

New differential pressure standard at KRISS

S. Woo, I. Choi, H. Song, B. Kim

Mechanical Metrology Group, Korea Research Institute of Standards and Science, Korea

Abstract

The accurate measurement of differential pressure at low-line pressure is important in many industrial and commercial activities. The Korea Research Institute of Standards and Science(KRISS) has completed the development of a low differential pressure primary standard covering a range from 1 Pa to 15 kPa for operation with line pressures of 100 kPa. The standard is based on a double pressure balance and includes a test-instrument manifold with pressure controllers. It has a peculiar automatic weight handling mechanism which enables the various weights easily to add or remove from the piston without breaking the reference vacuum during calibration. The performance of the standard has been evaluated using commercial precise differential pressure gauges.

Key words: differential pressure gauge, standard, differential pressure, calibration

1. Introduction

Nowadays there are increasing demands for more accurate measurement of differential pressure at low-line pressure due to the development of semiconductor and environmental industries. Some of the differential pressure gauges used to satisfy these demands are the capacitance diaphragm gauge and the silicon resonance gauge. Calibration of such precise differential pressure gauges is an important activity which is performed by many manufactures and calibration laboratories who seek the lowest measurement uncertainties. The Korea Research Institute of Standards and Science(KRISS) has completed the development of a low differential pressure primary standard covering a range from 1 Pa to 15 kPa for operation with line pressures of 100 kPa. The standard is based on a double pressure balance and includes a test-instrument manifold with pressure controllers. It has a peculiar automatic weight handling mechanism which enables the various weights easily to add or remove from the piston without breaking the reference pressure during calibration [1]. The performance of the standard has been evaluated using commercial precise differential pressure gauges.

1.1 Principle and Apparatus

Generally, the pressure P_i generated by a single pressure balance under absolute mode can be expressed as

$$P_i = \frac{M_i g}{A_e} + P_{vac} \quad (1)$$

where M_i is the initial mass, including the mass of piston, bell and main weights, A_e is the effective area of the piston and cylinder unit, and g is the local acceleration due to gravity. P_{vac} is the residual pressure in the space around the piston and is close to zero.

Differential pressure standard using double pressure balance technique is well known method. As shown in figure 1, two identical pressure balances are connected to each port. To generate the nominated line pressure, mass is applied to both high and low pistons. An initial cross floating equilibrium between high and low pistons is achieved by adjusting the mass applied to the one of two pistons until there is no pressure differential. To generate differential pressure, additional mass Δm is added to the high piston. The increase in pressure will also cause a small change in the area of the piston-cylinder due to its pressure dependent nature, but it is small enough to ignore. Changes in piston-cylinder temperature between establishing the initial cross-float and making the subsequent differential pressure measurement affects the area of the piston-cylinder and should be taken into consideration when calculating the differential pressure. If changes in piston-cylinder temperature are small and reference vacuum pressures are constant during measurement, the approximate differential pressure Δp generated by a twin pressure balance under absolute mode can be expressed as

$$\Delta p = \frac{\Delta m \cdot g}{A_{ch}(t_H, p_H)} + \rho_f g \Delta h \quad (2)$$

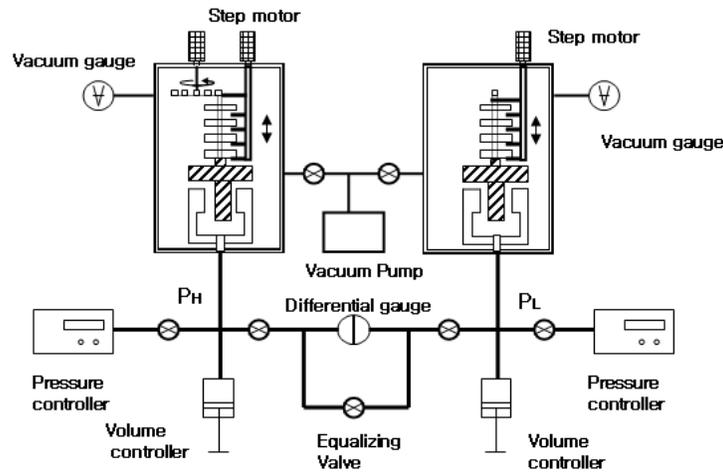


Figure 1. Schematic of the KRISS double pressure balance.

where t_H is the temperature of the piston-cylinder, p_H is the pressure generated by the high piston, ρ_f is the gas density, and Δh is the height difference change between two reference levels.

Figure 1 schematically shows the calibration system for a differential pressure gauge. To achieve high sensitivity and accuracy, two piston-cylinder assemblies

with 35 mm diameters are used. In order to minimize fluctuations caused by reference pressure disturbances, reference pressures were maintained as high vacuum state below 0.1 Pa. To load and unload small masses easily without breaking the vacuum, new weighting loading devices were developed. Figure 2 shows one of the weight loading devices used in twin pressure balance.

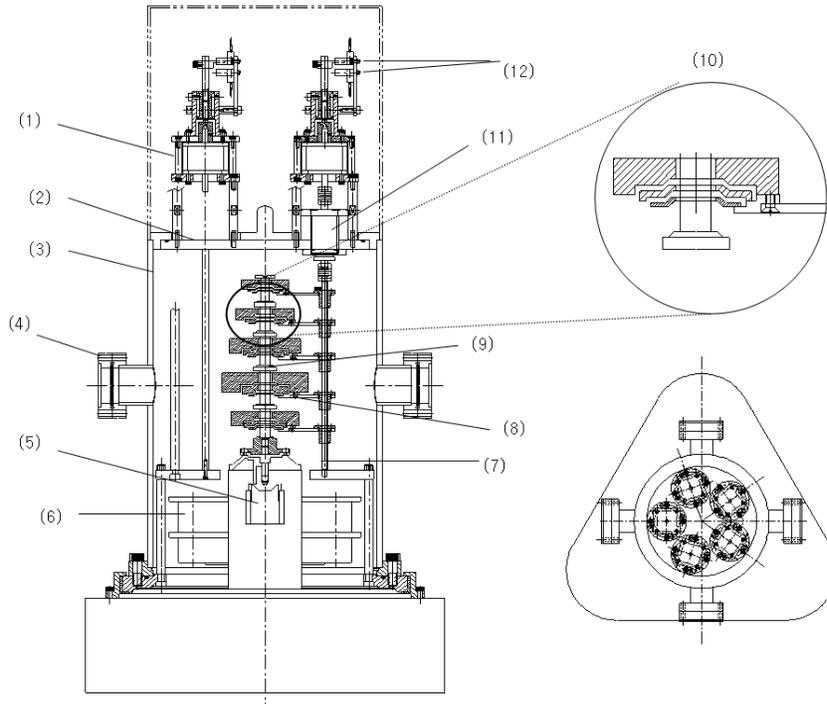


Figure 2. One of weight loading devices (1) stepping motor; (2) upper plate; (3) stainless steel chamber; (4) 2.75" port; (5) piston; (6) tare weights; (7) screw shaft; (8) weight lifter; (9) weight lifting shaft; (10) combined weight set; (11) rotary feed-through; (12) photo interrupter.

2. Experiment and Discussion

For the calibration of differential pressure gauge, the ABABA method was used. This method is well described in other paper [2]. Before measurement, zero adjustment of differential pressure gauge is done. In state A, the line pressures generated by the low and high pistons are almost in equilibrium. The reading of the differential pressure at this condition is R_1 . In state B, the differential pressure is applied by loading a small weight Δm on to the high piston. The reading of the differential pressure at this condition is R_2 . Next step is done by unloading the small weight Δm from the high piston. The reading is R_3 . The procedure is repeated to obtain readings of R_4 and R_5 . Final differential pressure is calculated from the average of two differential pressures as follows.

$$\Delta p = \frac{1}{2} \left[\left(R_2 - \frac{R_1 + R_3}{2} \right) + \left(R_4 - \frac{R_3 + R_5}{2} \right) \right] \quad (3)$$

Using the differential pressure standard, several capacitance diaphragm gauges were calibrated. Figure 3, figure 4 and figure 5 show the calibration results of three types of CDGs (MKS, USA) having a full scale range of 13 Pa, 133 Pa, 1.3 kPa respectively. The reading of 13Pa CDG shows that the difference from standard pressure is within 0.03 Pa. The results for 133 Pa CDG are presented in figure 4, where the shift of span is 0.4% of full scale. Figure 5 shows calibration data sets for two CDGs, each having a full scale range of 1.33 kPa. The results indicate that these gages are slightly nonlinear than other FS ranges even though the nonlinearity is not so large.

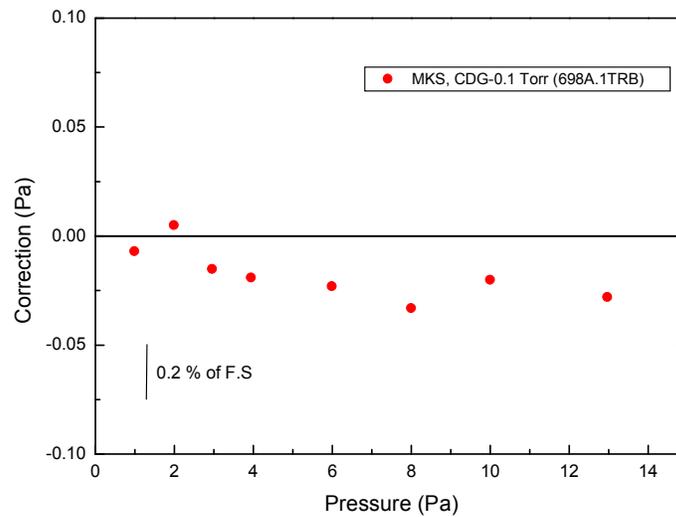


Figure 3. Calibration of a 13 Pa (0.1Torr) CDG.

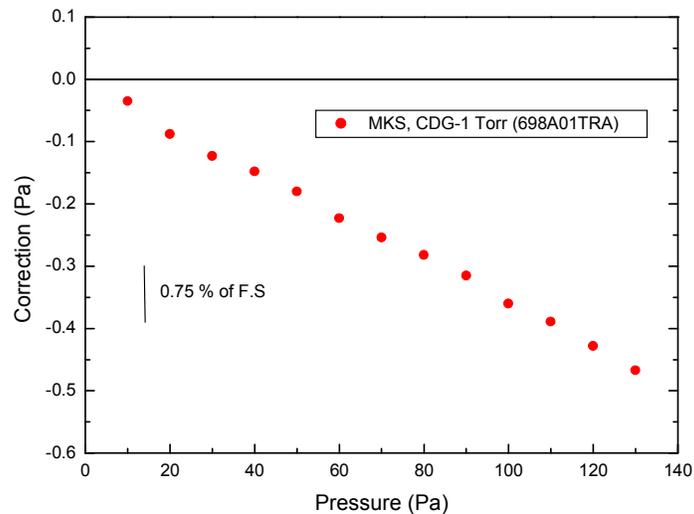


Figure 4. Calibration of a 133 Pa (1Torr) CDG.

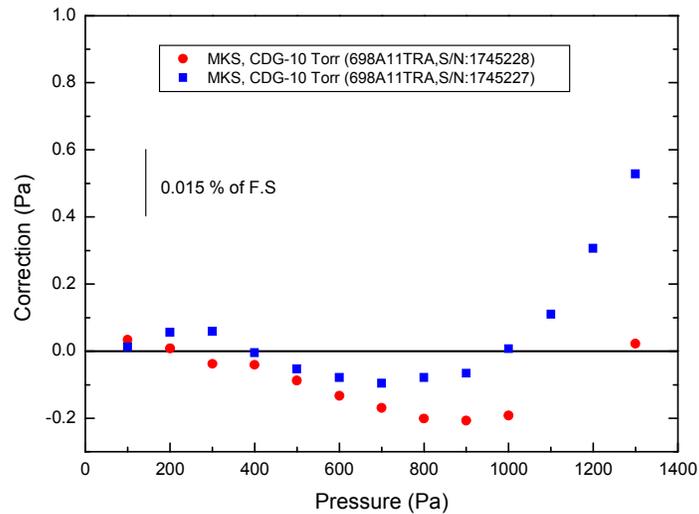


Figure 5. Calibration of a 1.33 kPa (10Torr) CDG.

3. Conclusion

We have developed a new differential pressure calibration system using double pressure balance as the primary pressure standard. The calibration range is from 1 Pa to 15 kPa. To reduce the uncertainty and calibration time, we have developed new weight loading devices. Using this system we could easily calibrate three types of precise differential pressure gauge.

References

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