WEIGHT OF THE THERMO-INSULATED CONTAINER EQUIPPED WITH ELECTRIC HEATER

Alexander L. Dmitriev

St. Petersburg National Research University of Information Technologies, Mechanics and Optics,

St. Petersburg, 49 Kronverksky Prospect, 197101, Russia

Experiment with weighing of the thermo-insulated container in form of three tight metal vessels, in which the internal one is heated up by an electric spiral, is briefly described. Results of the experiment show a rather strong temperature reduction of weight of the vessel made from titan with a relative value in the order of $10^{-6} K^{-1}$.

Keywords: gravitation, weight, temperature

Researches of influence of temperature of bodies on results of their exact weighing are actual not only in gravimetry and metrology of mass, but also in connection with importance of this problem for physics of gravitation. The body temperature is a measure of energy of chaotic movement of the microparticles it is made of, which is directly connected with their speed and acceleration; the temperature - the factor describing the electromagnetic interaction of particles of a body. Forces of gravitation also cause the acceleration of bodies, and researches of deep and not trivial interrelation of acceleration and gravitation have fundamental importance.[1-4] Last years these researches draw special attention in connection with the fact that in a number of experiments there is observed a rather strong negative dependence of the force of gravitation on the temperature.[5-7]

A simple experiment with weighing of the tight thermo-insulated container, inside which the electric heater is placed, has been described below.

The design of container in form of three thoroughly hermetically sealed rigid metal vessels, enclosed in each other, is shown in FIG. 1.

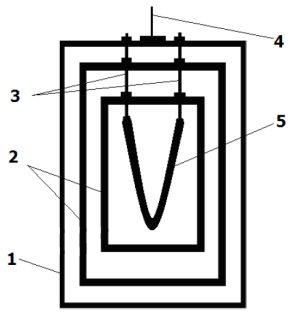

FIG. 1. The design of the container. 1 - a vessel made of steel, 2 - vessels made of titan, 3 - copper electrodes, 4 - a suspension bracket, 5 - an electric spiral.

Full weight of the container is 166.8 g, diameter of the external steel cylinder is 40 mm, height is 53 mm, thickness of walls of the steel cylinder is 1.5 mm, walls of the titan cylinders is 2 mm. Heater - a wire spiral made of Nichrome with weight of 540 mg and electrical resistance of 10.5 Ω; the voltage of the power source is 12.5 V, duration of the spiral heating is 20 s.

Weighing of the container before and after the heater switching ON was made on analytical balance of ADV200 make by the elongation method with the period of readout of the current values of weight being about 18 s. Duration of operations of removal and installation of the container for connection to the power source is 1.5 $\min$, accuracy of selective readouts of the container weight is not worse than 50 mcg. An example of typical experimental time dependence of the container weight is given in FIG. 2.

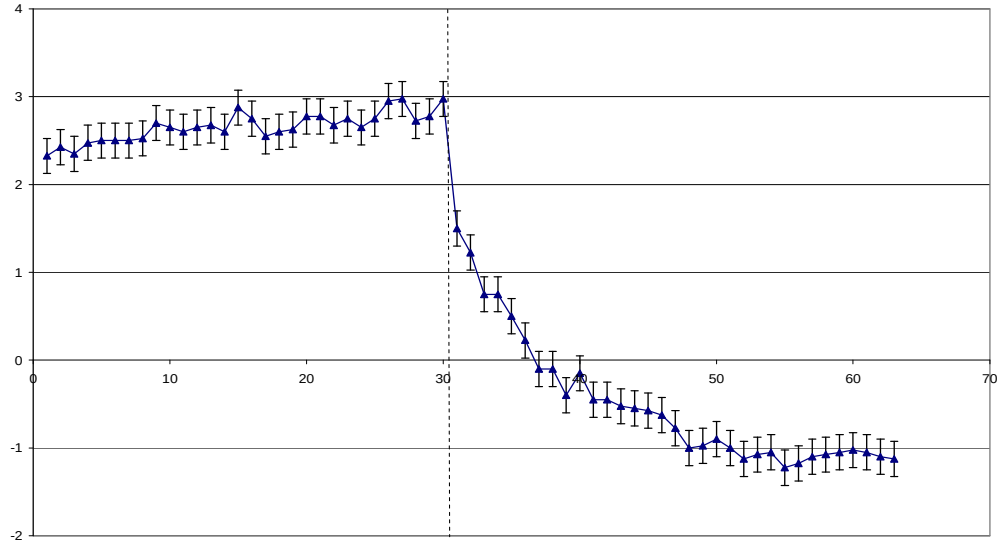

FIG. 2. Time dependence of change of the container apparent weight. The dash line specifies the "moment" of ON and OFF of the heater. One division on the vertical scale corresponds to 100 mcg , the period of weight readouts is 18.2 s .

Significant, more than 300 mcg in value, reduction of the container weight during heating and first 2-3 minutes after action of the heater, has regular character and is not connected to errors of operation of removal and installation of the container on the beam of analytical balance (it is proved to be true by the repeated careful measurements).

Principal causes of changes in weight of the hermetically sealed container with the heated up spiral are:

- change of buoyancy of a weighed body, owing to temperature-dependent change of volume of the external steel vessel;

- convective flows of air near the wall of the external vessel, owing to its being heated;

- temperature changes of weight of the electrical spiral and weights of the container, to the greatest degree, weights of the internal cylinder.

Change of the surface temperature of the external cylinder is shown in FIG. 3.

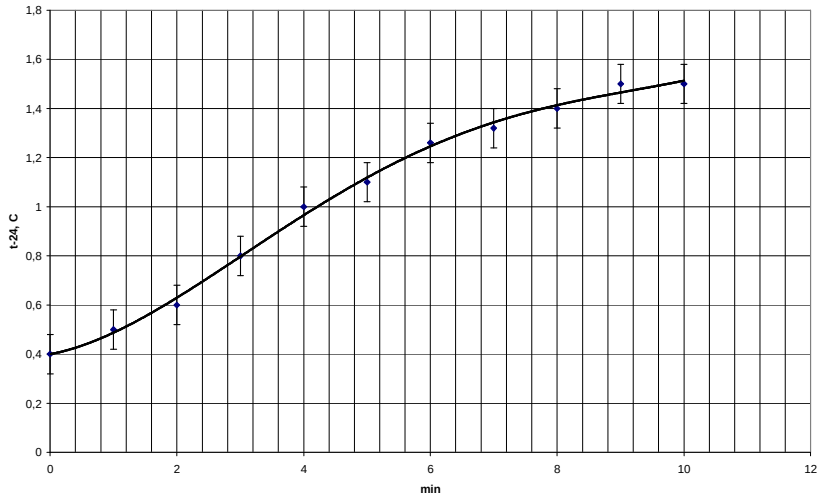

FIG. 3. Change of the surface temperature t of the external cylinder. Time of heating is 20 s , the moment "0" corresponds to ON position of the heater.

Obviously, in the first three minutes of measurements the increase ΔT of temperature of the external steel cylinder does not exceed 0.4 K .

Change Δm_1 of apparent weight of the container, caused by change of volume of the steel cylinder owing to

thermal expansion of its material is equal to:

$$\Delta m_1 = \frac{3\pi}{4}\rho d^2 h\alpha\Delta T\,, \qquad (1)$$

where ρ - density of air, α - factor of linear expansion of material of the cylinder, d - its diameter, h - height. At $\rho = 1.19 kg/m^3$, $\alpha = 11.9\cdot 10^{-6}$ and $\Delta T = 0.4K$ $\Delta m_1 \approx 1 mcg$.

Change Δm_2 of apparent weight of the container, caused by deformations of walls of the cylindrical vessel, owing to temperature change of air pressure ΔP within its volume, as it is possible to show on the basis of the theory of elasticity [8], is equal to:

$$\Delta m_2 = \frac{\pi\rho h d^3\Delta P}{4\delta E} + \frac{\pi\rho d^3}{16}\sqrt[3]{\frac{3(1-\nu)d\Delta P}{2\delta E}}\,, \qquad (2)$$

where δ - thickness of walls, E - the modulus of elasticity and ν - Poisson's ratio . The size ΔP is connected to change of temperature $\Delta\overline{T}$ of air within the volume of the external cylinder $\Delta P = P\Delta\overline{T}/T$, where P - normal pressure of atmosphere and T - temperature of air in the cylinder. For example, at $\Delta\overline{T} = 1K$, $T \approx 298K$, $P \approx 1.013\cdot 10^5 N/m^2$, $\Delta P \approx 340 N/m^2$. At $\delta = 1.5mm$, $E \approx 2\cdot 10^{11} N/m^2$, $\nu \approx 0.3$, $\Delta m_2 \approx 50 mcg$.

The given estimate is overestimated, as in the second addend of formula 2, describing deformation of face walls of a vessel, such walls are presented by thin membranes; actually, the deflection of end faces is less than it is supposed in conclusion 2.

The change Δm_3 of apparent weight of the container, caused by air convection due to difference ΔT of temperatures of surface of the external steel cylinder and temperatures of air in the closed box of analytical balance, will be estimated on the basis of [9] according to which

$$\frac{\Delta m_3}{A d^{1/4}\Delta T^{3/4}} = 9.2\cdot 10^{-7} gcm^{-9/4}K^{-3/4}\,, \qquad (3)$$

where the area of lateral surface of the cylinder is $A = \pi dh$. With the maximum difference $\Delta T = 0.4K$, $\Delta m_3 \approx 40 mcg$.

Reduction of weight of the container during the first 2-3 minutes of measurements is equal to about 350 mcg which exceeds the sum ($\Delta m_1 + \Delta m_2 + \Delta m_3$) by more than three times.

The observed "defect" of masse Δm_4 with value of 260 mcg can be explained by temperature change of weight of the container with weights m_v of the internal titan vessel in the greatest degree.

As shown by the thermo-physical calculations, the change ΔT_v of temperature of the internal vessel in the first minutes from the moment ON of short-time switching on of the heater is equal to about 10 K ($\Delta T_v = \Delta Q/m_v c$, where $\Delta Q \approx 100 J$ - the energy transferred to a vessel during heat exchange $m_v = 0.02kg$, $c = 574\ \mathrm{J/kg}\cdot K$ - the specific thermal capacity of titan).

The factor γ describing relative temperature change of weight of an internal vessel,

$$\gamma = \frac{\Delta m_4}{m_v\Delta T_v}\,, \qquad (4)$$

which is not less than $1.5\cdot 10^{-6} K^{-1}$ that is close to the values of this factor earlier obtained for metals.[5,6]

The detailed description of dynamics of temperature change of the container weight can be executed with account

for specific features of the container design, and also for the design and the mode of operation of the electric heater.

So, the described experiment confirms the rather strong negative temperature dependence of weight of the container, containing a heated up vessel made of titan. Researches of temperature dependence of weight of materials, conducted in a wide range of temperatures, will allow to expand the existing concepts of physics of gravitational interaction and its connection with electromagnetism.

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