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Study on calibration procedure for differential pressure transducers

M. Kojima, K. Saitou and T. Kobata

National Metrology Institute of Japan, National Institute of Advanced Industrial Science and Technology. E-mail: m.kojima@aist.go.jp AIST Tsukuba Central 3, Tsukuba, Ibaraki 305-8563, Japan

Abstract

The indications of some types of differential pressure transducers are affected by the calibration procedure such as pressurization sequence, the line pressure and environmental conditions: it is known that hysteresis, zero drifts and span readings of some transducers depend on those parameters. When the calibrated transducer is used as a working standard in another calibration, therefore, it is necessary to use the same procedure as previous calibration. Otherwise, the calibration results sometimes differ according to the measurement condition. As an example, the different calibration results obtained by two working standards which have different dependency on pressurization sequence are shown in the report. Also the line pressure dependency of a transducer was evaluated by changing the line pressure from 25 kPa to 175 kPa in the range of differential pressure from 1 Pa to 1000 Pa.

Keywords: differential pressure standard, pressure transducer, calibration protocol, double pressure balances

1. Introduction

A number of accurate measurements on differential pressure have been required. The transducers used in those measurements often need a precise calibration to ensure their performance. To calibrate these transducers efficiently, NMIJ/AIST developed a new calibration system with a “comparative method” in addition to the conventional calibration system with double pressure balances (2PB). The new system can be operated more efficiently and conveniently than the conventional one. However, the pressure transducers usually have a dependency on the calibration procedure, the precise characterization of the pressure transducer used as a working standard is important. In the following, two calibration methods are mentioned and the dependencies of transducers on calibration procedure are described with calibration results.

1.1 Calibration Systems

1.1.1 Direct comparison with 2PB

Figure 1 shows a schematic layout of the calibration system using double pressure balances (2PB). At first, two pressure balances are connected to each port of a transducer under test (DUT) and generate nominally equal line pressures p_{L1} and p_{L2} (p_{L1} - p_{L2} ~ 0). The difference between these two pressures is measured as the zero offset of differential pressure. Then a small weight with a mass of Δm is added on either pressure balance to generate differential pressure Δp on the line pressure. The line pressure can be varied by changing the weights on both pressure balances. In our 2PB system, the pressures inside the both bell-jars are evacuated with a vacuum pump to avoid atmospheric disturbance in the reference pressure and stabilize the line pressure.

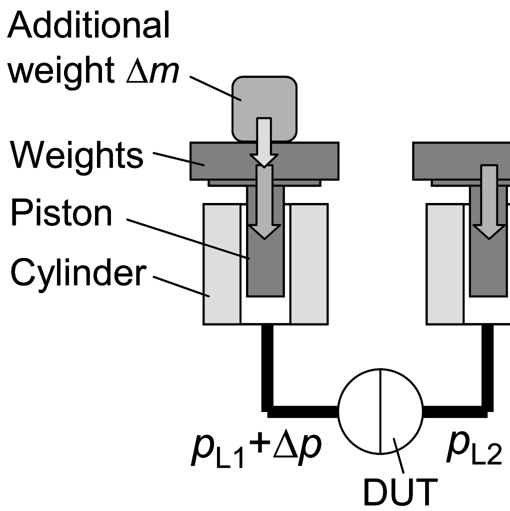

Figure 1: Schematic layout of the calibration system using double pressure balances for differential pressure transducer.

During the measurement, the line pressures generated with the two pressure balances gradually change with environmental parameters such as temperature of the piston-cylinder units, piston positions and reference pressures. These drifts from two pressure balances cause a change in the zero offset and differential pressure; therefore the drifts should be checked at short interval for the precise calibration.

To monitor the zero offset consistently, the calibration procedure called "ABABA" sequence is usually applied. The procedure is shown in figure 2: first, the indication of DUT is measured with state "A", which is zero offset, then it is measured with state "B", which is the differential pressure generated. These states are repeated several times. This procedure can provide small uncertainty, although it takes relatively long time to complete a calibration.

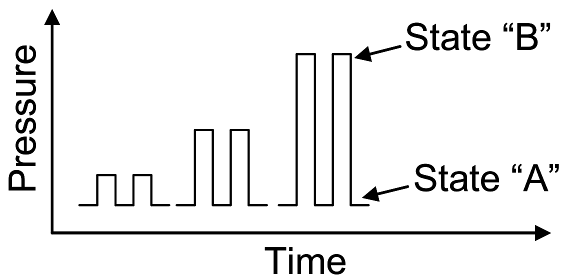

Figure 2: Example of measurement procedure with "ABABA" sequence.

1.1.2 Comparative Method

Comparative method is developed to perform the calibration more efficiently and conveniently than the method with 2PB. This method is realized by the calibration from digital pressure transducer to digital pressure transducer. Figure 3 shows the schematic layout of the calibration system of the method. The pressure transducer called working standard (WS) is assumed as a reference standard after it is calibrated with 2PB system. The calibration with the system is performed as follows: the calibration pressure is generated by a pressure controller and applied to both WS and DUT. Then the calibration result is obtained by comparing the indication of DUT and the standard pressure which is estimated from the indication of WS.

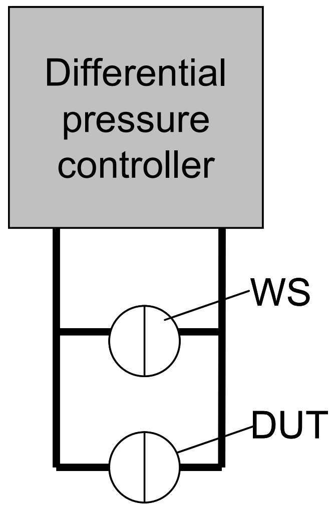

Figure 3: Schematic layout of the calibration system using comparative method.

In the comparative method, the pressure controller can be used to vary the pressure, so there are mainly two types of measurement procedures can be adopted such as shown in figure 4 (a) and (b): (a) ABA sequence (calibration pressure with zero) and (b) stepwise sequence (monotonically increasing/decreasing sequence).

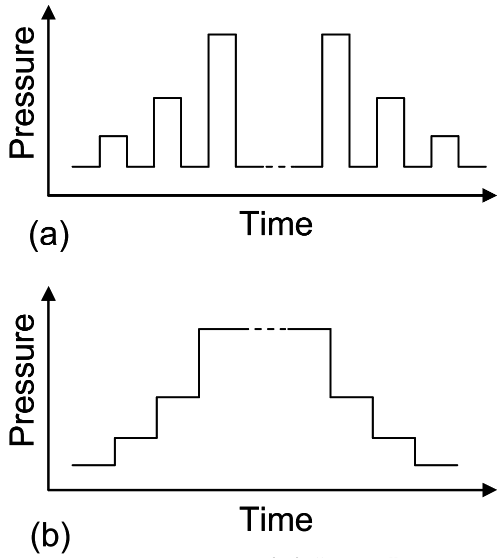

Figure 4: Measurement procedure with (a) "ABA" sequence and (b) stepwise sequence.

1.2 Calibration Procedure Dependency

1.2.2 Pressurization sequence dependency

The pressurization sequence for the comparative method should be similar as that is used in the pre-calibration for WS because some pressure transducers have hysteretic characteristics or different zero drifts according to the pressurization sequence.

No hysteresis was found with WS when it is calibrated by our 2PB system using ABABA sequence. This is because the pressure transducers always measure zero pressure before and after each calibration pressure. The zero drift measured with this procedure was also sufficiently small. On the other hand, hysteresis often takes place in the procedure with stepwise sequence. In addition, the amount of hysteresis depends on the pressure applied and pressure holding time.

For example, figure 5 shows the calibration result for one DUT (full span 10 kPa) which was calibrated by two different WSs (WS1 and WS2) at the same time. The calibration pressures were applied along the stepwise sequence, while both of WSs were pre-calibrated by 2PB system with ABABA sequence. The line pressure at the calibration was the atmospheric pressure and at the pre-calibration, it was 100 kPa in absolute mode. We can see that the calibration result obtained by WS1 shows clear hysteresis and zero drift, however that obtained by WS2 shows sufficiently small hysteresis. The difference between those two results is caused by the different characteristics of two WSs: They have different dependency on the pressurization sequence. From the result, the difference between the results was enough larger than the resolution of DUT, therefore it is important to consider the dependency into the uncertainty when the WS is used in the calibration with different pressurization sequence. Also the dependency of WS1 on the pressurization sequence was examined. Almost same results as that from WS2 was obtained by using ABA sequence instead of stepwise sequence.

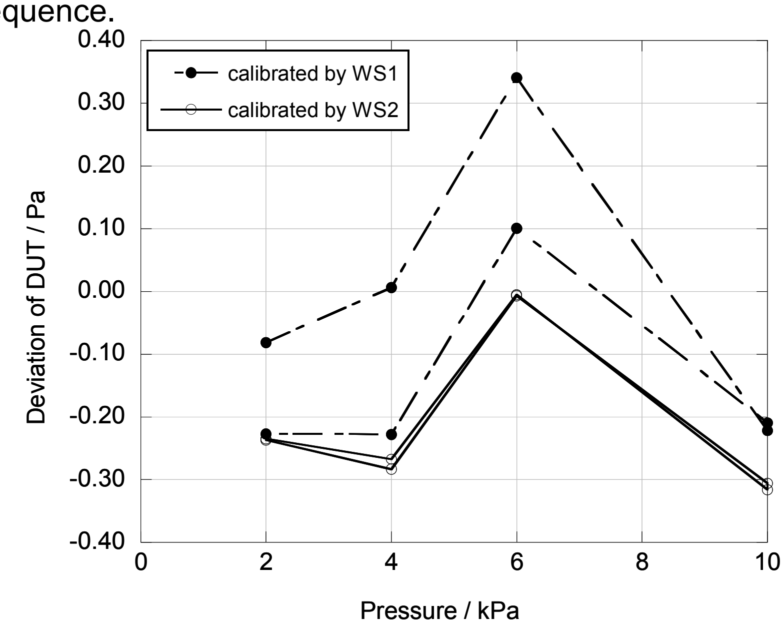

Figure 5: The calibration curves of a pressure transducer under test (full span 10 kPa) calibrated by two working standards. The solid lines were the calibration results by WS1 and the dotted lines were by WS2.

Therefore in the comparative method using WS, it is necessary to use similar procedure used in the pre-calibration. If the WS was calibrated with ABABA sequence, the ABA sequence should be applied by a pressure controller. Otherwise the standard pressure may not be estimated properly from the indication of WS because of the hysteresis or zero drift.

1.3 Line Pressure Dependency

Some pressure transducers have line pressure dependency: The span indications changes according to the line pressure.

Figure 6 shows the calibration curves of a differential pressure transducer (full span 1 kPa) obtained by changing the line pressure from 25 kPa to 175 kPa in the absolute mode. The differential pressures from 1 Pa to 1000 Pa were generated by 2PB at each line pressure. From the result, we can find that the indication of the transducer had dependency on the line pressure especially at differential pressure above 300 Pa.

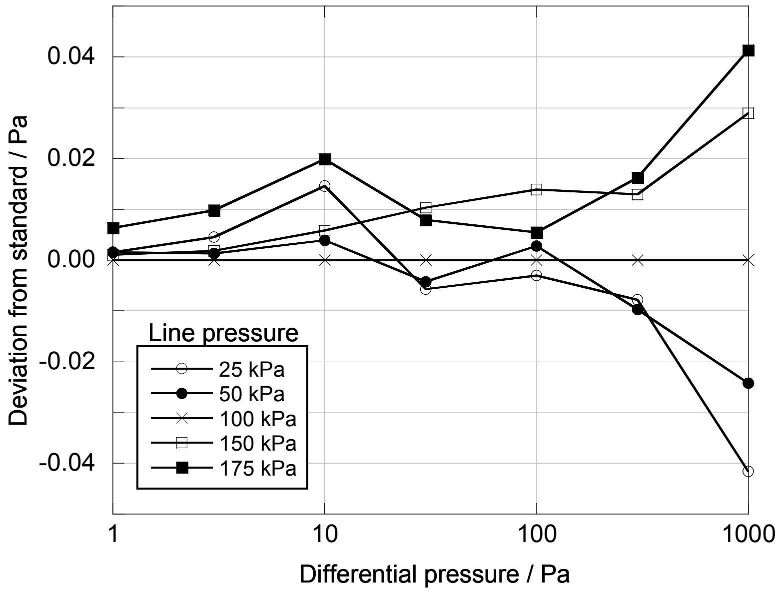

Figure 6: The calibration curves of a pressure transducer (full span 1 kPa) with line-pressure dependency. Each deviation in vertical axis is normalized by subtracting the deviation at line pressure 100 kPa.

To evaluate the effect, we extracted the calibration results for 300 Pa and 1000 Pa from figure 6 and re-plotted in figure 7. In figure 7, the results are plotted against the line pressure. We can see that this pressure transducer had a linear dependency to the line pressure.

From these results, it is important to perform the calibration at the same line pressure as the pre-calibration of WS to avoid the line pressure dependency.

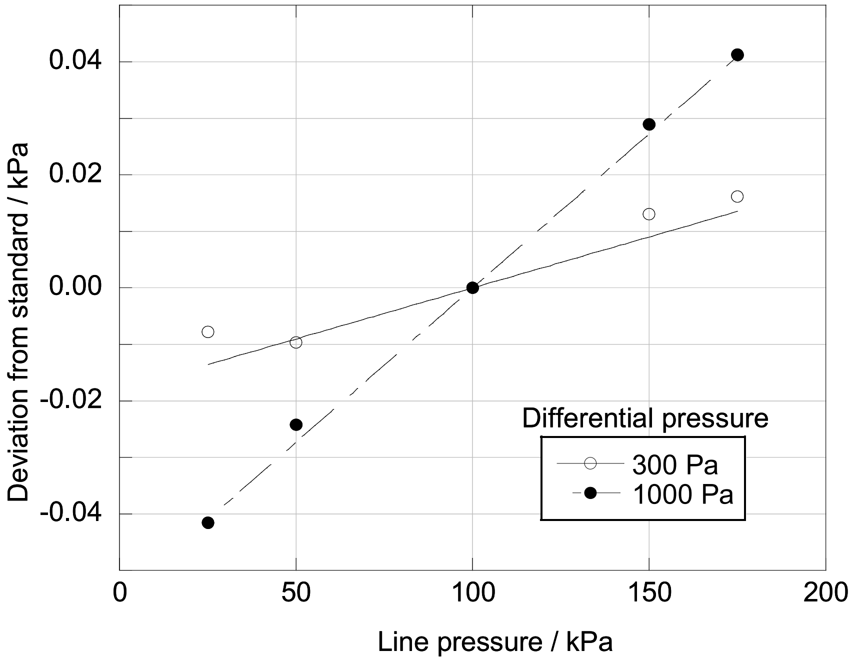

Figure 7: Calibration results for 300 Pa and 1000 Pa of differential pressures are extracted from figure 6 and plotted against the line pressure.

2. Conclusions

From our characterization, it has been confirmed that some differential pressure transducers have dependency on the calibration procedure such as pressurizing sequence and/or the line pressure. These dependencies should be considered when the transducers are used for the precise calibration or measurements; they should be used in the similar condition as they are calibrated previously.

References

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