

Towards establishment of remote calibration for pressure standards

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Abstract

A remote calibration technology for disseminating pressure standards has been developed. Currently, the technology is developed in two different pressure ranges. One is gas differential pressure from 10 Pa to 10 kPa with the line pressure of atmospheric pressure and the other is hydraulic pressure from 10 MPa to 100 MPa in gauge mode. In both pressure ranges, the measurement protocol for the remote calibration using a transfer standard has been examined. Also the transfer standard for the remote calibration has been developed in either pressure range. Using the protocol and the developed transfer standard, the demonstration experiments for the remote calibration were performed. In this paper, the measurement protocol and the transfer standard developed for the remote calibration are described and the results obtained from the experiments are shown.

Keywords: remote calibration, pressure standard, transfer standard, pressure transducer

1. Introduction

The National Metrology Institute of Japan (NMIJ/AIST) is currently providing the national pressure standards from 1 Pa to 1 GPa to our clients [1]. In our normal calibration, a calibration item is transported from the client to our calibration laboratory and is calibrated using the pressure standard. However, to provide the pressure standard effectively and efficiently, a new calibration method has been requested.

The remote calibration technique using both a transfer standard and an information technology has been developed at NMIJ/AIST towards the establishment of the remote calibration for disseminating the pressure standards. In the development, the following research topics have been investigated: i) Making a calibration procedure (protocol) for the remote calibration, ii) Development of reliable and convenient transfer standards, iii) Establishment of remote calibration services for disseminating pressure standards.

Currently the remote calibration technique is developed in two different pressure ranges. One is gas differential pressure from 10 Pa to 10 kPa with the line pressure of atmospheric pressure and the other is hydraulic pressure from 10 MPa to 100 MPa in gauge mode. In the development, the target expanded ($k = 2$) uncertainty of the remote calibration for the gas differential pressure is less than 0.010 % of the value or 100 mPa whichever is greater and that for the

hydraulic pressure is less than 0.01 % of the value.

In both pressure ranges, the measurement protocol for the remote calibration using a transfer standard has been examined. Also the prototype transfer standard for the remote calibration has been developed using precise pressure transducers in either pressure range. Using the protocol and the developed transfer standard, the demonstration experiments for the remote calibration have been performed between NMIJ/AIST and domestic pressure calibration laboratories. In this paper, the current state of the remote calibration technology for pressure standards is described.

1.1 Remote Calibration for Pressure Standard

In the remote calibration, a transfer standard is transported from the calibration laboratory to the remote site where the calibration item is equipped. Using the transfer standard, the calibration item is calibrated in the remote site.

Figure 1 shows the conceptual drawing for the remote calibration using a transfer standard. In the figure, the part surrounded by a fine line is the procedure to be performed by using Internet. The procedure for the remote calibration is described in the followings. First the client makes an application to the calibration laboratory for the remote calibration. If the application meets the requirements for the remote calibration, the calibration laboratory accepts the application. Then, the transfer standard is transported from the calibration laboratory to the client's site. Before the transportation, the calibration laboratory normally calibrates the transfer standard using the working standard. After the transfer standard arrives at the client's site, it is prepared for the remote calibration and is connected with a calibration item by support personnel. Then the calibration laboratory performs the remote calibration using the transfer standard according to the protocol. The transfer standard can automatically calibrate the calibration item in the client's site. The data acquired by the transfer standard is also automatically sent to the calibration laboratory through Internet. For ensuring the reliability of calibration, the remote site where the calibration is performed is monitored and the pictures are reported to the calibration laboratory by support personnel.

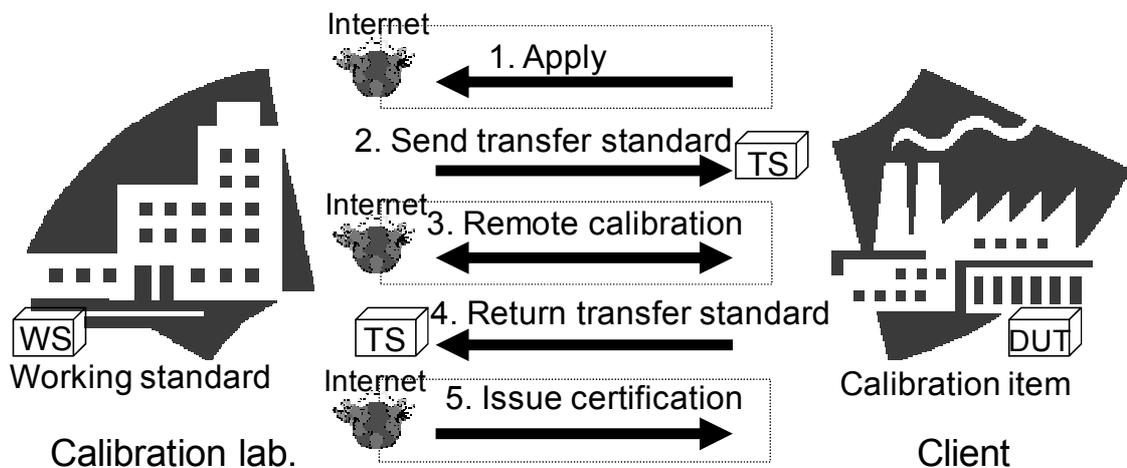


Figure 1: Conceptual drawing of remote calibration with transfer standard.

After the calibration is completed at the client's site, the client returns the transfer standard to the calibration laboratory. After the receiving, the calibration laboratory calibrates the transfer standard using the working standard. The calibration laboratory analyzes all the data acquired and finally issues a calibration certificate.

1.2 Transfer Standard for Remote Calibration

The transfer standard for the remote calibration requires several functions to perform the calibration in the remote site. First, automatic pressure control and measurement are necessary for performing the automated calibration, so an automatic pressure controller and precise pressure transducers should be included. Also, a means of measuring the environmental condition of the remote site where the calibration is performed is needed to check the calibration condition. Moreover, a means of communication is necessary to send the calibration results to the calibration laboratory using internet. For purposes of transportation, the transfer standard should be compact, lightweight and robust.

To perform the remote calibration for pressure standards accurately, precise and stable pressure transducers are indispensable. To develop the transfer standard, resonant silicon type transducers are used in the gas differential pressure and quartz Bourdon-type high-pressure transducers are used in the hydraulic pressure [2, 3]. For ensuring the reliability, the transfer standard in either pressure range is equipped with more than two pressure transducers.

Figure 2 shows the schematic drawing of the transfer standard for the remote calibration. The transfer standard consists of a pressure controller, more than two pressure transducers, a device for measuring environmental condition, a tilt meter for checking the inclination, an interface for GPIB/RS232C communication, a computer and a program. A camera to check the calibration setting is used. By running the program, the transfer standard performs the automatic calibration by controlling the devices mentioned above, and sends the measured data to the calibration laboratory through Internet.

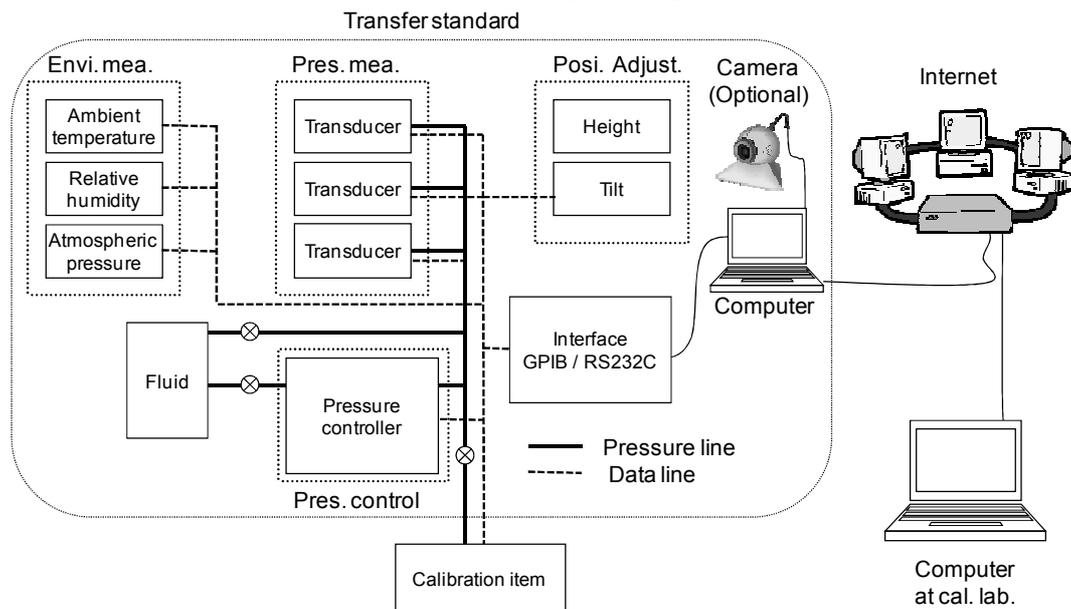


Figure 2: Schematic drawing of prototype transfer standard system for remote calibration.

1.3 Calibration Procedure

Before using the pressure transducers in the transfer standard for the remote calibration, their characteristics should be evaluated. The method for characterizing the pressure transducers has been examined [2, 3]. By the characterization, the behavior of pressure transducers during the remote calibration can be estimated and adequate corrections can be made for obtaining the correct pressure values.

The pressure transducers used in the transfer standards have been calibrated by the superior standards. From the calibration results, it has been confirmed that pressure transducers evaluated are enough stable compared with our target uncertainties for the remote calibration.

1.4 Procedure in Gas Differential Pressure

Figure 3 shows the procedure calibrating the pressure transducers in the gas differential pressure. The target calibration pressures are 10 Pa, 30 Pa, 100 Pa, 300 Pa, 1000 Pa, 3000 Pa, and 10000 Pa with line pressure of atmospheric pressure. By adding zero pressure measurements before and after the target pressure measurement, the pressure applied to the transducers was varied as shown in the figure, that is, 0 Pa \rightarrow 10 Pa \rightarrow 0 Pa \rightarrow 30 Pa \rightarrow 0 Pa \rightarrow ... \rightarrow 10000 Pa \rightarrow 0 Pa, then 0 Pa \rightarrow 10000 Pa \rightarrow 0 Pa \rightarrow 3000 Pa \rightarrow 0 Pa \rightarrow ... \rightarrow 10 Pa \rightarrow 0 Pa.

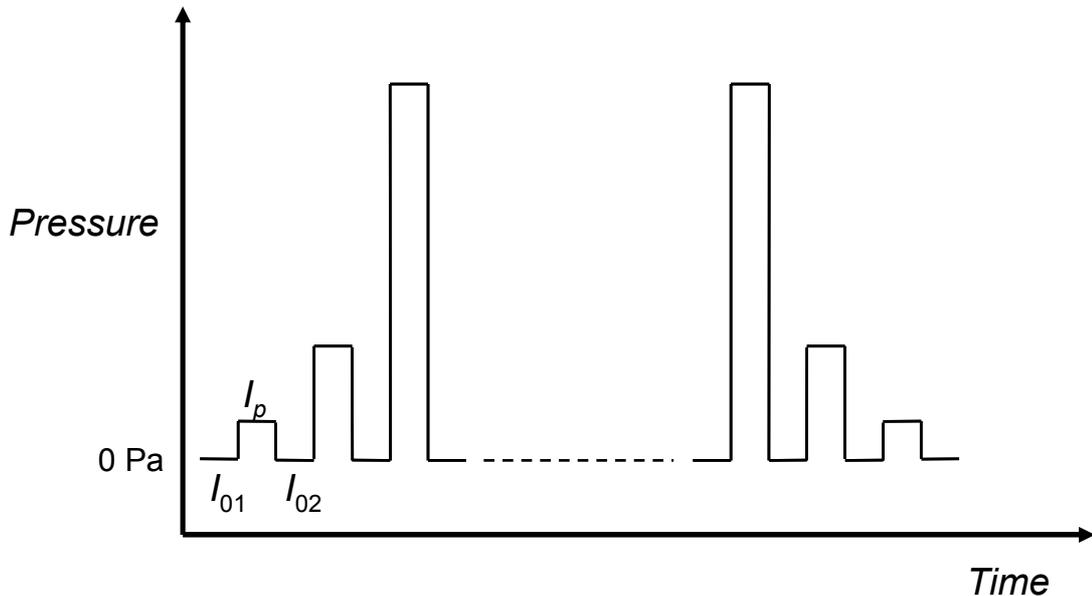


Figure 3: Calibration procedure for gas differential pressure.

One cycle measurement consists of the above ascending and descending pressure measurements and is repeated 3 times to calibrate the pressure transducers. Normally, one cycle measurement takes approximately 3 hours. At each pressure, the reference pressure applied by the working standard, P_r , and the indication of the pressure transducer calibrated, I'_p , are measured after pressure stabilization. By using the indications at the zero-pressure immediately before and after the target pressure, I'_{01} and I'_{02} , the correction for zero-pressure offsets can be made. The corrected indication at the target pressure, I , is expressed by the next equation.

$$I = I'_p - (I'_{01} + I'_{02})/2 \quad (1)$$

For i -th pressure transducer used in the transfer standard, the deviation of I_{tsi} from P_r , δI_{tsi} , at each target pressure is evaluated by the next equation.

$$\delta I_{tsi} = I_{tsi} - P_r \quad (2)$$

By taking the average of three δI_{tsi} from three cycle measurements at each pressure, the mean deviation from the reference pressure, ΔI_{tsi} , is obtained.

1.5 Procedure in Hydraulic Pressure

Figure 4 shows the procedure calibrating the pressure transducers in the hydraulic pressure. The target calibration pressures are from 10 MPa to 100 MPa in steps of 10 MPa in gauge mode. The pressure applied to the transducer was varied from 10 MPa to 100 MPa first, then from 100 MPa to 10 MPa in steps of 10 MPa as shown in the figure. One cycle measurement consists of the above ascending and descending pressure measurements and is repeated 3 times to calibrate the pressure transducers. Normally, one cycle measurement takes about 4 hours. At each pressure, the reference pressure applied by the working standard, P_r , and the pressure indication from the transducer calibrated, I'_p , are measured after pressure stabilization. By using the indication at the zero-pressure, I'_0 , the correction for zero-pressure offset is made. Although there are 2 zero-pressure measurements in one cycle, the indications at the initial and last zero-pressure are used for correcting the indications in the ascending and descending pressure, respectively. The corrected indication at the target pressure, I , is expressed by the next equation.

$$I = I'_p - I'_0 \quad (3)$$

For i -th pressure transducer used in the transfer standard, the mean deviation, ΔI_{tsi} , is evaluated at each target pressure as described in section 4.1.

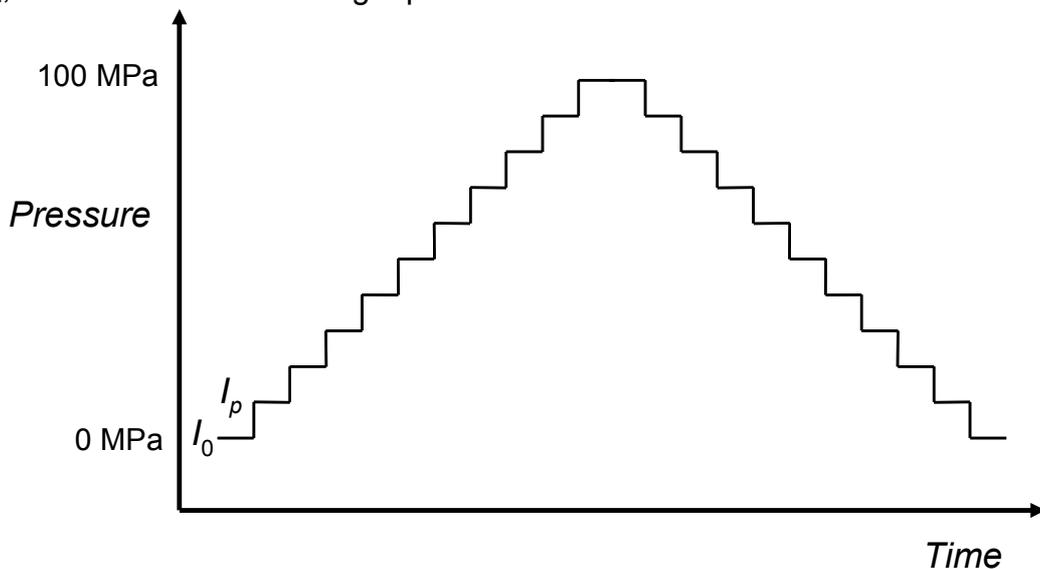


Figure 4: Calibration procedure for hydraulic pressure.

1.6 Remote Calibration Using Prototype System

For one remote calibration performed at the client's site, the complete cycle measurement described above was repeated 3 times and the corrected indication was obtained in the same way as mentioned previously. From the three cycle measurements, the mean difference between the corrected indications of the calibration item and i -th pressure transducer in the transfer standard, $\Delta I_{dut-tsi}$, is obtained at each target pressure. Since the mean deviation of the corrected indication of i -th pressure transducer from the reference pressure, ΔI_{tsi} , is already known, that of the calibration item, ΔI_{dut} , is estimated by the next equation.

$$\Delta I_{dut} = \sum_{i=1}^N \frac{\Delta I_{dut-tsi} + \Delta I_{tsi}}{N} \quad (4)$$

where N is the number of transducers in the transfer standard. As understood from the equation (4), ΔI_{dut} is obtained as the average value of the sum, $(\Delta I_{dut-tsi} + \Delta I_{tsi})$. By using more than two transducers in the transfer standard, the reliability of the calibration can be enhanced. The calibration value for the calibration item can be obtained from ΔI_{dut} .

The demonstration experiments for the remote calibration have been performed using the prototype transfer standard systems developed. Figure 5 and Figure 6 show the photographs of the experimental setups for the remote calibrations in the gas differential pressure and the hydraulic pressure, respectively. The pressure range of the transducers used in the transfer standard in the gas differential pressure was 10 kPa and that in the hydraulic pressure was 100 MPa. Each transfer standard was transported to the client's site and the remote calibrations were carried out.

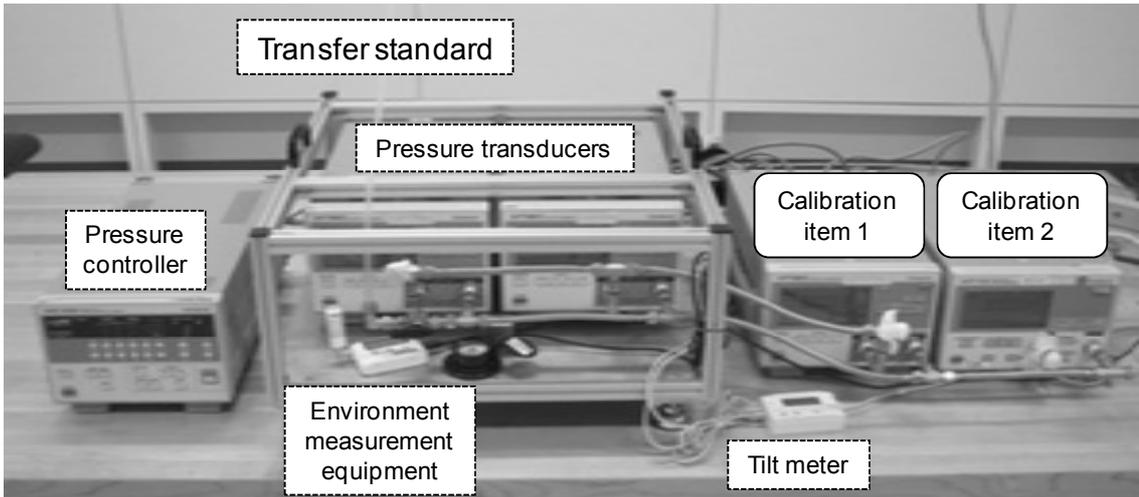


Figure 5: Experimental setup for remote calibration in gas differential pressure.

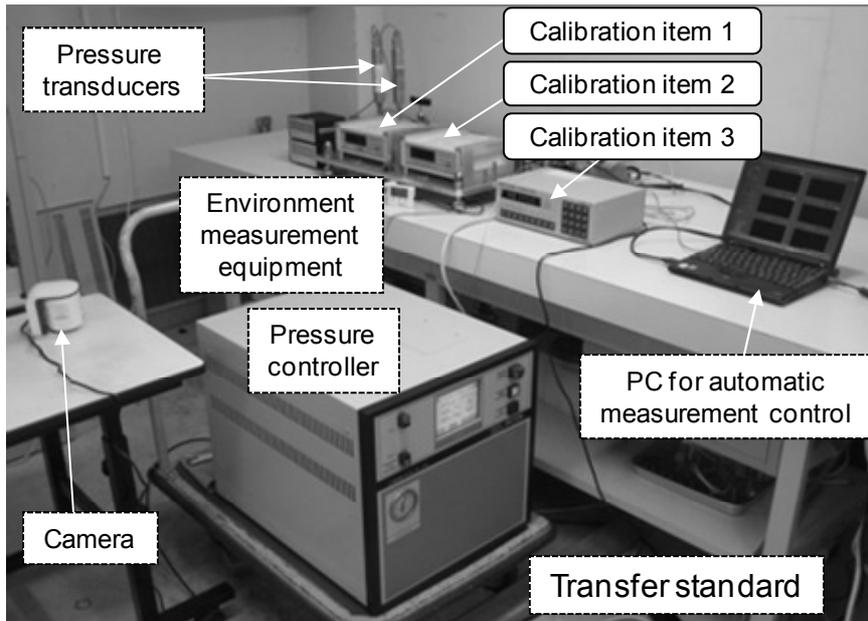


Figure 6: Experimental setup for remote calibration in hydraulic pressure.

Figure 7 and Figure 8 show the results of ΔI_{dut} obtained from the remote calibrations performed 2 times in the gas differential pressure and the hydraulic pressure, respectively. In either pressure range, the first and second remote calibrations were carried out independently. As shown in the figures, the differences between two results are enough small at each pressure. It has been confirmed that the results of the remote calibration are sufficiently reproducible compared with the target uncertainty in this development.

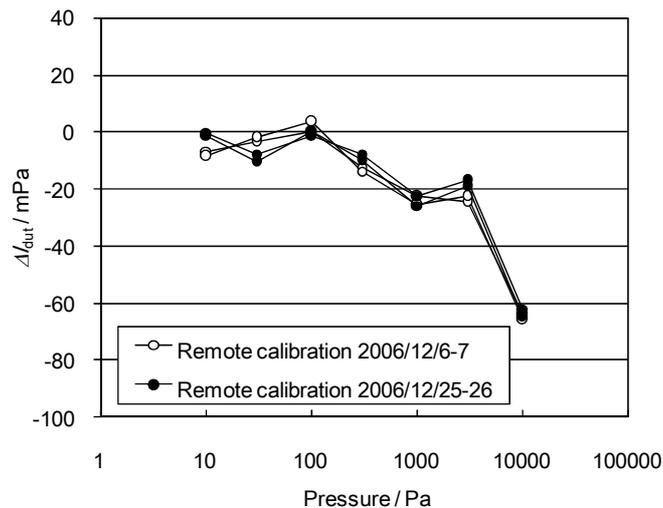


Figure 7: Results of demonstration experiment of remote calibration in gas differential pressure.

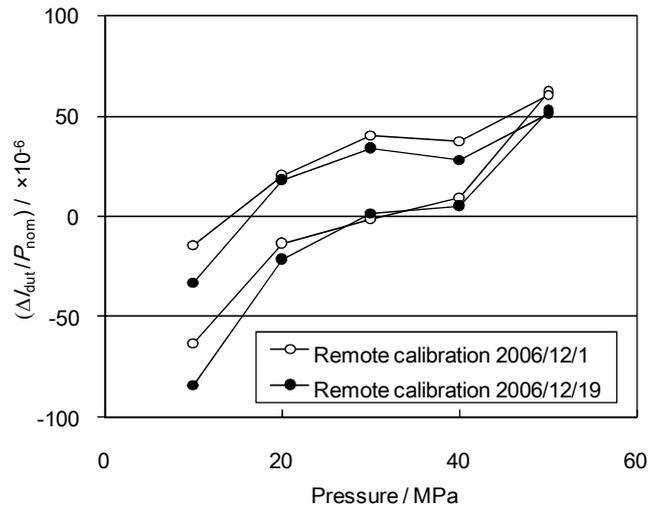


Figure 8: Results of demonstration experiment of remote calibration in hydraulic pressure.

2. Conclusions

A remote calibration technology for disseminating pressure standards has been developed. In this paper, the calibration procedure and the prototype transfer standard system developed for the remote calibration are described. Also the typical results of the demonstration experiments performed for the remote calibration are shown.

Recently, the integrated transfer standard which includes a pressure controller and more than two precise pressure transducers in a body has been newly developed in either pressure range. The demonstration experiments using the new transfer standards are currently performed. The technology has been advanced for establishing the remote calibration services for pressure standards.

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