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This Week's Citation Classic®

Foner S. Versatile and sensitive vibrating-sample magnetometer.
Rev. Sci. Instr. **30**:548-57, 1959.
[Lincoln Laboratory, Massachusetts Institute of Technology, Lexington, MA]

This paper described a method for measuring the magnetic properties of materials that has been accepted as a standard approach worldwide. The sample is vibrated and the resultant AC field produced by the sample is detected. [The *SCI*® indicates that this paper has been cited in over 400 publications since 1959.]

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The measurement method involves moving the magnetized sample to be measured in a periodic manner at small amplitude and detecting the periodic field change produced by the moving sample. This periodic field change is proportional to the magnetic moment of the sample, and the instrument based on this principle is called a vibrating sample magnetometer (VSM). The magnetic properties of a sample can be determined to high accuracy while eliminating many background effects.

The development of VSM was indirect. I was one of a few scientists permitted to do basic research in an applied physics group at Lincoln Laboratory working with ferrite microwave components. I volunteered to measure the magnetization of ferrites for this group. I used several standard techniques and built a then-conventional Sucksmith force balance that used mirrors and a long light beam to magnify the small displacement of a sample when exposed to an inhomogeneous field. The output was very sensitive to floor vibrations in the temporary building where we worked.

David J. Robbins, a bright young graduate student from Harvard University, worked with me on this force balance at Lincoln Laboratory during the summer of 1955. Unfortunately, he was killed during a lunch break while he was testing a high-performance motorcycle.

One evening I decided to try an AC magnetic induction method. Using a tube of Duco cement, a small replacement $2.00 loudspeaker, a conical paper cup, and a paper straw (the latter components were light and conveniently available at night from the lunchroom), the first working model VSM was assembled. For experimental simplicity and convenience, the sample was vibrated perpendicular to the transverse field produced by a conventional electromagnet. A general principle was developed for arrangements of even numbers of coils that permitted measurements of magnetic properties of a material while being insensitive to position and external fields to high order. Subsequently, I published a short note[1] in 1956 that described this first model. Our 500 reprints disappeared in three months (copying machines were not common then). I obtained the basic patent on the VSM, developed a more rugged arrangement, and found that a large part of my time was spent telling magneticians how to make a VSM. To minimize these interruptions, I wrote the 1959 paper cited here. In about six months, 1,000 reprints were exhausted and inquiries increased! Since then several thousand more reprints have been sent out. The terms VSM and Foner magnetometer have become generic terms in the literature, and the original papers are rarely referenced. (In the last Magnetism and Magnetic Materials Conference Proceedings,[2] almost 10 percent of the papers mentioned use of a VSM, but none referenced the original paper.)

I have used the VSM routinely since its inception for research in magnetism, and this method has been accepted as an ASTM standard method of magnetic measurement. The method is used worldwide for basic magnetic measurements, and recently there has been an increased use for studies of magnetic recording media. Several companies manufacture VSMs, and many papers continue to appear with modifications and applications.[3]

I believe this paper has become a *Citation Classic* because it put forth a powerful method for moving the sample in order to discriminate against background signals. This made it possible for a much broader community to study magnetic properties of materials conveniently.

1. **Foner S.** Vibrating sample magnetometer. *Rev. Sci. Instr.* **27**:548, 1956.
2. **Hasegawa R, Koon N C & Cooper B R,** eds. Proceedings of the Twenty-Ninth Annual Conference on Magnetism and Magnetic Materials. *J. Appl. Phys.* 55:1623-2634, 1984.
3. **Foner S.** Review of magnetometry. *IEEE Trans. Magn.* **MAG-17**:3358-63, 1981.

