ABSOLUTE GRAVITY MEASUREMENTS AT LNE

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Abstract

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We present the results of absolute gravity measurements in the laboratories where the LNE's watt balance experiment is conducted. Four stations were measured with three absolute gravimeters FG5 in October 2006. It represents 13 measurements over 6 days. Two stations were visited twice by one gravimeter. The results show an excellent repeatability of the absolute observations although their absolute values may differ up to 5 μGal. The results of the difference between the absolute measurements at the different points compare well to the measurements of a relative gravimeter Scintrex CG-5.

Introduction

In the framework of the LNE watt balance project [1], an accurate determination of g is required. Two pillars have been built in the LNE laboratory in Trappes: one for the watt balance and the other one to host the atomic absolute gravimeter developed at LNE-SYRTE at the Observatoire de Paris. This gravimeter should participate in the future to international comparisons and the pillars are built to welcome other gravimeters. Before the installation of the watt balance and the new atomic absolute gravimeter, we took the opportunity to make absolute gravity measurements on the pillars where they will be set up. A comparison of three absolute gravimeters involved in the last international comparison [2] was organized to make these absolute measurements from the 13th to the 17th of october 2006 : FG5#215 from Czech Republic, FG5#216 from Luxembourg and FG5#228 from France.

1. The watt balance project

The watt balance, which principle was proposed in 1975 by B. Kibble [3], is a project that aims at redefining the unit of mass, the kilogram, by weighing a mass with an electrical balance. The experiment is performed in two steps. During a "static" phase, the weight of a proof mass is balanced by a Laplace force exerted on a coil, in which a controlled current flows, placed in a magnetic field. During a second "dynamic" phase, the same coil is displaced at constant speed in the same magnetic field, and the induced voltage is measured. From these two measurements, one can establish a relation between the electrical and mechanical quantities, where the length of the coil and the magnetic induction, which cannot be measured precisely, disappear. The watt balance allows determining the Planck constant, providing gravity is also measured. An accurate measurement of g at the very position where the mass is located is necessary. It can be performed at a reference point nearby, and the tie between the reference point and the position of the mass needs to be determined. The aim of our project is to realize a measurement of the Planck constant with a relative accuracy of 10^{-8}, so it is imperative to secure a relative accuracy on g at 10^{-9}.

2. Stations measured

Two pillars (6 m × 5.5 m × 2 m) in two rooms have been specifically designed in the Maxwell building at LNE in Trappes (48°45'38.58" N; 1°59'3.85" E): one to welcome the watt balance (named BW) and the other one to welcome the absolute gravimeter (named GR) [4]. Two stations on each pillar were measured during this comparison: points 40 and 29 in the GR room and 223 and 9.29 in the BW room. Two measurements per day were performed by each absolute gravimeter, one during the day and one during the night. A few days before

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and after the absolute measurements, ties between stations and vertical gravity gradients were measured with a relative gravimeter Scintrex CG-5.

3. Results

Each participant processed their data independently. The final results were given at 122 cm above the floor. All the uncertainty budgets were not fully completed, so type B uncertainty was fixed to 2 μGal in that case [5]. The results are displayed in fig. 1.

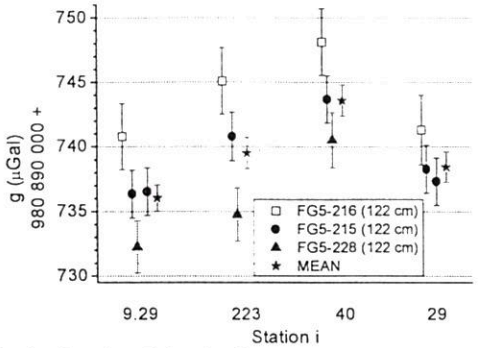

Fig. 1. Results of the absolute measurements at 122 cm above the floor

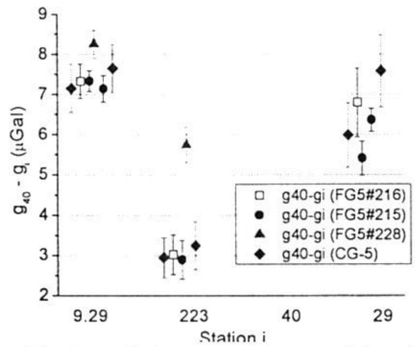

Fig. 2. Relative measurements with station 40 as the reference

There is a constant difference between devices and these offsets are not fully taken into account in the uncertainty budgets or are not evaluated in an accurate way. If we analyze the results with $E_n = \frac{g_n - g}{\sqrt{U_n^2 - U_g^2}}$ - where g_n and U_n are the absolute measurement and the uncertainty of the measurement n ; g and U_g are the weighted mean of measurements and its uncertainty-, it should be in agreement with the usual criterion for comparison : $|E_n| \leq 1$. We easily see on fig. 1 that the criterion is not established. To reach it, we got to expand the uncertainties close to 5 μGal.

Nevertheless, the statistical uncertainties of the gravimeters are similar. Moreover, the results of the FG5#215, which measured two stations twice, show the excellent repeatability of the measurements. The relative gravity differences are also calculated taking station #40 as the reference station with the statistical uncertainty of each device. They are displayed in figure 2 with the results obtained with the CG-5 measurements. We point out that the gravimeters give the same relative measurements except FG5#228 at station 223. Despite an offset may exist between the devices, it seems to be very stable at least over a few days. For the gravimeter FG5#228, the measurement at station 223 was performed after adjusting the *superspring*, so the device was not in the same conditions of measurement than at the two other stations.

Conclusion

Before installing the watt balance and the absolute atomic gravimeter, it was instructive to perform a first comparison of absolute gravimeters in our laboratory. The results of three absolute gravimeters which took part in the comparison are in close agreement, although an offset of about 5 μGal exists between the results. Statistical uncertainties of the gravimeters are similar and the results are stable. The relative measurements performed with the CG-5 agree within 1 μGal [4]. For a project like the watt balance, we need to know more about the offsets between absolute gravimeters and about the final uncertainty budget of each gravimeter. The next comparison in the laboratory will include the absolute atomic gravimeter. It will be very useful to compare different techniques. This should bring more information about the offsets and the accuracy of absolute gravimeters.

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