

CONFIDENTIAL

TECHNICAL INFORMATION

CALIBRATION AND TEST METHOD

for HYDROGEN LEAK DETECTION in AUTOMOBILES

Introduction

In the hydrogen gas detection application in automobiles, it is important to consider the relationship between the hydrogen concentration in the atmosphere and in the sensor compartment. This is because there are various fluctuation factors such as diffusion conditions and air flow speed in the detection area, which may vary the hydrogen concentration in/around the sensor compartment. These factors are related to the exchange rate of gas/air mixture between the atmosphere and sensor compartment.

In this technical information, the standard calibration and test conditions of FIS is explained.



Hydrogen detector: FH2-HY04

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1. Output signal of hydrogen detector: FH2-HY04

The FH2-HY04 hydrogen detector uses newly developed catalytic combustion type HW-19GP sensors. Fig.1 shows the circuit diagram and Fig 2a shows the sensitivity curve in terms of output signal changes and hydrogen concentration changes. As shown in this data, the sensitivity curve is a non-linear curve, so that it is necessary to calibrate the output signal in accordance with the hydrogen concentration. In the FH2-HY04, a sophisticated microprocessor provides accurate calibration for a wide concentration range from 0 to 40,000ppm with +/- 10% accuracy.

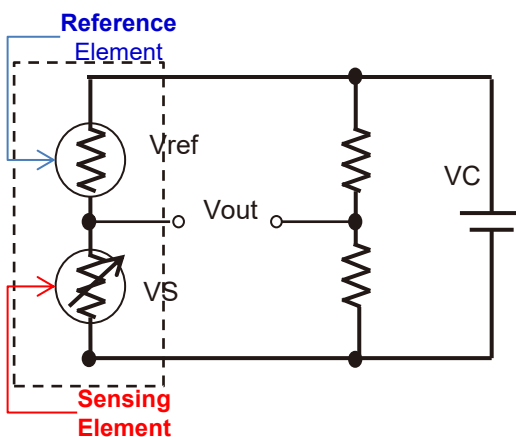


Fig 1a. Circuit diagram

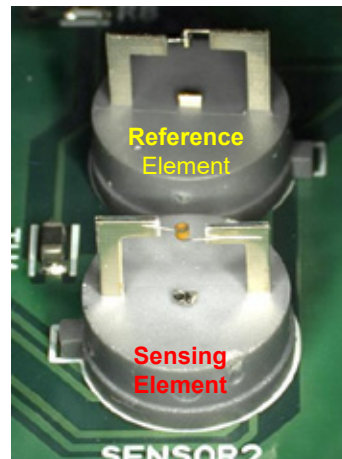


Fig 1b. GP Sensors



Fig 1c. Sensor+PCB

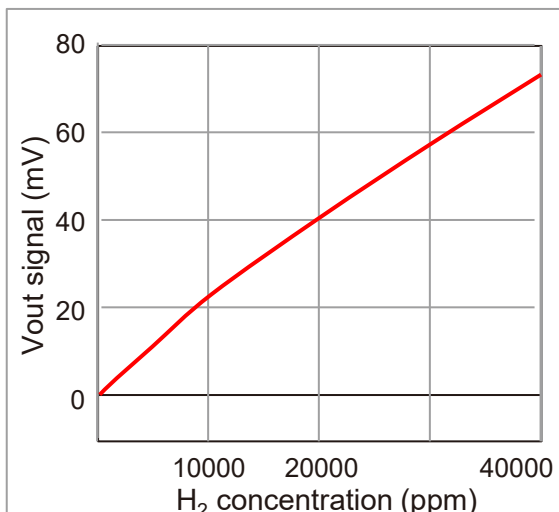


Fig 2a Concentration vs. output voltage

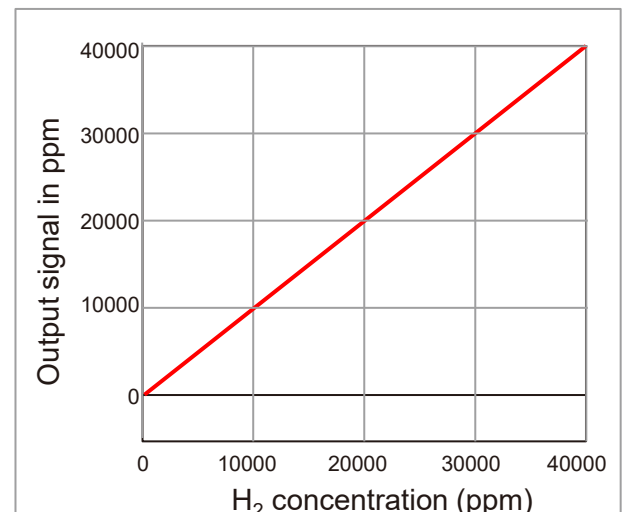


Fig 2b. Concentration vs. Output Signal

Both the sensing element and reference element are heated at 0.4V

- The temperature of sensing and reference coils are approx. 280°C
- In the presence of hydrogen, sensing element temperature increases and the bridge output signal (V_{out}) increases accordingly (non-linear curve).

The V_{out} signal at the following 8 concentrations are memorized in the microprocessor : 0, 5000, 10000, 15000, 20000, 25000, 30000 and 35000ppm

Applying a curve fitting from the pre-determined concentration calculation table, a liner output signal curve (i.e. PWM) is obtained.

2. Installation of hydrogen detectors in FCV

An extract from the statement of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) of JAPAN, 'Technical standard for vehicles using high pressure hydrogen fuel' Jun 23, 2011

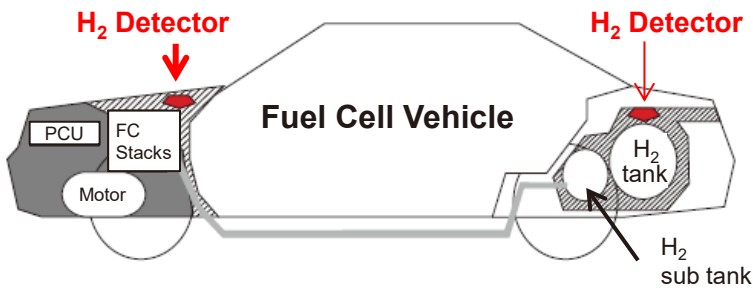


Fig 3. H2 detectors in FCV

- 3.8.1 The concentration of purged H₂ must be less than 4 vol.%
- 3.9.1 At least one hydrogen detector must be installed in any suitable location to detect a hydrogen gas leak.
- 3.9.2 In the event of hydrogen leaks, a safety system must provide a warning signal to the driver
- 3.9.3 In the event of hydrogen leaks, a safety system must shutoff the hydrogen supply

[To instantly detect any risks of hydrogen gas explosion]

- detecting hydrogen at lower concentration range than LEL of H₂ (4vol%): **below 2vol%**
- at the position where the hydrogen concentration tends to become high: **airtight area without air flow, above hydrogen tank(s) and/or FC stacks**
- Easy diffusion of H₂ into the sensor compartment: **sensor compartment must face down**

to be fixed to the upper panel in the hydrogen tank area

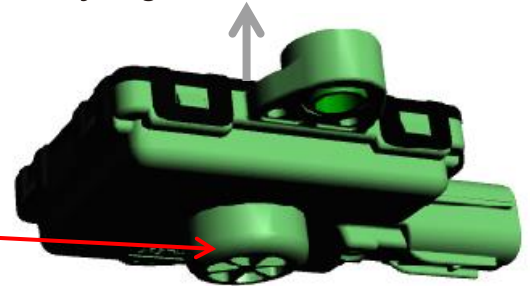


Fig 4. Mounting direction of H₂ detector

3. Calibration and test conditions

- Hydrogen gas diffuses easily in the atmosphere so hydrogen concentration will not reach to high levels in an open space with air flow (i.e. while the car is running).
- The highest risk of hydrogen explosion is if hydrogen gas leaks remain in a airtight area such as the storage space of hydrogen tank(s) and Fuel Cell Stacks, while the FCV is not running.
- In order to simulate the above condition in the test facility, we calibrate and test hydrogen detectors in a 'static atmospheric condition' in an air tight test chamber with no forced air flow.
- Basic conditions of calibration/test chamber are shown below:
 - Test chamber: with enough space to keep the hydrogen concentration constant
 - Space per detector: more than 3 liter per one detector
 - Example: using a 64 liter chamber, calibrating and testing 16 units per 1 batch)

- Placing a detector on the top inside lid of the test chamber
- Injecting specific volume of pure hydrogen gas to obtain specified H₂ concentrations in air.

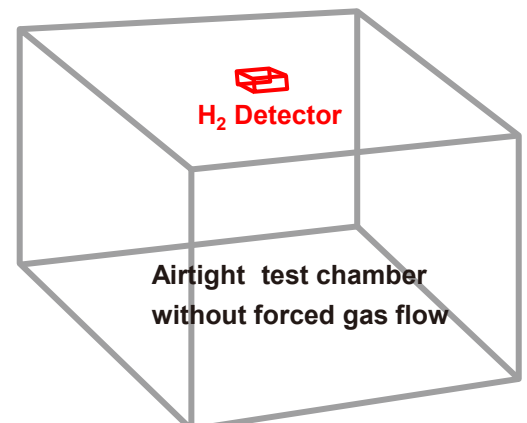
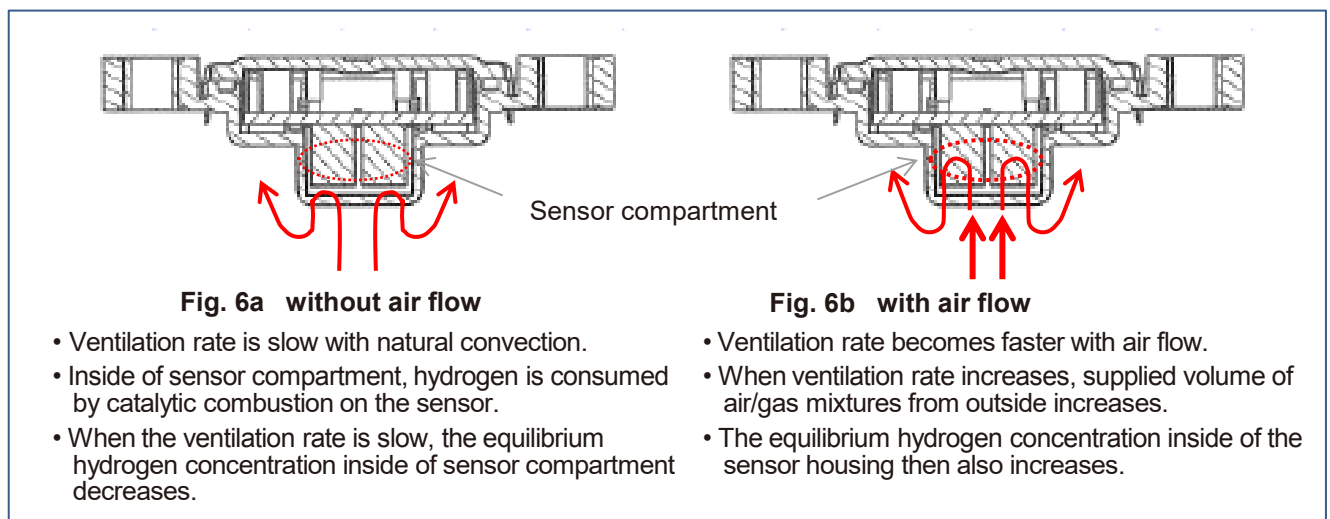


Fig. 5 Image of Standard Test Condition

4. Hydrogen concentration in the atmosphere and in the sensor compartment

The relationship between the hydrogen concentration in the atmosphere and in the sensor compartment is described as follows:

- When the hydrogen concentration increases in the atmosphere, hydrogen diffuses in the sensor compartment and combustion of hydrogen starts to occur on the sensor surface.
- The sensitivity of the detector depends on the hydrogen concentration in the sensor compartment.
- Since the sensor compartment is separated by the membrane filter which has a ventilation resistance, the correlation between the hydrogen concentration in the atmosphere and in the sensor compartment depends on the ventilation rate.



- Based on the above factors, when the detectors are calibrated in a static condition without forced air flow, they become most sensitive and provides 'the most safe detection capability' both in static condition and under dynamic air flow conditions.

5. FIS calibration and test condition: Static method

FIS uses a calibration/test chamber with the following conditions

- Test chamber: 64L (material: acryl)
- Temperature/humidity: Temperature/humidity controlled air (20 °C - 60%RH)
- H₂ concentration: 0 to 35000ppm (5000ppm steps)

[Procedures]

- specified volumes of pure hydrogen gas are injected into the test chamber
- hydrogen gas and air is mixed with ventilation fans for 1 minute
- fan is stopped and the atmosphere is stabilized for 1 minute
- the output signal is memorized in the microprocessor:

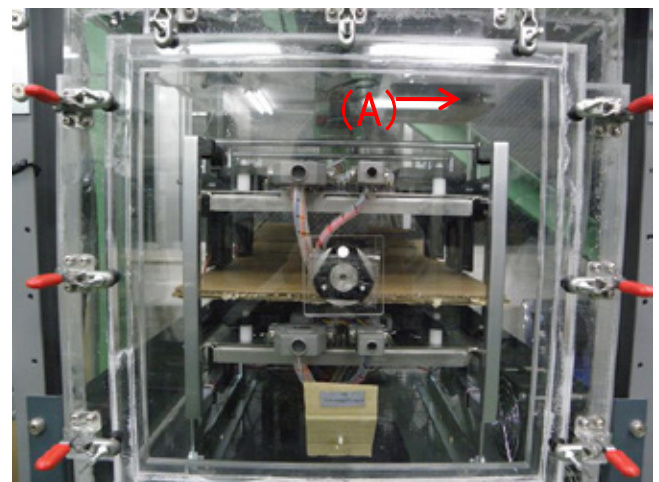


Fig.7 Calibration/test chamber of FIS

See Fig. 8 (next page) for details

Calibration and test flow

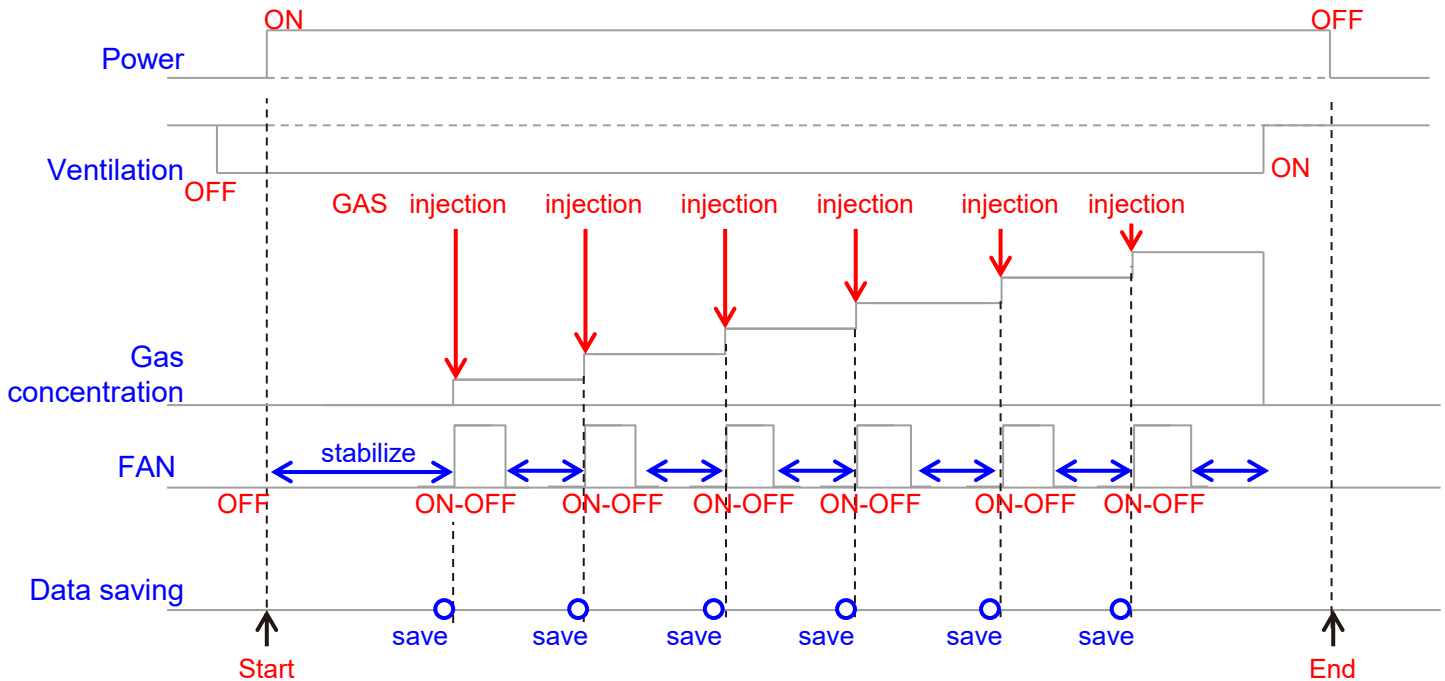


Fig.8 calibration and test process chart

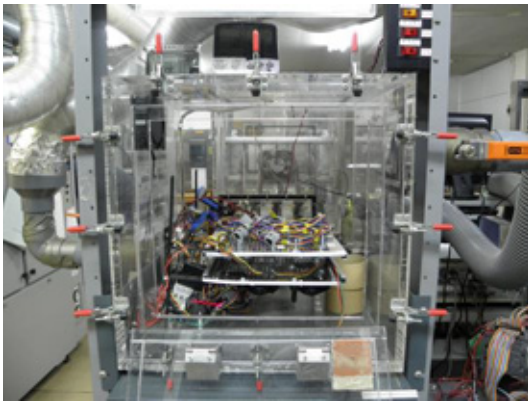


Fig 9a: Test chamber

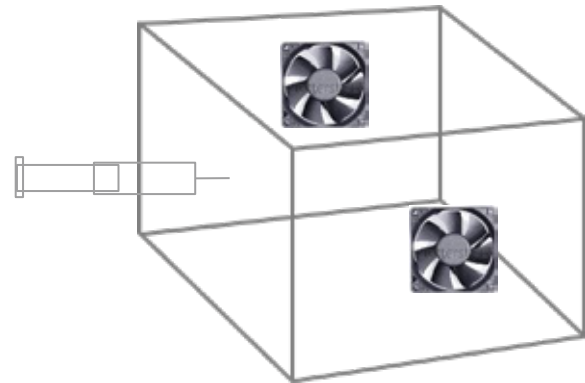


Fig 9b Gas injection to test chamber



Fig 9c Syringes

Fig 9d Pure gas Hydrogen

[Static volumetric method]

- Using an airtight chamber with specified volume
- Injecting calculated volume of pure H₂ gas (i.e. 99.99%) to obtain target concentration in the chamber, mixing with ventilation fan(s) for a sufficient period to equalize the concentration, stop ventilation to stabilize air circulation
- Creating a similar condition as actual hydrogen detection in automobiles

Part-1: Hydrogen detector FH2-HY02

6. FIS test condition-2: Flow method

For evaluation purposes FIS also uses a dynamic flow type test system with the following conditions

- Flow rate: 100mL/min
- using the gas flow attachment shown in Fig. 11, the output signal level is the same as the standard condition.

Notes:

The air flow rate dependency varies depending on the design of flow attachment (i.e. direction of air flow, diameter of air outlet, distance between the sensor housing and outlet, and other factors).

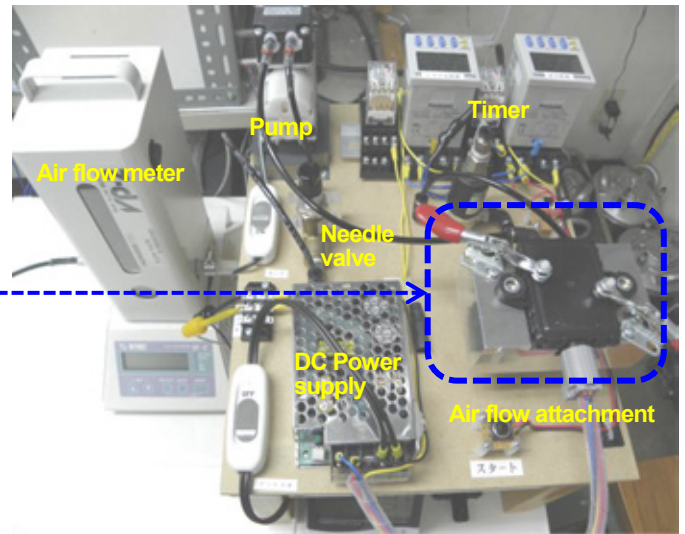


Fig. 10 FIS flow method measuring system

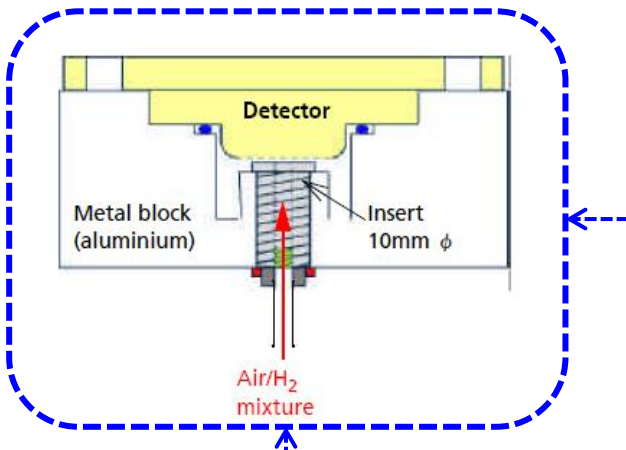


Fig. 11 Cross section of air flow attachment

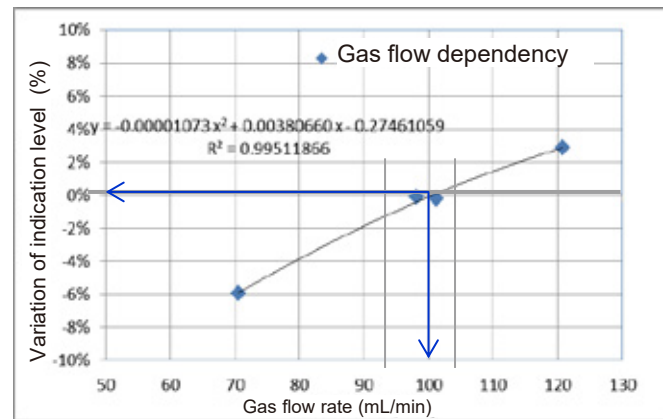


Fig. 12 Gas flow rate dependency

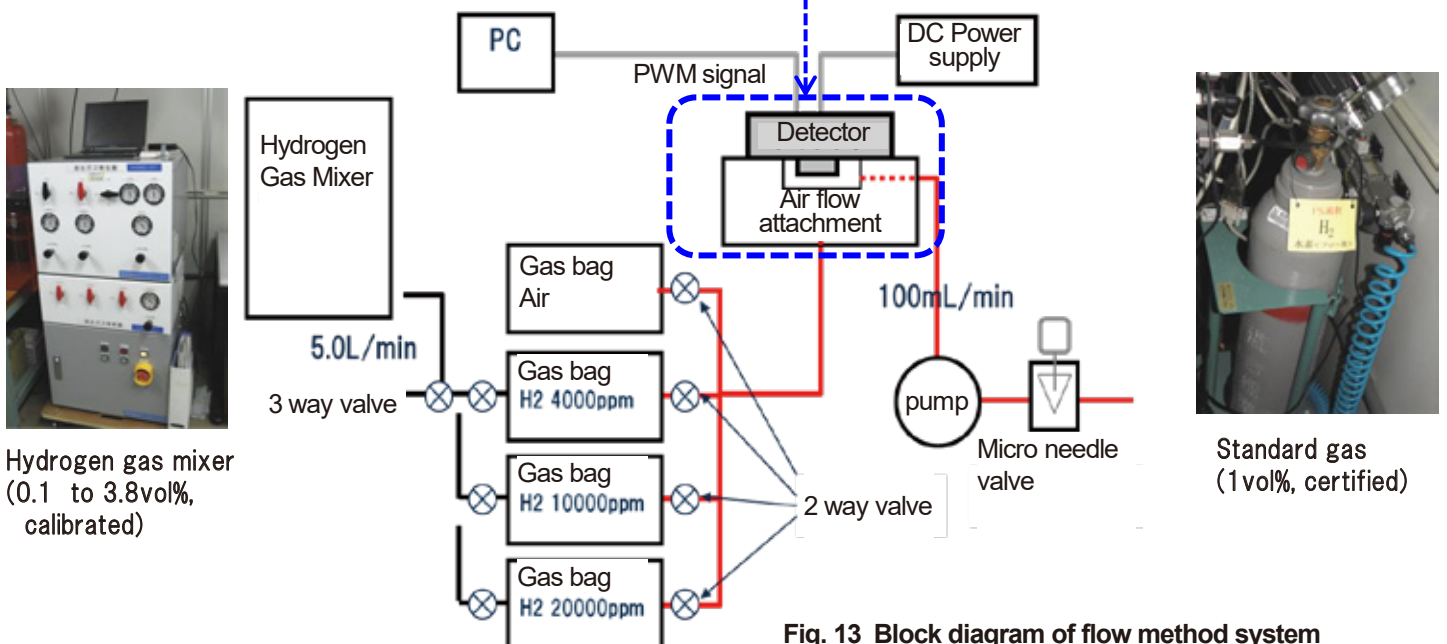


Fig. 13 Block diagram of flow method system

7. Technical support for calibration and test

It is important to establish an agreement in the test/evaluation results between FIS and users. As described in this technical information, there are various variation factors which may differ the test results for hydrogen detector evaluation. In order to avoid any unexpected disagreement of test results, we will provide any helpful information and/or materials for users.

Our support team offers:

- Providing details of our calibration and test methods
- Suggesting suitable test conditions for users
- Upon request, we will develop, produce and supply customized test chamber, equipment or total system according to the specifications from users.

Please contact

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沃尔特电子（苏州）有限公司
Volt Electronics (Suzhou) Co., Ltd
地址：苏州工业园区通园路199号联发工业园6栋2F

电话：0512-62986512/62986522
传真：0512-62986532
邮箱：service@volt-china.com
网址：www.volt-china.com