Usage History of Three Mass Comparators in the Past 19 Years

Masaaki Ueki*, Jian-Xin Sun and Kazunaga Ueda
Mass Standards Group, Research Institute for Engineering Measurement, NMIJ/AIST, Japan

ABSTRACT

Three mass comparators, MC100g with a readability of 0.001 mg, MC1kg with a readability of 0.001 mg, and MC10kg with a readability of 0.01 mg have been used for weight calibration ranging from 10 g to 10 kg at NMIJ/AIST since March 1996. In the past 19 years, minor troubles of unknown origin were happened a few times a year, and the weight exchanger of the MC1kg was replaced because of a serious damage due to an aftershock of "The 2011 off the Pacific coast of Tohoku earthquake". However, all of three mass comparators have been generally kept in a good condition. The mass comparisons are realized with a repeatability of manufacturer's specification or better. This paper describes the usage history of the mass comparators during the period from 1996 to 2015. The performances of the mass comparisons using the three mass comparators are also presented.

Keywords: Mass comparator, Mass measurement, Weight calibration, Reproducibility

1. INTRODUCTION

In generally, the reliability of mass measurements can be confirmed by referring to the mass value of calibrated weight. As a national metrology institute, the National Metrology Institute of Japan (NMIJ), Advanced Industrial Science and Technology (AIST) has been establishing and maintaining the mass standards ranging from 1 mg to 5000 kg based on the Japanese copy of Prototype Kilogram (No.6). These mass standards are disseminated to varieties users of the mass metrology in Japan. There are two kinds of weight calibration service in NMIJ/AIST. One of the services is specific calibration service according to Japan Calibration Service System (JCSS), and is named "jcss calibration". The jcss calibration services, which are regularly offered to the JCSS accredited weight calibration laboratories, are available for weights of class E_1 and E_2 specified in OIML R111[1]. These weight calibration services have been controlled by a quality management system of NMIJ/AIST according to the ISO/IEC 17025[2]. And three mass comparators, MC100g with a readability of 0.001 mg, MC1kg with a readability of 0.001 mg, and MC10kg with a readability of 0.01 mg have been maintaining as a calibration facility since March 1996.

2. THREE MASS COMPARATORS

The specifications of the three MC100g, MC1kg and MC10kg are summarized in Table 1. Three mass comparators are generally used for weight calibration the mass range from 10 g to 10 kg. All of the mass comparators are equipped with an automatic exchange mechanism for four weights. The mass comparator is connected to a personal computer through

Table 1 Specific feature of the mass comparators

Type	MC100g	MC1kg	MC10kg
Measurand	10 g to 100 g	200 g to 1 kg	2 kg to 10 kg
Mass comparator			
manufacturer	Mettler-Toledo	Mettler-Toledo	Mettler-Toledo
model	AT106H	AT1006	AT10005
capacity	111 g	1011 g	10.011 kg
readability	1 µg	1 µg	10 µg
repeatability*1	1.5 µg	2 µg	20 µg

*1: Manufacturer specification

*corresponding author information: M. Ueki m.ueki@aist.go.jp; phone 81 29 861 4001; National Metrology Institute of Japan, Tsukuba Umezono 1-1-1, Ibaraki, Japan, 3058563

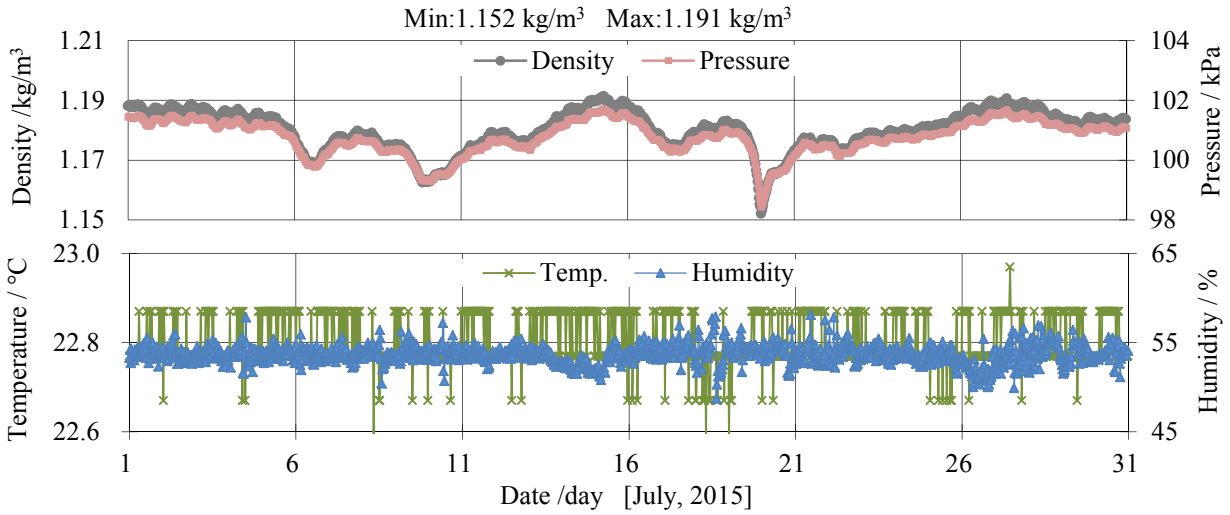


Figure 1: The results of measurement of temperature, relative humidity, atmospheric pressure and the air density of the weight calibration room (B103)

the RS-232C serial port, and is operated using control software provided by the manufacturer. The combined comparisons among 4 weights are performed full-automatically for specified combinations of the weights and with specified repetition numbers, being controlled by the personal computer. The combined comparisons among 4 weights, including repeated measurements take the measuring time of 8 hours or longer using the fully-automated mass comparator. A series of these mass comparisons has been made once a day and a result file is stored in a personal computer. The result file is named into the code name "O_OOOO.xls" which compounds the identification symbol for the comparator, and the four-digit measurement time number. The symbols "a", "b", and "c" are used to identify MC100g, MC1kg and MC10kg, respectively.

Three mass comparators are installed at a room B103 in a building 3-8, which is located in the central area of the AIST Tsukuba research center. The room B103 is an air-conditioned room, controlled within ±0.2 °C in day variation in the temperature range from 22 °C to 24 °C and within ±4 % in the relative humidity range from 40 % to 60%. To realize a dust-free ambient, the laboratory has met the specifications of a clean room of class 7, except that the air draft velocity is 60 cm/s or less. To evaluate the ambient conditions and the density of air in the rooms, the absolute pressure, temperature and relative humidity of air are measured using a set of apparatus. The indications of these monitoring instruments are collected to a personal computer through GPIP interfaces, and the density of air in the rooms is calculated using the international air density equation by CIPM. These calculations are made at every 10 min continuously for 24 hours of the whole day, and all the results are recorded on a hard disc of computers. Figure 1 shows the measured results of the temperature, the relative humidity, the atmospheric pressure and the calculated air density of the calibration room B103 in July 2015. The change in temperature is usually less than ±0.2 °C. For this reason, air density changes depend on atmospheric pressure, and air density was recorded to be the range from 1.152 kg/m^3 to 1.191 kg/m^3 in July.

3. MAINTENANCE OF THE THREE MASS COMPARATORS

In the past 19 years, the most difficult situation for the three mass comparators was the time when a huge earthquake with a magnitude of 9.0 was occurred at 14:46 JST on Friday 11 March 2011. This earthquake was named "The 2011 off the Pacific coast of Tohoku Earthquake" and also often known as the Great East Japan earthquake, and the 3.11 earthquake. Peak accelerations of 3.3 m/s^2 in horizontal direction, and 2.5 m/s^2 in vertical direction were observed in Tsukuba city. However, the quake had caused almost no damage to the sets of standard weights and mass comparators for weight calibration. After waiting for decay of aftershocks and reconfirming mass values of the sets of standard weights, the calibration services resumed 4 months with beware mass comparators at operating. In such situation, a

Table 2 Record sheet of measurement history for MC1kg with an example

Code	Date	Start time	Castomer	N.M. /g	Compared 4 weights				s_{46} /mg	Remark
					Pos.1	Pos.2	Pos.3	Pos.4		
b_1901	07-Jun-15	0:00	NMIJ	1000	A0	T5	A9	T6	0.0005	
b_1902	08-Jun-15	0:01	NMIJ	1000	A0	T5	A9	T6	0.0015	
b_1903	09-Jun-15	0:00	NMIJ	1000	A0	T7	A9	T8	0.0019	05:44 Intensity 3, rather strong earthquake
b_1904	10-Jun-15	0:01	NMIJ	1000	A0	T7	A9	T8	0.0007	

weight exchanger of the MC1kg was replaced because of a serious damage due to an aftershock of "The 2011 off the Pacific coast of Tohoku earthquake" occurred on 3 Dec. 2011. Although minor troubles of unknown origin were happened a few times a year, all of three mass comparators have been generally kept in a good condition. The NMIJ has continuously improved the accuracy and the efficiency of weight calibrations.

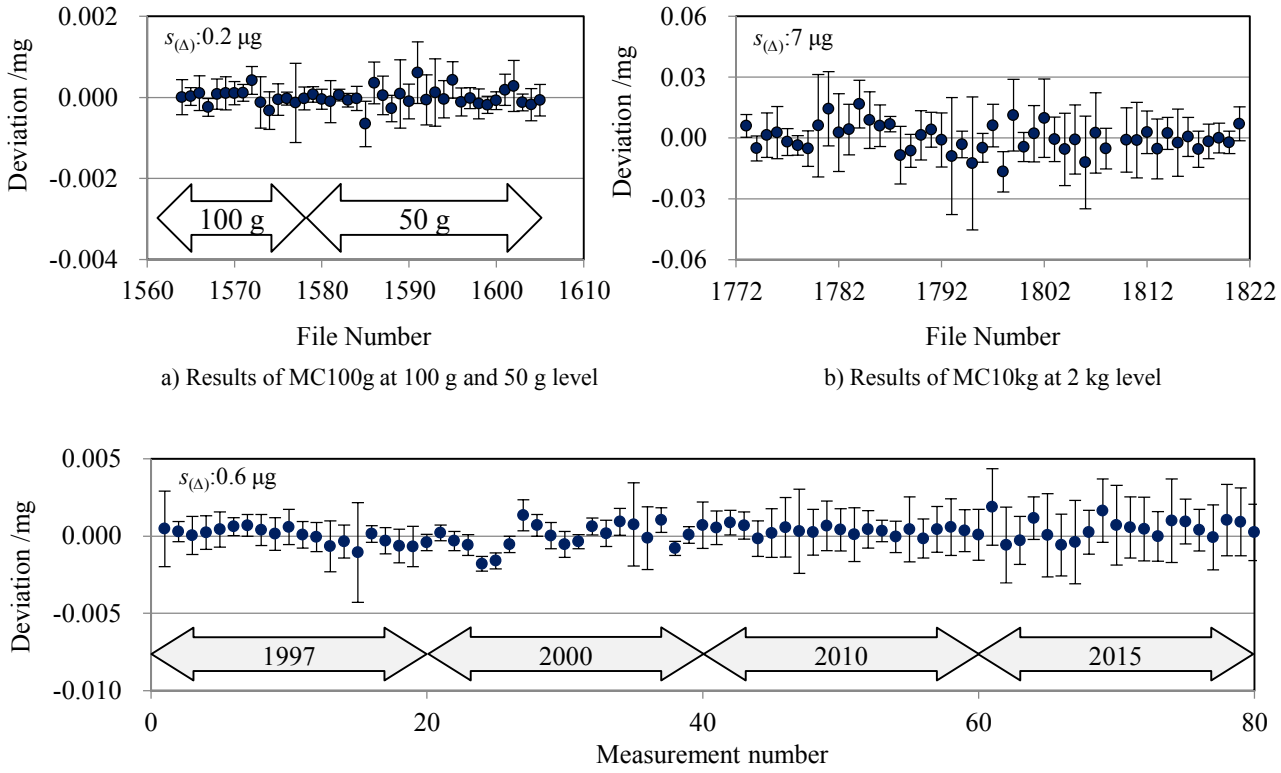
The three mass comparators are equipped with a 4-position weight exchanger and carry out fully-automated mass comparison with relative sensitivity from 10^{-9} to 10^{-7}. The mass comparisons among 4 weights, including repeated measurements take the measuring time of 8 hours or longer using the fully-automated mass comparator. A series of these mass comparisons has been made once a day and a history of measurements are summarized in a record sheet, where statistical analysis will be applied to the reviewing the results. Table 2 shows an example of a record sheet for MC1kg. Up to now, at least 1600 result files each of three mass comparators, namely more than 5000 files in total are backed up to a host computer for about 19 years.

4. PERFORMANCE OF THE THREE MASS COMPARATORS

The quality of calibration results using the three masa comparators is controlled in the following ways.
1) The mass comparison of test weights is carried out on the ABA method that is specified in OIML R111.
2) The calibration result is evaluated to be satisfactory, where;
   a) the standard deviation s_{46} obtained from the measurement of mass difference is smaller than 1/10 of the expanded uncertainty of class E_1 weight.
   b) the difference between the previous calibrated value and the new value of the check weight is smaller than 1/2 of the combined standard uncertainty of the reference weight.

4.1 REPRODUCIBILITY

In usual cases of weight calibration at NMIJ, one reference weight, one check weight and two test weights are set on the four position weight exchanger, and mass comparisons are made. The performance of mass comparators can be determined by the reproducibility of the calibration results of this check weight. These mass comparisons by the combined method are judged in the correctness from the compatibility between the new results and the previous calibration results made beforehand. To discuss the reproducibility, the calibration results for the check weights of 100 g and 50 g using MC100g are shown in Figure 2 a). Similarly, Figure 2 b) gives the results for 2 kg weight using MC10kg, and Figure 2 c) gives the results for 1 kg weight using MC1kg for the duration from 1997 to 2015. The ordinate in the figure gives the deviation from the average of the calibration results, and the abscissa does the file number or measurement number of the calibration. The error bar of each result shows the standard deviation of the 3 repeated measurements. The mean value of these standard deviations, $s_{(\Delta)}$ is also shown in the figure. As a result, the value, $s_{(\Delta)}$ was 0.2 μg for MC100g, 0.6 μg for MC1kg and 7 μg for MC10kg, respectively. And all of these values are better than that of the manufacturer's specification. As clearly seen in Figure 2 a) to c), any significant tendency is not found in the calibration results of the check weight, and it proves that the calibrations of the weights have been made with a dispersion of the level of the readability of the comparator. It takes a longer time for a series of the measurements



a) Results of MC100g at 100 g and 50 g level

b) Results of MC10kg at 2 kg level

c) Results of MC1kg at 1 kg level

Figure 2: Reproducibility of the calibration results of check weights by the three mass comparators

by the combined comparison method, being about three times as much as that by the conventional one-to-one comparison measurements. It has been, however, confirmed that the calibrations of weights can be realized with keeping a high reliability by monitoring the adequacy of the mass difference measurements.

5. SUMMARY

Since March 1996, the three mass comparators of MC100g, MC1kg and MC10kg have been maintained as a calibration facility which carries out the mass calibrations of class E_1 and E_2 weight. All of the mass comparators are equipped with the 4 position weight exchanger, and are performed full-automatically combined comparison among 4 weights. Up to now, at least 1600 series of measurement each of three mass comparators, namely more than 5000 measurements in total are performed in the mass range from 10 g to 10 kg. The reproducibility has been evaluated by experimental results of mass comparison in order to estimate the performance of each three mass comparators. The reproducibility of calibration results of the check weights was 0.2 µg for MC100g, 0.6 µg for MC1kg and 7 µg for MC10kg, obtained from the mean of the standard deviation, $s_{(\Delta)}$.

6. REFERENCES

1. International recommendation, Weights of classes E_1, E_2, F_1, F_2, M_1, M_{1-2}, M_2, M_{2-3} and M_3, *OIML R111* (2004).
2. International Organization for Standardization, General requirements for the competence of testing and calibration laboratories, ISO/IEC 17025 (2005).