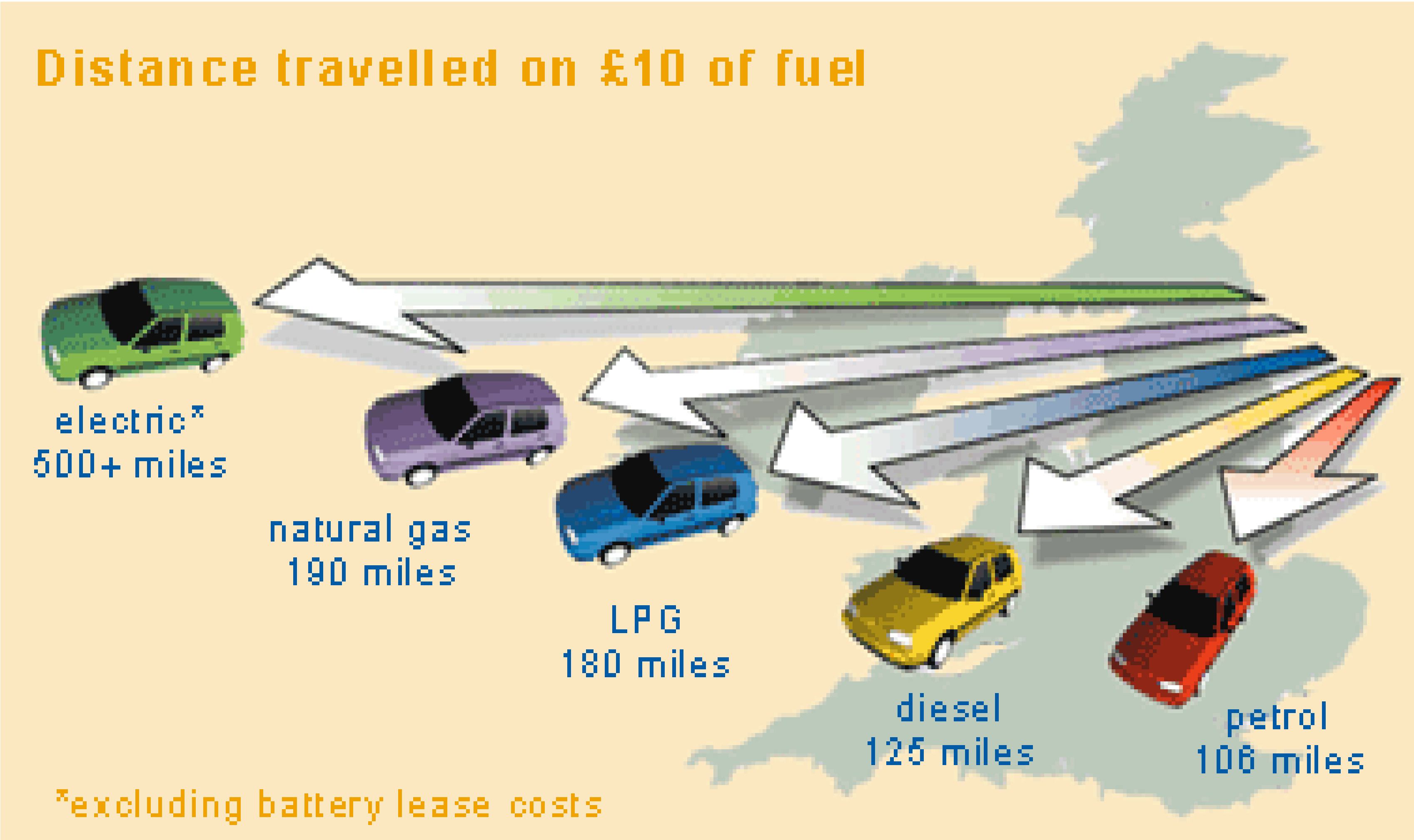
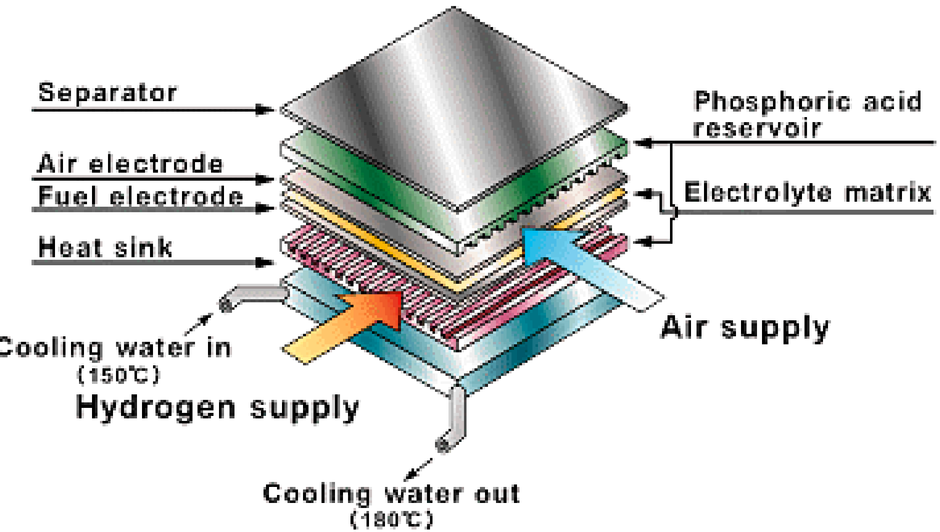
Fuel Consumption Test for Hydrogen FCVs

The argument for an alternative
But what are the snags !!



FUEL CELLS



Fuel cells generate electricity by combining oxygen and hydrogen without combustion.

The diagram below shows that, hydrogen fuel enters at the anode, oxygen (in the form of air) enters through the cathode. The hydrogen splits into a proton and electron, which move to the cathode and join with the oxygen to create water.

FUEL CELLS

- Fuel cells have short refuelling times and can travel further between refuelling than comparable battery powered electric vehicles (BEV). When fuelled by hydrogen, no emissions are produced and other fuels produce near zero emissions. The downside is that it is still a relatively young technology and thus requires time for costs to reduce to levels acceptable to the consumer.

FUEL CELLS

- Although hydrogen is a popular choice of fuel, it has a low density in liquid and gas phase. Methanol is the next choice as it can be readily derived from hydrogen but the reforming of methanol produces CO_2, although only 10% of what ICE's produce. The other advantage is that methanol can be handled as simply as gasoline and is easily produced from natural gas or biogas.

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Fuel Cell Vehicles

Although they are not expected to reach the mass market before 2010, fuel cell vehicles (FCVs) may someday revolutionize on-road transportation.

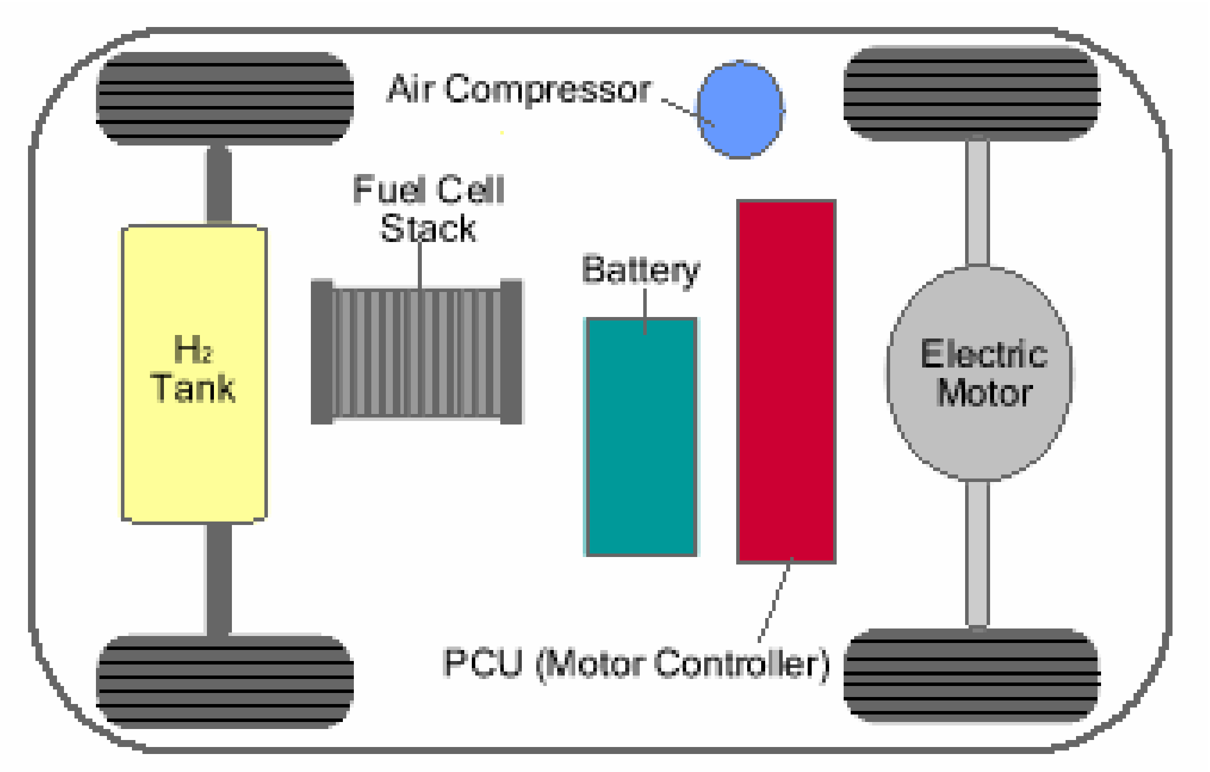
The potential to significantly reduce energy use and harmful emissions, as well as our dependence on foreign oil.
No Greenhouse Gases
No Air Pollutants (no smoke and harmful particulates)
Helps Strengthen National Energy Security
More Energy Efficient
Design Flexibility
Quieter

skateboard-shaped

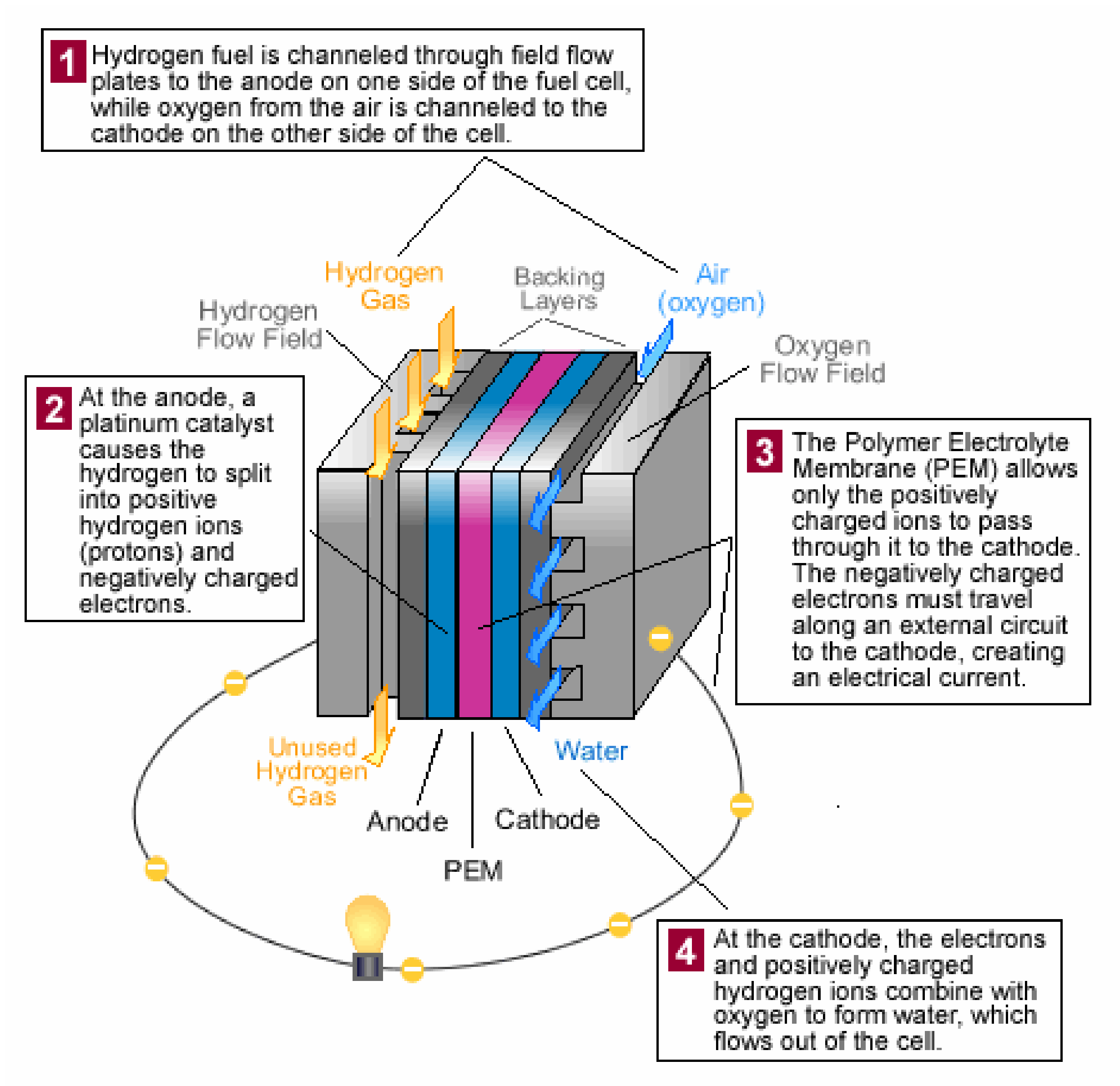
One Example of FCV – Ford's 3rd Generation

a Ni-MH high voltage battery with the hydrogen-powered fuel cell engine

Hydrogen FC System for Vehicle



How Fuel Cell Works

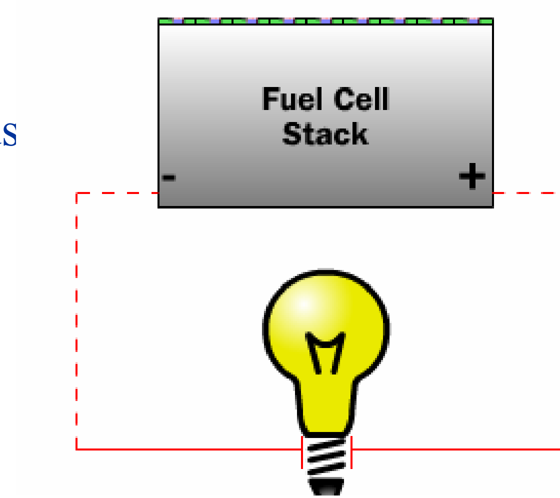


FC Stack

- Most fuel cells designed for use in vehicles produce less than 1.16 volts of electricity-far from enough to power a vehicle.

- Multiple cells must be assembled into a fuel cell *stack*.

- The potential power generated by a fuel cell stack depends on the number and size of the individual fuel cells that comprise the stack and the surface area of the PEM (Polymer Electrolyte Membrane, also called Proton Exchange Membrane).



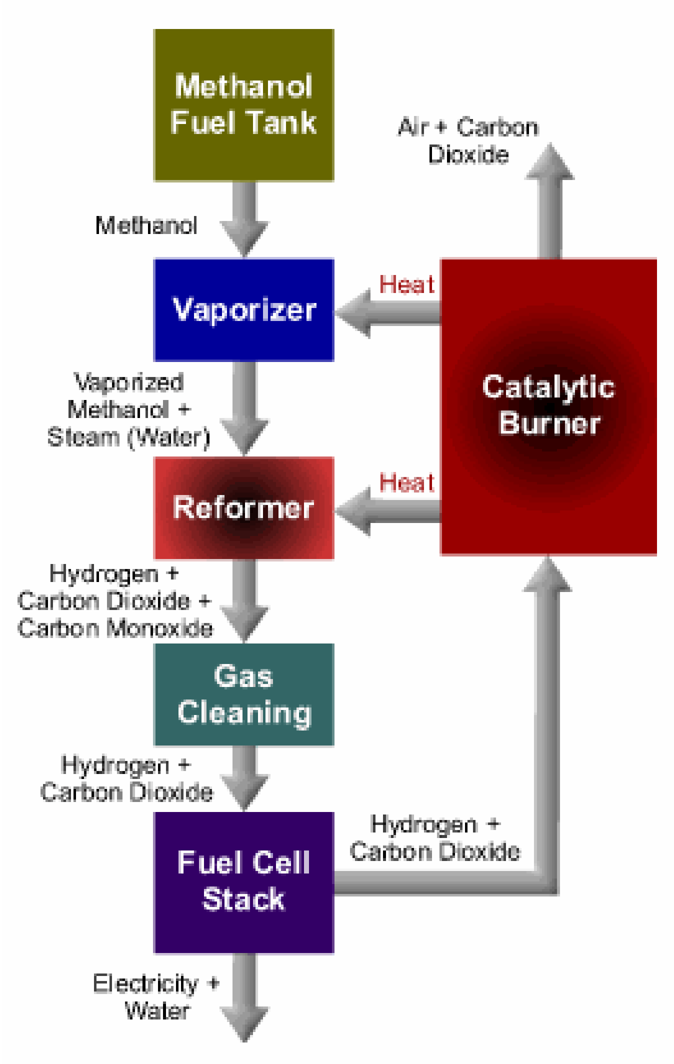
Various FCs

- FCVs can be fueled with pure hydrogen gas stored onboard in high-pressure tanks.

- They also can be fueled with hydrogen-rich fuels; such as methanol, natural gas, or even gasoline; but these fuels must first be converted into hydrogen gas by an onboard device called a "reformer."

- Solid oxygen FC

H2-Rich Fuel FC



Solid Oxygen FC

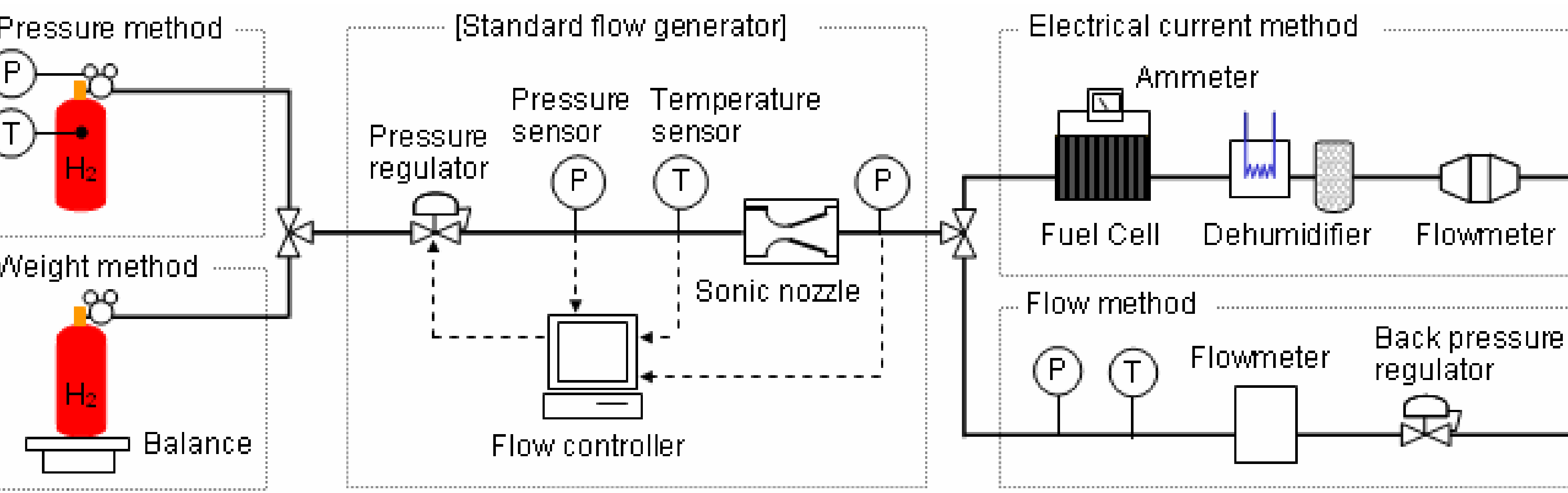
- Because of the high operating temperature (between 700 and 1000 °C), the SOFC can be made of non-noble and therefore relatively cheap materials

- It can convert several fuels other than hydrogen.

Challenges

- Onboard Hydrogen Storage
- Cold-weather Operation (Freezing, low T performance)
- Getting Hydrogen to Consumers
- Cost (the costs of the electrolyte membrane and catalyst - the catalyst is made of platinum)
- Safety
- Competition with Other Technologies (Hybrid, Diesel, GDI, HCCI)

Accuracy Verification Testing System for Measurement Method



Electrical Current Method

$$W = (n \times m \times \Sigma I)/(v \times F)$$

W = Fuel consumption [g]

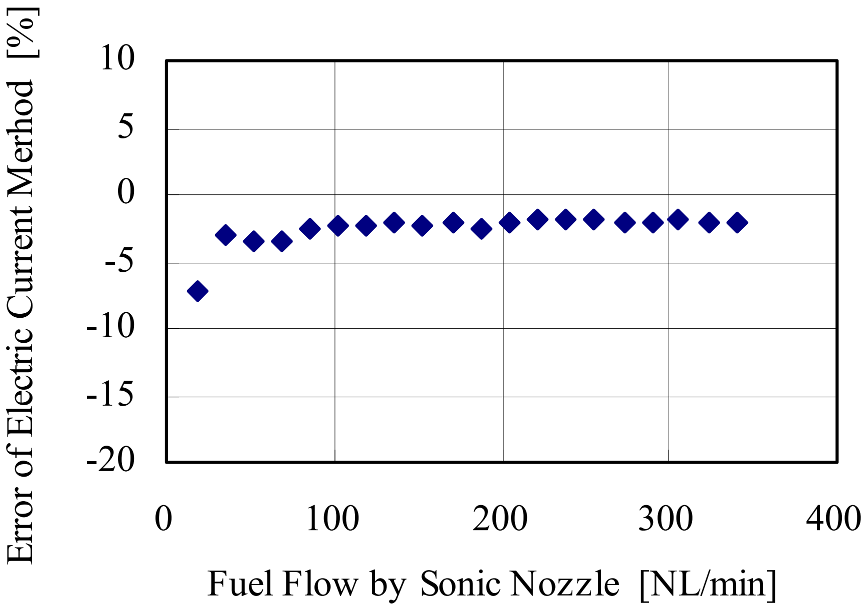
n = Number of cells of fuel cell stack

m = Molecular weight of hydrogen 2.016 [g/mol]

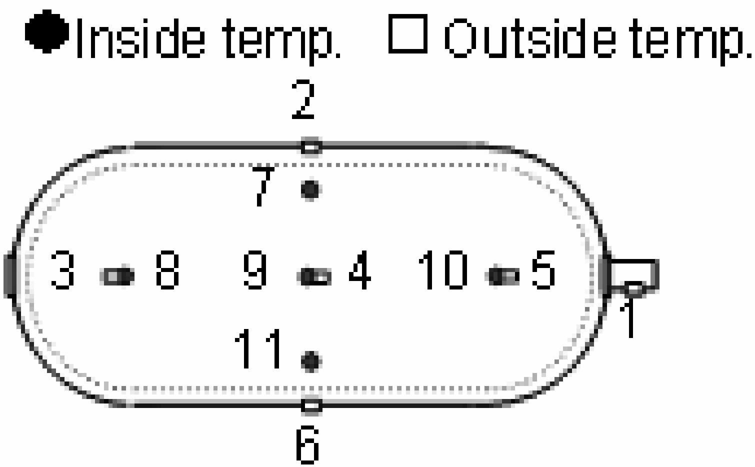
ΣI = Integrated current of fuel cell stack [A·sec]

v = Valence number of hydrogen 2

F = Faraday constant 9.6485×10^4 [C/mol]



PRESSURE METHOD (P/T METHOD)



1. Outlet pipe	7. Upper(in)
2. Upper(out)	8. Center-left(in)
3. Center-left(out)	9. Center(in)
4. Center(out)	10. Center-right(in)
5. Center-right(out)	11. Lower(in)
6. Lower(out)	12. Ambient

PRESSURE METHOD (P/T METHOD)

$$W = m \times \frac{V}{R} \times \left(\frac{P_1}{z_1 \times T_1} - \frac{P_2}{z_2 \times T_2}\right)$$

W = Fuel consumption [g]

m = Molecular weight of hydrogen 2.016 [g/mol]

V = Volume of hydrogen tank [m3]

R = Gas constant 8.314 [J/mol·K]

P1 = Hydrogen tank pressure before test [Pa]

P2 = Hydrogen tank pressure after test [Pa]

T1 = Hydrogen tank temperature before test [K]

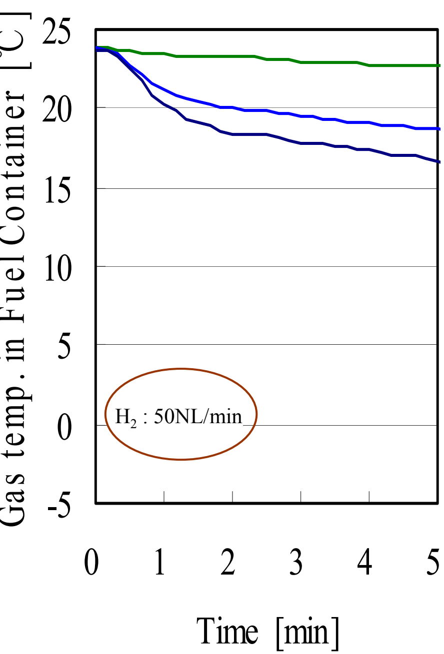
T2 = Hydrogen tank temperature after test [K]

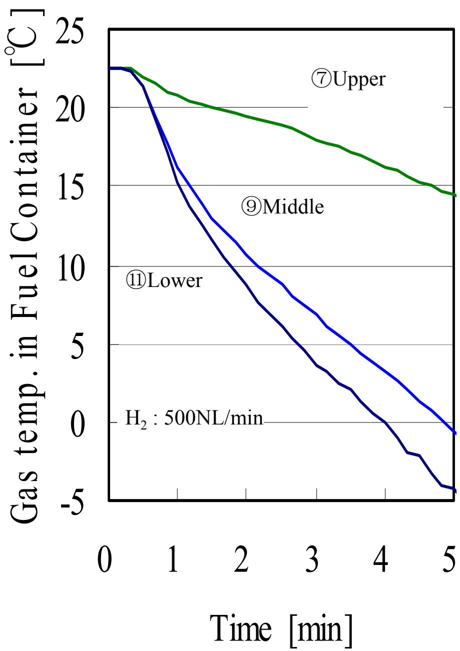
z1 = Compressibility factor at P1, T1

z2 = Compressibility factor at P2, T2

PRESSURE METHOD (P/T METHOD)

Change in Inside Gas Temperature and Tank Surface Temperature during Gas Discharge



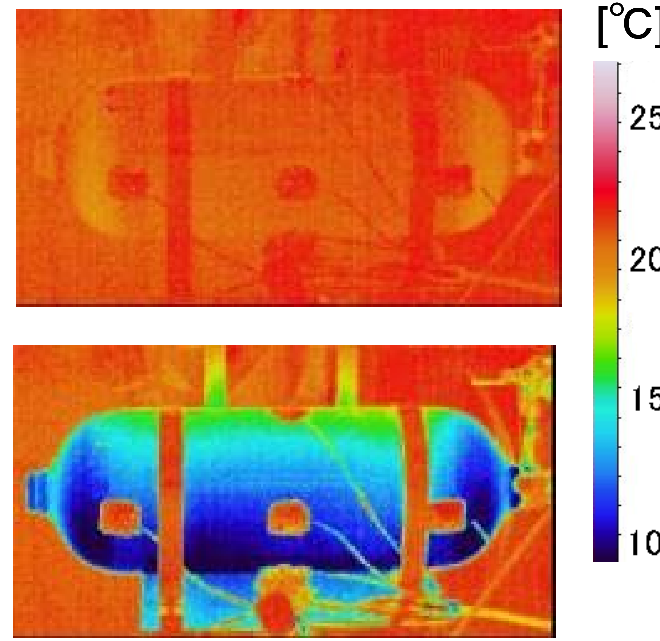


Time from gas discharge

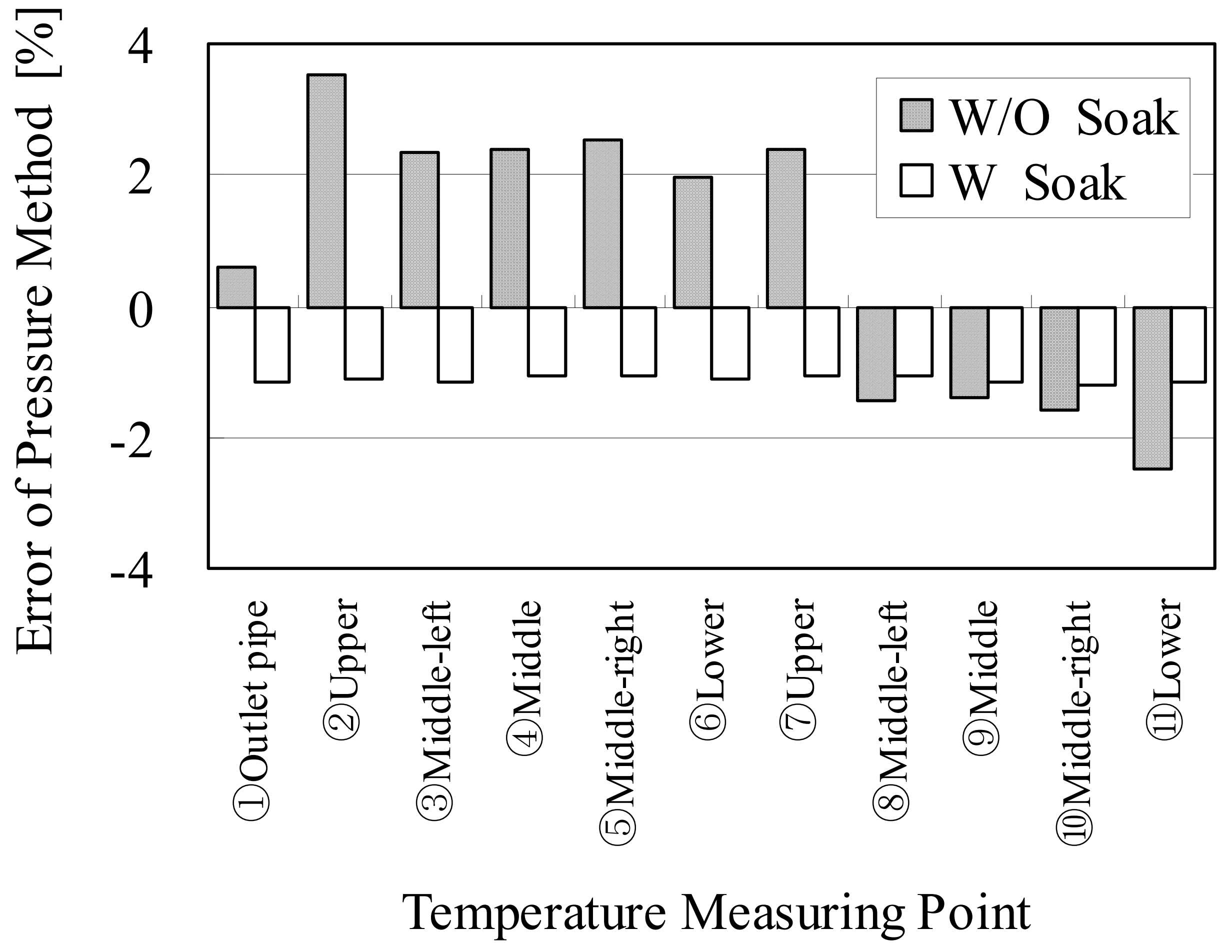
100[sec]

300[sec]

H_2 : 500NL/min



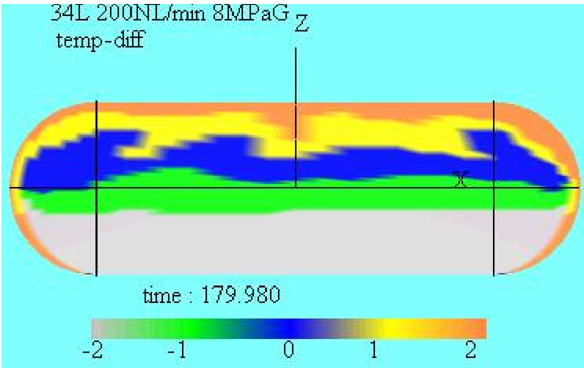
PRESSURE METHOD (P/T METHOD)



Influence of Temperature Measuring Point on Pressure Method

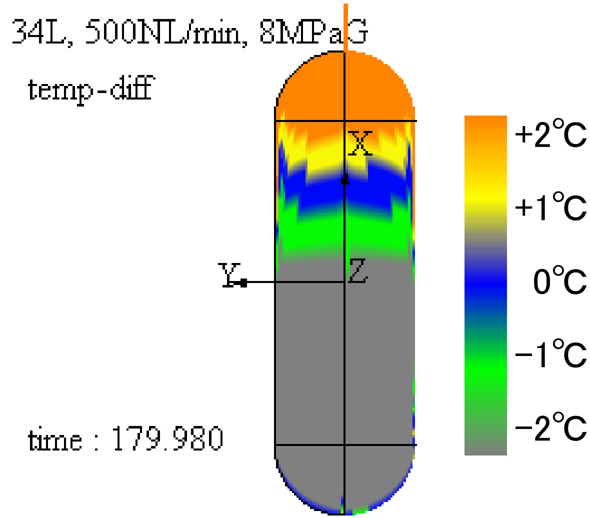
PRESSURE METHOD (P/T METHOD)

Gas Temperature Distribution in Vertical Cross-Section of Tank by Simulation



Tank volume: 34liters
H_2 flow rate: 200liters/min
Initial pressure: 8MPaG
Gas releasing time: 180s

(a) Horizontal position

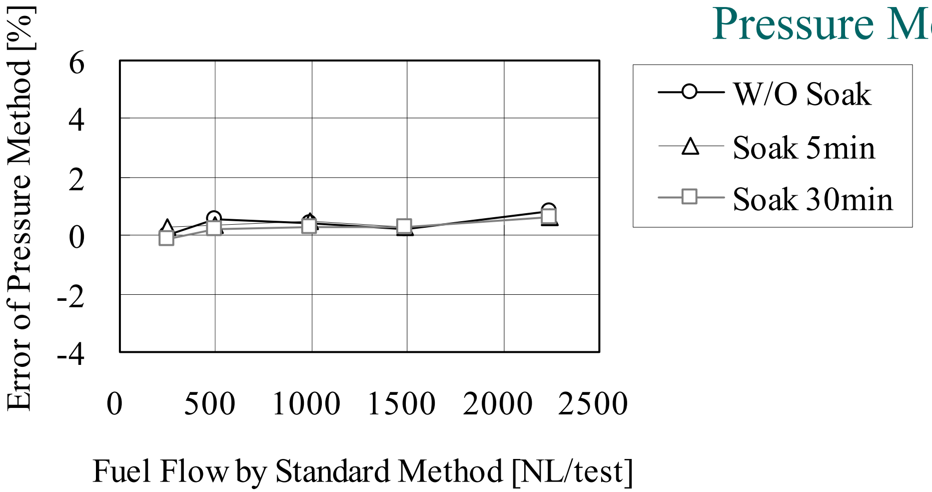


Tank volume: 34liters
H_2 flow rate: 500liters/min
Initial pressure: 8MPaG
Gas releasing time: 180s

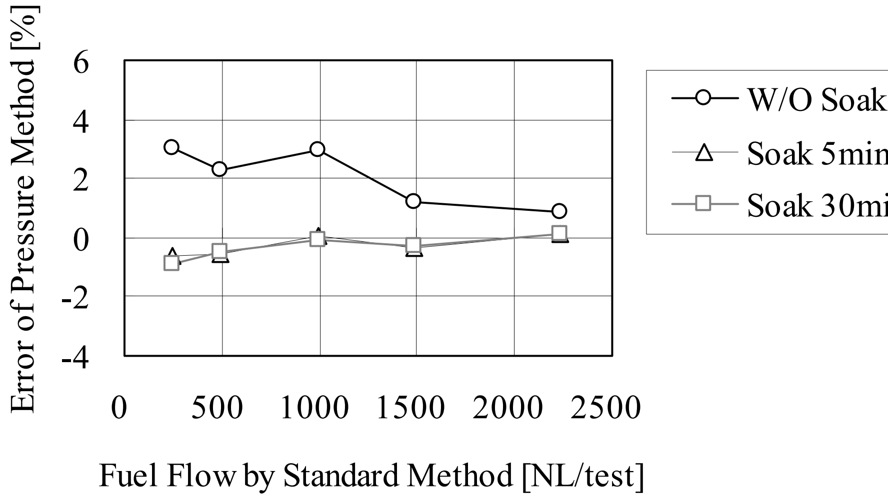
(b) Vertical position

PRESSURE METHOD (P/T METHOD)

Influence of Temperature Measuring Point and Soaking Time on Pressure Method (Tank Volume:20 liters)

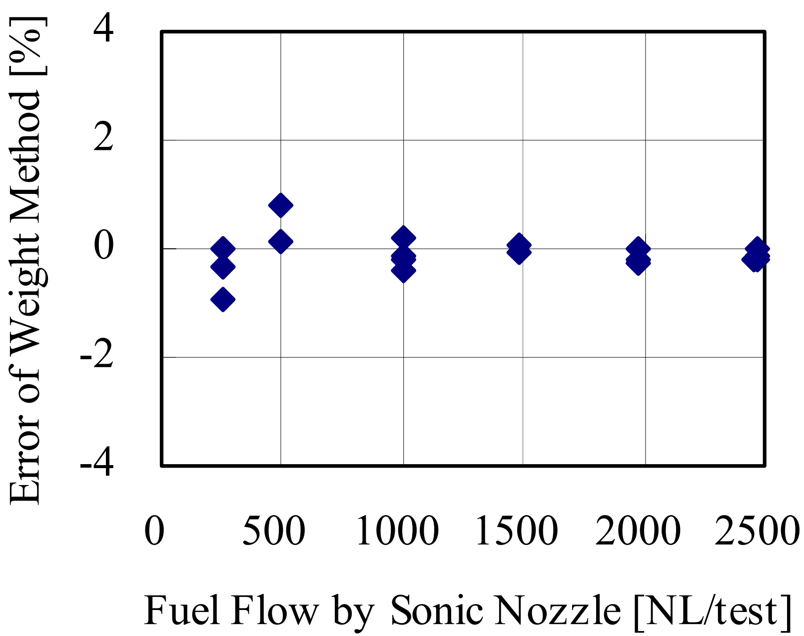


(a) Calculation from Inside Gas Temperature

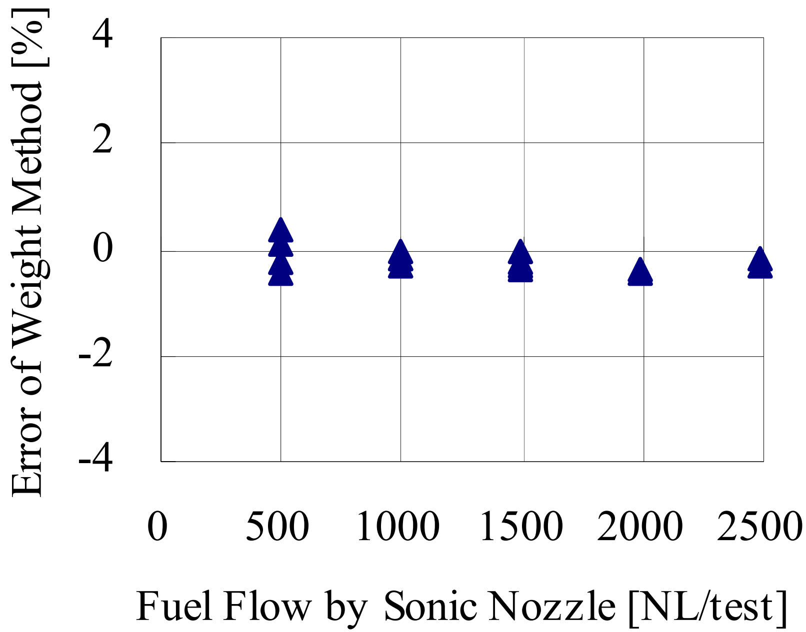


(b) Calculation from Tank Surface Temperatur

WEIGHT METHOD



(a) Ordinary H2 Tank (Cr-Mo steel, Volume:47liter, Maximum Pressure:14.7MPa)

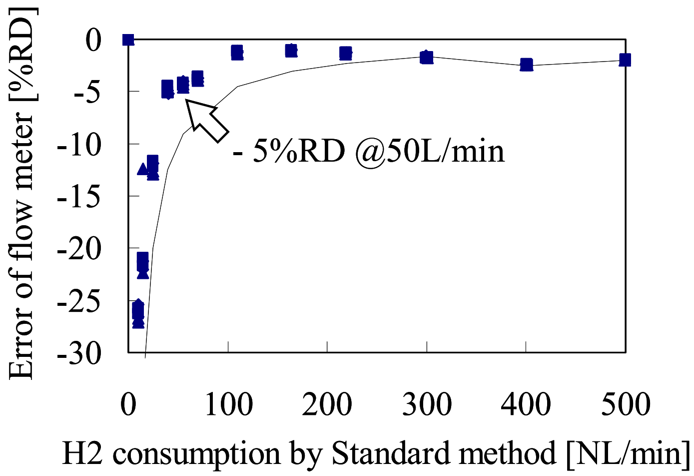


(b) Full-wrapped H2 Tank (Type3, Volume:74liter, Maximum Pressure:35MPa)

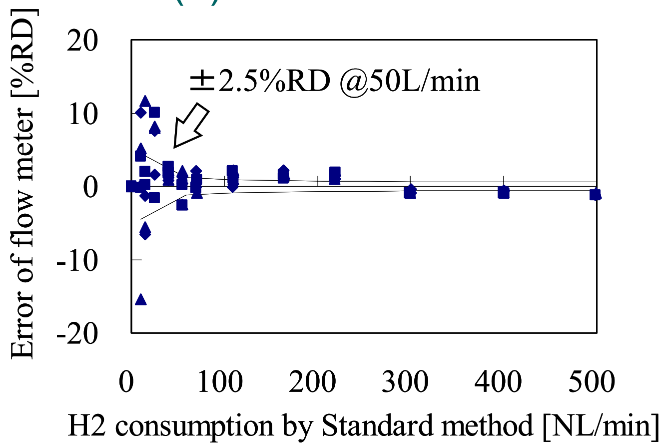
Error of Weight Method using Ordinary H2 Tank and Full-wrapped H2 Tank: The full-wrapped tank is about 3.5 times larger in capacity than a conventional hydrogen tank and, therefore, it is adaptable to testing of even large vehicles.

Flowmeter Methods

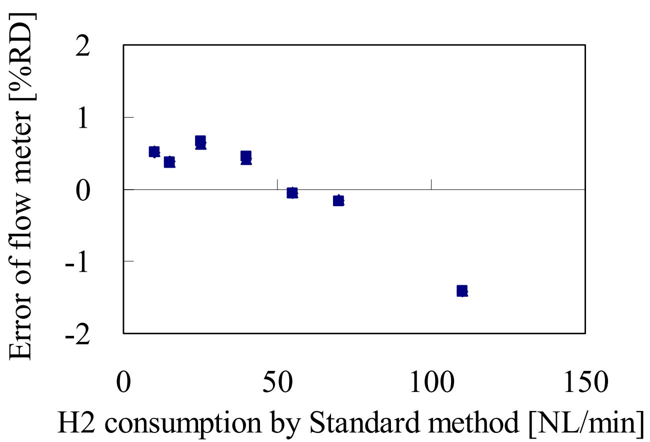
(a) Thermal Mass Flowmeter



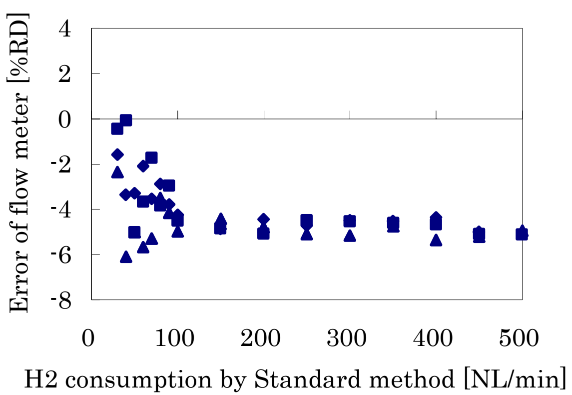
(b) Coriolis Flowmeter



(c) Volumetric Flowmeter

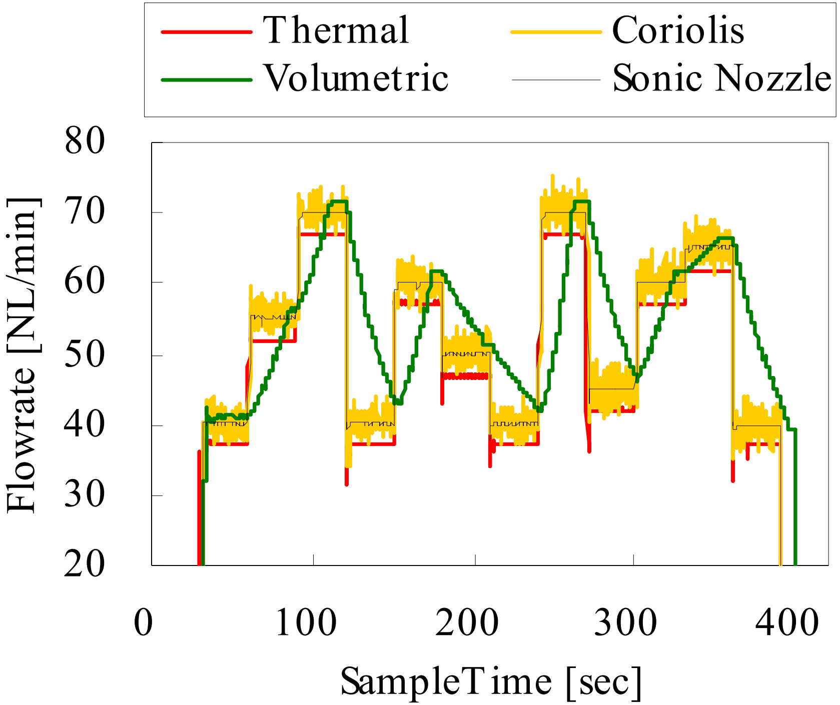


(d) Ultrasonic Flowmeter

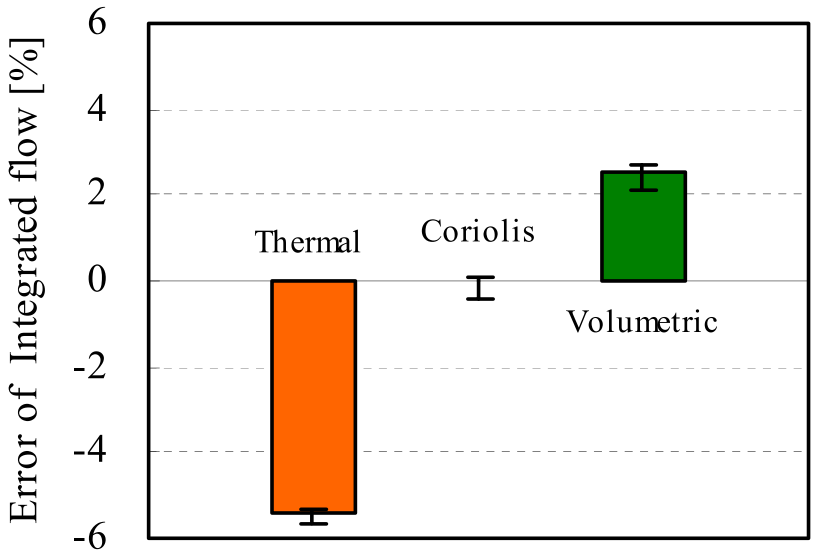


Characteristics of Flowmeter under Steady Flow Condition

Flowmeter Methods



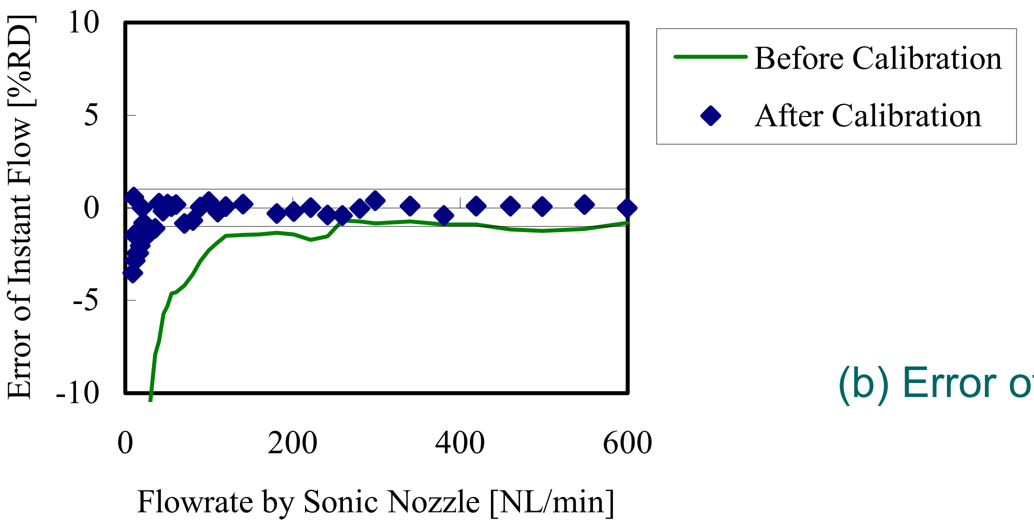
(a) Trend Data of Instant Flow



(b) Error of Integrated Flow for Weight Method

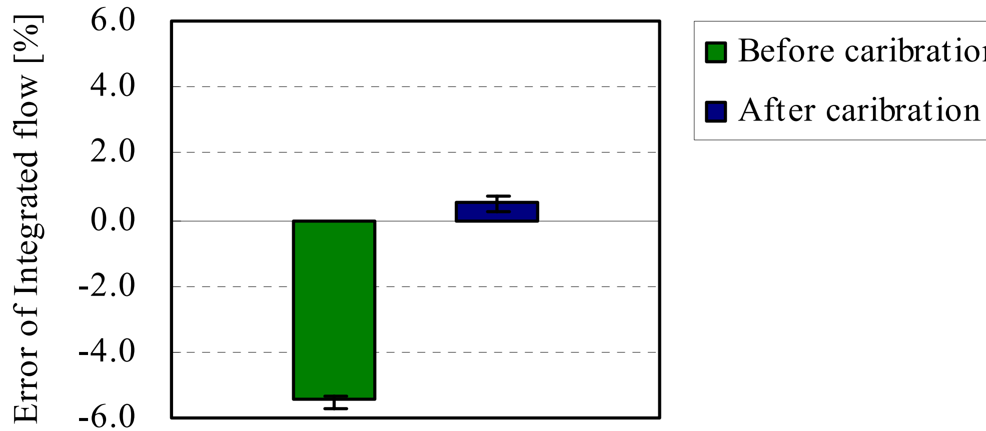
Characteristics of Flowmeter under Transient Flow Condition

Flowmeter Methods



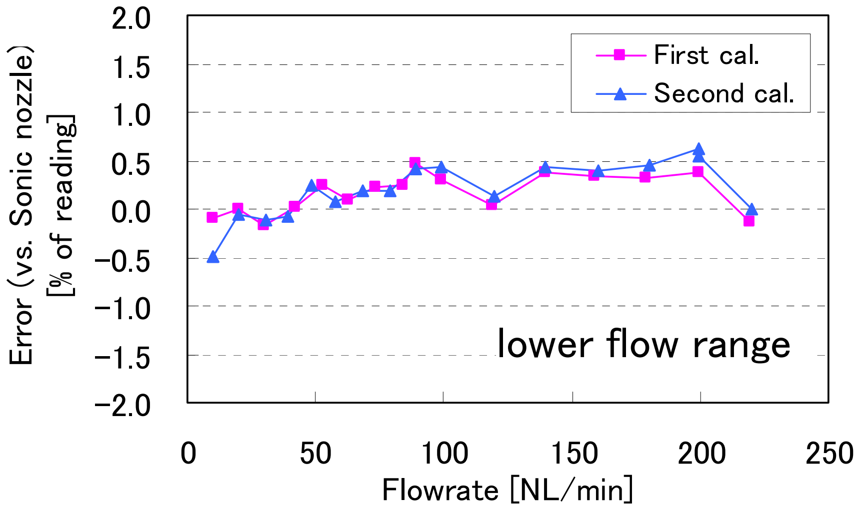
(b) Error of Integrated Flow for Weight Method

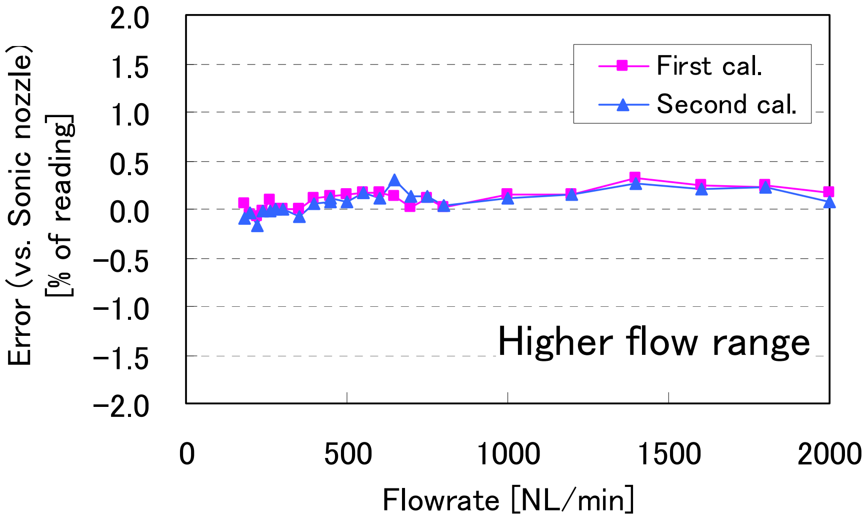
(a) Error of Instant Flow



Thermal Mass Flowmeter: Effect of Calibration using Sonic Nozzle and Hydrogen

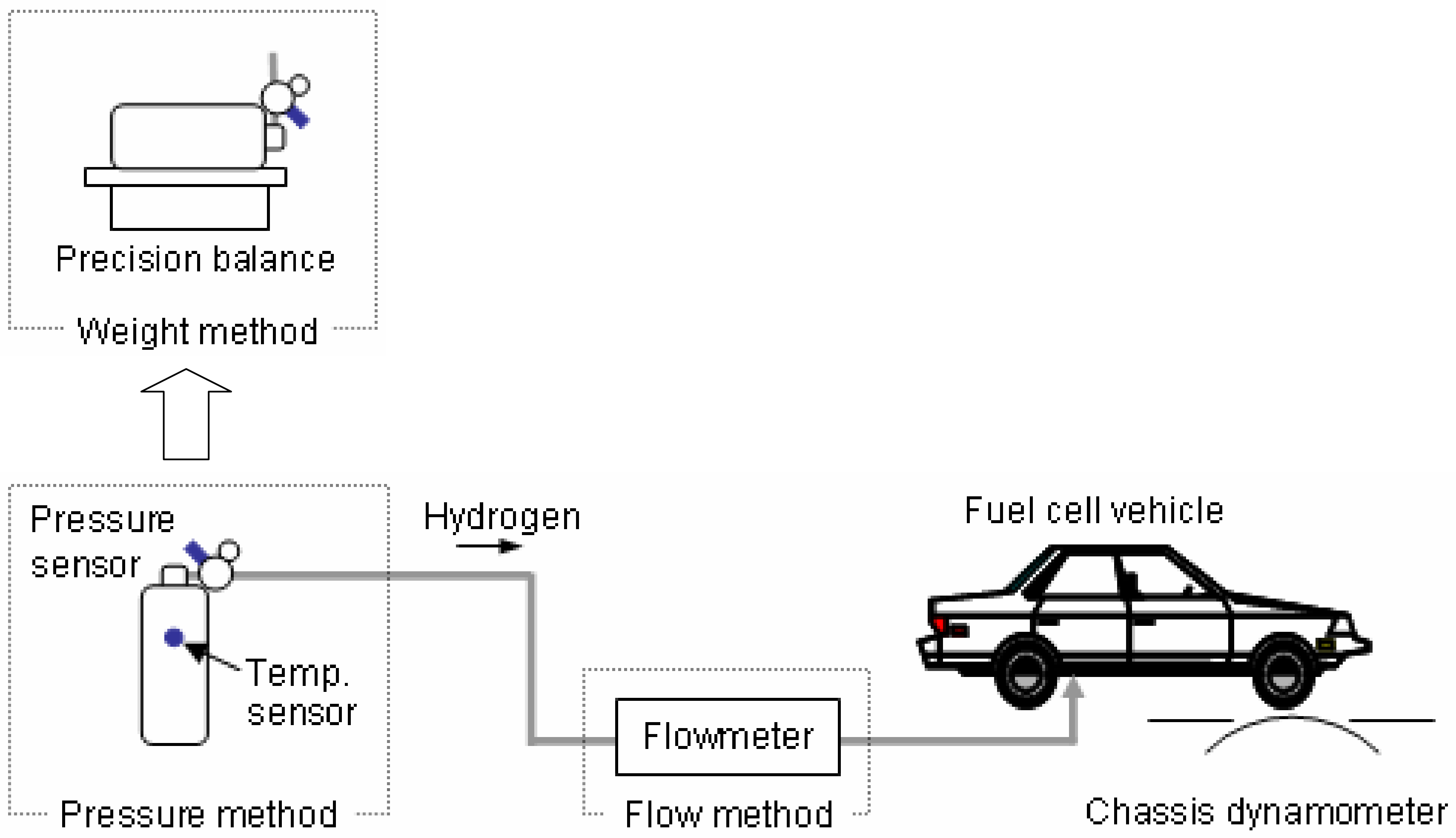
Flowmeter Methods





Calibration Results of Thermal Mass Flowmeter using Sonic Nozzles with Hydrogen

Pressure Method, Weight Method and Flow Method

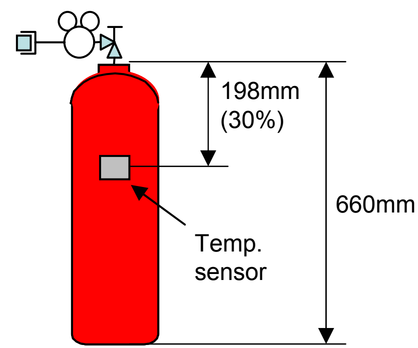


PRESSURE METHOD MEASUREMENT

Specification of Sensor for Pressure Method

Pressure sensor	
Range	0-16 MPa abs
Accuracy	(0.05% F.S.
Min. Graduation	1kPa （eq. to H2 0.2liters）

Temperature sensor (thermistor)	
Range	0-50(C
Accuracy	0.01-0.03(C
Min. Graduation	0.01(C



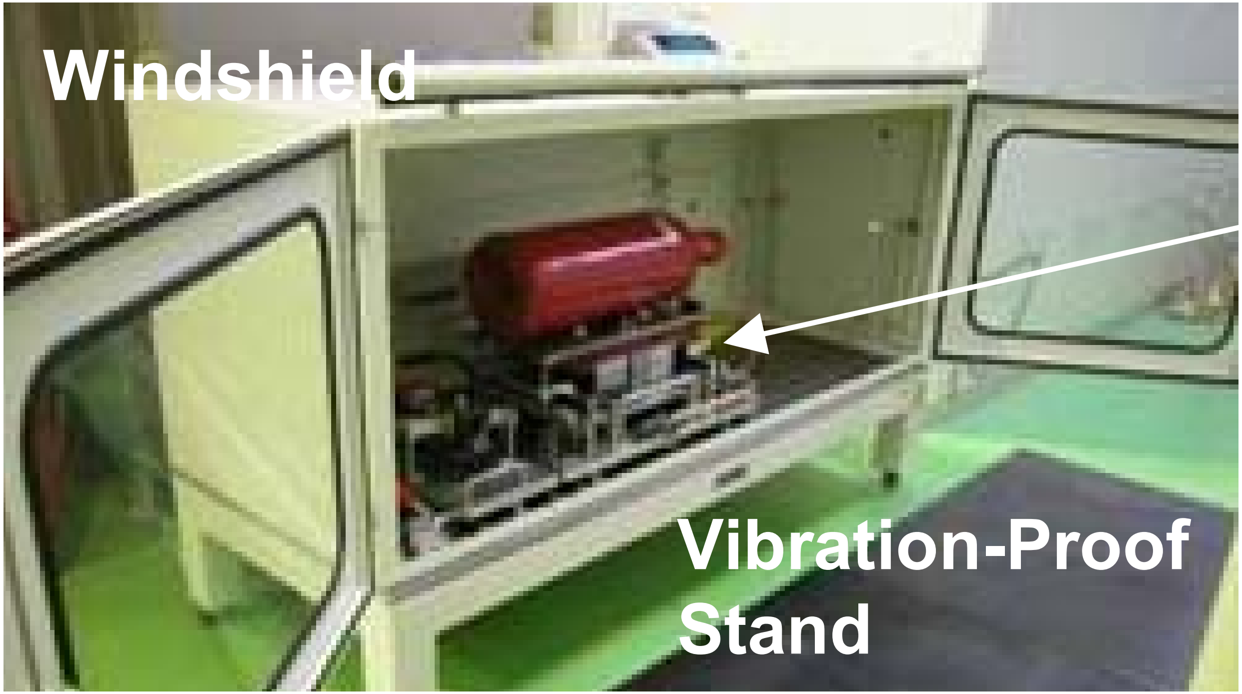
WEIGHT METHOD

$$W = g_1 - g_2$$

W = Fuel consumption [g]

$g1$ = Weight of hydrogen tank before test [g]

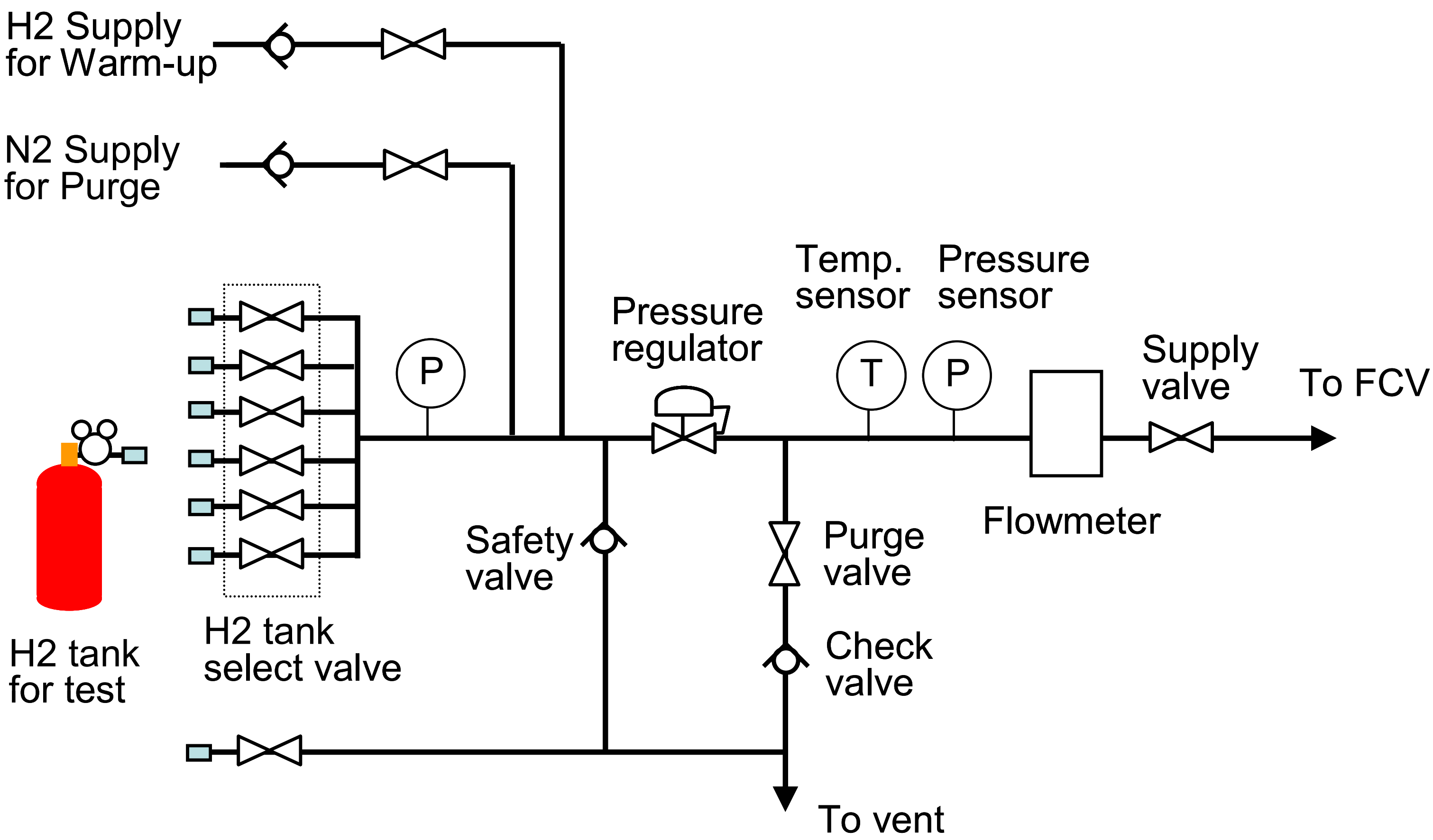
$g2$ = Weight of hydrogen tank after test [g]



Specification of Thermal Mass Flowmeter for Flow Method

Range	10–2000NL/min
Accuracy	±1% of reading
Sampling time	5ms
Pressure drop	16kPa@2000liters/min(nor.)

Hydrogen Supply Device for FCV Test

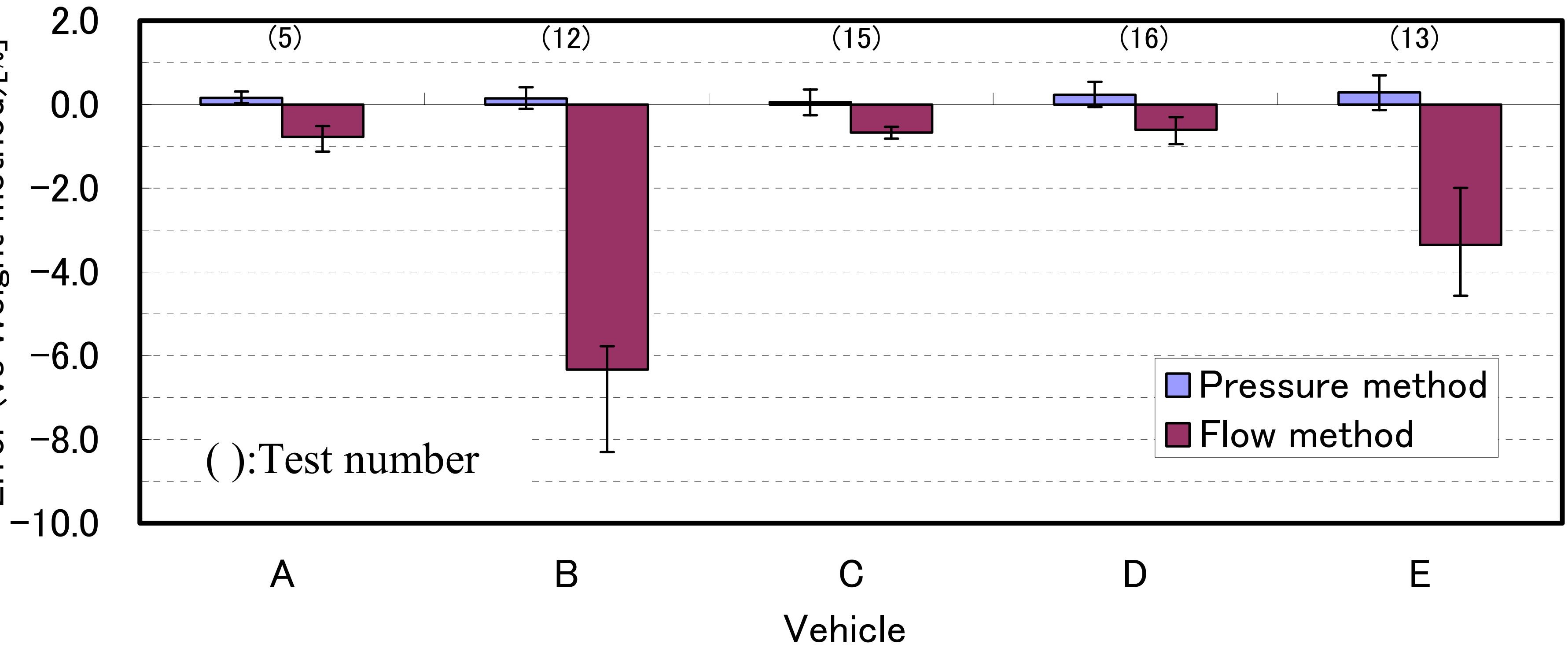


Test Result of Fuel Consumption Test

Test Vehicle（no special order）:

1. Toyota FCHV（Toyota Motor Corp.）
2. X-TRAIL FCV（Nissan Motor Co., Ltd.）
3. Honda FCX（Honda Motor Co., Ltd.）
4. F-Cell（DaimlerChrysler Japan Co., Ltd.）
5. HydroGen3（GM Asia Pacific Japan Ltd.）

Test Result of Fuel Consumption Test



(10･15mode, Test vehicle in FY2004)