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LABORATORY EQUIPMENT AND TECHNIQUES

SENSITIVE AUTOMATIC METHOD OF MEASURING TIME VARIATIONS OF MAGNETIZATION

By J. Mizia, K. Krop and H. Figiel

Department of Physics I, Academy of Mining and Metallurgy, Cracow*

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The paper describes an arrangement for investigating the magnetization relaxation of weakly magnetic materials, being an adaptation of the coercive force meter with internal one core astatic fluxgate. In particular, a unit for rapid switch-off the field in the coil and a compensation unit are described. Given are the range of applicability of the method and its sensitivity.

Introduction

The basic physical measurement when examining the magnetic relaxation phenomena is to determine the time change of magnetization. It is important here to know accurately a start moment of relaxation, and to be able to record the time changes of magnetization precisely. It is necessary that $\Delta I(t) \gg \delta I$, where δI is the error of the measurement. It is equally important to determine strictly other parameters bearing an effect on the range of measured relaxation times τ, *i.e.*, the value of the applied magnetic field H, the time during which it acts on the sample, and the speed with which it is being switched on and off. The initially used arrangement for investigating relaxation consisted of a coercive force meter with an internal one core astatic fluxgate [1, 21], with additional instrumentation in the form of a recorder and automatic switch for the probe. Owing to the fact that the relative change of magnetization, $\Delta I/I$, corresponding to time intervals up to 1000 seconds was of the order of 10 per cent, and for larger time intervals about 1 per cent, the error of the measurement was large.

Automatic switch-off the probe only after reduction of the variac at the input of the coil power supply, some two seconds after starting the reductin of field inside the coil, dimmed the image of the beginning of the relaxation.

These drawbacks have been removed by the use of units for rapid switch-off the field in the coil and compensator, described below.

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* Address: Katedra Fizyki I, Akademia Górniczo-Hutnicza, Kraków, Mickiewicza 30, Polska.

Unit for rapid switch-off of field in the coil

In the measurement circuit of the coercive force meter [3] the unit generating the field within the 0 to 1200 oersteds range in the region of the sample is a multilayer coreless coil. As the coil has high inductance (1.14 henry), it cannot be switched off abruptly because of the apperance of overvoltage and oscillations. Short circuting of the coil also does not give a good effect, because of the expotential character of current fading.

The devised unit makes it possible to switch the field in the coil on for a certain time and switch it off rapidly within some 0.08 second. During the switch off the field it acts as follows. After the unit is started up by a manual or time switch, a non-inductive resistor of resistance equal to that of the coil is included into coil circuit in series. The current in the coil drops to half its initial value. Then the coil is short-circuited; the current in the coil drops to a remanent value of order of 10 µamp, and the power supply is loaded with the non-inductive resistor. The next step is to open the load circuit of the supply unit, which reduces the remanent current in the coil to zero.

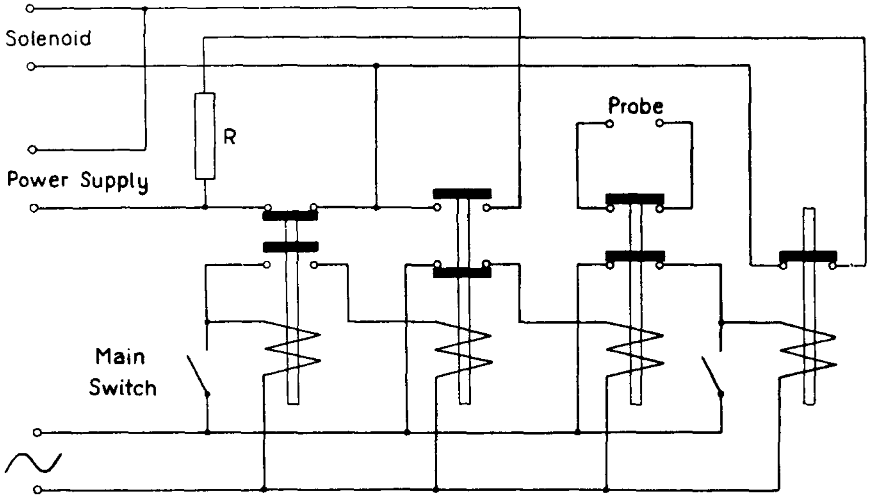

Fig. 1. Diagram of unit for rapid switch-off of field in coil

At the instant when the field fades out, the probe in the coil is disconnected; it was short — circuited during the time when there was a field in the coil, in order to protect the millioerstedmeter. A diagram of the layout is shown in Fig. 1.

Compensating unit

The use of the compensating unit had the purpose of increasing the accuracy of the measurement of $\Delta I(t)$, while simultaneously diminishing the measurement error. An inastatic probe was adapted as the compensating element, and was connected with the internal measuring probe, as shown in Fig. 2. The compensating probe, under the action of the Earth's magnetic field H_z, gives a voltage signal of amplitude proportional to the component of the field H_z parallel to the axis of the probe's cores; the probe is sensitive to the direction of the field H_z. By alternating its position with respect to the Earth's field we can get a signal of any amplitude between O and $V_{\max}$. The signal from the compensating probe is added to the signal from the measuring probe, and the resultant signal is fed into an amplifier. If the signal from the measuring probe is shrifted in phase by π with respect to the compensating signal, then at the output of the amplifier we obtain a signal whose amplitude is eqal to the amplitude difference of the incident signals.

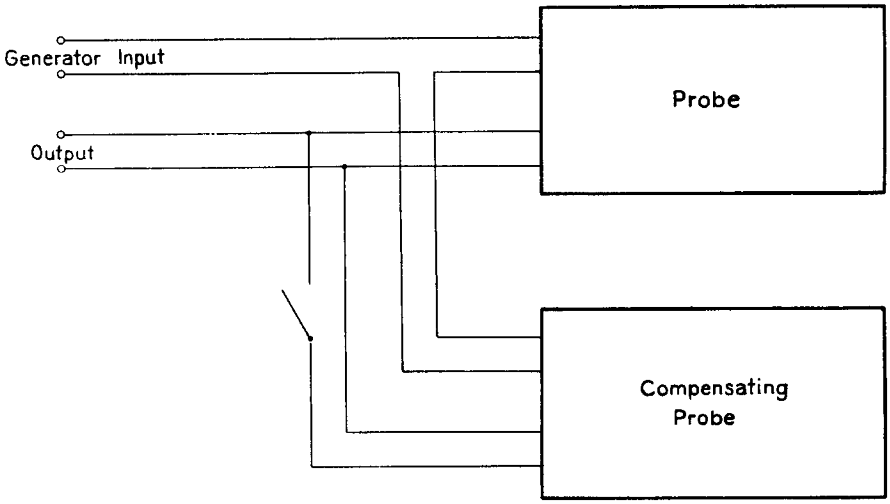

Fig. 2. Diagram of connection of measuring probe with compensating probe

The duration of the measurements is of the order of 10^4 sec. In this range of times the secular changes of the Earth's field can be neglected, and the day-to-day changes (0.05%) are also negligible. The use of a permanent magnet could give a more stable signal of reference, under condition, however, that the probe and the magnet would be screened from the Earth's field. Placing the probe in the Earth's field seems to be the simplest means of obtaining a signal of constant amplitude, which is very important in the compensation method.

Owing to the mutual shunting action of the probes, whose measuring windings are connected in parallel, the resultant sensitivity is lessened with respect to that of the probe operating alone. This can be compensated by increasing the sensitivity of the amplifier.

Range of applicability and accuracy of compensation

The compensation methods were applied in studies on the relaxation of Co particles precipitated from a Cu–1%Co solid solution. Rod-shaped samples 6 mm in diameter and 30 mm long were used in the tests. The maximum signal that was compensated corresponds to a deflection of 35 scale units of range ×500 of the millioerstedmeter, which in turn corresponds to a magnetization of $I = 1.068$ gauss. By changing the distance between the sample and the measuring probe it is possible to compensate bigger values of sample magnetization.

Improvement of the compensation sensitivity (*i.e.*, passing to more sensitive ranges of the instrument below ×5 millioersteds with a compensated signal) does not give the reqired effects owing to the high noise background caused by alternating magnetic fields and amplifier noise. The compensating circuit makes it possible to have a maximum 100-fold increase in the measurement of ΔI and a decrease of the relaxation measurement error from 1 per cent to about 0.06 per cent of the nominal value of the measured magnetization.

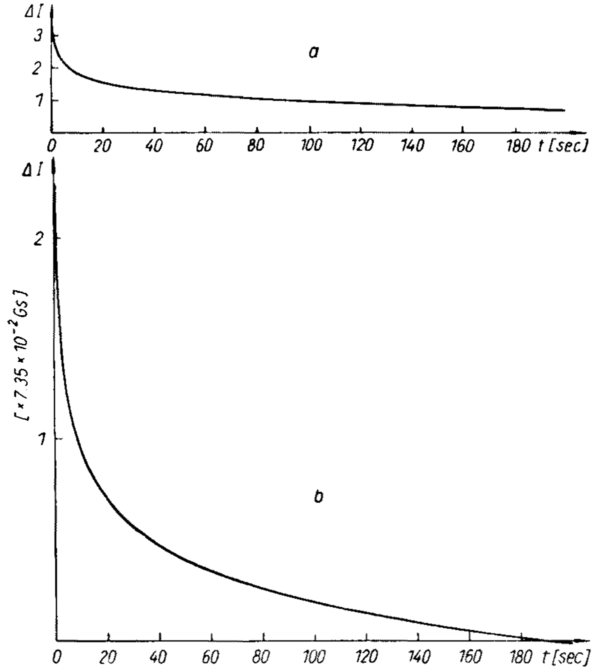

Fig. 3. Comparison of relaxation curves: *a)* obtained with the earlier equipment, *b)* obtained with that described in the present paper

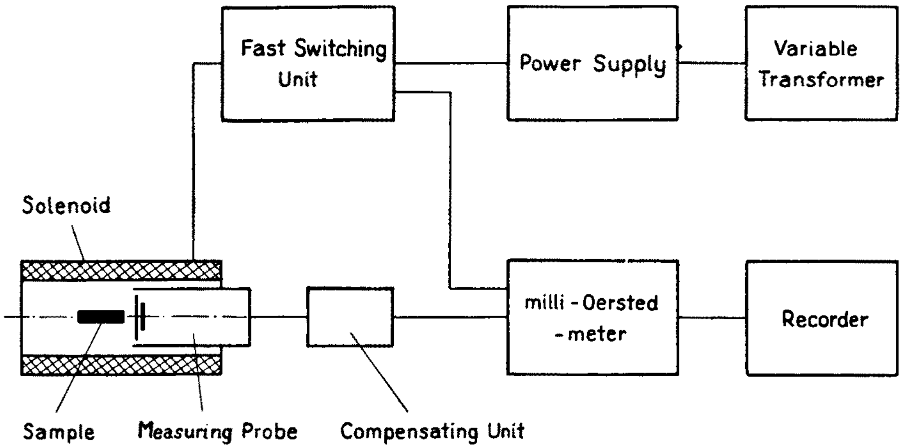

Fig. 4. Block diagram of arrangement used in relaxation studies

To illustrate the refined qualities of the improved equipment we present the relaxation curves of Cu–1% Co (Fig. 3) annealed for 16 hours at a temperature of 600° C as recorded by both the unimproved apparatus and the improved unit desribed here. The block diagarm of the set-up for investigating relaxation is given in Fig. 4.

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