GD SERIES VIBRATORY GAS DENSITY METERS

***SUZUKI Jun-ichi* [*1]**

We have developed the GD series vibratory gas density meters, each of which is designed for a specific application. The series offers three main applications: a gas density meter, gas calorie meter, and hydrogen purity meter. A hydrogen purity meter, the latest addition to the GD series, has been designed for hydrogen gas concentration monitoring in the turbine cooling process at power plants. It indicates the concentrations of three gases—hydrogen (H_2), carbon dioxide (CO_2), and air—and, by itself alone, accomplishes the tasks which have traditionally required two thermal-conductivity gas calorie meters. In respect to performance, the series offers improved characteristics against external vibration, noise, and temperature changes. The vibrator is supported by four O-rings, which completely absorb external vibration and the influence of noise has been greatly reduced by incorporating many filters in the electric circuit. Furthermore, software updates have improved the accuracy of temperature compensation.

INTRODUCTION

We rolled out the first vibratory gas density meter ten years ago and since then have continued supplying it. The past ten years have seen changes in the target applications and requirements for functions that have made it easier to use. Conventional gas density meters can measure the density, specific gravity, calorie, molecular weight, and concentration of a gas, but do not feature functions required for some particular applications. Such applications include the cooling of a power plant turbine using hydrogen gas. Normally, the turbine is surrounded by hydrogen gas, which is replaced with carbon dioxide and then with air at periodic inspections. To monitor this entire procedure with a conventional gas density meter, the user needs to change the set value and perform calibration each time the ambient gas is replaced, or to prepare three meters for individual gases. However, we have now added a hydrogen purity measurement function to our gas density meter so that one gas density meter can cover this specific application all by itself, thus offering man-hour and cost reductions (i.e., reduction of total costs of ownership). In terms of performance, the new model has improved performance together with enhanced robustness against vibration and noise.

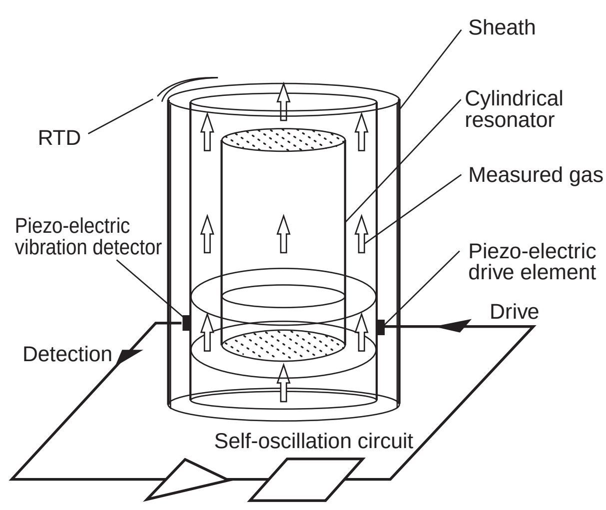
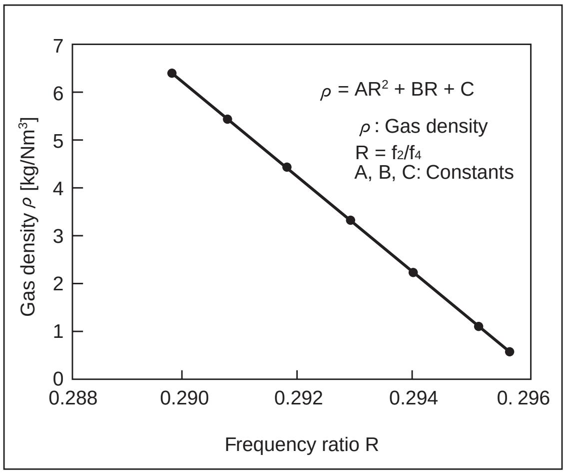


Figure 1 Principle of Measurement

*1 Industrial Automation Business Headquarters



The resonant frequency fi can be expressed as:

$$f_i = A \times \left(\frac{\Delta_i}{\rho_i (1 - \sigma^2)} \right)^{\frac{1}{2}} \times (1 + \alpha T) \times \left(1 + \gamma \log \left(\frac{t}{t_0} \right) \right)$$

The frequency ratio R can be expressed as:

$$R = \frac{f_i}{f_j} = \left(\frac{\rho_j}{\rho_i} \cdot \frac{\Delta_i}{\Delta_j} \right)^{\frac{1}{2}}$$

A : Constant
ρ_i : Resonator's density plus equivalent fluid's density of i th-order mode
Δ_i : Constant frequency of i th-order mode
σ : Poisson ratio
α : Temperature coefficient
γ : Coefficient rate of change with time
T : Temperature
t : Time

Figure 2 Variation of Density and Ratio between Resonant Frequencies in Two Modes

PRINCIPLE

Figure 1 shows the principle of measurement. The resonant frequency of a thin-walled cylinder varies with the density of the gas flowing inside and outside of it. Hence, measuring the resonant frequency will obtain the density of the flowing gas. Two pairs of piezo-electric elements are fitted to the cylindrical resonator along the same circumferential plane: one pair for drive, and the other for detection. The former pair generates two different vibration modes of the resonator independently. Although the resonant frequency can be expressed by the first equation shown in Figure 2, it is difficult to obtain the gas density from a single resonant frequency since the temperature effect is too large to be compensated for completely. Hence, the density of the gas is obtained based on the ratio between two resonant frequencies so as to reduce the temperature effect. Another merit of applying the frequency ratio is that the effect from deterioration with age can be reduced. The graph in Figure 2 depicts the relationship between the density of gas and the ratio between resonant frequencies in two modes. The density of the gas can be approximated by a quadratic equation of the ratio between the resonant frequencies. While, because the density of the gas varies with the temperature and pressure, these values are also measured simultaneously for compensation and the density at the standard conditions (at 0°C, 1 atm) is computed.

Figure 3 shows the relationship between seven kinds of measured values in a gas density meter. First, a density meter obtains the density of the gas under measurement conditions (namely, the actual density) based on frequency signals from the sensors. Next, the density meter converts the actual density of the gas to the density under standard conditions or the density under a user-specified temperature and pressure based on temperature and pressure signals.

Fundamentally, a vibratory gas density meter can only measure the density of a gas. Nevertheless, if the densities of the individual components of a mixed gas containing two components are known, the concentrations of those individual components can be obtained from the measured density of the mixed gas. Furthermore, from these concentrations, it is possible to determine the molecular weight, specific gravity, and even the calorie of mixed gas. However, the concentrations of component gases cannot be obtained from a mixed gas containing three or more components, except in special cases.

MODEL LINEUP

Figure 4 shows the converters and detector in the GD series. The GD300S detector can be used in a wide variety of environments since it has a raintight structure for outdoor-use and is intrinsically safe (approved under the Technology Institution of Industrial Safety, Japan). For converters, two models are offered: a general-purpose model and TIIS explosion-proof model. Also, the CE Mark has been obtained for the combination of the detector and converter, which means that the GD series meets global standards. Besides these models, the EJA310 absolute pressure transmitter is also included in the standard lineup.

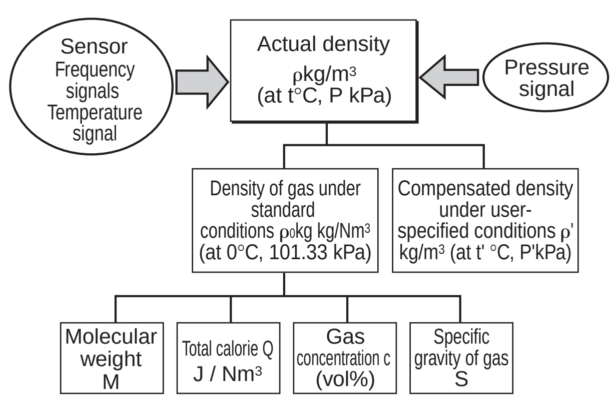


Figure 3 Relationship between Seven Kinds of Values Measured with a Gas Density Meter

Figure 4 Model Lineup of GD Series

The detector and pressure transmitter (EJA310) are connected to a converter. The display unit of the converter indicates the various measured values shown in Figure 3, as well as the temperature, pressure and frequencies. The converter outputs two analog 4-20 mA signals and one contact signal.

FEATURES

The GD series offers the following advantages in comparison to conventional gas density meters:

(1) Reduced Effect from External Vibration
Figure 5 depicts the structure of the sensor. Four O-rings supporting the resonator prevent the resonator from being effected by external vibration by absorbing it from all directions. Figure 6 shows an example of the effect of external vibration on the resonator. The acceleration of 2 G was applied in this example; however, since the resonance point of the sensor is nearly 200 Hz, the acceleration of the sensor itself exceeds 10 G at its resonant point. Nevertheless, Graph (1) in Figure 6 shows the maximum effect on the density reading to be 0.3 g/Nm^3, which can be said to be negligible.

Another merit of this structure is that it prevents vibration from being transferred via wiring and piping. Generally, even if a sensor is vibration-insulated with insulation rubbers, external vibration can be transferred via gas piping and wiring and it is very hard to prevent this from occurring. While, in the structure shown in Figure 5, the resonator is completely floated using O-rings, which in turn shuts out any vibration transferred via piping and wiring. These O-rings work not only as vibration-insulators, but are effective sealing against gases and act as heat-insulators.

(2) Two-wire Transmitting
The connection between a detector and converter requires multiple wires with conventional models, but now only two wires needed, which slashes the man-hours required for wiring at installation. The 24-V DC power supply, temperature signal (from RTD), and two oscillation frequencies of the resonator (2 kHz and 6 kHz) are superimposed together and transmitted by these two wires.

(3) Accurate Temperature Compensation
As shown in Figure 5, an extremely small Pt100 RTD is installed inside the path for the measured gas in order to increase the accuracy of measuring the temperature of gas.

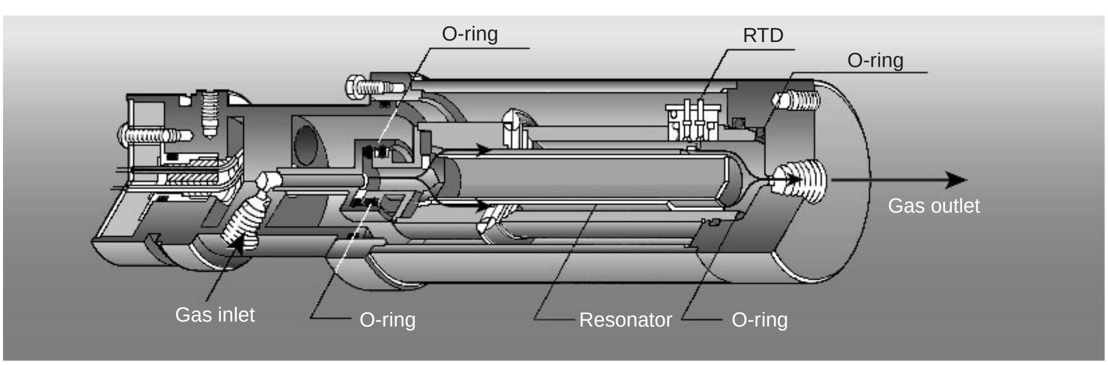


Figure 5 Sensor Structure

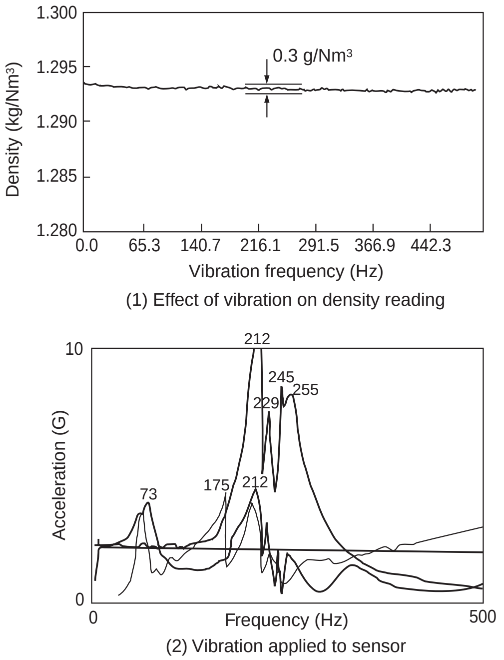


Figure 6 Effect of Vibration on Sensor

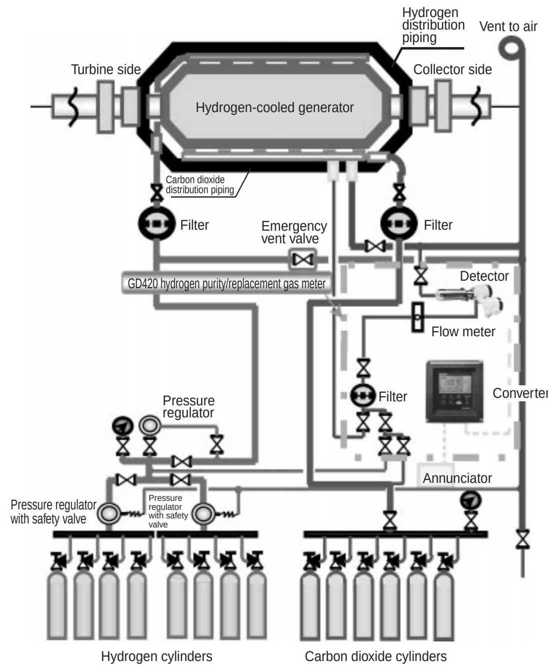


Figure 7 Hydrogen-cooled Power Generator and Monitoring of Replacement Gas Concentrations

The temperature effect of the resonator is compensated with a cubic approximation equation, leading to improved accuracy.

(4) Enhanced Noise Immunity

Thorough measures to eliminate the effect from noise were taken in order to obtain the CE Mark, including the use of many noise filters, shield plates, and a double-shielded cable between the detector and converter.

APPLICATIONS

As aforementioned, the functionality of the GD series has been enhanced with the addition of a hydrogen purity meter to the existing density meter and calorie meter. One application that makes use of these new functions is shown in Figure 7. A large-scale power generator in a power plant is cooled by hydrogen gas. A running generator unit is therefore filled with hydrogen gas at a pressure rate of 0.2-0.6 MPa abs. The concentration of the hydrogen gas is normally controlled at 98% and the remaining 2% is air. If the concentration decreases, then hydrogen is fed from cylinders. At periodic inspections, the hydrogen is exhausted from the generator and carbon dioxide is fed from carbon dioxide cylinders to replace the inert gas. After this, the carbon dioxide is then replaced by air and an inspection can finally be carried out. The procedure is performed in reverse at startup.

This application is necessary for measuring the concentrations of hydrogen in air, the concentration of hydrogen in carbon dioxide, and the concentration of air in carbon dioxide. The GD420 in the GD series is offered in three models:

(1) Hydrogen purity meter that measures the concentration of hydrogen in air
(2) Replacement gas meter that measures the concentrations of hydrogen and air in carbon dioxide
(3) Hydrogen purity/replacement gas meter that has the functions of both (1) and Traditionally, with density meters of the thermal conductivity type, two kinds of meters have been needed for this application. Now, however, a single GD420 covers this application, thus allowing the user to slash maintenance costs.

In addition to this application, the GD series includes a calorimeter (GD410) used for precision calorie control of natural gas and liquid natural gas as well as a density meter for various gases (GD400).

CONCLUSION

We have developed a gas density meter with the new additional function of hydrogen purity measurement to meet the specific requirements of particular applications. This new density meter alone covers the tasks that have required two conventional density meters of the thermal conductivity type. We believe that in the application of hydrogen purity measurement, this new model will help users to reduce maintenance costs. ◆

REFERENCE

(1) Naofumi, Demizu. et al. “Model DG8 Vibratory Gas Density Meter,” Yokogawa Technical Report, Vol.33, No.4, pp.35-40,1989, in Japanese.