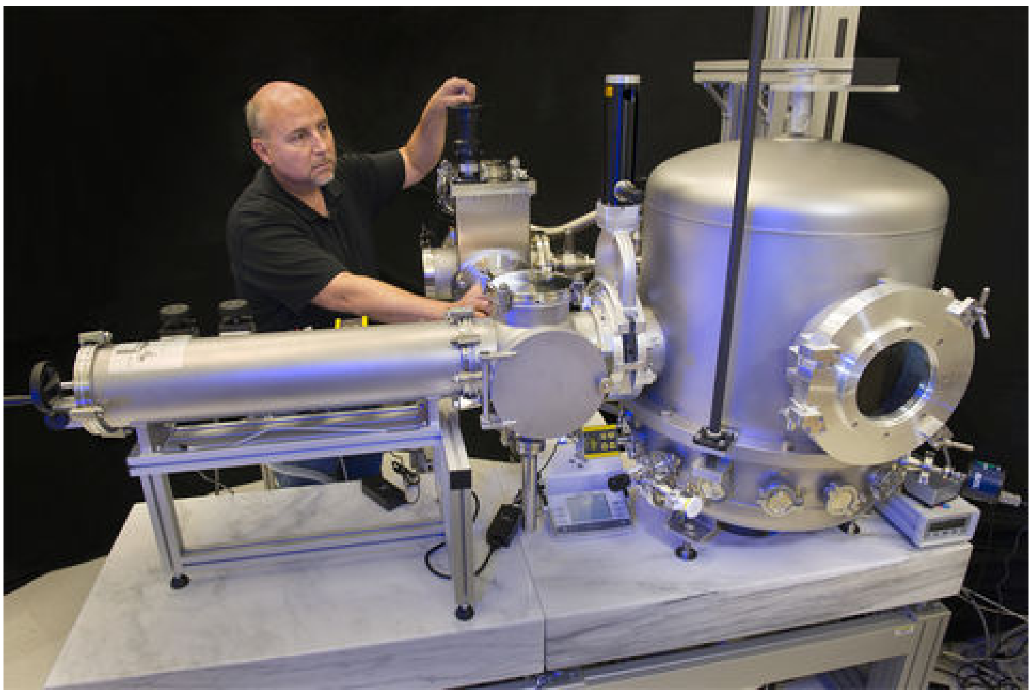
Disseminating the new kilogram—an international 'dry run'

November 29 2016, by Jennifer Lauren Lee



NIST's Patrick Abbott with one of the two smaller balances, used for the vacuum-to-air studies. Credit: National Institute of Standards and Technology

When the kilogram, the world's basic unit of mass, gets a new definition in 2018, it will be based not on a physical artifact but a constant of nature. However, researchers will still need to "realize" the new definition, or translate it into a physical object, to make it possible to distribute the new standard to the laboratories and industries that need it. Of the two methods that are major contenders for this realization process – watt balances and silicon spheres – both require delicate measurements in vacuum.

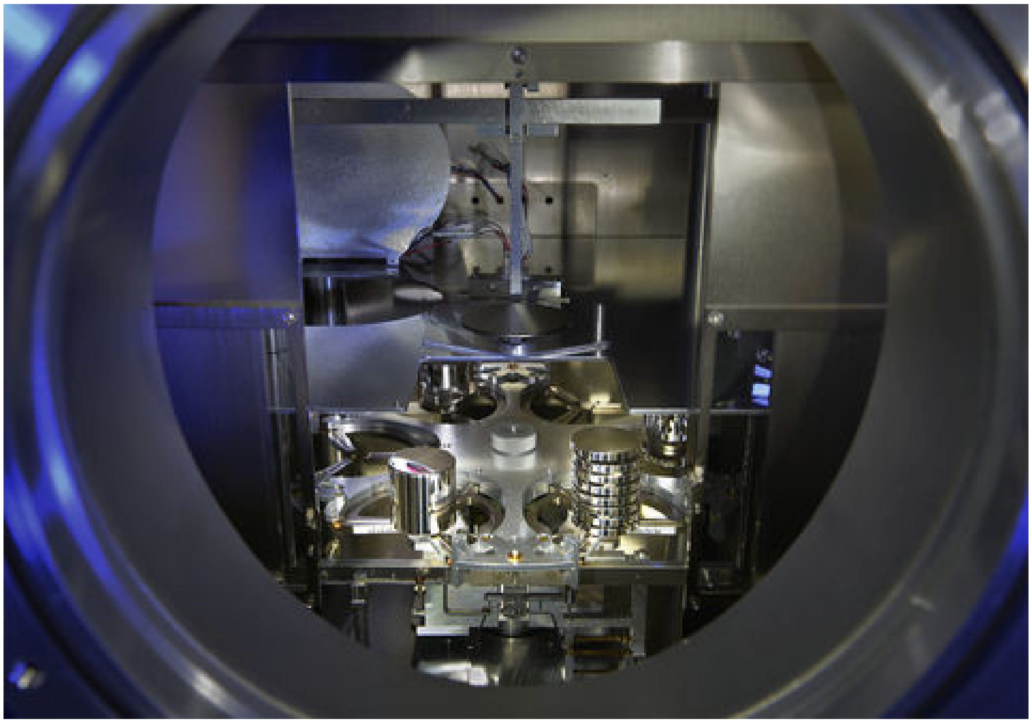
But most day-to-day mass measurements take place in regular air. This means that in order to disseminate the new kilogram, researchers must find reliable ways to compare a mass measured in vacuum to one measured in air.

The world's national metrology institutes (NMIs) are each developing protocols to use in their own countries. But someone needs to check to make sure that their various methods are working well and getting comparable results.

So the International Bureau of Weights and Measures (BIPM), an intergovernmental organization that has custody over the current official kilogram standard, asked a few NMIs to perform a dry run of their proposed methods of dissemination, as part of a pilot study to ensure that the plans for distributing the new definition are feasible. NIST just completed its dry run this month.

"For this pilot study, each NMI has done a primary realization of a kilogram using either a watt balance or silicon sphere," says Patrick Abbott of the Mass and Force Group in NIST's Physical Measurement Laboratory. "The idea was: How well can we take that primary realization and pass it on?"

Presently, the U.S. standard for mass is a plum-sized cylinder of platinum-iridium called K20, which is regularly calibrated against the world's current definition for the kilogram – the International Prototype Kilogram (IPK), housed at BIPM headquarters in Paris. After redefinition, K20 will be replaced by a new U.S. standard: the NIST-4 watt balance.



A close-up of the inside of the small apparatus used for the vacuum-to-air studies. A kilogram standard (left) is ready to be compared to a stack of discs (right). The two objects have the same nominal mass, are composed of the same material, and have roughly the same shape – but the right-hand object has a greater total surface area. By measuring how the standards' masses change relative to each other in both air and in vacuum, researchers can calculate how an object's mass changes with exposure to air. Credit: National Institute of Standards and Technology

NIST staff began the pilot study by calibrating a sample mass, made of platinum-iridium, in their watt balance. But the next step – transferring the calibration to masses in air – was a bit tricky. Air contains water and other impurities that are adsorbed by the surfaces of the masses used in the calibration process. So a mass measured in air will be slightly heavier than that same mass measured in vacuum. The nagging question for metrologists is, by how much?

NIST researchers have prepared a couple of ways to overcome this problem. The first involves a room-sized double-decker instrument that uses magnetic levitation to float a mass in the air, to balance it against a mass in vacuum, and do a direct comparison of the two. Eventually, this instrument – called the Magnetic Suspension Mass Comparator – will be the preferred method of disseminating the kilogram. But it is still being constructed and tested, so it was not used in the dry run.

The second method involves using a set of smaller instruments at NIST. These balances are able to compare the masses of two objects at a time in either regular air or in vacuum. Prior to the dry run, NIST staff used one of these apparatus to conduct a study gauging exactly how much mass is added to an object when it goes from vacuum to air, based on its material and the smoothness of its surface.

With this information, the NIST researchers took the mass that had been calibrated using the watt balance, removed it from vacuum, and compared it – in air – to a pair of stainless steel working standards, of the type that might be used to calibrate customers' weights. The team applied the corrections that it gathered from its adsorption studies to make the jump from vacuum to air.

To connect these findings to the current definition for mass, the team also measured all of these test masses against one of the official U.S. mass standards, whose definition is tied to the IPK.

Abbott says he expects the BIPM will be ready to share results from the pilot study by early next year. Other participating NMIs include the National Research Council of Canada (NRC Canada) and France's Laboratoire National de Métrologie et d'Essais (LNE), each of which has its own watt balance, as well as the National Metrology Institute of Germany (PTB) and the National Metrology Institute of Japan (NMIJ), which use silicon spheres.

Provided by National Institute of Standards and Technology

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