

Constant Pressure and Vacuum Transporter for 1 kg Mass Standards

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Abstract

This report describes the design and intended use of a mass transporter for transferring 1 kg mass standards between different locations and pressure environments without compromising the atmospheric conditions and, therefore, maintaining stability of the surface and mass values of the artifacts. This transporter is intended for transferring 1 kg artifacts between a vacuum mass comparator and the next upgrade of the National Institute of Standards & Technology (NIST) Watt balance.

Disclaimer

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Introduction

Mass measurements in vacuum are playing an increasingly important role in mass metrology and new capabilities for vacuum mass metrology are being pursued at numerous National Metrology Institutes (NMIs) and at the International Bureau of Weights and Measures (BIPM). The alternative realizations of the Kilogram using the Avogadro and Watt balances experiments operate under vacuum conditions; therefore, it is crucial to transfer mass standards in vacuum or under stable atmospheric pressure conditions between different experiments in order to minimize any instability due to climatic changes.

The transporter described in this report is designed specifically for the transfer of a 1 kg mass standard between a vacuum mass comparator located in the National Institute of Standards and Technology (NIST) Mass Laboratory and the next upgrade of the NIST Watt balance that resides in another building on the NIST campus. Future modifications, including miniaturization, will be done with the aim to transfer artifacts between different NMIs and the BIPM.

Description of the vacuum transporter at NIST

The NIST vacuum transporter consists of several main operational components: cubical chamber, weight handler, weight handler mover, weight restraint, and gate valve. With the exception of the weight handler, these parts were commercially available. Materials used to make the in-house designed and fabricated components include aluminum alloys, stainless steel, and Teflon.

The cubical chamber and its parts are mounted on a specialized cart. Its connection to the vacuum balance chamber installation is described below.

Cubical chamber and its functional parts

A mass standard resides within the commercially-available, stainless-steel cubical chamber (“cube”). Various components are attached to the cubical chamber in order to maintain the standard within the cube or move the standard from the cube to the vacuum balance. Refer to Figure 1.

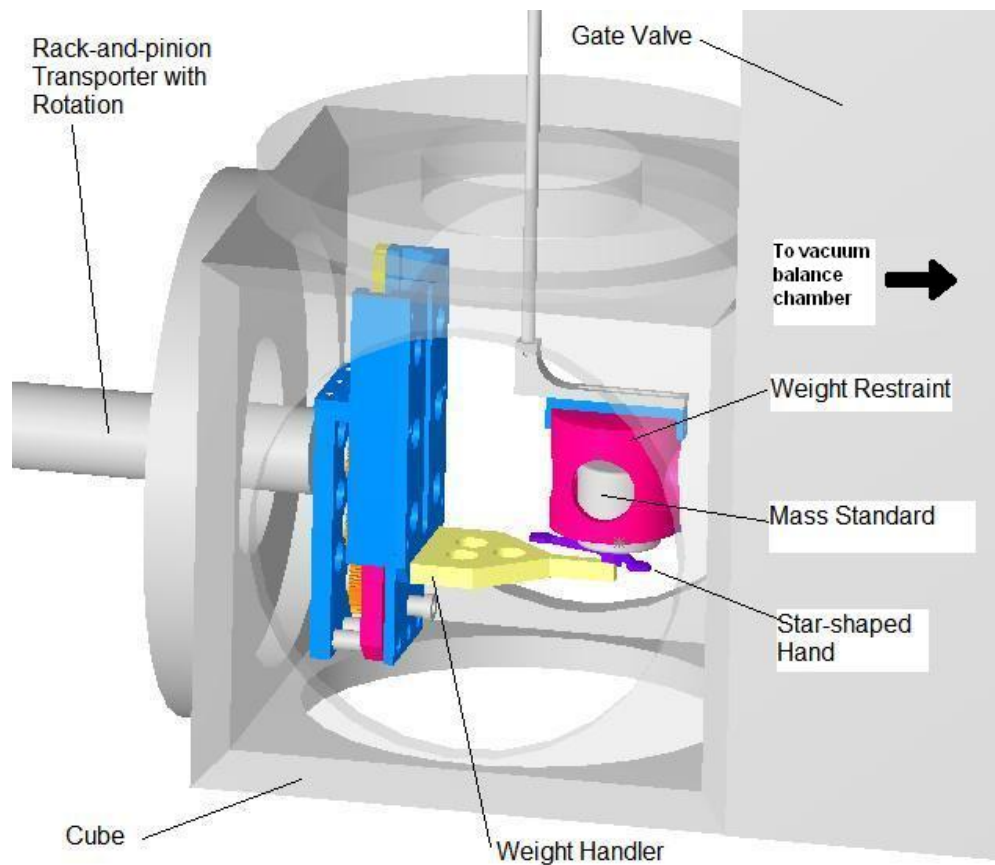


Figure 1. Vacuum transporter components.

The weight restraint mechanism is mounted on the cube's top. This mechanism consists of a commercially-available, manually-operated rack-and-pinion shaft mounted on a flange on the top of the cube. Inside the cube an in-house fabricated Teflon cage is attached to the end of the shaft. When the weight is fully retracted into the cube, the cage is lowered over the weight. The cage is large enough so that it does not normally touch the weight when the weight is centered but is small enough to keep the weight from falling off the weight handler. The function of the top of the cube (i.e., control of the weight restraint) does not change.

A flange is located on the bottom of the cube to allow for the attachment of valves and tubing to a vacuum pump and gauge. The function of the bottom side may change as the need arises.

The front of the cube has a flange with a window to allow one to see the contents of the cube. The function of the front side may be changed to a door with window port as the need arises.

The back of the cube has a flange that allows for manual access to the cube interior. The function of the back side may also change as the need arises.

A gated valve is mounted on the right side of the cube. Through this gate valve the mechanical weight handler moves the weight from the cube into the vacuum balance chamber. The gate valve is permanently connected to the cube and it connects to another gate valve (and nipple) that is mounted on the vacuum chamber into which the mass will go. The function of the right side of the cube does not change.

A commercially-available, vacuum-compatible, manually-operated rack-and-pinion transporter with rotation is mounted on the left side of the cube. This is one part of the weight handler which provides lateral movement as well as an interior shaft that can be rotated from outside to operate the weight handler (described below). The function of the left side, like the right side and top, does not change.

Mechanical weight handler

The mechanical weight handler was designed and fabricated in-house of commercially-available parts when available. Most of the weight handler is made of an aluminum alloy while its bearing slide (highlighted in red in Figure 2) is made of Teflon. The weight handler is connected to the end of the rack-and-pinion transporter with rotation. Refer to Figure 2. A mass standard sits upon the purchased 3-point star-shaped "hand" of this weight handler. The hand meshes with the turntable configuration of the vacuum balance (not shown) allowing a mass standard to be placed onto the balance.

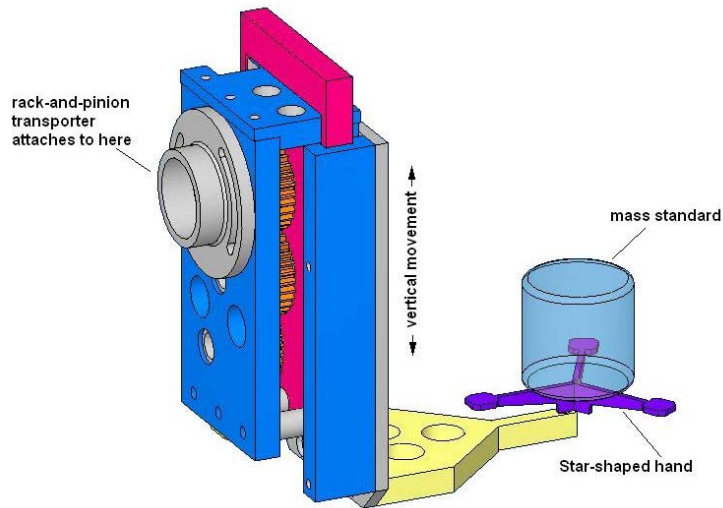


Figure 2. Mechanical weight handler.

In operation, the rack-and-pinion transporter moves the weight handler (with mass standard) laterally from the cube through the two gate valves and into the vacuum balance chamber. Upon reaching a certain point within the balance chamber, the rack-and-pinion's rotation feature comes into play allowing the weight handler to lower the mass standard onto the turntable of the balance.

Cubical chamber stand and cart

The cube and its components are installed on an in-house designed and fabricated aluminum-alloy stand. Refer to Figure 3. This stand raises the cube to the level of the vacuum chamber port and is manually adjustable. The stand is placed on a specialized aluminum-alloy cart (not shown) with four wheels to allow the vacuum transporter to be moved away from the vacuum chamber. This cart also has a small vertically adjustable range.

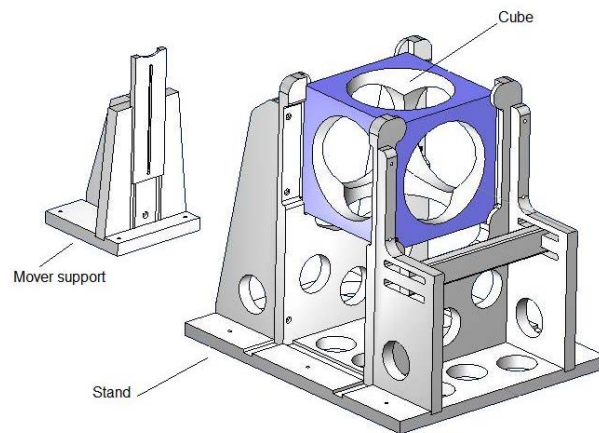


Figure 3. Stand for vacuum transporter.

Granite table and extension shelf

The vacuum balance chamber is mounted on a large granite table (see Figure 4). Because of space constraints, the granite table has an aluminum extension shelf attached to it. This extension allows the vacuum transporter to be rolled farther away from the vacuum balance chamber than the granite table allows. Along the sides of the granite table, extending from the extension shelf are two rails. These rails prevent the transporter from rolling off the sides of the table.

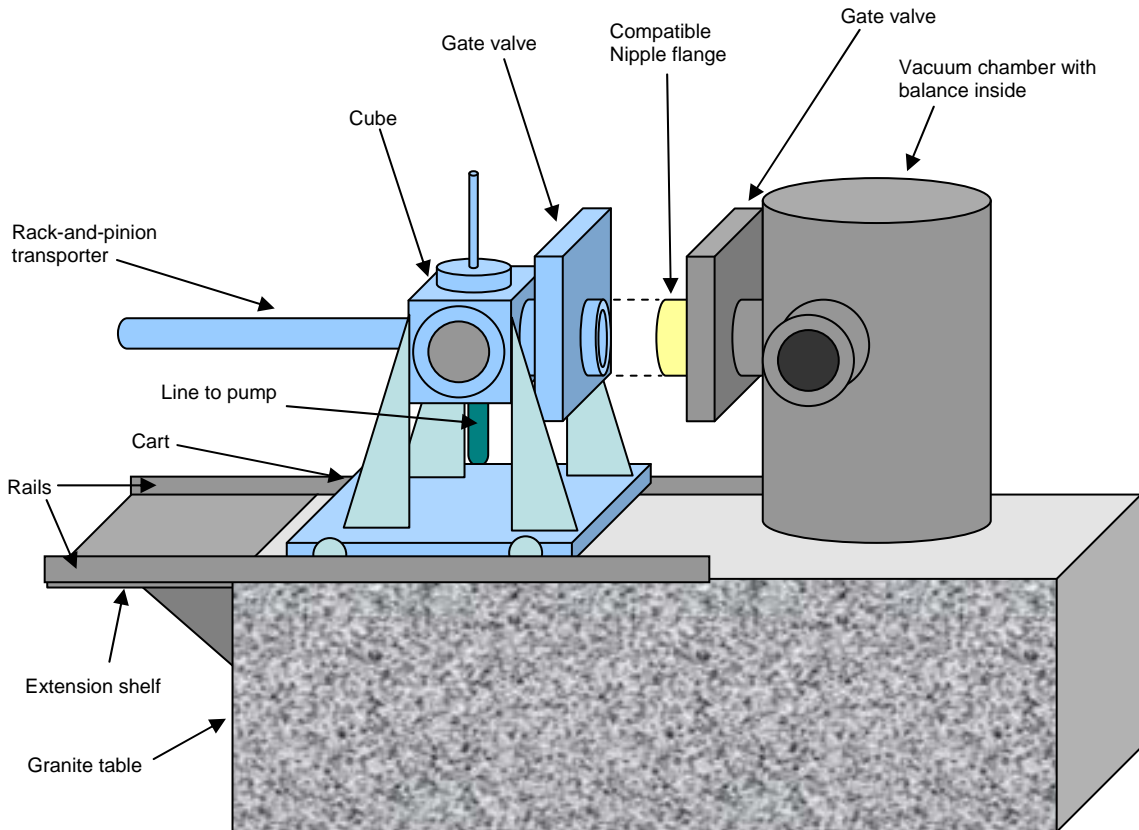


Figure 4. View of vacuum transporter, vacuum balance chamber, cart, granite table and extension.

Connection of the vacuum transporter to the vacuum balance chamber

The vacuum transporter connects to the vacuum balance chamber through the balance chamber's gated left port (see Figure 5). Both the vacuum transporter and vacuum balance chamber have gate valves to isolate or connect to each other. In between the gate valves is a nipple. The gate valves are connected to this nipple with standard clamps.

On the vacuum balance's left side is a rectangular opening that is large enough to allow the mechanical weight handler to maneuver the weight onto a position on the balance's turntable.

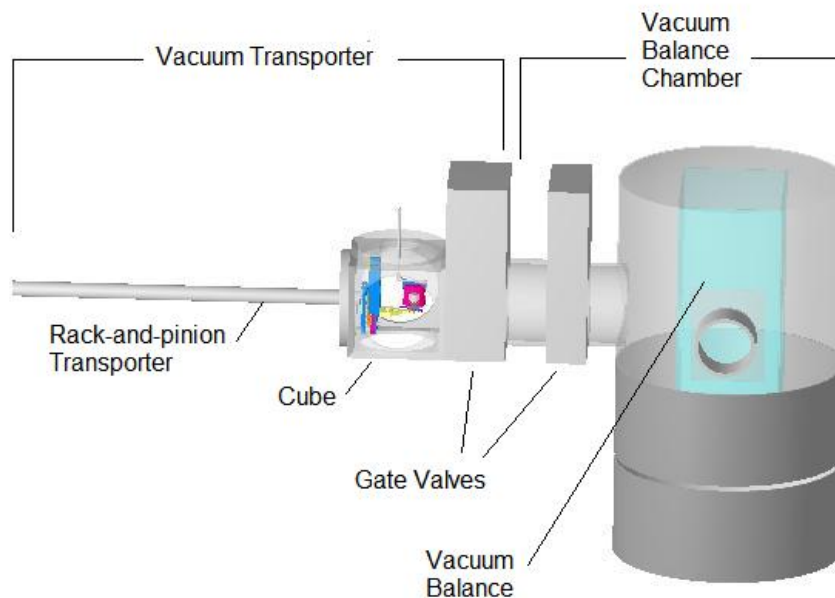


Figure 5. Connection of vacuum transporter to vacuum balance chamber.

Description of the vacuum transporter operation

After a 1 kg mass standard has been manually placed onto the star-shaped hand of the transporter, the cube is closed, the weight restraint is lowered over the standard, and the cube is pumped down to the desired vacuum pressure. Although, this is done for the cube, the rack-and-pinion transporter is, as a result, also pumped down since it is directly connected and opened to the cube.

When the desired vacuum pressure is reached, the vacuum transporter is rolled towards the vacuum balance chamber. Its height is adjusted to match the centers of the gate valves on the cube and the vacuum balance. (The sideways movement of the transport is guided by the rails of the table extension.) When clamped into place, the nipple between the two gate valves is pumped down to the same vacuum pressure by the transporter's pump. If the pressures in the cube, nipple, and vacuum balance are the same, then both gate valves are opened and the mass standard can be moved into the balance.

Before moving the weight handler, the weight restraint is manually raised upwards so it will clear the way for lateral movement. Upon reaching its highest point, the restraint is locked into place.

The weight handler is moved laterally by manual operation of the rack-and-pinion transporter. This moves the weight handler from the cube, through the cube's gate, the nipple, and through the vacuum chamber's gate valve. Upon reaching a certain point in the vacuum balance chamber, the rotation feature of the transporter causes the weight

handler to lower the weight vertically, placing the mass standard onto the balance turntable position. To return the mass standard to the cube, the opposite sequence of operations is performed.

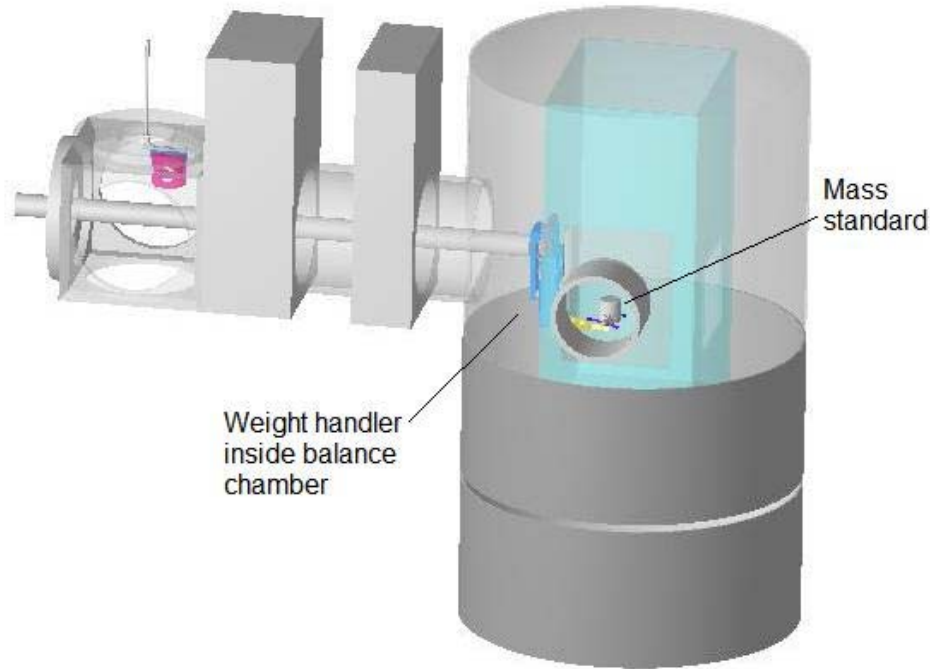


Figure 6. Mass standard in vacuum balance.

Conclusion

This mass transporter has been designed within the constraints of the vacuum balance setup in NIST's Mass Laboratory. Slight modifications would likely be needed to work with other vacuum balance setups. At a minimum, possible modifications could include using a different nipple to connect the vacuum transporter and a vacuum balance setup. The nipple would need to be compatible with the gate valve of the transporter and a gate valve (or other opening) of another vacuum balance chamber. Further changes to the vacuum transporter or changes to other existing vacuum balance setups may be required to manipulate the mass standard into the vacuum balance chamber.

The current design of this mass transporter allows for only manual operation of its mechanical parts. A future version of the transporter may include enhancements such as computer controlled motorization. Also, a reduction in size and weight is desirable.

Further modification could include changing its purpose. While its original aim is to transport a mass standard across a geographical distance, it could be modified to measure the capabilities of the NIST mass levitation system [1] by moving a kilogram mass between its two chambers.

Reference:

[1] Z. J. Jabbour, P. J. Abbott, E. R. Williams, R. Liu, V. J. Lee, "Magnetic Levitation System for the Dissemination of a Non-Artifact Based Kilogram," IMEKO 20th TC3, 3rd TC16, and 1st TC22 International Conference, Nov 27, 2007, to Dec 01, 2007, Merida, Mexico.