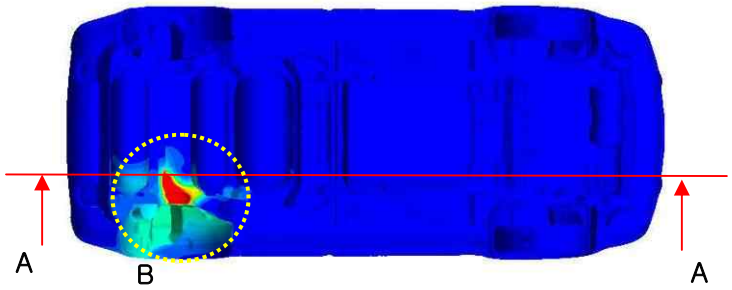


Hydrogen Safety

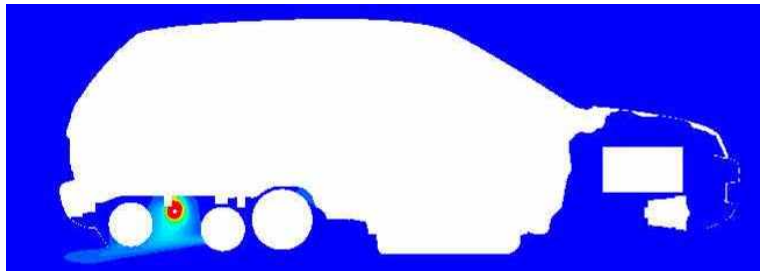
Leakage Analysis for a moving vehicle

- when hydrogen leaks for a moving, the area of leakage exits hydrogen
  → the hydrogen sensors of leakage point reach 4 % H_2

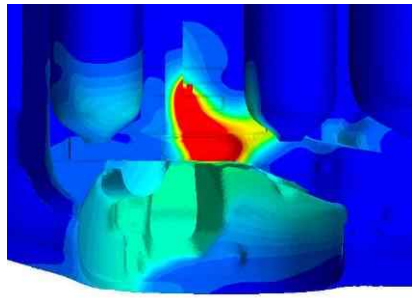




자동차 하부 **VIEW**

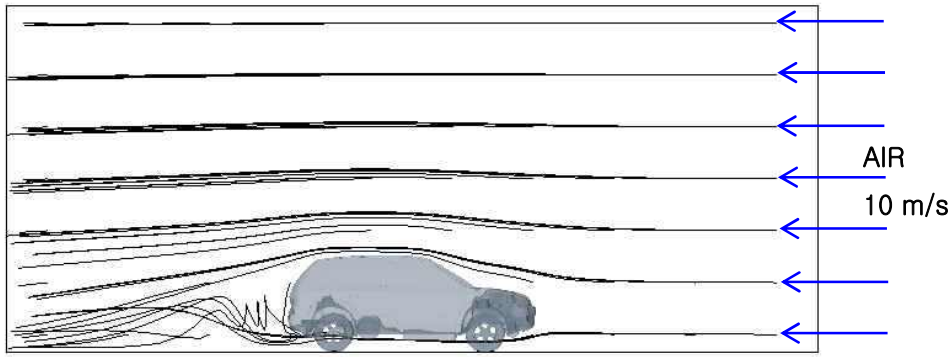


SECTION A-A

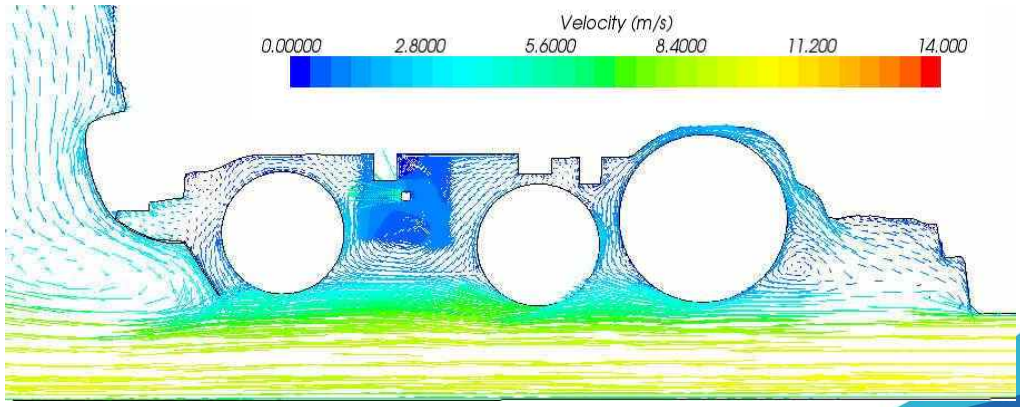


DETAIL B

- when hydrogen leaks for a moving, Hydrogen leaked is diffusion to the outside by the outside air flow



the outside air flow



The area of hydrogen contaioner (SECTION A-A)

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Vehicle Operation Safety

Frontal Impact Test

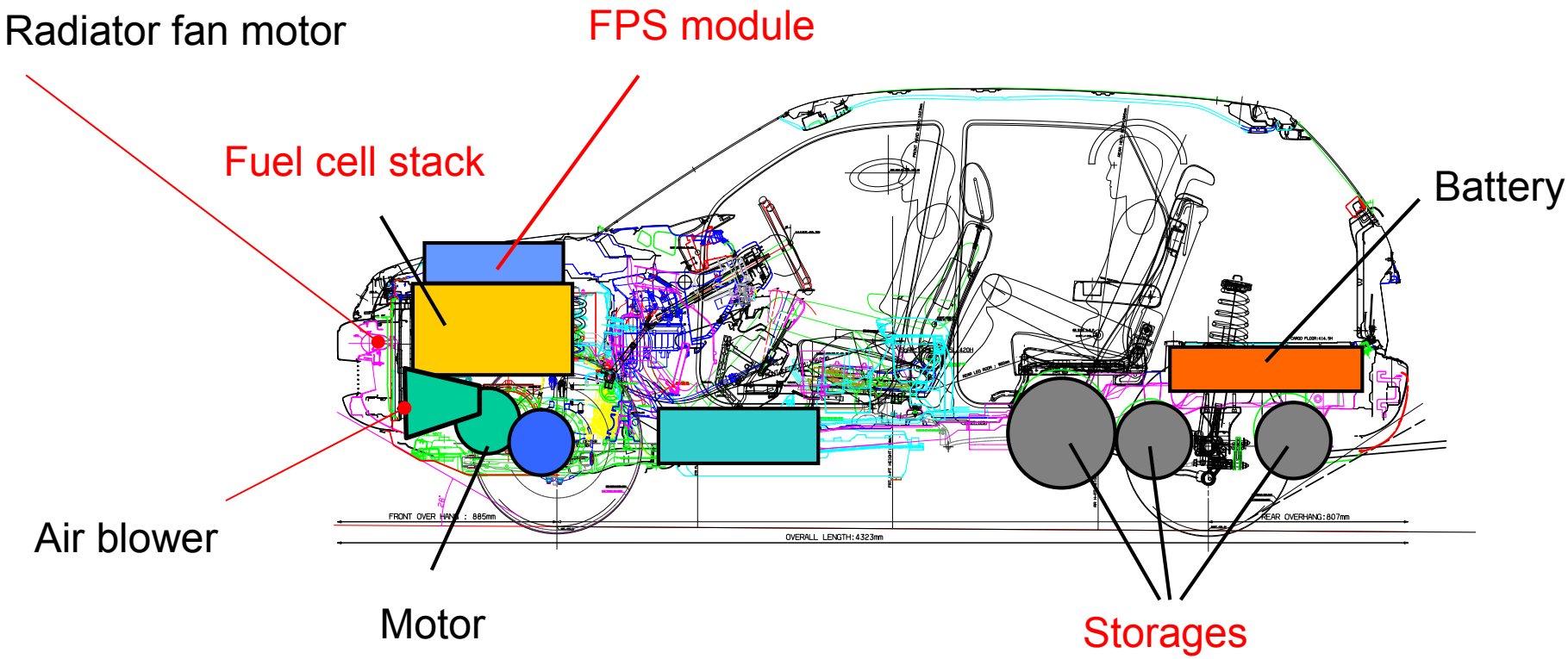
- **Goals**
  - Verification of vehicle fuel system integrity, electrical safety and occupants safety

- **Test Vehicle**
  - Fuel cell vehicle (SUV)

- **Test Conditions**
  - KMVSS article 91, 102
    : 48 km/h full frontal impact test with hybrid Ⅲ 50 %ile male dummies
  - Filled with helium 90 % of normal working pressure (152 liter × 31.5 MPa)
  - During the crash, opened storage valve (severe condition)

Vehicle Operation Safety

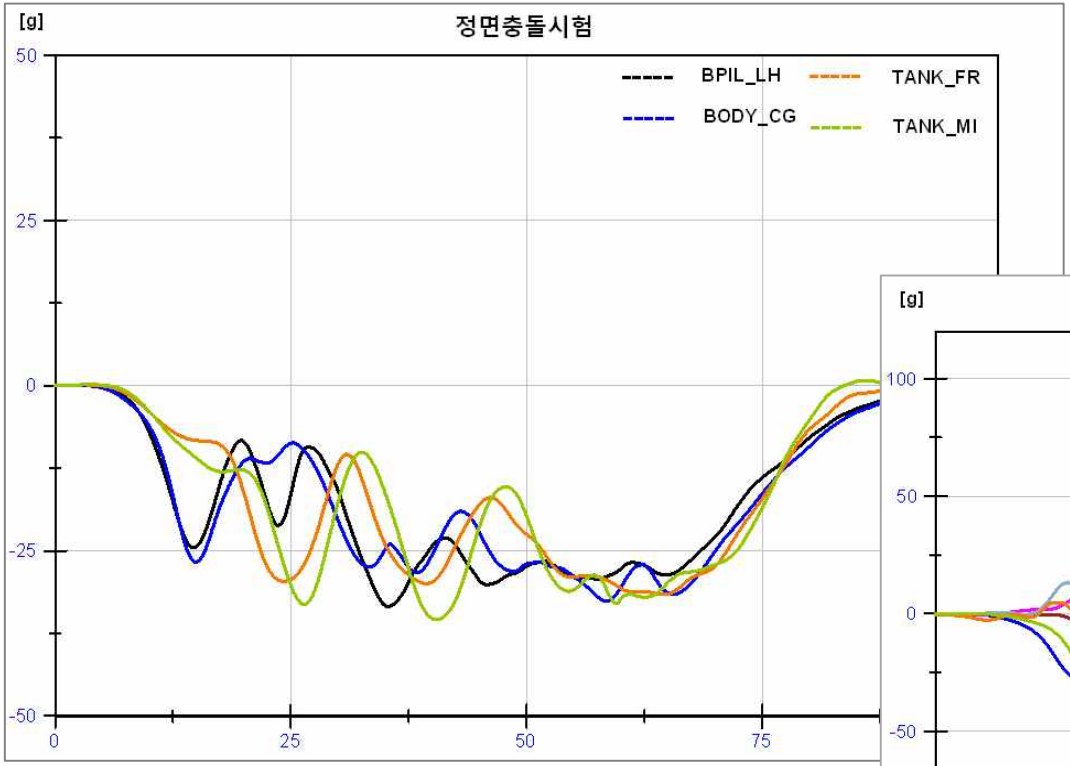
Frontal Impact Test : Locations of acceleration sensors

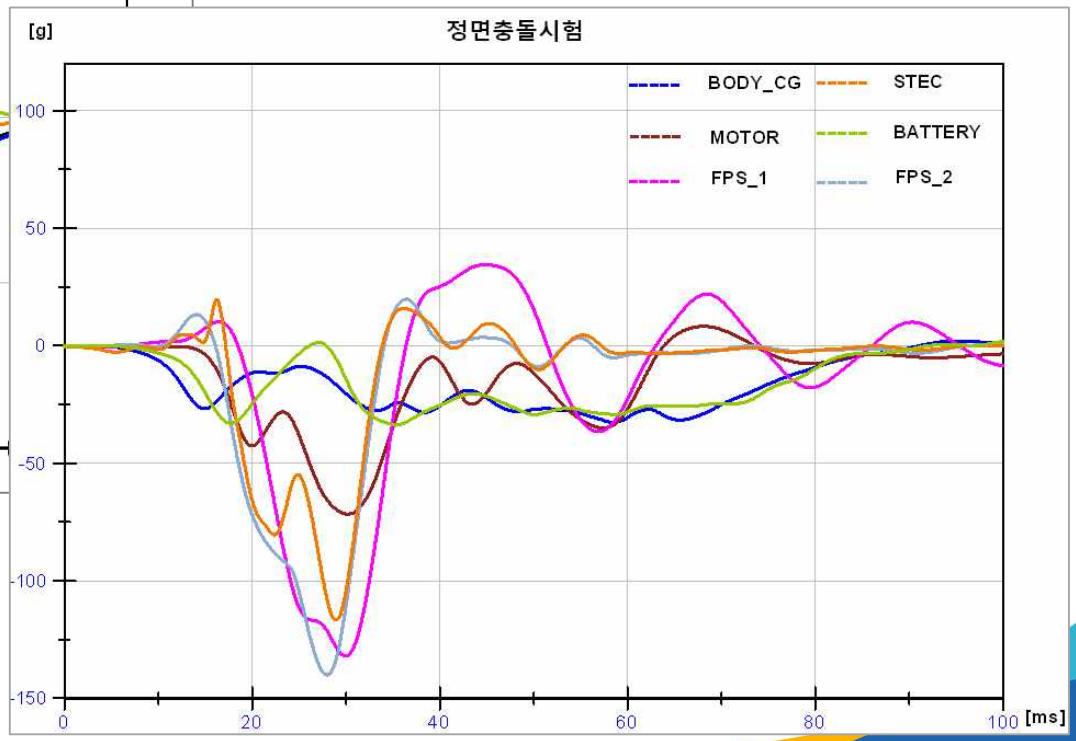


FPS: Fuel Processing System

Vehicle Operation Safety

Frontal Impact Test : Acceleration Curves



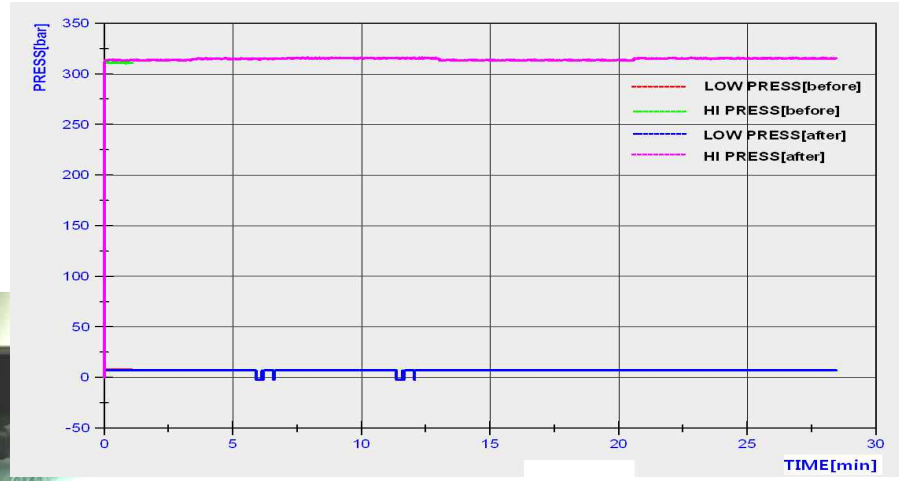


- At body, storages, battery: about 30 g
- At stack and FPS, located in front of vehicle, high : 120~140 g

Vehicle Operation Safety

Frontal Impact Test : Results

- **After frontal impact, no helium leakage**
  - High pressure sensor : 31.5 MPa
  - Low pressure sensor : 0.8 MPa
  - Even though FPS and stack were exposed to high acceleration(120~140 g), no helium leakage
  - Met occupant safety requirements



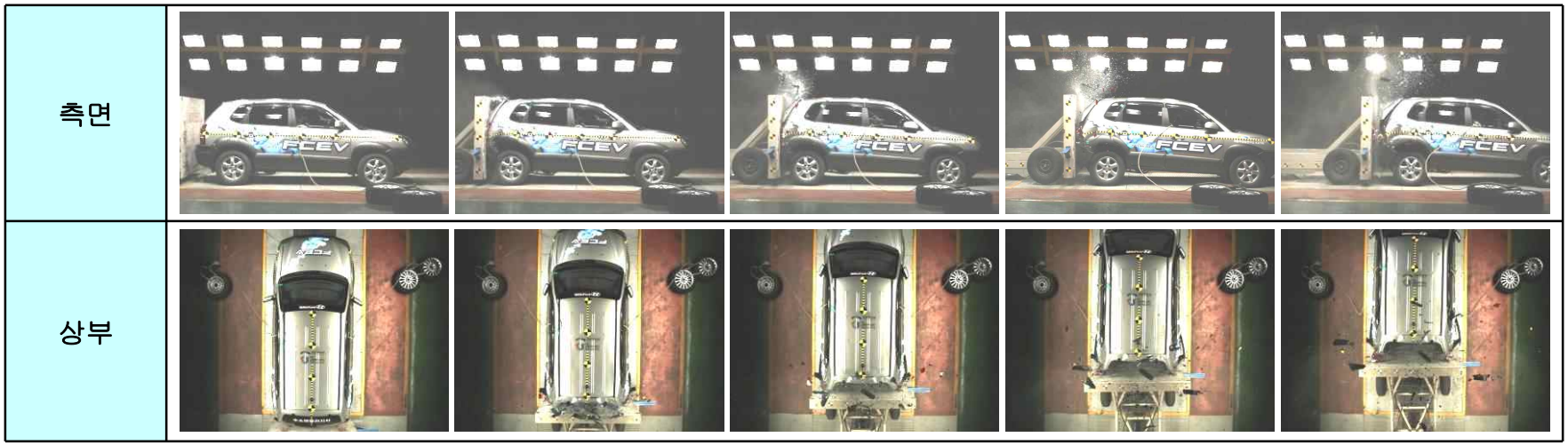
Vehicle Operation Safety

Rear Impact Test

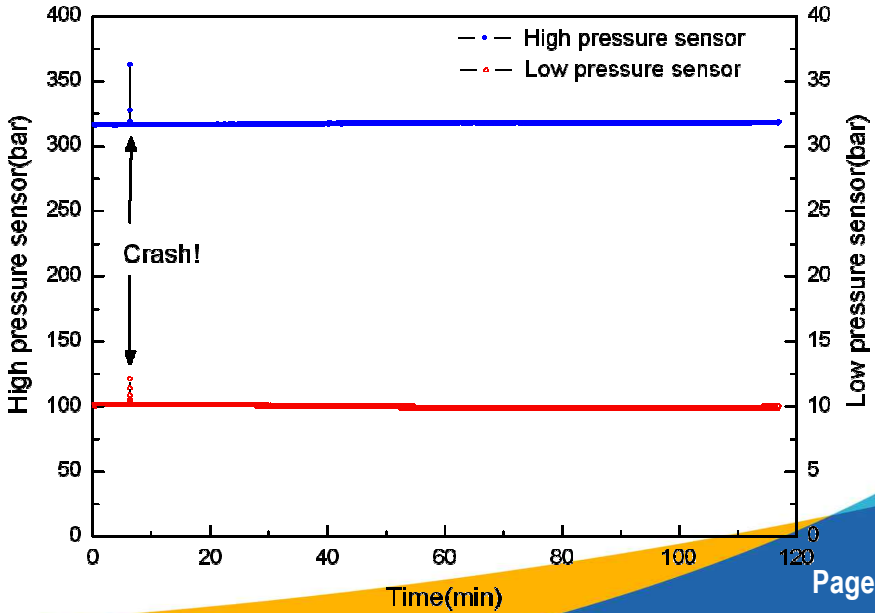
- Test Vehicle : SUV (2002kg)
- Test Condition : 48.1km/h, Moving barrier(1,805 kg)
- Test material and Pressure : Helium, high(33MPa)/Low(1MPa)
- Container Deformation sensors : 21 EA
- Locations of acceleration sensors : Body 3 EA / Container 4 EA
- Pressure sensors : High 1 / Low 1

Vehicle Operation Safety

Rear Impact Test : Results



- **After frontal impact, no helium leakage**
  - High pressure sensor: 33 MPa
  - Low pressure sensor: 1.0 MPa



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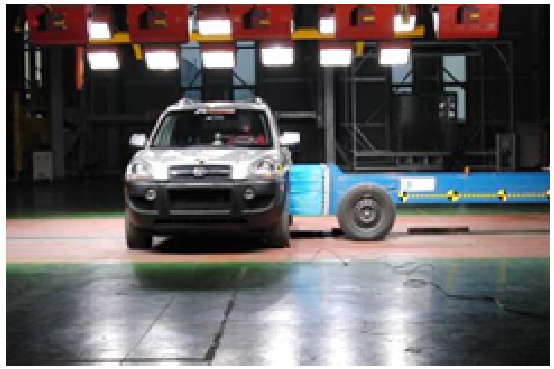
Vehicle Operation Safety

Side Impact Test

- **Goals**
  - Verification of vehicle fuel system integrity, electrical safety and occupants safety

- **Test Vehicle**
  - Fuel cell vehicle (SUV)

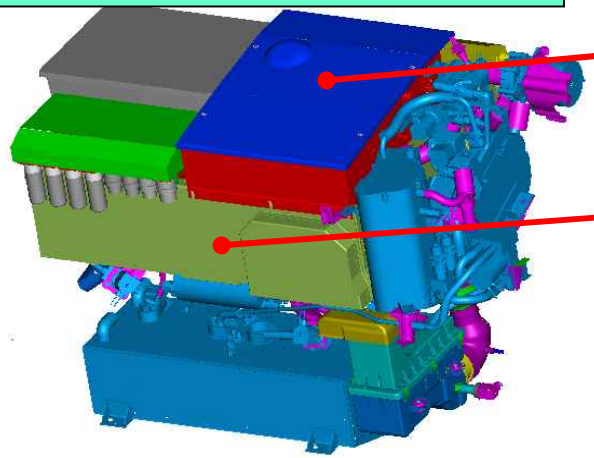


- **Test Conditions**
  - KMVSS article 102
    : 50 km/h side impact test with deformable moving barrier (950 kg)
  - Filled with helium 90 % of normal working pressure (152 liter × 31.5 MPa)
  - During the crash, opened storage valve (severe condition)

Vehicle Operation Safety

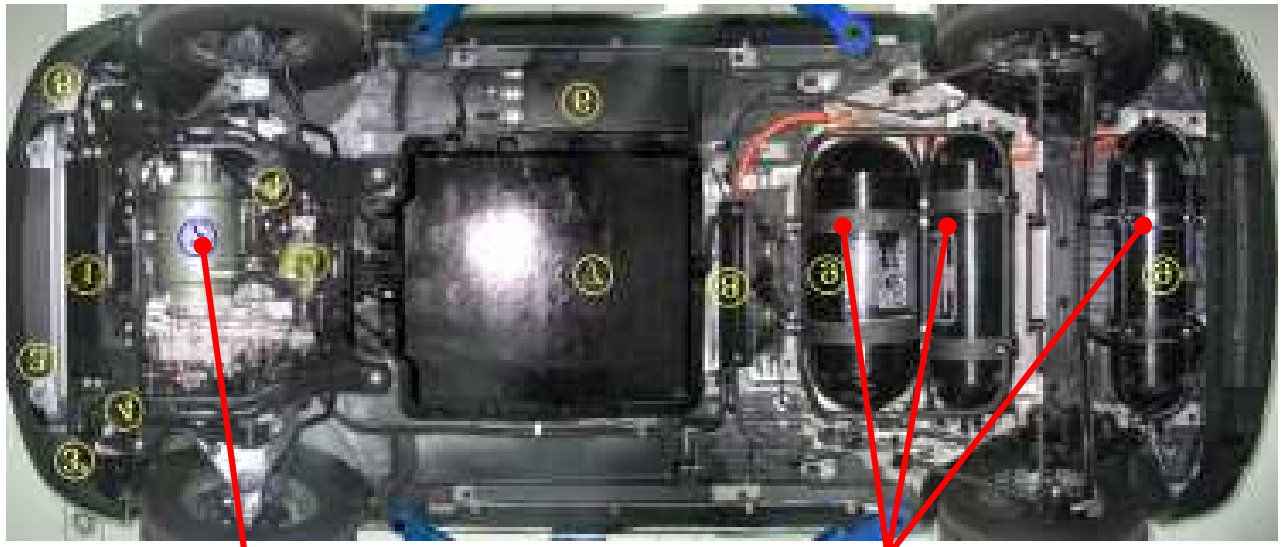
Side Impact Test : Locations of acceleration sensors

Battery



FPS module

Stacks

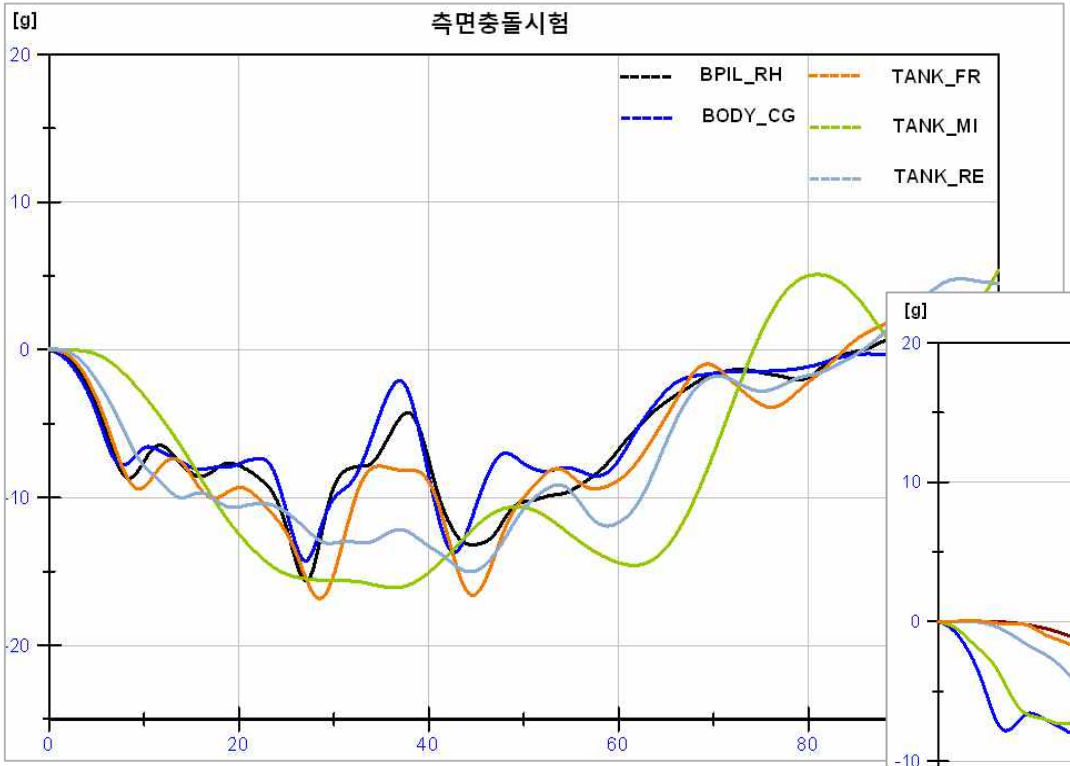


Motor

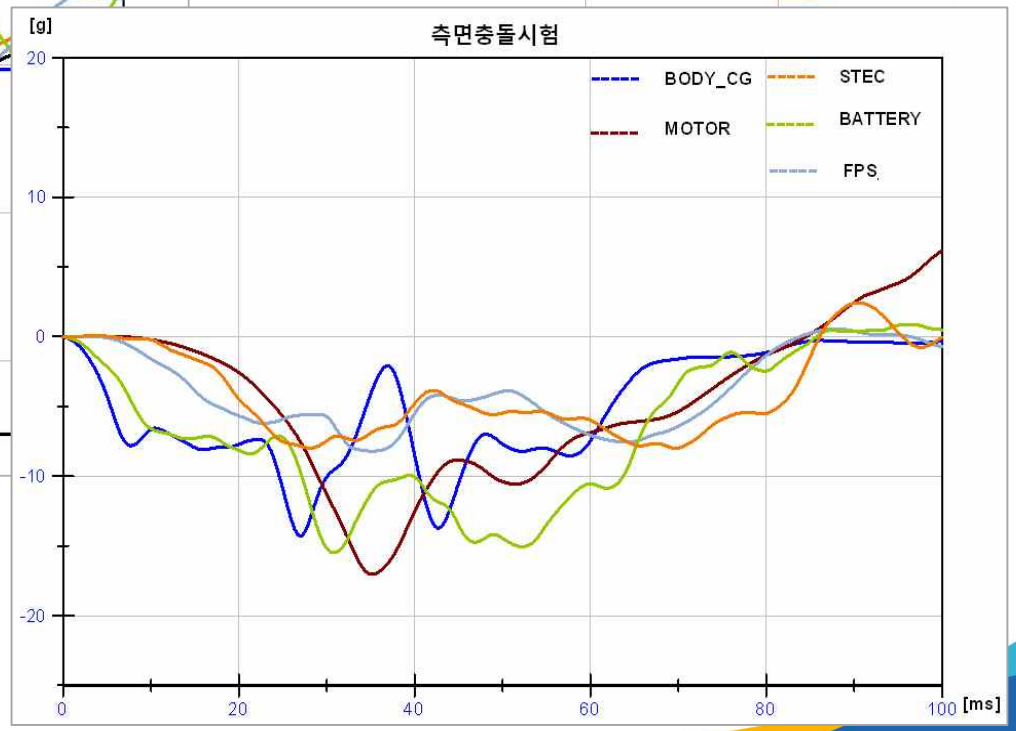
Storages

Vehicle Operation Safety

Side Impact Test : Acceleration Curves



- Accelerations at body, storages, battery were similar
- Accelerations at stack and FPS were relatively lower because they were located in front of vehicle



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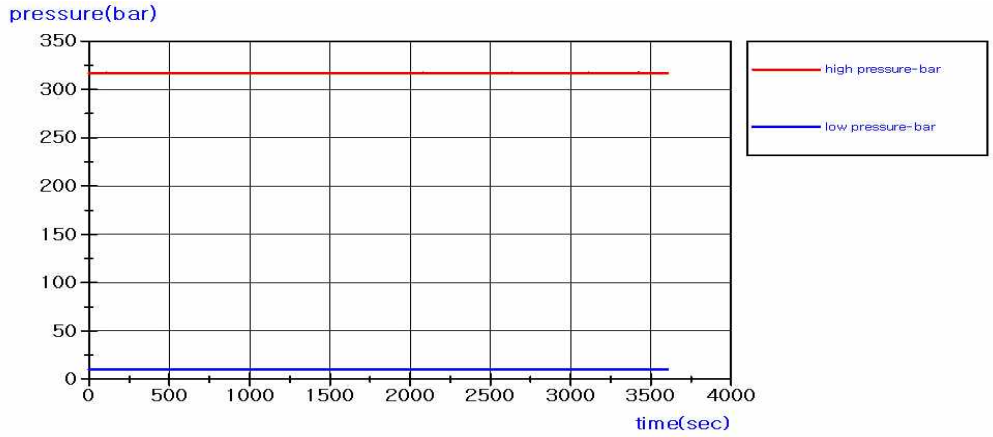
Vehicle Operation Safety

Side Impact Test : Results

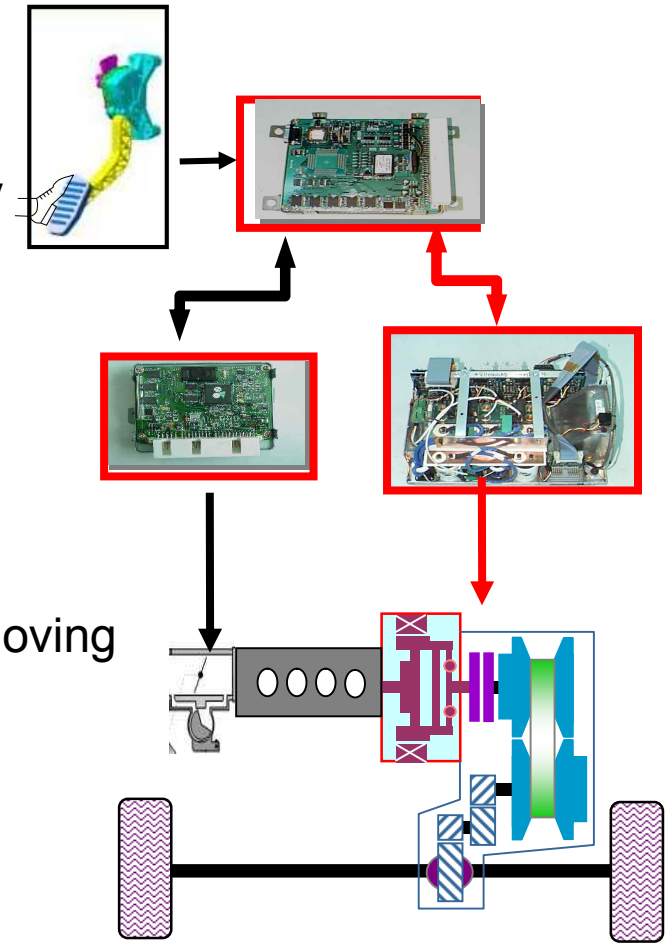
- **After impact, no helium leakage**
  - High pressure sensor: 31.5 MPa
  - Low pressure sensor: 0.8 MPa
  - Met occupant safety requirements



Vehicle Operation Safety

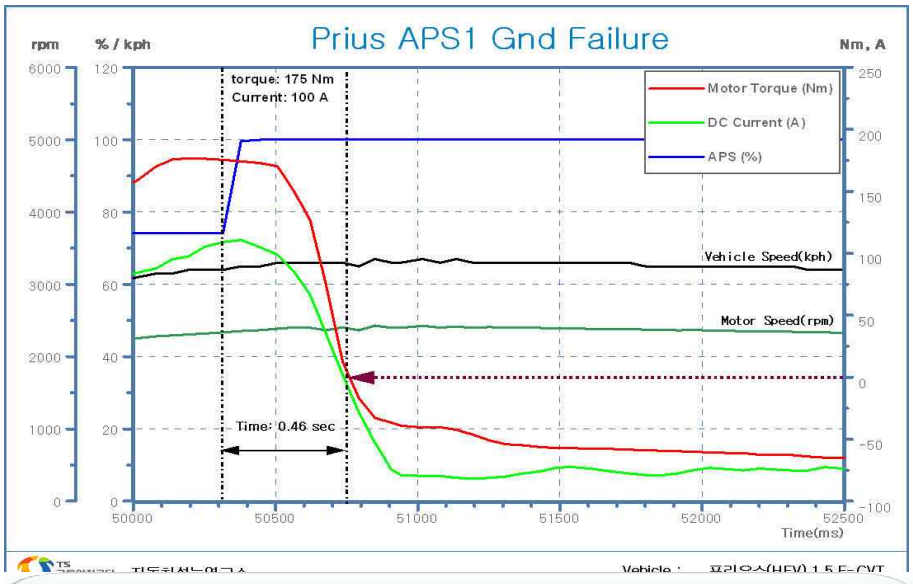
Fail-safety Evaluation

- **Goals**
  - Verification of the Acceleration Control System Safety
- **Test Vehicle**
  - Hybrid vehicle : Prius THS-Ⅱ, Verna, NEV
- **Test Conditions**
  - KMVSS article 87 & Test Procedure 25
  - Fail condition : the normal state by wire cutting or removing
    - Prius : APS #1 GND, U-Phase Current Signal
      Motor Temperature
    - Verna : APS #1 GND, Resolver S1 Signal
      Motor Temperature

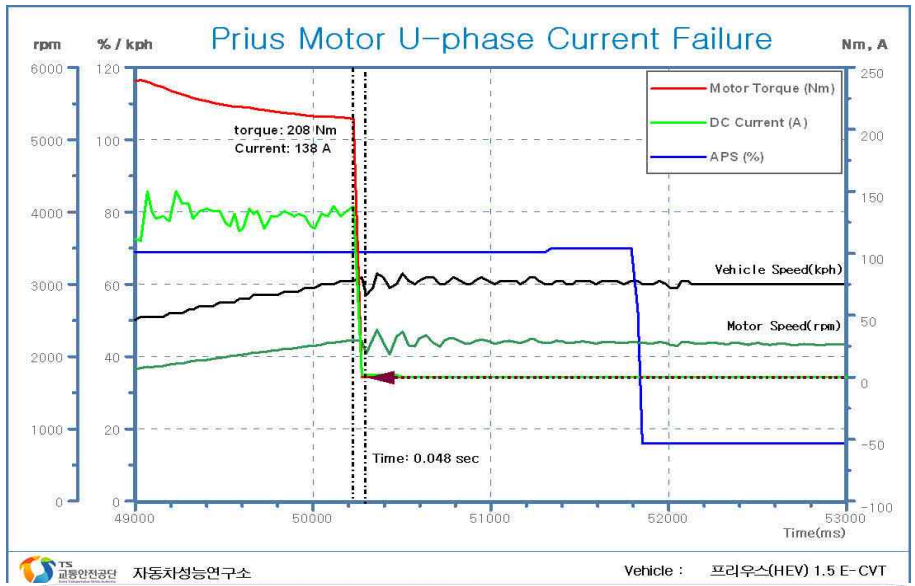


Vehicle Operation Safety

Prius THS II (EV driving)



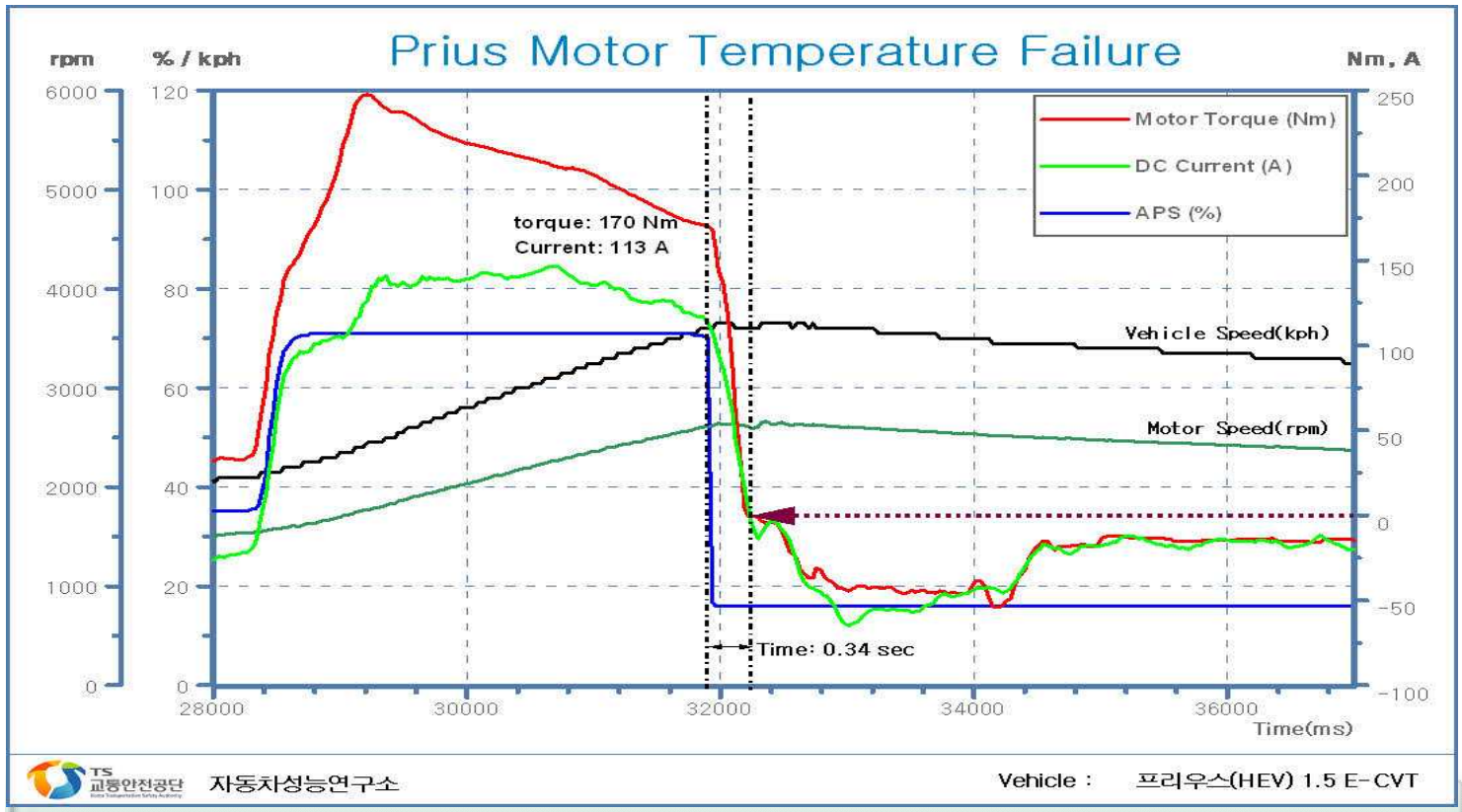
- APS 1 Gnd Failure
- Idle Return Time : 0.4 sec
- Max Torque :175Nm, Current :100A



- U-Phase Current Signal Failure
- Idle Return Time : 0.04초
- Max Torque :208Nm , Current :138A

Vehicle Operation Safety

Prius THS II (EV driving)



- Motor Temperature Sensor Failure
- After Failure, Normal Condition
- Max Torque : 170Nm , Current : 113 A

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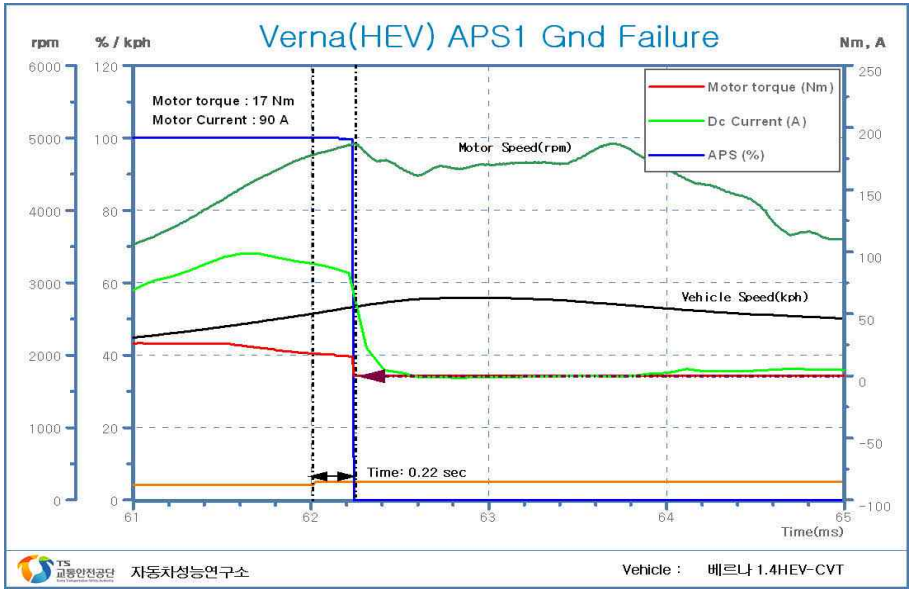
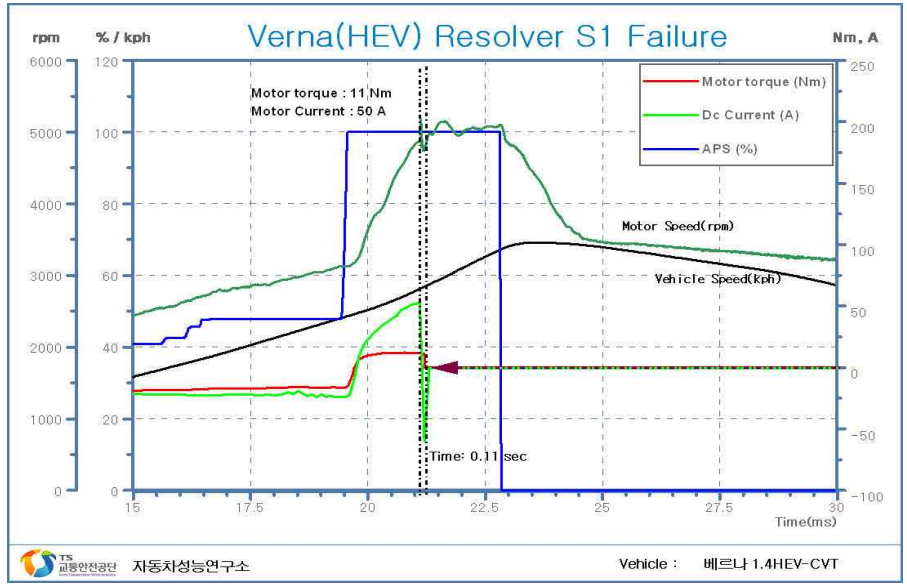
Vehicle Operation Safety

Verna (HEV)





- APS 1 Gnd Failure
- Idle Return Time : 0.22 sec
- Max Torque :17Nm, Current :90A

- Resolver S1 Signal Failure
- Idle Return Time : 0.11초
- Max Torque : 11Nm , Current :50A

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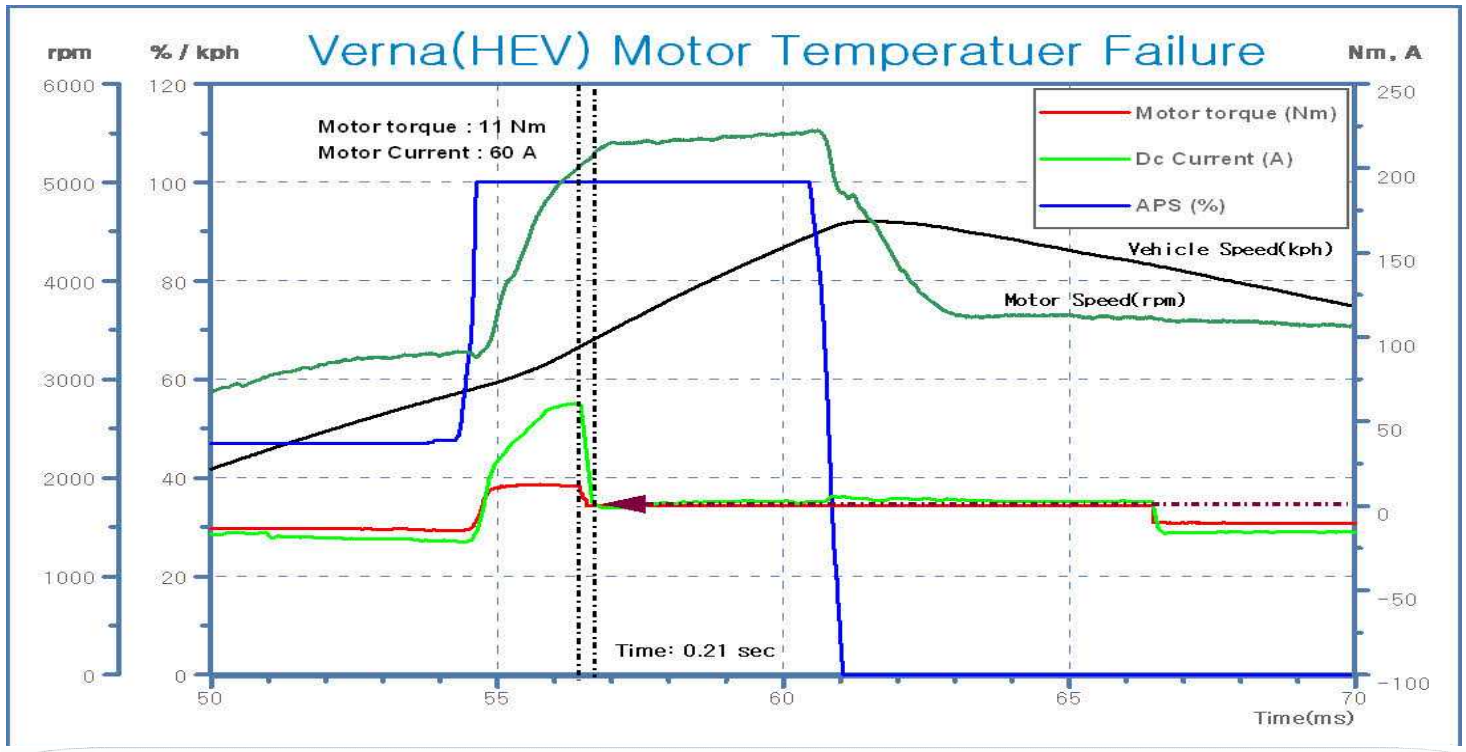
Vehicle Operation Safety

Verna (HEV)



- Motor Temperature Sensor Failure
- After Failure, the motor power shut off
- Max Torque : 11Nm , Current : 60 A

Vehicle Electric Safety

Post Crash : Frontal Impact

❑ Insulation Resistance after Crash

- Traction battery ↔ vehicle body: 4.8 kΩ /V (req.: 100 Ω/V)
- Small amount of electrolyte spillage

❑ Remarks

- Because frontal part of vehicle was severely damaged, accessibility for Insulation resistance measurement was poor
- Poor accessibility may lead to electric shock
- Need to specify measurement method of electrolyte spillage (7%, 5 liters) and electrical energy (within 0.2 Joules)

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Vehicle Electric Safety

IN-USE : Direct Contact

IPXXD (Test wire)

IPXXB (Test finger)

- **Test Results**
  - IPXXB, IPXXD Evaluation : Pass
    - · Passenger/ Luggage compartment
    - · Bonnet/Underneath
    - · Connectors
  - Marking and Color orange

(Bonnet)

(Underneath)

(Luggage)

Vehicle Electric Safety

IN-USE : Isolation Resistance

➢ Test Results

- Minimum Value : 100 ohms/volt of the working voltage for DC buses

  500 ohms/volt of the working voltage for AC buses

· lowest insulation resistance was between outer cover of stack and terminal of stack(-) : 1.28 kΩ/V

Vehicle Electric Safety

IN-USE : Indirect Contact

- Test Results
  - Criteria : less than 100 mΩ
    - · High voltage box enclosure ↔
      Chassis : **5.4 mΩ**
    - · Supercapacitor enclosure ↔
      Door hinge : **316.2 mΩ**
    - · Supercapacitor enclosure ↔
      Chassis : **45.4 mΩ**

Conclusion

- **Hydrogen Safety**
  - Conducted the Single Failure Conditions Test of Hydrogen Leakage
  - Confirmation of proposed GTR Draft
- **Vehicle Operation Safety**
  - Conducted full scale vehicle frontal and side, rear impact tests
  - No malfunction in vehicle fuel system integrity after impact tests
  - Confirmation of proposed GTR Draft
- **Vehicle Electrical Safety**
  - In-use and post-crash, electrical isolation and electrical continuity met GTR
  - In case of frontal post-crash, because of severe damage to frontal part of vehicle, it is not easy to measure electrical continuity

In this study, the main objective is to develop technology that the structure and equipment of the hydrogen fuel cell vehicles should meet the safety of the citizens to protect the lives such as hydrogen and high-voltage devices

Thank you very much for your attention !

Acknowledgement

This research was supported by a grant (07-Transport System-Furture-02) from Transportation System Innovation Program funded by MLTM

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