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Accurate and High Throughput Mass Determination with Table-Top Robotic Systems

Cost-effective solutions for your calibration and dissemination processes

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Abstract

Due to limitation on space and budget new developments in mass metrology are shifting towards table top robotic systems offering higher productivity at lower cost. Moreover ingenious technological designs guarantee the highest accuracy.
The Dual Robotic Arm System is designed for simultaneous management of reference and test weights, therefore increasing throughput, as none of the weights have to be returned to the magazine during the weighing process. Assembled with a patented multi-weight handler, mass dissemination of the national MassScale with groups of up to four test weights can be managed. Fulfilled with 120 magazine positions such robots are optimized for overnight and weekend mass determination or dissemination, without requiring operator intervention.

These robots not only cover mass dissemination requirements from NMI´s but also optimized for use in the standard mass calibration segments of OIML E2 to F2 and ASTM Class 1 to 3 weights.

In conclusion, this paper discusses how the newest compact robotic systems meet various customer needs via offering flexible options when it comes to weighing range and readability, plus how these systems enhance throughput and accuracy. The transition from manual work towards robotic solutions results in cost savings long term with the added benefit of optimizing precious laboratory space will be reviewed.

Introduction

Weight calibration is a typical process to determine the unknown mass of weight, which can be either carried out manually or automatically. Handling weights manually, especially in the lower weighing range (1 mg to 10 g) has notable negative impacts when it comes to accuracy, repeatability and effectiveness. Robotic systems for mass determination and dissemination have been available on the market for around 20 years. Improved accuracy and calibrating larger numbers of weights without human interaction were the reasons behind choosing robotic mass comparators. However, not only is the market significantly growing but the requirements of the customers are changing as well. Calibration laboratories generally require high throughput at the same time guaranteeing accuracy whereas the main aspects for National Metrology Institutes are high performance and automated dissemination from their National 1 kg reference, frequently with overnight & weekend calibration. The requirement moving towards greater technical solutions is increasing, while limited laboratory space and restricted budget are undoubtedly key drivers too, when it comes to choosing the right instrument. These demands greatly challenge the manufacturers and urge them for new developments.

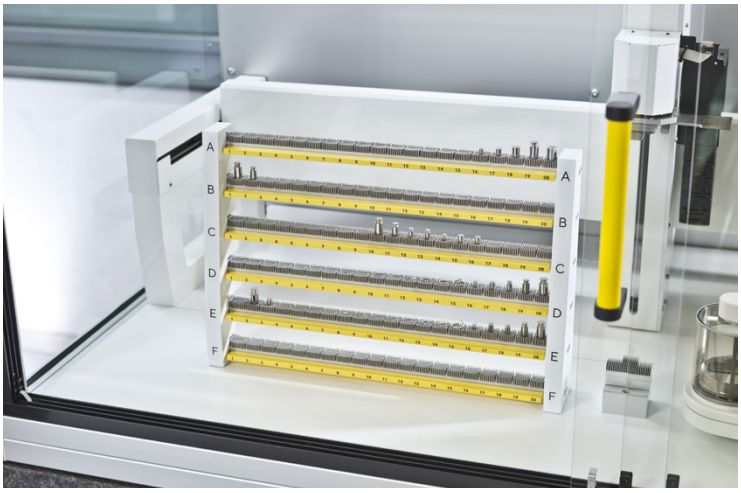
Principles

Today's modern robotic system should ideally offer more variants in the same coverage to comply with the needs of various customer segments and should seek affordable price, meet requirements for small footprint meanwhile ensuring the highest accuracy. Dissemination of the mass scale without any manual intervention and fast speed calibration of weights or weight sets with enough weight magazine space for optimized overnight and weekend calibration should be offered. The new Sartorius Table Top Robotic Mass Comparators (CCR-Compact Series) are built to meet the above mentioned requirements.

Picture 1: Sartorius CCR-Compact Table Top Systems

Shorter Time, Lower Costs

Laboratory automation and the growing emergence of robotics have transformed the typical workflow for many NMI's, as well as local government and private mass laboratories. Automated solutions can accomplish the tasks with less hands-on which consequently leads to significantly increased productivity and lowered total costs. Beyond cost-saving the driving acceptance of robotics is the fact that the cost of error is very high. Handling weights at the range of 1 mg to 10 g is very difficult and even fairly low error rates can have a profound impact on the outcome of the results. By taking out the human element, consistent quality can be guaranteed. The Table Top Mass Comparators from Sartorius are equipped with 120 magazine positions for OIML- and ASTM- shape weights including cylindrical or knob-weights in addition to wire and flat weights in the complete range from 1 mg to 10 g. 120 magazine positions make it possible for such a robot to work overnight or during the weekend without any human intervention.



Picture 2: 120 magazine positions allow continuous processing of the measurements overnight or over the weekend. The magazines are designed to take any possible weight shapes used for OIML-class and ASTM-class weights.

Variability

When it comes to mass determination at the range of 1 mg to 10 g National Metrology Institutes and Legal Metrology Labs who are accredited to Class E1 require high performance with a readability of 0.1 µg. In order to manage calibration and mass dissemination requirements, Sartorius offers two table-top systems equipped with 10 g / 0.1 µg or 6 g / 0.1 µg mass comparators (Table 1). Both systems are supplied with a dual robotic arm, where the design of the multi-weight handler allows mass dissemination with groups of up to four test weights. An additional variant is offered to calibration laboratories typically accredited to E2 or F1 (Table 1). These laboratories usually do not require a costly mass comparator or a multi-weight handler, but instead need high accuracy combined with high throughput at an affordable price. For such customers in either local government or in the private sector Sartorius offers a robot equipped with a Cubis® II microbalance (10 g / 1 µg), a dual arm system with two single weight handlers at an attractive price. Both the two single and the patented multi-handler dual robotic arms manage handling of the reference and test weights simultaneously, to speed up the processes with the most efficient motion sequences and handle the weights with highest precision and consistency. This saves a significant amount of time, because no returning of the reference weights to the magazine or to a parking position is needed. The application rages according to OIML R111 and ASTM E617 are indicated in Table 2 and Table 3.

Variant	Capacity / Readability	Repeatability (Typical)*	Robotic Arm Technology	Magazine Positions
CCR10.7-C	10 g / 0.1 µg	0.2 µg	Dual arm system with multi-weight- and single-weight handlers	120
CCR6.7-C	6 g / 0.1 µg	0.2 µg	Dual arm system with multi-weight- and single-weight handlers	120
CCR10.6-C	10 g / 1 µg	0.5 µg	Dual arm system with two single-weight handlers	120

Table 1: CCR-Compact series up to 10 g

* Repeatability s under optimal contitions: 0.2 µg / 0.2 µg / 0.5 µg

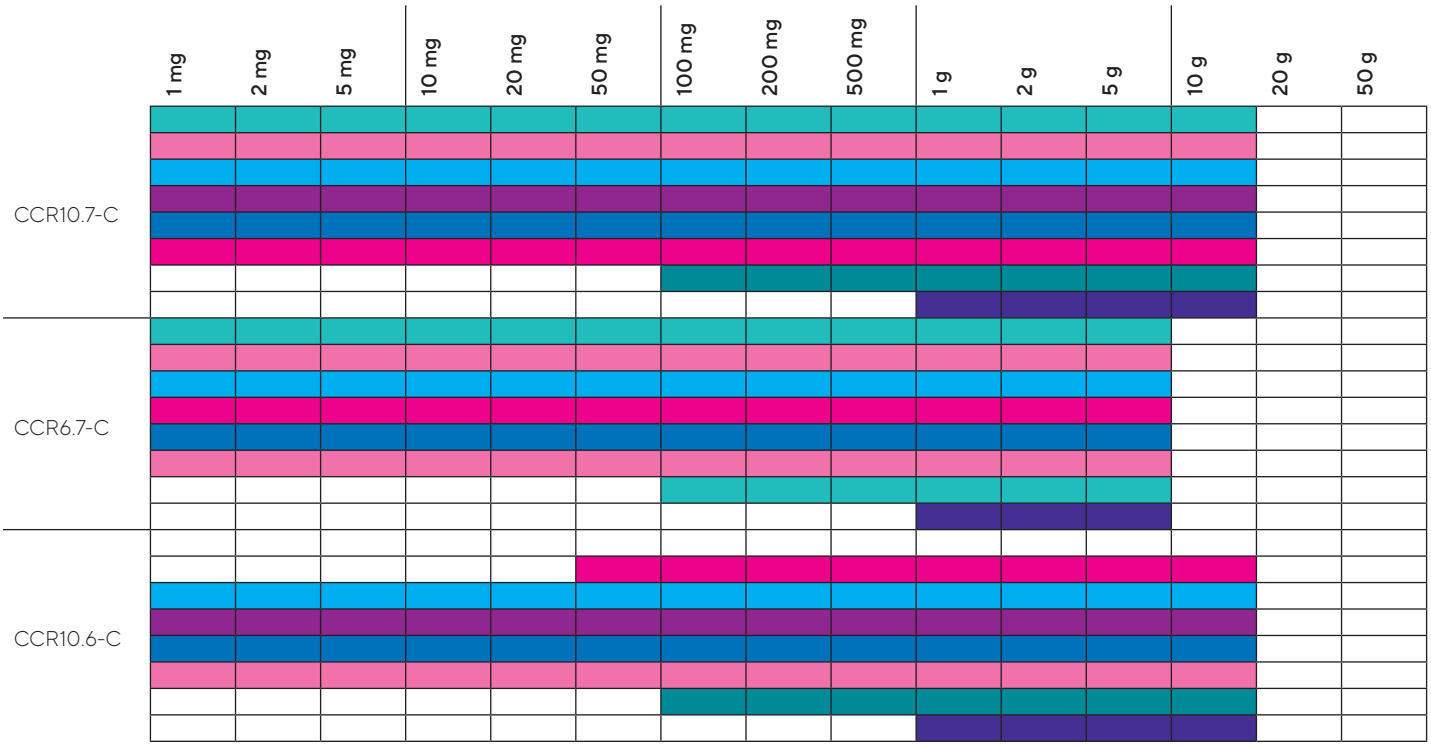


Table 2: Application ranges according to OIML R111

R111 E1 E2 F1
F2* M1 M2 M3

*Reference Standard with 1/5 uncertainty contribution of the E1 tolerance limit

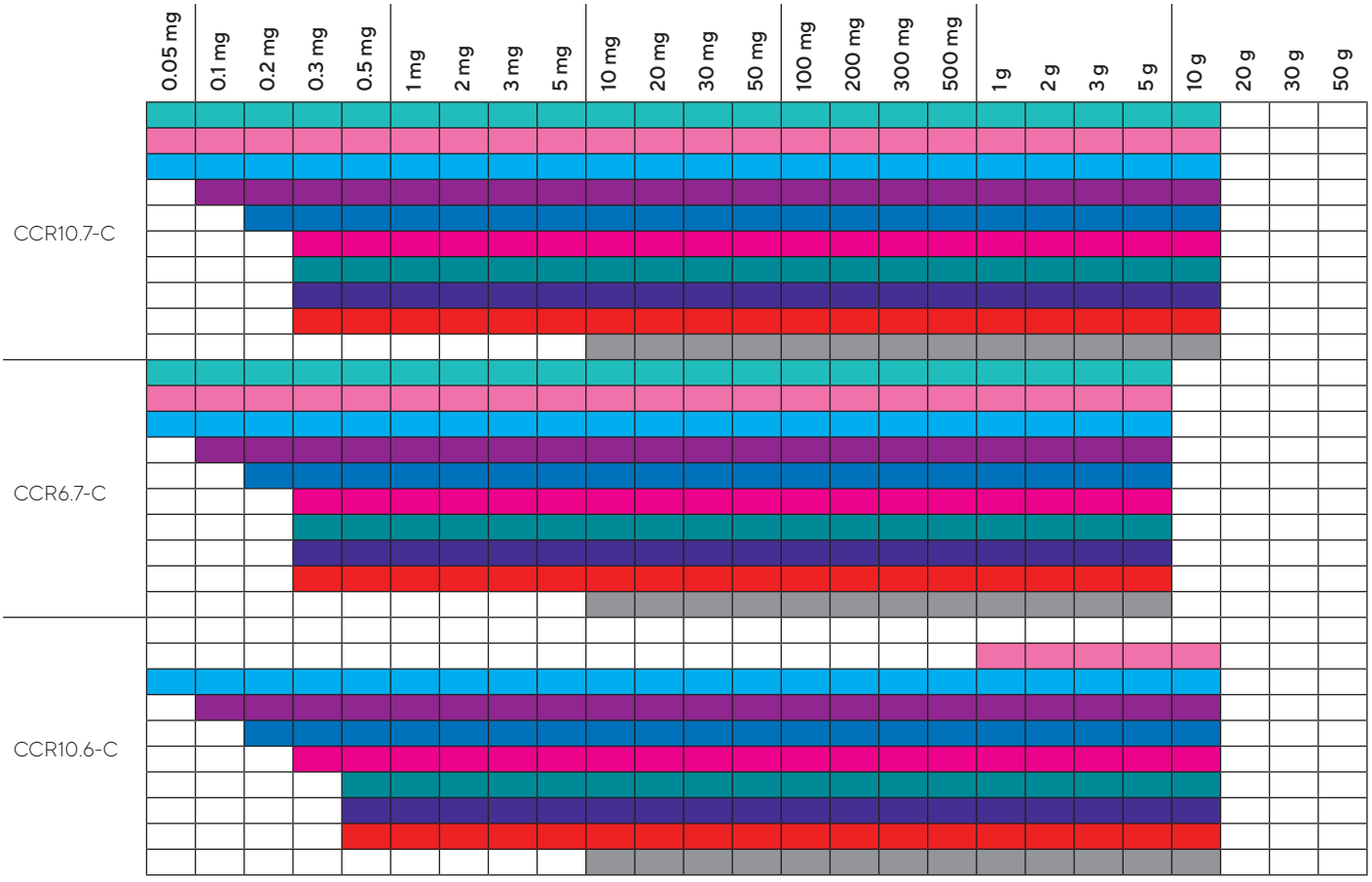


Table 3: Application ranges according to ASTM E617

Class 000 Class 00 Class 0 Class 1 Class 2
Class 3 Class 4 Class 5 Class 6 Class 7

Small Footprint

The dimensions of the robotic system are 1200 x 800 x 760 mm, which are of the ideal size to fit on a weighing table. Where the need arises, Sartorius offers two types of weighing tables designed for this system.

Design and Technical Details

The flexible design of the robot systems was developed due to the differing applications of mass determination.
At least 3-axes of movement are required to handle the weights in the magazine and to transfer them to the mass comparator. According to the high accuracy mass determination of reference standards with 1/5 uncertainty of the E1 tolerance limit, all main axes have to be stable and solid to guarantee reproducible readings from the mass comparators. In addition it is imperative that the positioning of the handler entering into magazine positions and onto the weighing pan requires stable and reproducible movements of the robot system.

The dual arm system with two single weight handlers was developed for easy and fast transportation of the weights directly between the weight magazine and the weighing cell. Therefore the vertical axis of the portal robot system is equipped with an axis of rotation on which two fork-shaped weight handlers are fixed and are set at an angle of 90 degrees. To load/unload the reference and test weight from magazine onto the weighing pan, the two weight handlers only have to be rotated 90 degrees in front of the mass comparator in order to fulfill a complete mass determination.

Picture 3: Dual arm system with two single weight handlers

The dual arm system with patented multi weight handler was designed to take a maximum of 4 weights as a sample, the single handler then takes the reference weight to be compared against. The special weight handlers are designed to take any possible weight shape used for OIML-class weights. After collecting up to four individual weights from the magazine, they are assembled at the special sample magazine position. The multi-handler can then collect the four weight sample which is ready for the measurement process. Therefore, there is no need of returning the weights to the magazine or to a parking position.

Picture 4: Dual arm system with multi-weight-and single weight handlers

Alll mass comparators are equipped with automatic doors to open the weighing chamber. The door movement is controlled by the robot system's application software. For details on technical specifications please refer to Table 4.

Picture 5: Weighing Cells are equipped with automatic doors

The control unit consists of 2 main parts, which are installed in the top of the of the robot system housing. These are the controller for the driver motors managing all necessary movements of the portal robot system plus a PC with the installed operating software.

The operating software for the robot system consists of modules for controlling the desired mass comparison sequences and an evaluation module for calculating the measurement results using all the features necessary for this. The structure of the evaluation software is essentially comprised of the following sub-modules:

- Determination of the conventional mass by substitution weighing
- Highly accurate mass determination by substitution weighing
- Dissemination of the mass scale. Recording the climate data synchronously to all balance readings to calculate the air density using the CIPM formula

Variant		CCR10.7-C	CCR10.6-C	CCR6.7-C
	Unit	Value	Value	Value
Electrical Weighing Range	g	3.5	10.1	6
Nominal maximum load	g	10.5	10.1	6
Readability	µg	0.1	1	0.1
Repeatability at maximum load (5 x ABA)	µg	0.5	0.7	0.3
Repeatability at 5 g (5 x ABA)	µg	0.3		
Repeatability at 1 g (5 x ABA)	µg	0.15		0.15

Table 4: Technical Specifications

Number of weight cycles are depending on the class calibrated and the minimum number should be choosen according to OIML R 111 (Table 5) or ASTM E617 (Table 6).

Class	E_1	E_2	F_1	F_2	M_1, M_2, M_3
Minimum Number of ABBA	3	2	1	1	1
Minimum Number of ABA	5	3	2	1	1
Minimum Number of $AB_1...B_nA$	5	3	2	1	1

Table 5: OIML R111 Values

Class	000,00,0	1	2 and 3	4 and 5	6 and 7
Minimum Number of ABBA	3	2	1	1	1
Minimum Number of ABA	5	3	2	1	1
Minimum Number of $AB_1...B_nA$	5	3	2	1	1

Table 6: ASTM F617 Values

Discussion

Thanks to the unique design elements, the Sartorius Table-Top Mass Comparators not only speed up the mass determination processes with their most efficient motion sequences but they also handle the weights with highest precision and consistency.

References

(1) "OIML R 111" International Organization of Legal Metrology, Paris, 2004

(2) "ASTM E617" ASTM International, United States

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