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VERY HIGH TEMPERATURE PERMEAMETER

by John P. Barranger
Lewis Research Center
Cleveland, Ohio

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by John P. Barranger

National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio

ABSTRACT

A new permeameter measures the magnetizing force and the corresponding magnetic induction up to the temperature of 1000°C in a vacuum or an inert atmosphere. Two massive symmetrical yokes close the magnetic path around the specimen which consists of a rod of solid material or a bundle of sheet material. The yokes are made of a specially processed alloy of 9% iron, 91% cobalt, a high temperature soft magnetic material. A coil surrounding the specimen supplies a magnetizing force of up to 100 oersteds and a separate coil is used to measure the magnetic induction. Auxiliary coils provide additional magnetizing force resulting in a longitudinal distribution of flux uniform to within 1%. The magnetizing force is calculated from the coil current while a fluxmeter is used for the induction. The null balance type permeameter utilizes the magnetic potentiometer principle with yoke compensating coils to cancel the effects of the reluctance of the yoke and the joint gaps. Very close agreement was obtained at room temperature when compared to the standards laboratory MH and Fahy type permeameters. Normal induction curves as a function of temperature for the yoke material is also presented.

INTRODUCTION

The requirement of the space program for high temperature power conversion equipment has revived interest in the accurate measurement of properties of magnetic materials at high temperatures. Two of the National Bureau of Standards (NBS) permeameters, the Sanford-Winter MH¹ and the Fahy Simplex² are not easily adapted to high temperatures. A high-temperature (HT) null-type permeameter has been developed, which, unlike either of the NBS permeameters uses a magnetic potentiometer^{3,4} with a magnetic core to cancel the effects of the reluctance of the yoke and the joint gaps.

It is the purpose of this paper to (1) describe the new permeameter, (2) compare its performance at room temperature to the NBS permeameters and (3) illustrate its use by presenting normal induction curves as a function of temperature for a 9% iron, 91% cobalt alloy.

DESCRIPTION

The new permeameter, Fig. 1, measures the magnetizing force and the corresponding magnetic induction up to the temperature of 1000° C in a vacuum or an inert atmosphere. The specimen is a solid rod or a bundle of sheet material up to 1.27-cm wide and 0.317-cm thick with a minimum length of 16.5 cm. All coils have a rectangular cross section and are made by slipping alumina tubing over nickel wire. The central and end coils are wound on alumina bobbins that surround the specimen.

A magnetizing force of up to 100 oersteds is supplied by the H coil and is calculated from the coil current. The value of induction is obtained from the B coil using a fluxmeter or ballistic galvanometer with corrections made for the cross sectional area of the coil.

The end auxiliary magnetizing coils, which are electrically and magnetically in series with the H coil, provide additional magnetizing force resulting in a longitudinal distribution of flux uniform to within 1%.

Two massive symmetrical yokes close the magnetic path around the specimen. To minimize the introduction of undesirable stresses into the specimen, most of the weight of the upper yoke is supported by the central coil alumina bobbin. Each of the yokes consists of a compensating coil wound on a magnetic core. The core is a 9% iron, 91% cobalt high temperature soft magnetic alloy, made from electron beam zone refined starting materials, alloyed by arc melting and rolled to 0.028-cm thick sheet. The symmetrical construction of the yokes promote uniform flux distribution throughout the cross section of the specimen.

The magnetic potentiometer is a coil wound on a magnetic semi-circular core of the same alloy as is used in the yokes. The ends of the magnetic strips are extended to the specimen surface through cut-outs in the alumina bobbin.

To examine the role of the magnetic potentiometer in the determination of H, let us call the part of the specimen between the magnetic potentiometer extensions in Fig. 1 the active part of the specimen. By Ampere's circuital law,

$$\left[\int \mathbf{H} \cdot d\mathbf{l} \right]_{\text{active part of specimen}} + \left[\int \mathbf{H} \cdot d\mathbf{l} \right]_{\text{magnetic potentiometer}} = 0.4 \pi NI \quad (1)$$

where I is the magnetizing current and N is the number of turns in the H coil. Suppose now that the compensating coils provide the necessary magnetomotive force to null balance or cancel out the second term in Eq. (1). If H is uniform, then

$$H = 0.4 \pi NI/L \quad (2)$$

where L is the length of the active part of the specimen.

The electrical circuit is a modification of the usual ballistic measurement method. A compensating coil current reversing switch is ganged to the magnetizing current reversing switch so that the two currents are switched simultaneously. The compensating coil current is adjusted to obtain zero magnetic potentiometer output at each value of magnetizing current.

PERFORMANCE

The room temperature performance of the HT null-type permeameter was compared to the MH and Fahy permeameters. A solid bar of type C1020 carbon steel was sent to the Materials Research Institute at NBS for calibration on their MH permeameter. The normal induction curve data points for each instrument are plotted in Fig. 2. As can be seen very close agreement was obtained. For the Fahy test, the upper yoke was replaced with a test coil wound uniformly on a nonmagnetic form and mounted between two iron blocks. Again, very close agreement was achieved for a bundle of silicon iron sheet.

The permeameter was used to show the effect of temperature on the normal induction curve of the 9% iron, 91% cobalt alloy, the core material used in the magnetic potentiometer and the yokes. In Fig. 3 the initial 25° temperature curve was measured in the "as rolled" condition. The final 25° temperature curve illustrates the improvement in permeability obtained after one annealing run.

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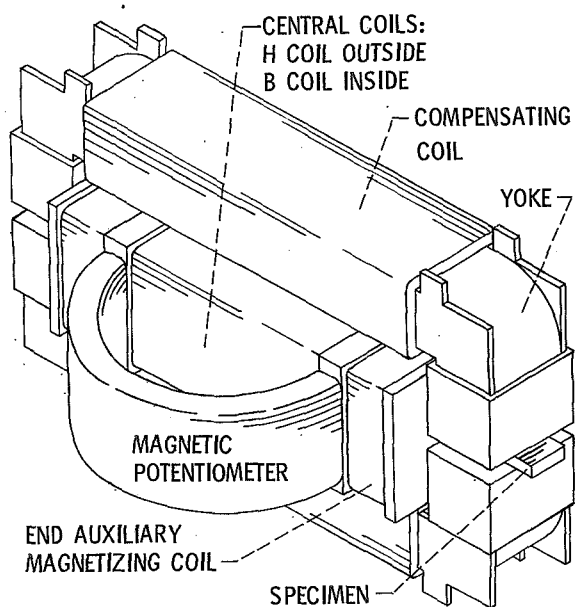


Figure 1. - HT null-type permeameter.

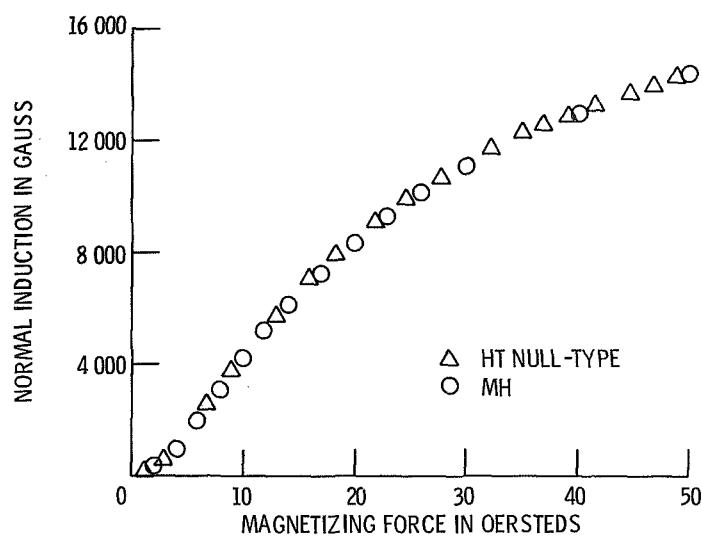


Figure 2. - Comparison of HT null-type and MH permeameters.

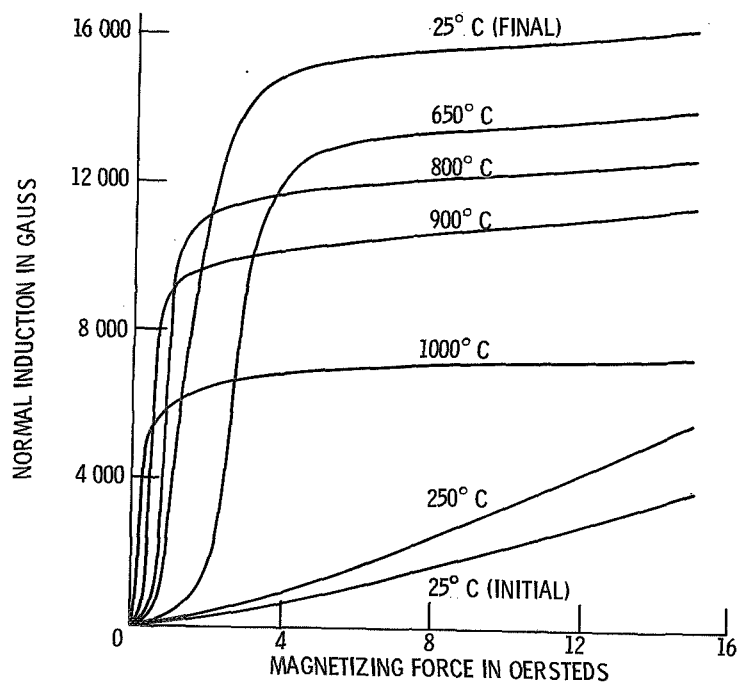


Figure 3. - Effect of temperature on normal induction curve of the 9 percent iron, 91 percent cobalt alloy in the direction of rolling