



Sartorius CCL1007
1 kg Prototype
Mass Comparator

For Dissemination of the Mass Scale and Calibration of Weights



Sartorius has developed a unique mass comparator with the Bureau International des Poids et Mesures (BIPM) and the Institute for Process Measurement and Sensor Technology at the Technical University of Ilmenau in Germany. This mass comparator enables the differences in mass among 1 kg mass standards to be accurately determined to 0.1 of a microgram. The construction and functionality of the load alternator are based on the known BIPM FB2 technology. The prototype mass comparator is designed for highly accurate mass determination. The unit has been developed to create and maintain the national mass scale as well as to be used for research and development tasks. Features, especially with regard to the new definition of the kg standard, have been incorporated for the Avogadro project.

Applications for the new 1 kg prototype mass comparator

- Deriving national mass standards from the primary standards of national metrology institutes (NMIs)
- High-precision mass determination of the national 1 kg prototype for disseminating the mass scale in the range of 100 g to 1 kg
- Redefinition of the SI unit "kg" based on the Avogadro constant by using a silicon sphere
- Experimental determination of air density by comparative weighing of buoyancy artefacts



CCL1007: load alternator with silicon sphere and weights

Top right cover photo courtesy of the PTB

Construction of the Mass Comparator – Modular Design Concept



CCL1007: vacuum chamber

CCL1007

The Sartorius prototype mass comparator is equipped with an 8-position load alternator as well as a substitution and adjustment device. The complete measurement device is installed inside an enclosed airtight chamber, which can be evacuated. The electronics and a built-in computer with special software control are used to program the required measuring routines.

The weight-handling mechanism of the load alternator can be controlled either manually or automatically by software commands transmitted over the interface. The mass comparator is suitable for comparing both cylindrical and spherical test objects. Moreover, it has built-in adjustment weights which are easy to calibrate at the touch of a key. A climate station for on-line recording of ambient temperature, humidity and pressure is an optional accessory.

The weigh cell consisting of a measuring chamber (vacuum chamber) with an integrated nanogram weight cell and an 8-position load alternator.

The vacuum chamber can be operated either under airtight or high-vacuum conditions. The exterior surface finish of the vacuum chamber is painted white. All sealing areas are free of paint. The quick-loading doors make it easy to position test objects on the load alternator and substitution weights on the weigh cell. The vacuum chamber has a number of easy-to-access flanges for any customer-specific use.

The construction of the load alternator and measuring system selected for the prototype mass comparator allows easy exchange of the weigh cell. This is especially advantageous for servicing purposes and for other scientific studies.

The control unit is supplied with a computer and all necessary operating software.

The entire control technology including the driving motors as well as the control computer are positioned in a compact rack. This rack can be set up at a maximum distance of up to 2.5 m from the vacuum chamber. The design of the rack can be extended for customer-specific applications so that it is possible to integrate further modules.

The vacuum pump stand provides a metering function to monitor the evacuation and venting time (optional).

The vacuum system consists of an oil-free pump stand (comprised of a turbo-molecular pump, pre-pump, valves, power supplies and control electronics/control unit). It is suitable for a pressure range of 0.0001 Pa to standard barometric pressure (105,000 Pa).



CCL1007: vacuum chamber with control unit



Option: pump station with integrated turbo-molecular pump

Applications

- Use as a prototype mass comparator for dissemination of primary standards of national metrology institutes (called NMIs for short in the following) from the national mass standards (kilogram prototype) of the various countries
- Dissemination of the mass scale of NMIs in the range of 1 mg to 1 kg (adapter plates required for weighing groups)
- Measurement of mass (100 g to 1 kg) within the scope of international comparison measurements (key comparisons) and calibrations for government institutes, calibration laboratories and industry according to the attainable uncertainties of measurement given in the CMC tables of the BIPM
- Experimental determination of the air density by comparative weighing of special plummets in air and under vacuum
- Measurement of the mass of 1 kg silicon spheres (also within the scope of the Avogadro project to determine the Avogadro constant and redefine the kilogram as a unit of mass)
- Experiments to study the influence of cleaning procedures and of the effects of sorption and convection on the measurement of mass and to study the long-term stability of mass standards

Software and Interfaces

- The operating software of the prototype mass comparator allows complete control of the sequence of mass comparisons.
- The Sartorius prototype mass comparator is supplied with computer control, a PC with the Microsoft Windows® operating system installed and a network interface port.
- It is possible to perform either a fully automatic or a manual measurement sequence using system control and data collection. The software is based on Microsoft Windows®.
- Results can be exported as files in a choice of ASCII (.txt) or Microsoft Excel® (.xls) formats. Data export with a resolution of 0.01 μg is possible.
- Software documentation including a complete description of all commands for controlling the prototype mass comparator via interface(s) is provided.
- The data collection software saves the results along with the parameters (date, time, etc.) in a database.
- A measurement report can also be generated.



CCL1007: loading device and quick-loading door



Metrological Features

Max. capacity	1,011 g
Resolution	0.1 µg
Typical repeatability, std. deviation "s"	$s \leq 0.3 \mu\text{g}$
Linearity	$\leq 1 \mu\text{g}$
Electronic weighing range	2 g
Adjustment weight	1 g
Stabilization time	$\leq 60 \text{ s}$
Sensitivity drift	$\leq 1 \text{ ppm/K}$
Dimensions:	
Vacuum chamber (W × D × H)	940 × 840 × 1,100 mm
Max. diameter of	
– Cylindrical weights	95 mm
– Spherical weights	100 mm
The minimum weight diameters, excluding the carrier plates, for:	
– Cylindrical weights	34 mm
– Spherical weights	45 mm
Helium leakage rate	$\leq 10^{-7} \text{ mbar} \times \text{L} \times \text{s}^{-1}$
Pressure range	$10^{-6} - 1,000 \text{ mbar}$
Application ranges:	
OIML – R111, classes	$\leq \text{E1 } 100 \dots 1,000 \text{ g}$
with adapter plates for weighing group	$\leq \text{E1 } 1 \text{ mg} \dots 1,000 \text{ g}$
Silicon spheres	$\varnothing \leq 95 \text{ mm}$

Vacuum chamber, load alternator and control unit

The 8-position load alternator accommodates OIML weights up to 1,000 g as well as silicon spheres with a maximum diameter of 95 mm. A three-point load receptor with an open circle diameter of 30 mm enables secure positioning of the objects.

The vacuum chamber is used for measurements either under airtight or high vacuum applications. Weights or spheres can be conveniently placed on the load alternator through a flange that is accessible by a quick-lock device. Additional access flanges are included for measuring sensors, motor control and electronic connectors, and similar.

The control unit is supplied with all operating software and accessories required. It has a computer and installed control software for controlling the drive unit.

Permissible ambient conditions (outside the vacuum housing)

Within the range of the following climate conditions, our specifications given above are attained:

- Relative humidity within a range of 45% to 60%
- Temperature range from 19°C to 23°C
- Maximum allowable temperature change $\geq 0.1 \text{ °C/h}$ within a range of $\pm 0.5 \text{ °C}$ in 24 h



CCL1007: weighing cell and load alternator

Sartorius AG
Weender Landstrasse 94-108
37075 Goettingen, Germany

Phone +49.551.308.0
Fax +49.551.308.3289

www.sartorius.com
www.massmetrology.com