LA-9437-MS

UC-28
Issued: July 1982

LA--9437-MS

DE82 019492

Radiation Effects on Samarium-Cobalt Permanent Magnets

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RADIATION EFFECTS

ON SAMARIUM-COBALT PERMANENT MAGNETS

by

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ABSTRACT

With the recent advances in rare-earth-cobalt (REC) permanent magnet technology, new applications are being implemented that were previously not feasible. One such application is the use of permanent magnetic lenses for accelerator and beam transport systems. In many of these areas the magnetic transport systems are subjected to high radiation levels. Consequently, there is considerable interest in the United States and abroad in the possible changes in the magnetic field when subjected to radiation. This is a description of our approach in performing the field measurements before and after irradiating samples of samarium-cobalt permanent magnets.

I. METHOD OF MEASUREMENT

While measurements of the magnetic fields seem rather simple, there are several constraints that must be considered in this particular exercise. Techniques using flux coils, Hall effect gaussmeters, NMR gaussmeters, and rotating coil gaussmeters were considered in light of the sample size and handling limitations. Relatively small samples were required since REC permanent magnets are limited to relatively small sizes by the present technology. The technique selected had to be immune to radiation from the exposed samples. Reproducibility of the sample location, magnitude of the output signal, and ease of performing the measurements of the irradiated samples were also major considerations. We chose to rotate cylindrical REC permanent magnet samples magnetized across the diameter (Fig. 1) in a laminated iron return yoke. Coils around the yoke provide a large, easily measured voltage output signal. The device is essentially a small, simple generator.

II. APPARATUS

The sample is mounted in a threaded aluminum cell, Fig. 2. Aluminum was selected for the cell material to minimize the residual radiation. The sample cell is attached to a threaded spindle on the nonmagnetic stainless steel flywheel. A 1/20-HP, 3600-RPM, hysteresis synchronous motor rotates the sample within the core. Both the motor and core assembly are doweled to the aluminum base plate for positive location. Sample cells are easily changed through the open aperture in the core assembly using a 0.9-m long steel rod. The test apparatus is shown in Fig. 3.

III. SAMPLES

The two materials investigated supplied by Hitachi Magnetics Corp. were Hicorex 90B (Co_5Sm) and Hicorex 96B (5:1 compound with Pr substituted for 1/3 of the Sm). Both materials were fully magnetized and stabilized to 100°C.

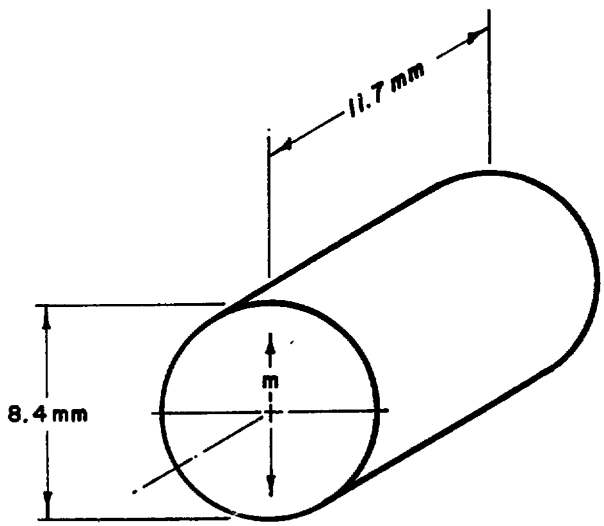

Fig. 1
REC Permanent Magnet Sample Configuration.

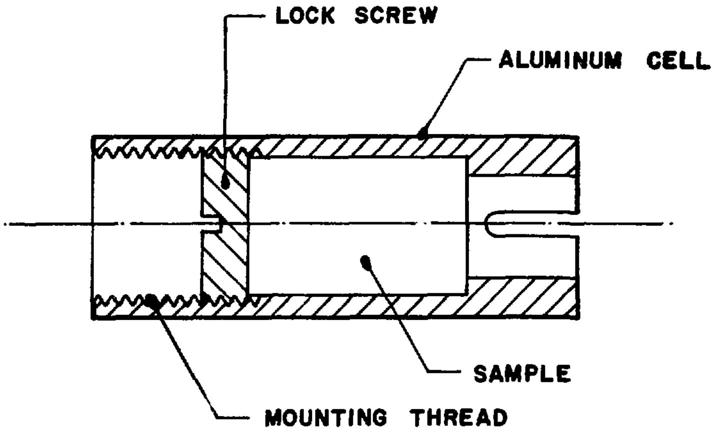

Fig. 2

Sample Holder.

Fig. 3

Permanent Magnet Field Test Apparatus.

The intrinsic and normal demagnetization curves for 90B and 96B are shown in Fig. 4. Five samples of each of the two materials were investigated.

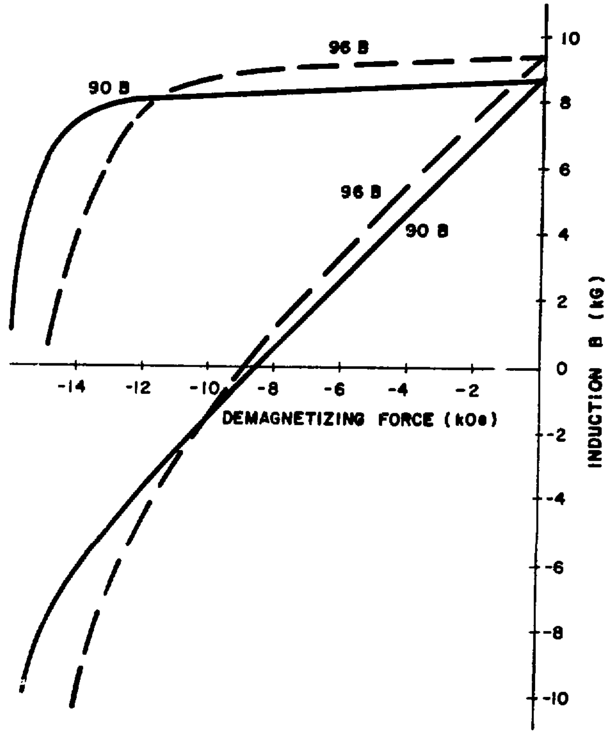

Fig. 4

Intrinsic and Normal Demagnetization Curves.

IV. IRRADIATION PROCEDURES

Magnet samples were irradiated at the LAMPF radiation effects facility, which provides access to spallation neutrons produced by the interaction of the LAMPF 800-MeV proton beam with various isotope production targets and the LAMPF beam stop. Nickel and cobalt activation foils were attached to each group of samples. Gamma spectroscopy on the activated foils allowed determination of the neutron fluence vs energy as shown in Fig. 5. The curve shown presents the integral neutron fluence; that is, for any energy on the abcissa, the ordinate gives the total number of neutrons per square centimeter having energies greater than or equal to this energy. The shape of the spectrum was similar for the three groups of magnets irradiated, while the fluences (for E > 0.1 MeV) were 1×10^{15} n/cm^2, 2.5×10^{17} n/cm^2, and 1.1×10^{18} n/cm^2. Temperatures near the magnet samples (as measured by thermocouples) did not exceed 140^{o}C at maximum proton beam current.

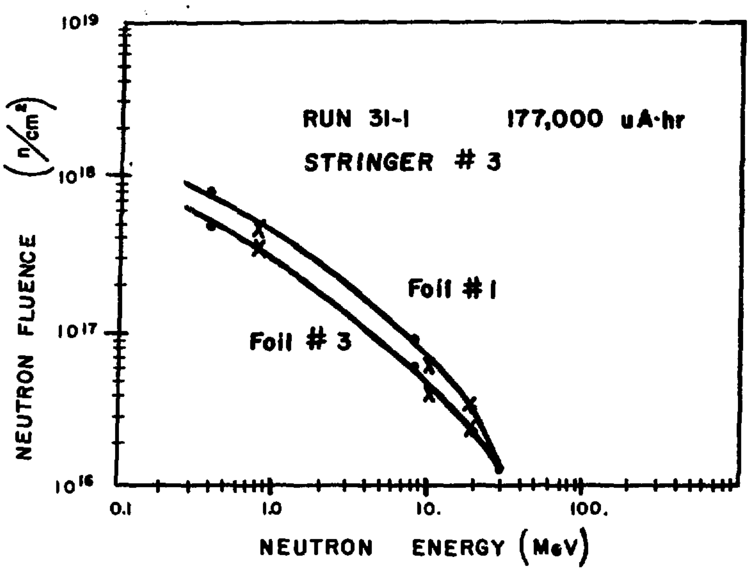

Fig. 5

Neutron Fluence vs Energy.

V. MEASUREMENTS

Voltage output measurements made with a 3 1/2-digit Fluke multimeter both before and after irradiation are shown in Table I.

TABLE I

Voltage Output Measurements

Material	Sample Number	Before Irradiation (V)	After Irradiation (V)	Dose Level (n/cm^2)	Contact Activation (R/hr)	Max Temp. (°C)
Hicorex 90B	90C2045-1	3.18	3.18	1.0×10^{15}	0.050	-
	-2	3.21	3.19	2.5×10^{17}	4.0	120
	-3	3.20	3.17	2.5×10^{17}	4.0	120
	-4	3.10	3.08	1.1×10^{18}	20.0	140
	-5	3.19	3.13	1.1×10^{18}	20.0	140
Hicorex 96B	96C2045-1	3.18	3.18	1.0×10^{15}	0.050	-
	-2	3.17	3.16	2.5×10^{17}	4.0	130
	-3	3.20	3.19	2.5×10^{17}	4.0	130
	-4	3.19	3.15	1.1×10^{18}	20.0	140
	-5	3.17	3.10	1.2×10^{18}	20.0	140

V. CONCLUSIONS

The apparatus provided large voltage output signals and the sample handling was convenient.

While the loss in magnetic field was quite small (~2%) it can probably be attributed to the fact that the samples were stabilized to 100°C but reached 140°C during the irradiation.

Hicorex 96B would be expected to exhibit greater degradation because of its lower coercivity.

Future studies should include higher dose levels and samples should be stabilized to higher temperatures in order to isolate the cause of field degradation.

ACKNOWLEDGEMENTS

Although this was a rather simple activity it could not have been accomplished without the unique capabilities of LAMPF. State-of-the-art magnet samples were provided by F. G. Jones of Hitachi Magnetics Corp. E. J. Schneider provided valuable assistance in the design of the measuring equipment.