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UNCERTAINTY EVALUATION OF LOW PRESSURE BY MEANS OF CROSS-FLOAT

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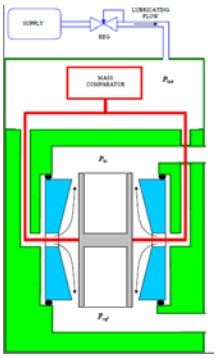
Abstract: KTL has forced piston gauge which generate very low pressure (1 Pa~ 1400 Pa) stable. Prior to forced piston gauge, we calibrate with digital manometer or capacitance diaphragm gauge below 1400 Pa (uncertainty : 0.011 %). This paper will introduce uncertainty evaluation of new standard by means of cross-float.

Keywords: forced piston gauge, low pressure, evaluation of uncertainty, cross-float

1. PRINCIPLE OF FORCED PISTON GAUGE

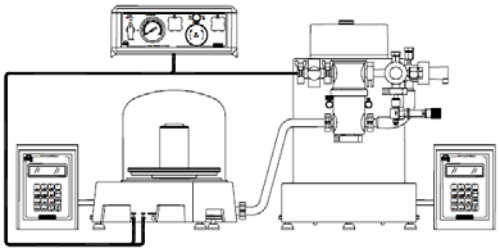
Force resulting from pressure across the piston is measured by a force balanced load cell. Piston is mechanically held at its center and connected to the load cell by a double universal joint system. Piston is centered by gas flow through conical gap of 1 to 6 micrometers. Lubricating gas is 40 kPa higher than P*ref*. Lubricating gas flows through center of cylinder through same passage as piston force coupling system. Load cell is in lubricating gas, not the measured pressure.



$$P = \frac{K_{cal} \times N}{A_0(1+(\alpha_c+\alpha_p)(t-t_l)} \qquad (1)$$

2. CALIBRATION - CROSS FLOAT

Normal Cross-float is the method used to determine the cross sectional area of the piston cylinder which is one of the main factors in determining the accuracy of a piston gauge. Known weights are added to the piston gauge under test until the pressure is balanced with a known comparison standard. The difference in weight applied to each standard is used to determine the difference in X-sectional area of the piston cylinder. Force piston gauge is composed of piston-cylinder and load cell realize the standard of pressure like piston gauge. But in case of Forced piston gauge, another method is required for traceability with cross-float. Connect the standard piston gauge and volume controller and FPG test port with T type and eliminate VLPC and connect metering valve at VLPC port. VLPC is not required when cross-float. Pressurize slowly to target pressure and open ball valve when deadweight rotate. Calculate the standard pressure and read the FPG indicate 'N' value when FPG keeps stable in a few second. Repeat this work from 1.5 kPa to 15 kPa at interval of 1 kPa.



3. UNCERTAINTY EVALUATION

Uncertainty evaluation is composed of Type A evaluation and type B evaluation. Type A evaluation is the method by the statistical analysis of series of observations. Type B evaluation is the method of evaluation of uncertainty by means other than the statistical analysis of series of observations. In case of this calibration, type A evaluation is standard deviation of effective area (A0) by means of linear square method. Type B evaluation is composed of factors of standard piston gauge and load cell. Combined standard uncertainty is the positive square root summation of type A and type B. Expanded uncertainty is obtained by multiplying a coverage factor. As recommended at ISO, uncertainty evaluation of cross-float requires mathematical model. Mathematical model is like that (2),(3),(4)

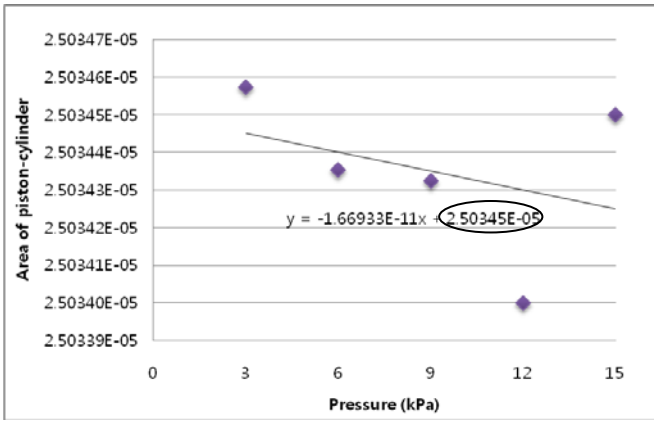
$$P_s = P_t \qquad (2)$$

$$P_s = \frac{\sum mg\left(1-\frac{\rho_a}{\rho_m}\right)}{A_0(1+\lambda P_n)[1+(\alpha_r+\alpha_w)(t-t_r)]} \qquad (3)$$

$$\frac{\sum mg\left(1-\frac{\rho_a}{\rho_m}\right)}{A_0(1+\lambda P_n)[1+(\alpha_c+\alpha_p)(t-t_L)]} = \frac{F_t}{A} \qquad (4)$$

The area (A) of forced piston gauge is obtained by (4) equation from 3 kPa to 15 kPa at intervals of 3kPa. Calculate the y-intercept by means of linear square method,

that is the effective area of FPG and type A uncertainty can be obtained by standard deviation of ‘y’ and slope ‘a’ and intercept ‘b’.



$$u_a = \sqrt{s_a^2 + x^2 s_b^2 + 2x s_a s_b r(a,b)} \qquad (5)$$

Type B uncertainty from standard piston gauge is calculated by (3). It has 11 factors of uncertainty. 11 factors are Mass, acceleration of gravity, density of air, density of mass, effective area of piston-cylinder, pressure distort coefficient, nominal Pressure, thermal expansion coefficient of piston-cylinder, the gap of lab temperature and reference temperature, verticality, reproducibility. Type B uncertainty from Ft is known by specification of load cell.

4. CONCLUSION

We calibrated a forced piston gauge which can measure low range and control using cross-float method. As a result, we improve uncertainty below 1400 Pa than ever before (0.011 % -> 0.006 %) and can keep traceability from pressure standard.

5. REFERENCES

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