

Flow Measurements for Future Environment and Energy Technology

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Abstract The role of flow measurement is already very important for trading of high pressure natural gas and liquid hydrocarbon. Various new technologies are developed for these flow measurements, such as accurate and reliable ultrasonic flowmeter and Coriolis flowmeter using sophisticated computer software. However, present research and development for environment and energy technology requires flow measurement in very different conditions and it is becoming more difficult and important to meet these requirements.

In this presentation, development of flow measurements for exhaust gas from vehicles and standard gas production for environment chemical analysis are introduced. New flow standard of pulsating flow and very small gas flow are developed for these purposes. Hydrogen is considered as the clean next generation energy and many technologies are being developed such as fuel battery. A new flowmeter for hydrogen is required to evaluate fuel battery performance. An ultrasonic flowmeter is developed for hydrogen. Also, up rating of existing nuclear power plants is considered as the useful method to reduce exhausting CO₂ from power station. Calibration method of large ultrasonic flowmeter used for the up rating is discussed.

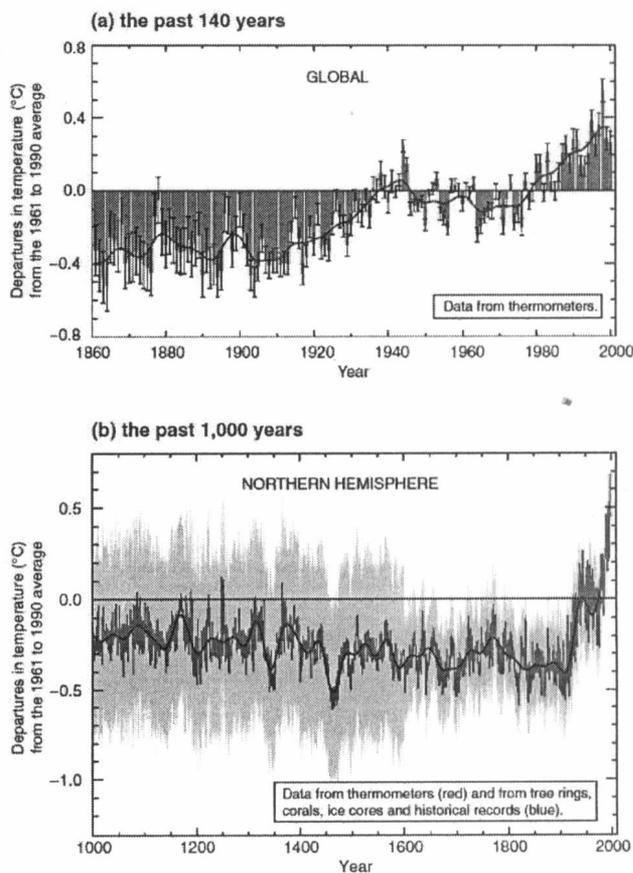
Keywords: Environment, Energy, Exhaust Gas, Hydrogen, Nuclear, Ultrasonic Flowmeter

1. Introduction

The third assessment report on the science of climate change has been made by the Intergovernmental Panel on Climate Change (IPCC) in 2001^[1]. The global average surface temperature has increased over the 20th century by about 0.6 °C according to the assessment report. Also, global average sea level has risen between 0.1 and 0.2 meters during the 20th century. These changes have been caused by emission of so called greenhouse gases such as CO₂ due to human activities. It was also predicted that the global average surface temperature will increase by 1.4 to 5.8 °C in the next 21th century depending the climate modeling and wide area of beach and many islands will sink.

The United Nations Framework Convention on Climate Change (UNFCCC) has been set up to cope with the problem. The important KYOTO Protocol^[2] was adapted at the Conference of UNFCCC in Kyoto, Japan, on 11 December 1997. The main goal of the KYOTO Protocol is to reduce greenhouse gases about

Variations of the Earth's surface temperature for:



From the third report of IPCC

5 % from the emission level of 1990. However, this Protocol can be only entered into force when more than 55 countries signed and their total CO₂ emission is more than 55 % of the total world emission. Although 84 countries signed already, still their emission is 44 % of the world emission, because large counties are reluctant to sign.

In these circumstances, more extensive and international new researches for future environment and energy technology should be made because even the Protocol actually enter into force by a single large country's sign, it is quite difficult to achieve the goal of the Protocol with the present level of technology without decrease of economical activities in the world. These new technologies cover wide range of development, fuel cell, hydrogen vehicle, advance diesel, efficient nuclear power, new materials and so on. Flow measurement can contribute to these developments, because most of technologies require measurement of very difficult conditions and very accurate measurements.

The paper introduces some of new projects at NMIJ for these purposes.

2. Reduction of CO₂ emission

Development of flowmeters for hydrogen fuel dispensers and hydrogen gas

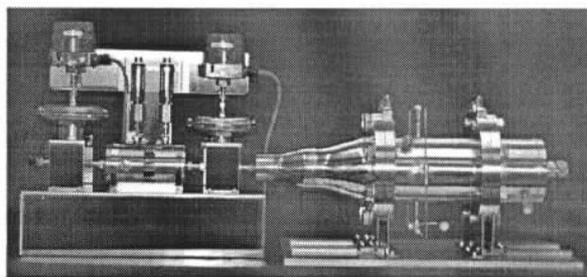
2.1. New flowmeters for hydrogen fuel dispenser

The sources of CO₂ emission are the firstly Power stations (22 %) and the secondly Vehicles (16 %). Emission of CO₂ from natural gas fuel is about 30 % less compared to oil fuel. Therefore, vehicles with natural gas fuel are promoted in many counties. For example, more than 10,000 Compressed Natural Gas (CNG) cars are used in Japan today and there are more than 200 CNG station.

Most CNG dispensers use a Coriolis flowmeter for flow measurement of natural gas. Natural gas is compressed up to 25 MPa.

Car manufacturers are developing hydrogen cars and hydrogen dispensers are also required to be developed for infrastructure preparation. It is necessary compress hydrogen higher than CNG to have enough fueling in

one time. Therefore, flowmeter should be able to measure high pressure gas up to 70 PMA and very low density gas. Although many manufacturers still use a Coriolis flowmeter for flow measurement of hydrogen, NMIJ started a new project to a sonic nozzle and ultrasonic sensors. It is thought that a dispenser is a trading instrument and is required long term stability for metrological sealing. It is very difficult to achieve long term stability by a Coriolis flowmeter at the present moment.

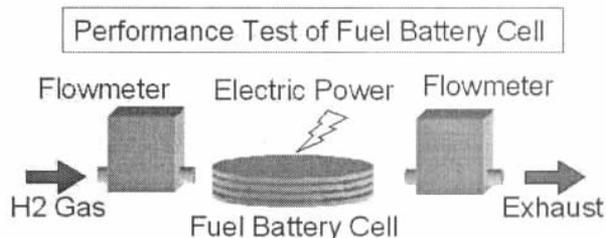


Sonic Nozzle Type Flowmeter for Hydrogen Dispenser

2.2. New flowmeters for hydrogen gas

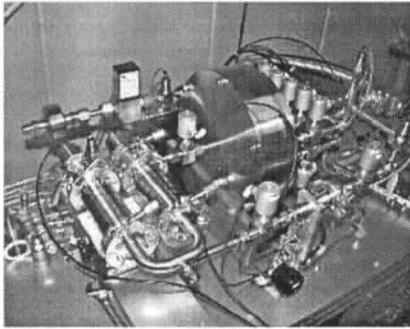
It is expected that fuel battery will be clean energy in the future. Various kind of fuel batteries are being developed in many countries. There are still 3 major breakthrough points in the development of the fuel battery; long term reliability, low cost and high efficiency.

Performance test is required to be as accurate as possible because improvement of efficiency is usually very small. However, accurate performance test is very difficult because flow measurement of input hydrogen fuel is very difficult. NMIJ has a new project for flow standard of hydrogen gas and development of hydrogen flowmeters^[3].



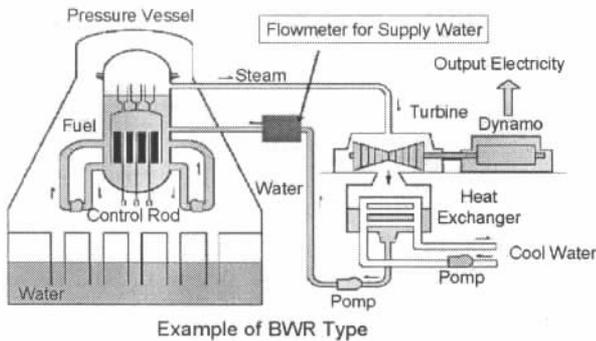
Ultrasonic flow meter was developed for hydrogen gas because existing thermal type flowmeters are not accurate enough. Detecting signal of ultrasonic pulses

are very weak in hydrogen gas, are attenuated about 1/30 compared to air. Therefore, special care is required to achieve better S/N ratio.



3. Accurate flow measurement for up-rating of nuclear power plants

Although many people are not in favor of new construction of nuclear power plants because of radioactive contamination, it is not feasible to replace all of them to oil or natural gas power plants which will generate large amount of CO₂ emission. Therefore, it is considered that up-rating of existing nuclear power plants would be useful way to reduce CO₂ emission at the present moment.

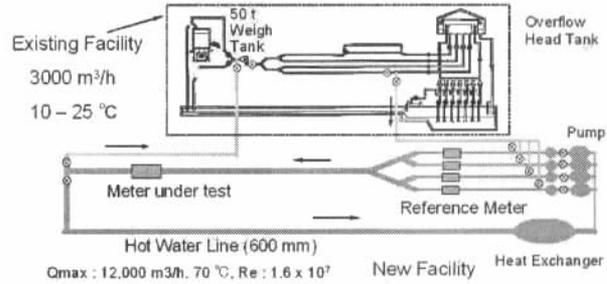


Output of a nuclear power station is controlled by monitoring flow rate of supply water and flow nozzles are used to measure the flow rate in most cases. Uncertainty of the flow nozzle is estimated about 2%. Therefore, the maximum power of nuclear stations is set 2% lower than the designed maximum power for the safety reason.

An ultrasonic flowmeter can be more accurate than a flow nozzle; provably uncertainty can be reduced less than half. If uncertainty of the flowmeter of water

supply is halved, one oil power plant can be closed and 100 ML of oil consumption will be decreased every year in Japan.

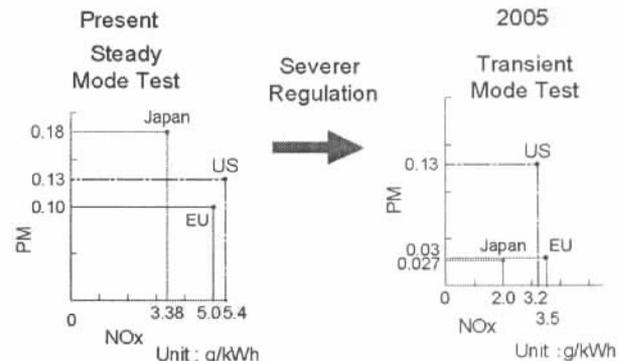
The only problem is calibration facility of the flowmeter, because the flowmeter is used at very high Reynolds Number of about 1.4×10^7 . There exists no such a large facility in the world. NMIJ started a new project to construct such a large facility and calibrate ultrasonic flowmeter with small uncertainty as possible.



4. Flow measurement of vehicles exhaust

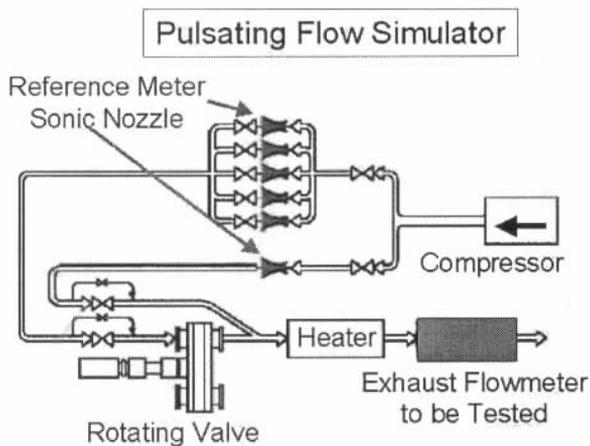
Diesel engine vehicles are considered to be energy efficient compared to the gasoline engine vehicles. However, exhaust from diesel engine has more pollutant, such as Suspended Particulate Matters (SPM) and NO_x. Especially SPM is considered suspected cause of cancer.

Today, most governments promote use of vehicles with diesel engine, and on the other hand they are introducing severer exhaust control. Especially, they are going to introduce transient mode engine test for pattern approval of diesel engine considering actual traffic pattern in a city.



A flowmeter to measure exhaust gas flow directly is essential for the transient mode engine test. However, exhaust gas from vehicle is very difficult to measure because of high temperature more than 500 °C, very strong pulsating flow, high humidity more than 15 %, dusty flow and high response measurement is required.

The project to develop flowmeters for the exhaust gas and their calibration facility were started at NMIJ.



Pulsating flow is generated by a rotating valve for the calibration facility. Constant flow rates are set by combination of sonic nozzles. The facility can calibrate a flowmeter up to 500 °C.

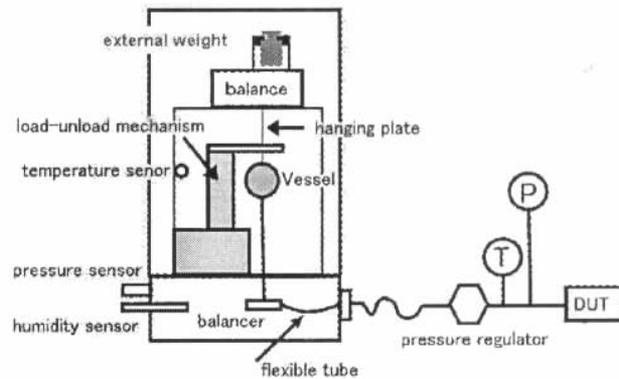
Three kinds of flowmeters were developed, vortex shedding flowmeter, diode LDA flowmeter and ultrasonic flowmeter. The vortex shedding flowmeter has advantages of low cost and long term reliability. The diode LDA flowmeter has advantages of high speed response and high temperature measurements. The ultrasonic flowmeter has advantages of low pressure and dust proof characteristics. High temperature type sensor is being developed using new materials. Also, Langevin type sensor is under development now.

5. Flow measurement for environmental monitoring

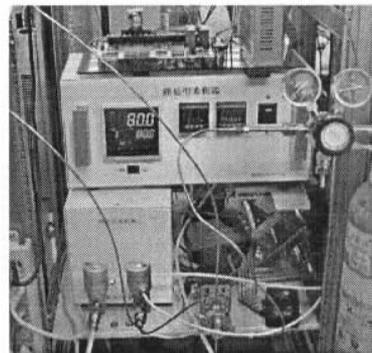
Most of environmental monitoring instruments have been changed from a wet type to a dry type instrument because of easy and low cost maintenance. However, standard gases are required to compare density of

monitored gases in the case of a dry type instrument. Kinds of monitored gas are increasing year by year and their density or concentration is decreasing. Therefore, the standard gases are produced in instruments by diluting component gases with a basic gas such as nitrogen. It is required that a very small flow of the component gases are required to produce low density standard gases.

Schematic diagram of the primary standard



NMIJ has a project to establish a very small flow rate standard down to 0.05 mg/min using a very small weigh tank and down to 0.01 mg/min using a constant volume tank system. Also, dilution standard has been developed for calibration of monitoring instruments dilution system. Flow rates of a component gas and a base gas are 3 to 6 mg/min and is 3 to 6 g/min. Standard uncertainty of the system is 0.3 – 0.4 %.



Novel dilution system using small critical nozzles

6. Conclusions

Developments of new flowmeters and flow

standards are required for future environment and energy technology. The developments are mainly more accurate flow measurement in severer conditions. Ultrasonic technology, sonic nozzle and Coriolis flowmeter will be the key technology.

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