International Gas Union Research Conference 2011

Development of a Reuse Method for Gas Meter Components

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Abstract

A pressure sensor is a security component used in the intelligent gas meter. The pressure sensors used by Osaka Gas are characterized by: (1) a 100% retrieval rate within ten years after installation of the gas meter, (2) an established retrieval procedure, and (3) a single model complying with identical specifications. Taking advantage of these features, the authors developed a reuse method for pressure sensors. Specifically speaking, accelerated deterioration test conditions were established, a statistical procedure was developed for determining the reusability rate, and the criterion for evaluating reusability were clarified.

TABLE OF CONTENTS

Body of Paper

1. Introduction

In the field of electrical appliances subject to Japan's Home Appliance Recycling Law, material recycling has enjoyed successful growth. In contrast, components of electrical appliances have never been exploited as reusable resources. This is because the history of component use is usually unclear, making it difficult to guarantee the performance of recycled components. Cost efficiency, in most cases, is another hurdle for component recycling.

The gas meter typically used in Japan consists of a main unit, which is for measuring the gas flow rate, and security components including a pressure sensor, a gas shut-off valve, a seismoscope, and a microcomputer controller. Since the Japanese Measurement Law stipulates a validity period of 10 years for the certification of gas meters, approximately 6.9 million gas meters installed by Osaka Gas at its customers' residences, offices, and factories are retrieved completely within 10 years after installation. A portion of the retrieved gas meter main units are reused after refurbishing. The security components, however, have all been replaced with new ones, scrapping all the retrieved components.

Against this background, the following common features of the pressure sensor caught the authors' attention:

- Their service periods are generally the same, because gas meters are replaced within the mandatory renewal period of 10 years ;
- The procedure for retrieving the sensors has already been established;
- Because all the sensors are of the same model and are made according to identical specifications, their construction, shape, and performance are the same.
- The sensors are purchased in bulk from a manufacturer and leased to gas meter assembling/manufacturing companies by Osaka Gas.

Focusing on these advantages, the authors started the development of a reuse method for pressure sensors. The issues that had to be addressed were: the determination of accelerated deterioration test conditions, a statistical determination procedure for the reusability rate, and the criterion for evaluating reusability.

2. Basic Characteristics of Pressure Sensor

2.1. Construction and Function of Intelligent Gas Meter

In earthquake-prone Japan, intelligent gas meters are widely used for their function of automatically shutting off the gas supply upon detection of an earthquake (approximately 200 gal or greater) and other emergency situations.

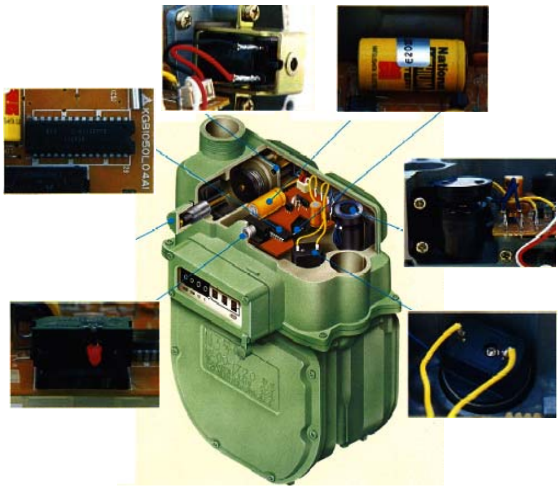
The gas meter used by Osaka Gas automatically shuts down the gas supply system (1) when:an earthquake of approx. 200 gal or greater occurs, (2) when the gas supply pressure drops, (3) when the gas is discharged for an unusually long period at a constant flow rate, or (4) when an excessively large discharge volume or surge in the gas flow rate is detected.

The gas meter now in use emits a warning signal when:a small-volume leakage is suspected, such as when the gas is discharged for 30 days or more without interruption.

The construction of an intelligent gas meter and the function of its security components are shown in Fig. 1:

Gas shut-off valve
Gas supply is shut off by a pulse signal sent from the microcomputer controller. This valve is built in the gas meter inlet section.

Power supply
A lithium battery is used as the power supply for the microcomputer and gas shut-off valves. The battery lasts more than 10 years.



Microcomputer controller
This controller judges whether the gas operating condition is normal or abnormal, and gives various operational commands.

Seismoscope
When an earthquake of approx. 200 gal or more occurs, a signal is transmitted to the microcomputer controller.

Indicator lamp
This lamp flashes when the microcomputer judges the gas operating condition as abnormal.

Pressure sensor
When the gas pressure drops abnormally (approx. 300 Pa or less), this sensor sends a signal to the microcomputer controller.

Fig. 1 Construction of intelligent gas meter and function of security components.

2.2. Construction and Operating Principle of Pressure Sensor

A pressure sensor is a security component installed in an intelligent gas meter and operates when the gas supply pressure falls to a level lower than 300 Pa. When the supply pressure is in the normal range, the diaphragm installed in the sensor is pushed upward due to the gas supply pressure. This diaphragm elevation is transmitted to the plunger, which pushes up the contact, thereby inactivating the sensor. When the supply pressure drops below 300 Pa, the diaphragm and the plunger both sink downward, and the sensor is thereby activated. The construction and operating principle of the pressure sensor are shown schematically in Fig. 2.

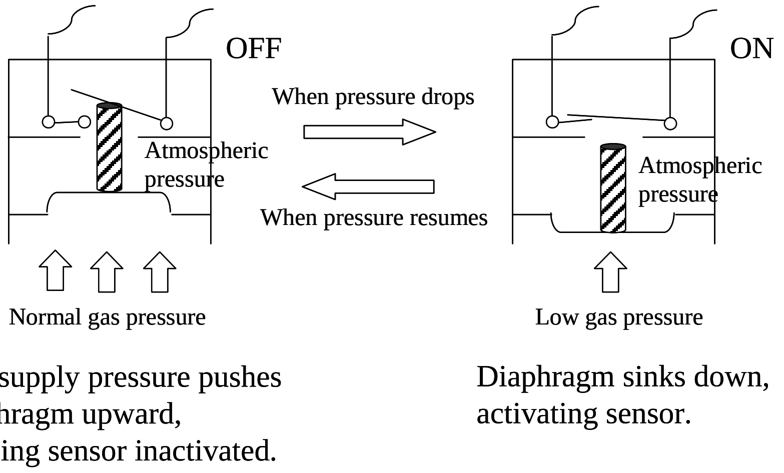


Fig. 2 Construction and operating principle of pressure sensor.

3. Test Method

3.1. Basic Concept of Pressure Sensor Characteristic Evaluation

To determine whether a pressure sensor is still reusable, it is necessary to confirm that the sensor meets the characteristic requirements with regard to the specified items (Table 1) even after the sensor was replaced due to the expiration of the initial validity period (10 years). The most important point is that the sensor is activated without fail once the supply pressure falls below the 200 Pa threshold value as stipulated in the Gas Business Law.

Table 1 Characteristic Evaluation Items for Pressure Sensor

Characteristic evaluation item	
Performance characteristics	Minimum inactivating pressure
	Maximum inactivating pressure
	Minimum activating pressure
	Maximum activating pressure

To correctly evaluate sensor reusability, the authors took a statistical approach by comparison of unreusable sensors (i.e., sensors activated at a pressure lower than 0.2 kPa) between those retrieved after 10-year use and those retrieved and reused for another 10 years (20-year use in total). The basic concept of pressure sensor characteristic evaluation is shown schematically in Fig. 3:

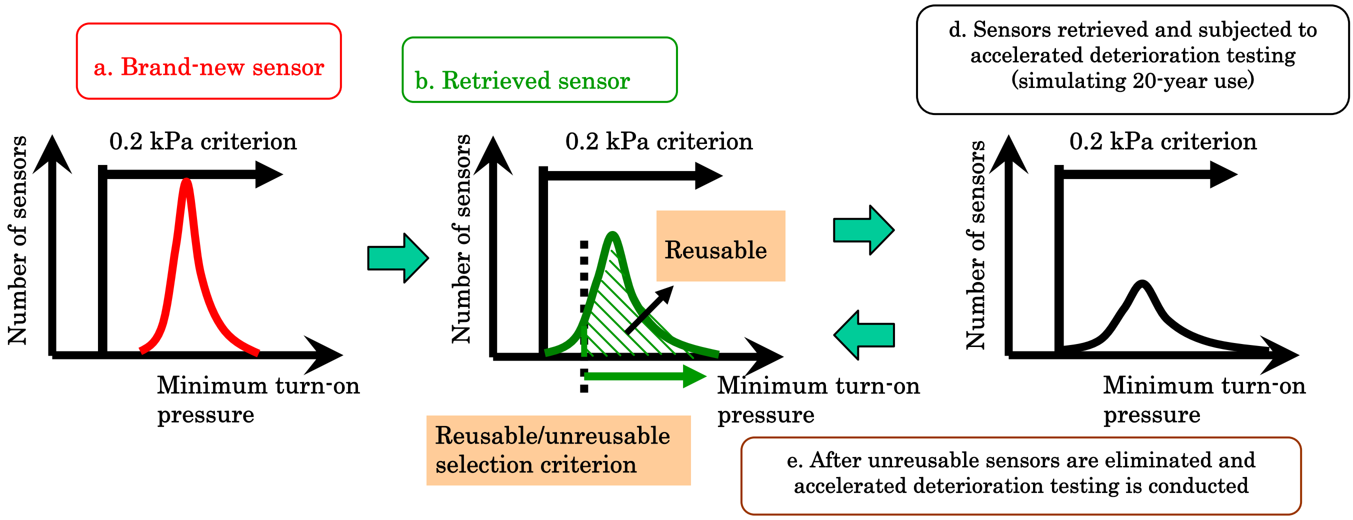


Fig. 3 Basic procedure for pressure sensor characteristic evaluation.

a. Measure the minimum activating pressure (Pon0) for brand-new sensors. Because the measured values are distributed, obtain the cumulative probability of incidence (qon0) for sensors not meeting the 0.2 kPa criterion by using a distribution function allowing the most accurate approximation.
b. Measure the minimum activating pressure (Pon1) for sensors retrieved after 10 years of use. Because the measured values are distributed, obtain the cumulative probability of incidence (qon1) for sensors not meeting the 0.2 kPa criterion by using a distribution function allowing the most accurate approximation.
c. Measure the minimum activating pressure (Pon1-1) for brand-new sensors that have been subjected to accelerated deterioration testing. Because the measured values are distributed, obtain the cumulative probability of incidence (qon1-1) for sensors not meeting the 0.2 kPa criterion by using a distribution function allowing the most accurate approximation.
d. Measure the minimum activating pressure (Pon2) for sensors retrieved after 10 years of use and subjected subsequently to accelerated deterioration testing. Because the measured values are distributed, obtain the cumulative probability of incidence (qon2) for sensors not meeting the 0.2 kPa criterion by using a distribution function allowing the most accurate approximation.
e. From retrieved sensors, eliminate those having significantly low activating pressures. Conduct accelerated deterioration testing by using the remaining sensors and measure their minimum activating pressures (Pon2-2). Because the measured values are distributed, obtain the cumulative probability of incidence (qon2-2) of sensors not meeting the 0.2 kPa criterion by using a distribution function allowing the most accurate approximation.

The key to success of the authors' attempt was to determine the accelerated deterioration test conditions that enable Pon1=Pon1-1 and qon1=qon1-1 while taking into consideration the conditions of gas meter use. This is because if the test conditions are determined properly and 10 years of use is thereby simulated correctly, the degree of deterioration of the sensors that have been retrieved after 10 years of use and subjected to the testing should be the same as that.of the sensors retrieved and reused for another 10 years (20 years in all).

The authors also had to determine the criterion for reusability/unreusability that enables Pon1=Pon2-2 and qon1=qon2-2 so that the minimum activating pressure for the retrieved sensors (10-year use) is maintained for another 10 years.

3.2. Accelerated Deterioration Test Conditions

Table 2 shows the major accelerated deterioration test items that were determined after consideration of the conditions of gas meter use during the 10-year period following installation.

The authors determined the test conditions for these test items on the precondition that there is the same activating pressure distribution for brand-new sensors having undergone the tests shown in Table 2 as for retrieved sensors (after 10-year use).

Table 2 Major Accelerated Deterioration Test Items

Accelerated thermal deterioration
Accelerated humidity deterioration
Thermal shock resistance
Low-temperature storage resistance
Corrosive gas resistance
Repetitive use durability

The determined test procedure is as follows:

① Measure the characteristics (e.g., the activating pressure) for the brand-new sensors (100 sensors), and process the measured values statistically.

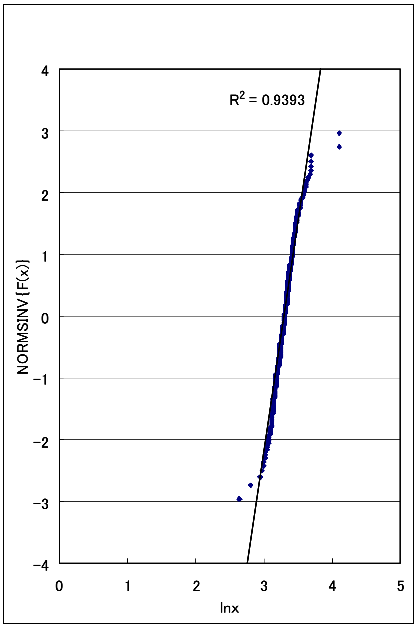
② Measure the characteristics of the sensors retrieved after expiration of the initial certified period (700 sensors after 10-year use) , and process the measured values statistically.

③ Conduct the accelerated deterioration testing by using the sensors retrieved after expiration of the initial certified period (50 sensors for each of 14 test items).

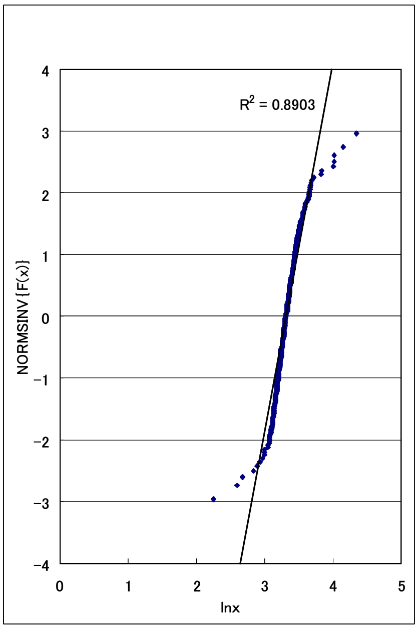
④ Measure the characteristics of the sensors retrieved after expiration of the initial certified period and then subjected to the accelerated deterioration testing (700 sensors). Process the measured values statistically.

4. Test Results

The statistically processed measured values of sensor activating pressure indicated that the log-normal distribution allowed the most accurate approximation of cumulative probability (Fig. 4).



Sensors retrieved after expiration of initial certification



Sensors retrieved after expiration of initial certification and subjected to accelerated deterioration testing

Fig. 4 Probability distribution of minimum acxtivating pressure measurements.

Next, unreusable cases were calculated by using the log-normal distribution. In detail, the authors calculated the unreusable cases among retrieved sensors (after 10-year use) and the cases among those retrieved and subjected to accelerated deterioration testing (equivalent to 20 years of use) based on a given criterion value for reusability/unreusability. As a result of comparing the cases obtained from various criterion values, the authors successfully identified the value that ensures the minimum activating pressure for retrieved sensors (after 10-year use) to be usable for another 10 years.

5. Inspection Procedure for Sensors Retrieved After Certification Expiration

The reuse of pressure sensors in intelligent gas meters started in October 1999. The following is the reuse procedure followed by Osaka Gas:

① When a gas meter certification expiration approaches, Osaka Gas replaces the gas meter with a new one that has passed the mandatory certification testing. The old gas meter is retrieved by Osaka Gas.

② The retrieved gas meter is sent to a gas meter assembling/manufactur- ing company. After receipt of the gas meter, its coating is removed, its exterior is cleaned, and the upper case is detached from the main unit of the meter before the components installed inside the upper case are detached.

③ The upper case is cleaned and inspected. The pressure sensor, saved for reuse, is installed. The installed sensor is inspected for proper operation and then for reusability based on the specified inspection standard. A “Reuse” stamp is affixed on the meter once it has passed the inspections (to prevent the meter from being reused again and again). The upper case is reinstalled onto the main unit.

④ The meter is weighed and tested by national authorities for certification. After coating is applied, the meter undergoes functional inspection of its microcomputer controller. When certification is given by the Japan Gas Appliances Inspection Association (JIA), a JIA sticker is affixed to the meter, which is then packed and shipped.

6. Conclusion

At Osaka Gas, the reuse of pressure sensors in intelligent gas meters started in October 1999. The number of pressure sensors reused until today totals about 3 million, according to the record of gas meter assembling/manufacturing companies alone. This large number of reused sensors has brought about significant cost reduction to Osaka Gas, which purchases pressure sensors directly from a manufacturer in bulk. Although the precise amount of reduced cost cannot be disclosed here because it is not desirable for a gas supplier to announce the purchase price of a new pressure sensor and the cost necessary for reusable sensor selection and inspection, the saved cost amounts to hundreds of millions of yen. More than 10 years have passed since sensor reuse started at Osaka Gas. Today, the scrapping rate of pressure sensors is confirmed to be 5% or less. When this figure is compared with the initially estimated rate of 6%, it would be quite reasonable to conclude that the accelerated deterioration test conditions and the statistical procedure for reusability rate determination which the authors propose have been proven to be useful. Furthermore, the reduced number of scrapped pressure sensors indicates that the authors’ study is also beneficial to environmental conservation.

List of Tables

List of Figures