

## A NEW MAGNETIC COUPLING FOR THE SEPARATION OF MICRO-BALANCE AND REACTION VESSEL IN EXPERIMENTS WITH CONTROLLED ATMOSPHERES\*

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### ABSTRACT

A new magnetic coupling is outlined in which the balance and the pan or crucible could be separated.

### INTRODUCTION

In physico-chemical research continuous weighing of samples in aggressive gases, vapours or liquids and recording of the results is sometimes desirable. It would be advantageous, in these cases, if the balance and the pan or crucible could be separated to such an extent, that the balance is not exposed to the atmosphere in the sample chamber. Inversely, it could be necessary, to protect the atmosphere around the sample against outgassing of the balance, especially in ultra-high-vacuum experiments. Thus the sample should be totally separated from the balance. This is possible by a magnetic coupling, with which a ferromagnetic body is kept in free magnetic suspension by a magnet. The body supports the balance pan, while the magnet is suspended from the beam of the balance proper. Therewith, the lines of force, which pass through the non-magnetic wall of the recipient, represent, so to speak, a link in the connection between the sample and the balance. This link transmits the weight of the sample through the chamber wall without friction. It is well known, that free magnetic suspension of a ferromagnetic body, in the considered case preferably a permanent magnet, implies automatic control. A commercially built magnetic suspension balance (Sartorius-Gast) therefore uses a controlling winding and an inductive distance sensor for the approach of a conductor which is fixed to the lower magnet<sup>1</sup>. An auxiliary control circuit adapts the distance to the load. A maximum load of 30 g is measured with an accuracy of 10  $\mu$ g.

### METHOD

In order to extend the principle of the magnetic coupling into the microgram range, the weight of the structural elements has to be drastically reduced. Moreover,

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the flexible leads to the control winding and to the sensor are inconvenient. It is therefore advisable to fix the coil and the sensor to the casing of the balance. In this case, it is to be apprehended, that the field of the coils exerts a disturbing vertical force onto both carrying and suspended magnet. This effect can be avoided by combining two measures, of which the first is one of design, the second one of control technique.

A rod-shaped magnet is suspended from the balance, keeping a second one underneath in free suspension. The distance of the poles is converted into an electric signal, which, after sufficient amplification causes a current through the control coil. As a first step, this coil is arranged symmetrically to the poles of the magnet, thereby reducing the disturbing force.

This is the first measure to reduce the corresponding error. The second consists of an auxiliary circuit, which reduces the mean of the current in the control coil to zero by integral control. Thus, the error is reduced to a permissible value. Figure 1 shows the arrangement and the corresponding circuit. On the left side, the pair of rod-shaped magnets is visible, the upper one connected to the balance beam, the lower one carrying the load. The distance between the pole faces is electro-optically measured and—at first sight—kept constant by a proportional differential integral controller, which feeds the winding around the magnets. The winding is split to let the beam of light pass. Thus, the position of the lower magnet is stabilized, while the upper one is kept at constant height by the beam of the balance which is supposed to be self-compensating.

It is now interesting to measure the forces, which are exerted by the winding onto the magnets. For this purpose the coil is fixed to the pan of an electromagnetic precision balance and simply weighed, following Newton's third law.

Figure 2 shows the results. The forces are drawn as a function of the weight and

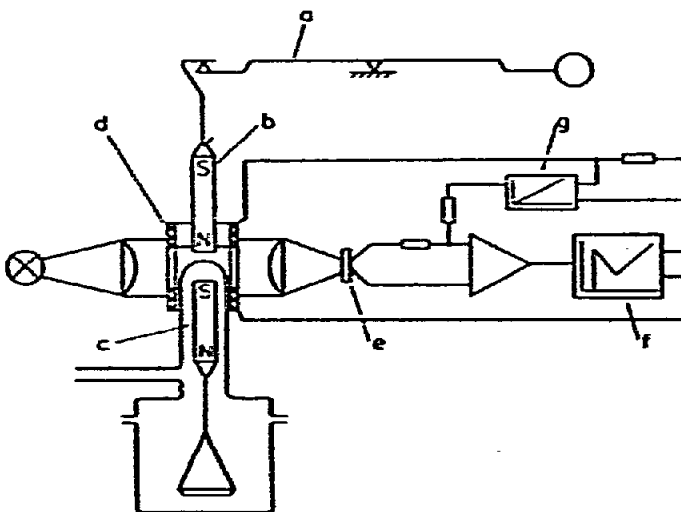


Fig. 1. A new magnetic coupling for microbalances. a = Balance beam; b = upper magnet; c = lower magnet; d = control winding; e = photocell; f = position controller; and g = integrator.

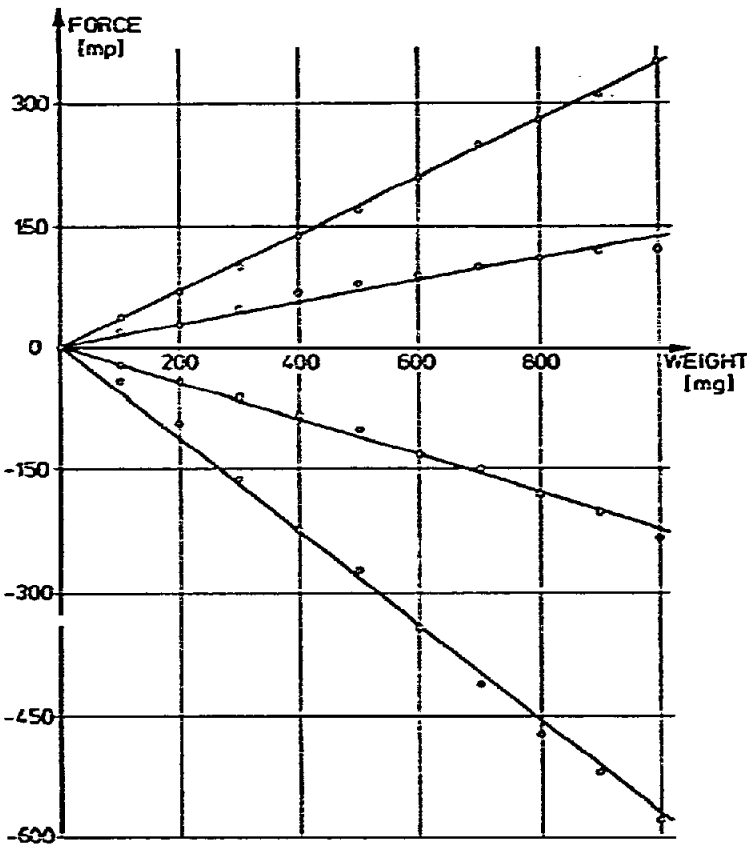


Fig. 2. Force relationship with symmetry as parameter for a pair of rod-shaped magnets in cylindrical coil.

of the displacement of the magnets, which are cemented to a spacer and attached to a micromanipulator, while the coil is excited by a direct current. It is to be seen, that the straight lines, representing the relationship between weight and force change their slope, when the position of the pair of magnets is varied. In a certain position, the slope is zero, no forces arise.

This step may reduce the disturbance to the one milligram range. The next step consists in the reduction of the current through the control winding, when equilibrium is reached. In Fig. 1, it can be seen, that the current through the control winding produces a signal voltage across a constant resistor. The signal is fed to the input of an integrator whose output has a bearing upon the input of the position control. The distance of the two magnets will therefore vary in such a way, that the current through the control winding disappears. This is shown in Fig. 3, which presents the load applied to the lower magnet, the position of the magnet, and the current through the coil as a function of time.

On application of a certain fixed load, the distance at first increases, then it is reduced to a value below the initial one. Current is, at first, steeply raised, then it goes down to zero.

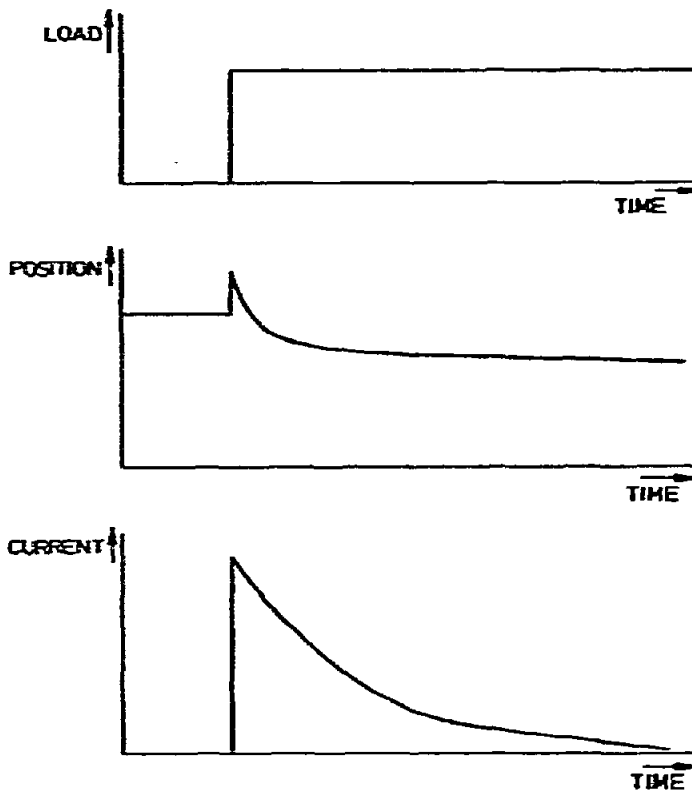


Fig. 3. Load, position and current in a magnetic suspension as a function of time.

Because the effects of design and control multiply, there is a justified hope, that the new coupling will indeed be useful for experiments in the microgram range. In order to avoid the loss in symmetry, brought about by a change of load, a helical spring of suitable compliance could be inserted in the suspension of the upper magnet. The above-mentioned combined measures can also be applied to a magnetic coupling for top pan balances.

#### ACKNOWLEDGEMENT

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#### REFERENCE

- 1 Th. Gast, *Vakuumtechnik*, (1965) 41.