Laboratory Experiment for Testing the Gravi-Magnetic Hypothesis with Squid-Magnetometers.

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Gyromagnetic and magnetomechanical phenomena have been widely examined in the 1930's - 1940's revealing the Barnett effect /1/, which results in a magnetization by rotation. Rotating superconductors also show the Barnett effect /2/. The magnetic field generated within a rotating superconductor is proportional to twice the specific charge, which agrees well with the predictions of the London theory.

We believe that in addition to this effect there is another magnetization process in nature which is proportional to the total mass of the rotating body or more precisely to its total angular momentum.

Fig. 1 shows the angular momentum (on the y-axis) versus the magnetic moment (on the x-axis) of various stars. This linear relationship has stimulated Blackett /3/ in 1947 to set up the gravi-magnetic hypothesis that a rotating mass measured in gravitational units has the same effect as a rotating charge measured in electrical units:

$$\sqrt{\gamma}\, m = \sqrt{k}\, q \quad \text{(for a rotating body)} \qquad (1)$$

(γ = gravitational constant, k = Coulomb constant $\frac{1}{4\pi\varepsilon_0}$, m = mass, q = electrical charge). After some calculation one finds that the ratio of magnetic moment to angular momentum is a constant, leading to Blackett's equation

$$\frac{m_{mag}}{L} = \frac{\frac{1}{2}\,\frac{4\pi}{\mu_0}\,B r_0^3}{\frac{2}{5}\, m r_0^2\, \omega} = \frac{1}{2}\,\frac{\sqrt{\gamma}}{\sqrt{k}} \qquad (2)$$

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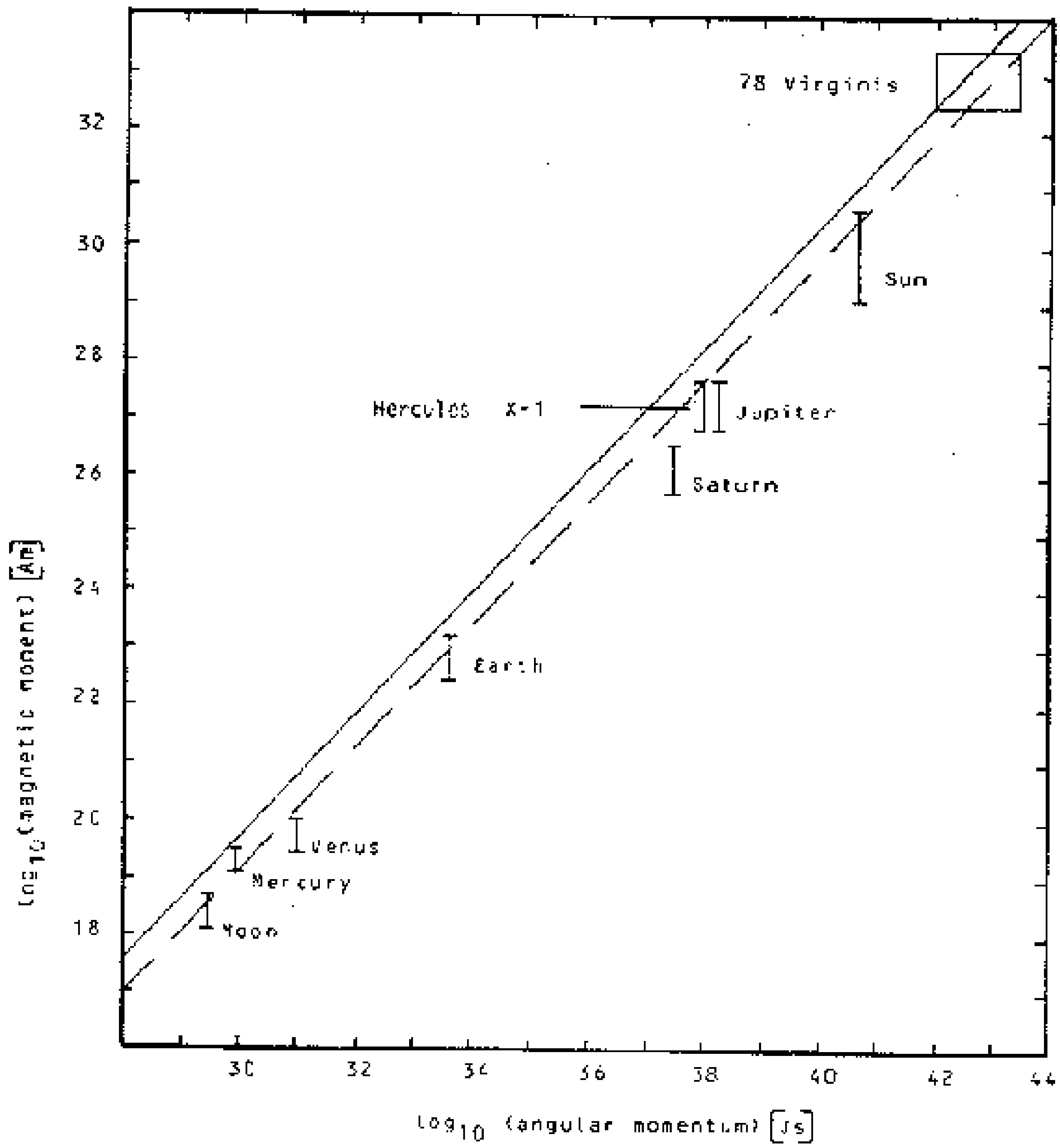

Fig. 1 (from Ref. /4/)

Angular momentum versus magnetic moment for various stellar objects. The dottet line is a regression line for the experimental data. The drawn out line corresponds to Blackett's relation. It is also equivalent to the maximum of the radial field, eq. 4, according to Heim's differential equation 3.

(m_{mag} = magnetic moment , L = angular momentum, μ_0 = magnetic vacuum permeability, ω = angular velocity, m = mass, r_0 = radius of the rotating body).The astrophysical data can actually be fittet very well by a regression line close to $m_{mag} = (\sqrt{\gamma} / 2 \sqrt{k}) \cdot L$.

The gravi-magnetic hypothesis is of some interest in geophysics. According to a simple model it is assumed that the gravi-magnetic field is the primary field. The magnetic field contribution produced by the convection currents in the core of the earth is a secondary induction process. It is directed in opposition to the gravi-magnetic field according to Lenz's rule. This secondary induction field weakens the primary field so that the observed geomagnetic field is smaller than the gravi-magnetic field. For this reason the upper limit of the geomagnetic or stellar magnetic fields is determined by the gravi-magnetic field.

Since Blackett's hypothesis there have been a number of attemots to verify this correlation in a laboratory experiment. These attempts were not succesful, so that the gravi-magnetic hypothesis was abandoned. However in 1979 Sirag /4/ pointed out that these experiments did not test the gravi-magnetic hypothesis at all. Due to the fact that magnetometers were not sufficiently sensitive, additional assumptions were necessary at that time to measure effects large enough to be seen in laboratory experiments.

But now, with the availability of Squid magnetometers, there is a real chance of measuring such an effect, if it exists at all.

In 1984 Heim /5/ published a differential equation relating the electric and mass current densities to the curl of the magnetic field vector, which slightly approximated becomes

$$\nabla \times \sqrt{\mu_0}\, \vec{H} = \sqrt{\mu_0}\, \vec{j}_e + \sqrt{\gamma}\, \vec{j}_m \qquad (3)$$

He obtained this equation by setting up the gravitational tensor in analogy to the electromagnetic tensor but with a somewhat different metric. By combining these two tensors linearly he formed a tensor describing both the gravitational and the electromagnetic behaviour of matter. By solving equation 3 for the sphere one finds for the radial component of the magnetic field on the surface, in the absence of electrical current:

(μ = relative permeability, α geographic latitude, $\beta = \frac{4\pi\gamma}{c^2}$)

$$B_r(r_o,\alpha) = \frac{3}{10\pi} \frac{\sqrt{\beta\,\mu_o}}{1-2/\mu} \omega \cdot m \cdot \frac{\sin\alpha}{r_o} \tag{4}$$

and for the tangêntial component

$$B_t(r_o,\alpha) = \frac{3}{20\pi} \frac{\sqrt{\beta\,\mu_o}}{1+2/\mu} \omega \cdot m \cdot \frac{\cos\alpha}{r_o} \tag{5}$$

In the case of stars the maximum of the radial component of the magnetic fields evaluated with the aid of equation 4 has the same magnitude as the one predicted by Blackett's gravi-magnetic hypothesis.

Fig. 2 shows the field lines for a sphere of uniform density and with $\mu = 1$ using the complete solution of Heim's differential equation (3). The field density increases towards the axis of rotation. It has a minimum on the equator near the surface. This behaviour supports Runcorn's measurements in 1952 /6/ showing an increase of the magnetic intensity in the direction of the earth's center. Runcorn's measurements were regarded by Blackett as a decisive argument against his gravi-magnetic hypothesis, because his relation, equation 2, applied to the interior of the earth with $m \sim r_o^3$ would predict a decreasing magnetic field. However, regarding the complete solution of Heim's differential equation it is evident that Blackett's relation, equation 2, can only be valid on the surface of a rotating body and not in its interior.

By assuming that our Squid magnetometer can resolve 10^{-13} Tesla the rotational frequency for ϱ_m = 5000 kg/m³ should be greater than 300 cps. The decrease of the magnetic field along the equator for this case is shown on the right of fig. 2.

One version of a possible set-up is shown in fig. 3. The rotating mass is contained in a vacuum chamber. A loop shaped-superconducting shield to confine the field lines is inserted into a hole in the center of the rotating cylinder. The Squid magnetometer can be mounted anywhere along the loop. The bearings are pneumatic to avoid magnetic interactions. The whole assembly can be cooled to He-temperature.

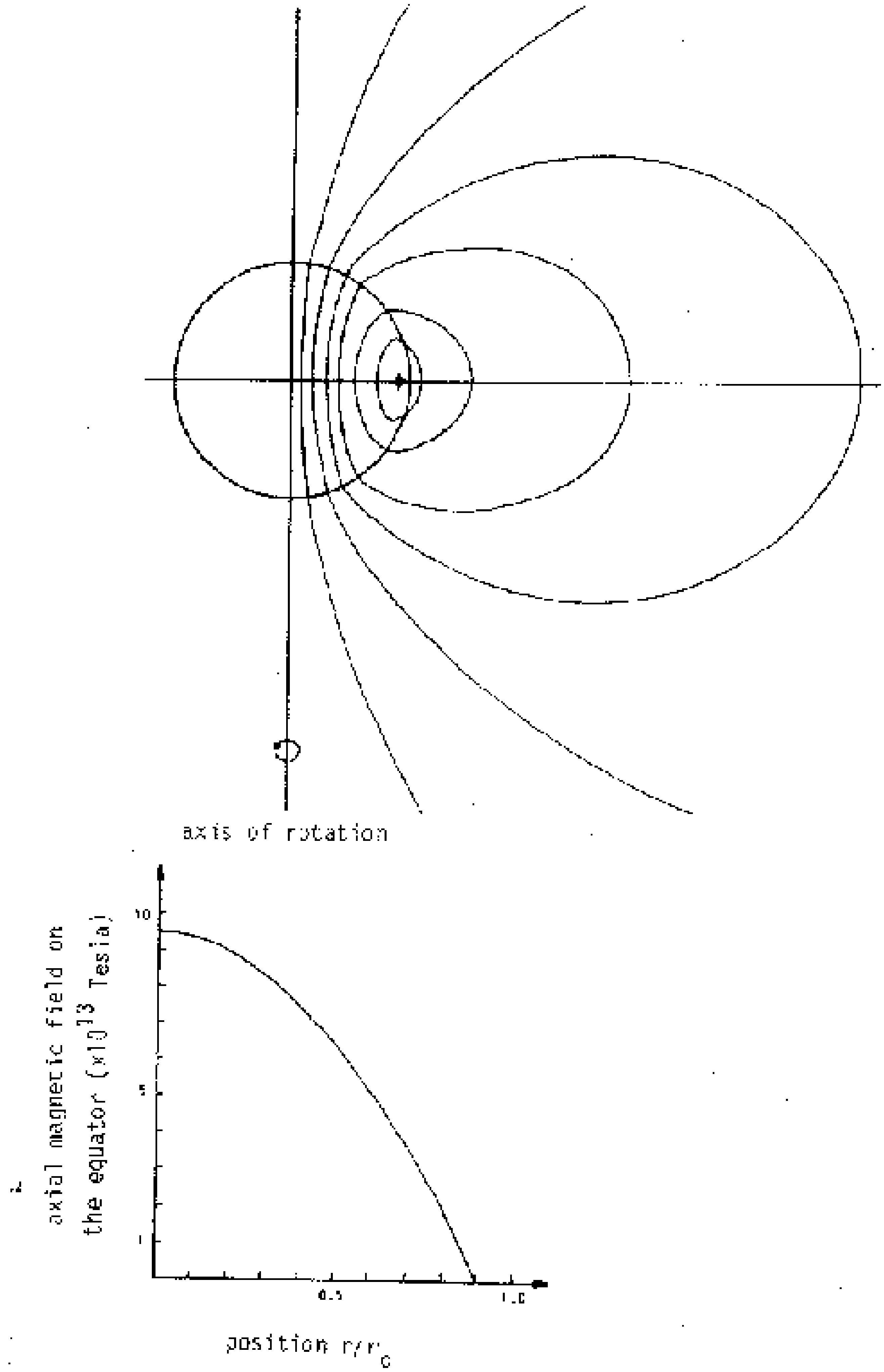

Fig. 2

Magnetic field lines for a sphere of uniform density and relative permeability $\mu = 1$. The diagram below shows the magnetic field as a function of r/r_0 for a sphere with $\nu = 300$ cps, $\rho_m = 5000$ kg/m³, $r_0 = 0.05$ m.

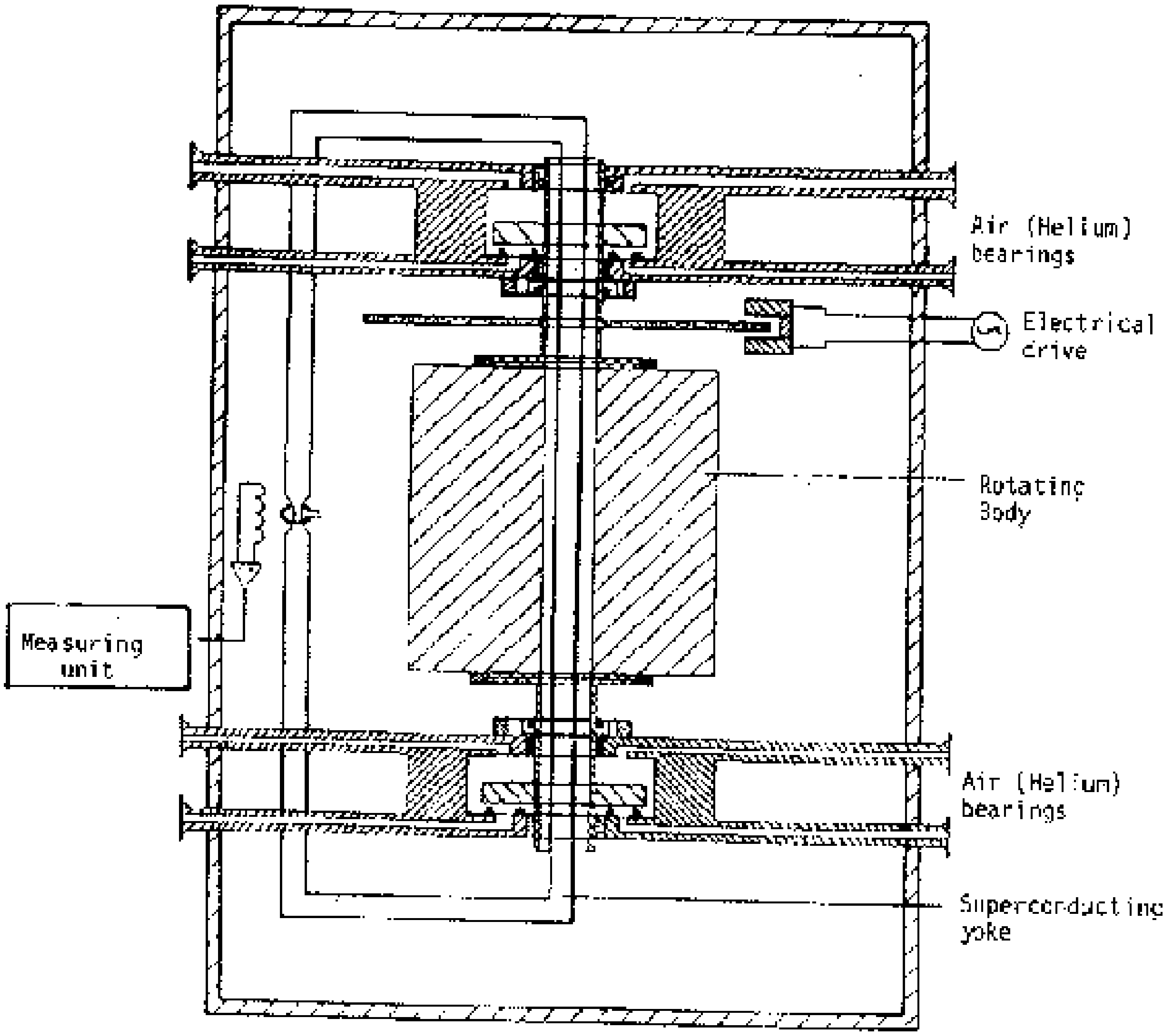

Fig. 3 Schematic diagram of experimental set-up

Since the magnetic field has a maximum on the axis, the aim of our experiment is to measure the field in the center of the rotating body. The body itself should not exhibit the Barnett effect. Hence, materials with non-saturated spinmoments such as conductors or ferromagnets have to be avoided.

Since the effect to be measured is very weak the whole assembly will have to be installed in a magnetically shielded chamber. Such a chamber is available in Berlin. The experiment will be carried out in co-operation with the Squid group at the Physikalisch-Technische Bundesanstalt.

References

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