THE TANGLED WEB OF MAGNETIC TAPES

By Hans Fantel

"History," said the social philosopher Max Weber, "is a web of unintended consequences." The invention of tape recording bears out his point. This mainstay of modern musical life sprang from inspired inadvertence just sixty years ago — an anniversary duly celebrated in Germany if hardly noted elsewhere.

As a technical reporter for *The New York Times,* I once had occasion to interview Heinz Thiele, the last survivor among several co-inventors of magnetic tape. It was from him that I learned the curious circumstances surrounding this development.

At the time, fifteen years ago, Thiele was in his eighties — a small man, wispy, spry, tensely alert. He maintained an informed interest in the vast ramifications of his work. Tape, after all, had not only transformed the preservation and distribution of musical performances. It also provided the basis of a new information technology that ranged from videotape to databases and space exploration — from the Walkman to the Milky Way.

I met Thiele near his home in the steep-gabled, half-timbered Rhineland town of Deidesheim, whose local vintage — a splendid Riesling — helped extend the old man's memory back to the 1920s. At that time, Thiele was an assistant in the laboratory of Dr. Fritz Pfleumer, a chemical consultant in Dresden. "We weren't even working on tape," Thiele recalled. "That hadn't yet occurred to us. Our problem was cigarettes."

Gold-tipped cigarettes were all the rage in the 1920s, but the bronze powder forming the "gold" kept coming off on people's lips. Pfleumer was looking for some way to keep smokers ungilded. In the course of this work, he hit on a method for embedding the metal particles in a plastic binder instead of merely dispersing the metal in the cigarette paper, as had been done before. Another problem was that the cigarettes had to be placed in their box with all the tips at the top. Dr. Pfleumer automated the inspection process by magnetizing the metallized tips so they could be electromagnetically scanned to verify their position — a bold idea for its day.

As it happened, Pfleumer was fond of music — a devotee of the famous Dresden Opera — and dissatisfied with the hoarse, scratchy phonographs of that period. It struck him that his new cigarette technology — the electrical sensing of magnetized particles embedded in plastic — might lend itself to the registration of audio signals. By making a magnetizable ribbon, similar to that used for his cigarette mouthpieces, he expected to create a sound recording medium superior to the wax platters in common use at the time.

After fencing off his notion with a ring of patents, Pfleumer entrusted its further development to AEG, a large electrical company in Berlin with the resources to overcome the difficulties he himself had encountered in transforming his idea into a practical tape recorder. Thiele went to Berlin along with the project.

"He left the details to me," Thiele recalled. "Once he had formulated the basic concepts, he liked to keep out of the limelight. Basically, he was shy and elusive." Perhaps Pfleumer wanted to stay in the background during the Nazi period, but his penchant for privacy cost him the recognition he deserves. Despite the epochal importance of his invention, he remains an obscure figure in the history of science.

Thiele tackled formidable problems. The first tapes were restricted in range and very noisy. The project might have ended in the dustbin right there if Thiele hadn't belonged to the same hunting club as Dr. Wilhelm Gaus, a leading chemist of the Badische Anilin-und-Soda-Fabrik, a name that seemed too long even for Germans, who later settled for just the initials, BASF.

Stalking waterfowl in the marshes of the Spree, the two scientists pondered the problem. Eventually, Gaus voiced a hunch. Thinking as a physical chemist, rather than as an engineer, he didn't blame the recorder for the persistent trouble. He surmised that the iron filings used as magnetic particles were simply too big to accommodate the small waveforms of the higher audio frequencies and too irregular in shape to assure a quiet background. Instead of filing the iron,

he suggested a process of chemical precipitation to produce tiny, more uniform particles of ferric oxide for use in the tapes. By early 1934, the technique was sufficiently refined to yield the first usable recordings.

Surprisingly, there was little interest in this radically new way of sound recordings, Thiele recalled, until a curious incident made tape a top priority in the Third Reich. Reichsmarschall Hermann Goering had recorded one of his lengthy pep-talks to the *Volk* for later broadcast on thirteen wax discs. Not until air time was is discovered that Disc 10 was missing, making the harangue even less coherent.

"The next day," as Thiele tells it, "the director of the Reichsrundfunkgesellschaft [the German State Broadcasting Company] was hauled before Goering. The poor man probably expected to spend the rest of his life at Dachau." Even so, the broadcast executive handled himself with aplomb. Expressing no more than casual regret over the mix-up, he immediately proceeded to tell Goering about the newly developed tape techniques as a way of avoiding such mishaps. The canny politician and rabble-rouser immediately realized the propaganda potential inherent in utilizing magnetic tape, and before long all German broadcast stations were supplied with tape recorders.

These were used mainly for political messages, their musical potential remaining unexplored. Oddly enough, the first major musical recording on tape was made not by a German but by Thomas Beecham. In 1936, Hitler's government, all spruced up for the Olympics, seemed quite agreeable to many conservative Europeans, especially to the ruling class of England. As part of a rapprochement, Beecham often toured Germany — trips that culminated in the classic (and in the opinion of many still unsurpassed) 1937-38 recording of *Die Zauberflöte*, with a Berlin cast including Erna Berger, Tiana Lemnitz, Helge Rosvaenge, Gerhard Hüsch and Willi Domgraf-Fassbänder.

At a guest appearance in Ludwigshafen, Beecham was told of the existence of the new tape recorders. The veteran recording maestro was intrigued by the possibility of recording without interruption for side breaks every four minutes. As an experiment, he asked for the concert to be recorded in its entirety. The tape of that concert still exists, and Thiele played a copy for me. Dim and distorted by today's standards, it must have sounded impressive at the time.

Little awareness of the new tape technology penetrated beyond Germany, and that country's growing isolation after the Munich crisis precluded further exchanges. Throughout the war, British and American radio monitors wondered how Hitler's recorded speeches managed to sound like live broadcasts. The answer became clear in the final days of the Reich when U.S. troops stormed the studios of Radio Luxembourg. There they found a Telefunken tape reeling off Hitler's last-ditch incantations.

The American commander, Col. J. Ranger, packed up the machine as booty and shipped it to California, where army technicians and the newly formed Ampex Corporation studied it in detail. By 1947, Ampex manufactured its own greatly improved version, and when the 3M Corporation of Minnesota shortly afterward formulated a highly effective tape to accommodate a wide range of musical frequencies and dynamics, a new era of music had dawned.

But the man whose inventive flair planted the seed of this development was not to witness its maturation. Soon after the destruction of his house in the great raid on Dresden in February 1945, Fritz Pfleumer died, apparently of despondency and the privations of the time.

Reprinted from "Opera News," August, 1994 with the permission of Hans Fantel and Opera News.

JOINT MMM/INTERMAG '94 SESSION SUMMARY

Session DC - Thin Film Inductive Recording Heads

By Lamar Nix, Rocky Mountain Magnetics, Inc.

Session "DC" comprised an outstanding collection of papers on inductive thin film heads. Several papers treated track trimming methods and resulting recording density performance. Questions from the audience indicated that this is a subject of significant interest in the community. Track trimming included both trackwidth edge definition as well as undershoot (isolated transition) reduction. Two papers treated stress-magnetosrtiction interactions from processing. Finally "popcorn" noise and high momement poles continued to dominate attention in thin film inductive head considerations.

PRESIDENT'S COLUMN

Dave Thompson

This will be my last update as Magnetics Society President. You may recall that I ran on a slate of "If it's not broken, don't fix it." The Society remains solvent and focussed primarily on the technical activities of its journals, conferences, and chapters.

The most important change during my two year term is the move toward electronic information dissemination and electronic publishing. For example, the Administrative Committee (which elects the officers and controls the budget) must meet twice a year, usually at Intermag and MMM. Because of the joint conference this year, we are holding one of the meetings by e-mail. Several weeks into the process it is already clear that we are having real debates, unlike the meetings-by-mail of the past.

We are also ready to try conference announcements by e-mail. You know that the biggest problem that a conference organizer has is that the mailings have to go to the printer before the information is ready, and that people get the booklet too late to intelligently plan their attendance. In the future, the pre-conference information will be available on-line as soon as it is known.

The IEEE is moving to electronic publishing as fast as it can. It's easy to make people submit the text of their papers in electronic form, but the process for handling figures is still being standardized. Our biggest concern is that the proposed billing makes the new system substantially more expensive than the current way of doing things. Publications are our biggest budget item, so we are negotiating with the IEEE on this. There is no technical reason why electronic publishing would cost more . . . it's a question of the extra editing that they plan to do compared to the author-prepared copy of today. Of course, the first societies to switch over will be burned by the inevitable fiascoes of the IEEE's learning process. We'll change over as soon as it makes sense to do so.

MAGNETICS SOCIETY MERIT SCHOLARSHIP PROGRAM

We are pleased to announce the 1996 competition of the Magnetics Society Merit Scholarship Program. This program has been established for the children of Magnetics Society members through the annual nationwide scholarship competition conducted by the National Merit Scholarship Corporation (NMSC). NMSC is an independent, nonprofit organization whose major purposes are: (1) to identify and honor exceptionally talented high school students and to aid as many as possible in obtaining a college education, and (2) to enable business enterprises and other organizations to contribute more readily and effectively to the support of higher education through scholarship grants.

One Magnetics Society Merit Scholarship will be awarded in the Spring of 1996 to a student who will complete high school requirements and who will enter a regionally accredited U.S. college in 1996 to pursue courses of study leading to one of the traditional baccalaureate degrees.

The Magnetics Society winner will be chosen through the facilities of NMSC from among children of Magnetics Society members who are Semifinalists in the National Merit Scholarship Program. The winner will be chosen on the basis of test scores, academic record, leadership, and significant extracurricular accomplishments.

The Magnetics Society Merit Scholarship will be a renewable award covering up to four years of full-time study or until baccalaureate degree requirements are completed, whichever occurs first. The amount of the stipend accompanying the scholarship will be related to the individual winner's family financial circumstances. The maximum amount that will be awarded to a winner is $4,000 per year; the minimum will be $1,000 per year.

To enter the 1996 Merit Program, members whose children are high school juniors should be sure to have their child contact their high school counselor and arrange to take the 1994 PSAT/NMSQT (Preliminary SAT/National Merit Scholarship Qualifying Test) on October 11 or October 15, 1994. Students who are unable to take the 1994 PSAT/NMSQT must send a written request for information about possible alternate testing arrangements to NMSC no later than March 1, 1995. Write to: Department of Educational Services and Selection, National Merit Scholarship Corporation, 1560 Sherman Avenue, Suite 200, Evanston, Illinois 60201-4897.

Descriptive material and entry forms for the Magnetics Society Merit Scholarship may be obtained by writing to the Magnetics Society Scholarship Program Director listed below.

IMPORTANT: To be considered for the Magnetics Society Merit Scholarship, members' children who are notified through their high schools in mid-September 1995 that they have qualified as Merit Program Semifinalists must return an entry form to the Magnetics Society Scholarship Program Director by October 15, 1995.

Dr. Ernst Schloemann
Magnetics Society Scholarship Program Director
Raytheon Research Division
131 Spring Street
Lexington, MA 02173

1995 ACHIEVEMENT AWARD OF THE MAGNETICS SOCIETY

The Magnetics Society of the IEEE honors one of its outstanding members each year for his or her lifelong professional achievement. This is the highest award of the Magnetics Society and is given for scientific, technical and service contributions to the society. The award is presented at Intermag each year and consists of a diploma with citation and a cash prize.

The past award winners were Fred Luborsky 1981, Herb Storm 1982, Harold Lord 1984, Joe Suozzi 1985, Fritz Friedlaender 1986, Andrew Bobeck 1987, Floyd Humphrey 1988, Paul Biringer 1989, Daniel Gordn 1990, Emerson Pugh 1991, Yoshifumi Sakurai 1992, William Doyle 1993 and Richard Barker 1994.

Nominations are requested. For your convenience, please use the standard form for a Fellows nomination without references and endorsements (section #10-12). Any member of the Magnetics Society may nominate a candidate at any time. To be considered for the 1995 award, nominations should be received before January 1, 1995. Please send nominations to:

Floyd B. Humphrey
Chairman, Achievement Awards Committee
P.O. Box 722
Meredith, NH 03253-0722 Voice/FAX (603) 279-3395

40TH ANNUAL CONFERENCE ON MAGNETISM AND MAGNETIC MATERIALS

Philadelphia, Pennsylvania USA
November 6-9, 1995

The Fortieth Annual Conference on Magnetism and Magnetic Materials will be held at the Wyndham Franklin Plaza Hotel, Philadelphia, Pennsylvania USA. The Conference annually brings together scientists and engineers interested in recent developments in all branches of fundamental and applied magnetism. Emphasis is traditionally placed on experimental and theoretical research in magnetism, the properties and synthesis of new magnetic materials and advances in magnetic technology. The program will consist of invited and contributed papers. Selection of contributed papers is based on abstracts which are due on May 24, 1995. An Abstract Booklet will be available in advance of the Conference from the American Institute of Physics. Registrants will receive the booklet at the Conference. Proceedings will be published in the Journal of Applied Physics.

In addition, this year marks the 40th anniversary of the MMM Conference. Special activities will be held in honor of this event. Attendees from early MMM meeting will be invited to participate in the celebrations.

Individuals who are not on the Conference mailing list may obtain Conference information and details concerning the preparation of abstracts by contracting the conference coordinator: Diane Suiters, Courtesy Associates, 655 15th Street N.W., Suite 300, Washington, DC 20005; telephone (202) 639-5088, FAX (202) 347-6109 or the Publicity Chair: John Nyenhuis, Purdue University, School of Electrical Engineering, 1285 Electrical Engineering Building, West Lafayette, IN 47907-1285, telephone (317) 494-3524, FAX (317) 494-6440, email: nyenhuis@ecn.purdue.edu.

This topical conference is sponsored jointly by the American Institute of Physics and the Magnetics Society of the IEEE in cooperation with the American Physical Society, the Office of Naval Research for Testing and Materials and the American Ceramic Society. The meeting will be open to all persons subject to the registration fee of approximately $300 (marked reduction for students).

NATIONAL ENGINEERS WEEK 1995 WILL HIGHLIGHT ENGINEERING IN EVERYDAY LIFE

WASHINGTON, June 15 — The National Engineers Week Committee has announced the next year's celebration will emphasize the engineering of everyday life. The 45th annual National Engineers Week, scheduled for February 19-25, 1995, will feature a variety of national and local programs designed to increase public appreciation of the engineering profession by highlighting engineers' contributions to American life. Through its United States Activities division, The Institute of Electrical and Electronics Engineers Inc. joins 16 other engineering societies and several major corporations as sponsors.

National Engineers Week 1995 is chaired by the American Institute of Chemical Engineers (AIChE). Leslie G. McCraw, chairman and CEO of Fluor Daniel Inc., will serve as honorary chairman. The theme for the week is "Engineers: Turning Ideas into Reality," while the Discover "E" classroom program will inspire students to "Discover Engineering Every Day."

Discover "E" involves many thousands of engineer volunteers who motivate students to pursue math and science studies. Other national programs for the week include: technology fairs in shopping malls, science centers and local libraries; and the third annual Future City Competition, with engineers helping teams of middle-school students design cities of the 21st century.

Planning kits for National Engineers Week 1995 contain everything needed for individuals, Sections or companies to participate in the week's activities, and will be available in October. For free kits, contact National Engineers Week, P.O. Box 1270, Evans City, PA 16033, 412-772-0950. For more information on National Engineers Week, call National Engineers Week Headquarters at 703-684-2852, or IEEE Public Relations in Washington at 202-785-0017.

PANEL DISCUSSION ON UNITS IN MAGNETISM

By Ron B. Goldfarb

An evening panel discussion on magnetic units, attended by 150 participants, was held at the 1994 Joint MMM–Intermag Conference in Albuquerque, New Mexico. The session was organized by C. D. Graham, Jr., and moderated by R. B. Goldfarb. The panel members were asked to describe the use of magnetic units in their countries, and to make appropriate comments and recommendations. In addition to units, several panelists talked about the distinction between magnetic induction B and magnetic field strength H, and the conversion of equations. After the panelists' opening statements, the floor was opened for questions and discussion from the audience. Below are the panelists' summaries of their remarks. By agreement with the authors, this article is not subject to copyright.

Left to right: Arrott, Chikazumi, Street, Graham, Gibbs, Coey, Goldfarb.

C. D. GRAHAM, JR.
University of Pennsylvania

I would like to consider the units for magnetic susceptibility. Susceptibility is defined as the slope (usually the initial slope) of a plot of magnetization vs. field. The magnetization may be expressed as moment per unit volume M, or moment per unit mass σ. When dealing with small samples, or with a range of temperatures, the sample mass is usually better known than its volume, so σ is very commonly employed. In CGS magnetic units, we have an unofficial but widely used unit of magnetic moment m, called the emu, so that volume susceptibility is

$$\chi_V = M/H = m/VH \; [\text{emu·cm}^{-3}\text{·Oe}^{-1}]$$

and mass susceptibility is

$$\chi_m = \sigma/H = m/wH \; [\text{emu·g}^{-1}\text{·Oe}^{-1}],$$

where w is the sample mass. These units are clear and explicit.

In SI units, the parallel structure between volume and mass susceptibility is lost. Magnetic moment is in $[\text{A·m}^2]$, and field is in $[\text{A·m}^{-1}]$. The volume susceptibility χ_V is in $[\text{A·m}^2\text{·m}^{-3}\text{·A}^{-1}\text{·m}]$, which is dimensionless. Mass susceptibility χ_m is in $[\text{A·m}^2\text{·kg}^{-1}\text{·A}^{-1}\text{·m}] = [\text{m}^3\text{·kg}^{-1}]$, which is reciprocal density. It would help slightly to express field in teslas; then χ_V would be in $[\text{A·m}^2\text{·m}^{-3}\text{·T}^{-1}] = [\text{A·m}^{-1}\text{·T}^{-1}]$ and χ_m would be in $[\text{A·m}^2\text{·kg}^{-1}\text{·T}^{-1}]$. But the volume susceptibility unit and the mass susceptibility unit would still not be parallel in construction.

An SI equivalent of the emu is needed. I suggest the creation of the sim (SI moment): 1 sim = 1 A·m². (This is in a sense similar to the SI unit of pressure, where one pascal equals one newton per square meter.) It would also be helpful to have a single name for the SI unit of field, to replace the ampere per meter. There is no magnetic unit named for a Japanese scientist, despite the many contributions made to magnetism by Japan. Why not the honda, named for Kotaro Honda, a distinguished scientist and engineer? The symbol would be Ho, since H is already used for the henry. Using the sim and the honda, we have χ_V [sim·m⁻³·Ho⁻¹] and χ_m [sim·kg⁻¹·Ho⁻¹]. Volume susceptibility remains dimensionless, of course, but the units discreetly conceal this unpleasant fact and therefore avoid the current messy and confusing situation.

Alternatively, if field is expressed in teslas, χ_V is in [sim·m⁻³·T⁻¹] and χ_m is in [sim·kg⁻¹·T⁻¹]. In any case, experimental and theoretical values of susceptibility must have their units clearly stated; "susceptibility (SI)" or "CGS susceptibility" is inaccurate.

SŌSHIN CHIKAZUMI
Edogawa University (Emeritus, University of Tokyo)

The SI unit of magnetic field, $[\text{A·m}^{-1}]$, is too small, so numerical values measured in this unit are too large. For instance, the field produced by a superconducting magnet may be 8–16 MA·m⁻¹, the record value of a pulsed magnetic field is 450 MA·m⁻¹, and the exchange field in iron is 0.8 GA·m⁻¹.

Moreover the CGS unit of magnetic field, the oersted, is popular, and the irrational conversion factor $4\pi/10^3$ from $[\text{A·m}^{-1}]$ to oersted is troublesome. Thus, I would like to present a justification for the use of the tesla instead of the ampere per meter.

In MKSA units, in the E-H analogy, the fundamental formula relating the flux density or magnetic induction B, intensity of magnetization I, and magnetic field H is given by

$$B = I + \mu_0 H,$$

where μ_0 is the permeability of vacuum and has the value $4\pi \times 10^{-7}$ H·m⁻¹. In this connection, I propose the use of $\mu_0 H$ [T], which is to be called the "induction field," instead of H $[\text{A·m}^{-1}]$, to describe the magnetic field strength. The conversion factor from teslas to oersteds is 10^4, which contains no π, and the unit tesla is practical: In our examples above, the induction fields produced by superconducting magnets are 10–20 T, the record pulsed induction field is 560 T, and the exchange field in iron is 1000 T. In order to describe weak magnetic fields, such as the Earth's field, we can use prefixes such as 30 μT. (Since the unit $[\text{A·m}^{-1}]$ has a composite structure, the use of prefixes makes the name of the unit long and complex, as in "mega-ampere per meter." If ampere per meter were replaced by a single name, such as that of a famous magnetician, the situation might be improved. We do not have this problem with prefixes for tesla, because this unit consists of a single word.)

The advantage of using $\mu_0 H$ in place of H is that the definitions of permeability and susceptibility are greatly improved: Permeability is defined by

$$\mu = B / \mu_0 H,$$

and magnetic susceptibility is defined by

$$\chi = I / \mu_0 H.$$

Thus defined, μ and χ are dimensionless and are equal to the relative permeability and relative susceptibility, respectively. (Here, μ is the same as the CGS value, while χ is 4π times the CGS value.)

In conjunction with this proposal, I would like to make the following warning: *Never use B for magnetic field!* Even if one proposed to use the tesla, which is the unit for B, to describe the magnetic field strength, one should not confuse the concepts of H and B. Some textbooks on electromagnetic theory give the formula

$$\nabla \times \boldsymbol{B} = \boldsymbol{i},$$

where $\boldsymbol{i}$ is the current density. This formula is correct only in a region without magnetic materials, or only if $\boldsymbol{i}$ includes the intrinsic currents which cause the magnetization. If $\boldsymbol{i}$ is a measurable current density, Ampère's theorem gives

$$\nabla \times \boldsymbol{H} = \boldsymbol{i}.$$

Moreover, many people believe that the real field existing in magnetic materials is B, not H. This depends on the experiment. Since the Hall effect for magnetic materials is a function of both H and I, B is the relevant quantity. (However, the Hall voltage is not a unique function of B; the current senses a field which is a complex function of H and I.) However the force or torque exerted on the magnetization must be described by H, not B. This is because a term that is proportional to I forms the internal force. The situation is similar to the dynamic problem of solving for the path of a projectile. Even if the real force acting in the body includes the universal gravitational force between the different parts of the body, it is not considered because it is an internal force.

ROBERT STREET
University of Western Australia

The conversion to SI units of measurement in Australia was achieved through the efforts of the Metric Conversion Board (MCB). Its objective was to facilitate the introduction of SI units as the only legal units of measurement in use for trade in all the states and territories of Australia. The first industry to benefit from the introduction of metric units of mass and length was the horse racing industry. This was a deliberate policy initiated by the Chairman of the Board, who held the view that everything was trivial compared with the conversion of the horse racing fraternity to SI units.

In the changeover from the previously existing confusion known as the Imperial System of units, the MCB worked closely with the National Standards Commission, a statutory body responsible for legislation concerning units of weights and measures in use for trade. In my view, two things were primarily responsible for the undoubted success and the smooth transition to a radically new philosophy of measurement achieved by the Metric Conversion Board. The first was the enormous influence exerted by the late Alan Harper, a physicist from the National Measurements Laboratory of the Commonwealth Scientific and Industrial Research Organization (CSIRO). He held key positions on both the Board and the Commission. The second factor was a determination by the government that SI units of measurement were to be the only legal units in use for trade. This provided a powerful incentive for all sections of the community to learn and operate the new system of units.

Consideration was given to the specification of units to be used in electromagnetism. Commercial incentives arising from needs to specify quantitative information on the properties of magnetic materials did not exist. As we know, international conventions on magnetic units offer no clear guidelines. The question was too difficult to resolve, but CSIRO did adopt a policy which provides for the use of SI units, including SI magnetic units, in their publications.

It was not possible to make such a clear-cut decision in the universities and other research oriented institutes. SI units are almost universally adopted in the teaching programs of undergraduates. However, in graduate work there is the familiar schizophrenic approach in the choice of electromagnetic units. The most usual defense of this state of affairs is that the majority of international literature in magnetism uses the CGS system of units. At the present time there are no overwhelming advantages to be gained in adopting SI units to the exclusion of CGS. There will be a continuing need to be literate (and numerate) in both systems.

However, there are many advantages in moving to the universal adoption of a common system of units. In my opinion the SI is the only sensible candidate worthy of consideration. After this opening skirmish at the MMM–Intermag Conference in Albuquerque, I would propose that discussions continue at an international level by electronic mail. The objective should be to produce a modified SI (including the introduction of desirable names of units, consideration of quantities such as susceptibility, etc.) which can then be promulgated as an acceptable code for use in publications and trade in magnetic products internationally. My pet wishes are for a consistent constitutive equation, either $B = \mu_0(H + M)$ or $B = \mu_0 H + J$, and also for a name to be given to the unit of magnetic moment.

It is only when numerical answers are required to questions such as, how much energy? or how large a force? are units and relations between systems of units necessary. The latter steps are inevitable when magnetic materials are to be bought, sold, used, and compared. Why not agree to adopt a consistent system of units in reporting the properties of magnetic materials, bearing in mind that the numerical results required have to be in established units (joules, newtons, etc.)? Hence, we should aim at those adjustments of SI that improve the convenience of its use in describing the quantitative properties of magnetic materials.

ANTHONY ARROTT
Simon Fraser University

In discussing the equations of magnetism in both Gaussian units and SI, I believe there is a greater understanding that comes from being bilingual. With regard to units, the late William Fuller Brown, the founder of micromagnetism, wrote in his "Tutorial Paper on Dimensions and Units" (*IEEE Trans. Magn.*, vol. 20, pp. 112–117, January 1984), "If this seems a bit arbitrary and confusing, bear in mind two principles: first, dimensions are the invention of man, and man is at liberty to assign them in any way he pleases, as long as he is consistent

throughout any one interrelated set of calculations. Second, international committees arrive at their decisions by the same irrational procedures as do various IEEE committees that you have served on." To writers on the subject, Brown advised, "At all costs avoid conversion tables: with them, you never know whether to multiply or divide." On the other hand, relations such as $1\ T \Rightarrow 10^4\ G$ and $1\ G \Rightarrow 10^{-4}\ T$ are unambiguous.

While much has been published about conversions of units, it is not as common to find direct, line by line, comparisons of the equations of magnetism in the two systems of units, as is carried out in the appendix of Richard Becker's *Electromagnetic Fields and Interactions,* edited by F. Sauter, translated by A. W. Knudsen (Blackie, London, 1964). The rules for converting the equations are found in the basic reference, *Symbols, Units, Nomenclature and Fundamental Constants in Physics,* prepared by E. Richard Cohen and Pierre Giacomo for the International Union of Pure and Applied Physics, *Physica,* vol. 146A, pp. 1–68, November 1987. For each quantity in an equation in SI units, it is necessary to apply one set of rules to obtain the equation in Gaussian units. Even after the rules are applied, it is necessary to invoke the identity $\mu_0\epsilon_0 c^2 = 1$ to remove any left over $\mu_0\epsilon_0$. In going from equations in the Gaussian system to SI, one completes the conversion by using this identity to remove the velocity of light c.

If one uses starred variables for the Gaussian system and unstarred variables for the SI, the categories of conversions are:

$$(4\pi\epsilon_0)^{\frac{1}{2}} = E^*/E \text{ (electric field)} = V^*/V \text{ (potential)}$$
$$= Q/Q^* \text{ (charge)} = I/I^* \text{ (current)} = P/P^* \text{ (polarization)}$$

$$(4\pi/\epsilon_0)^{\frac{1}{2}} = D^*/D \text{ (electric flux density)}$$

$$4\pi\epsilon_0 = C/C^* \text{ (capacitance)} = R^*/R \text{ (resistance)}$$
$$= L^*/L \text{ (inductance)}$$

$$(4\pi/\mu_0)^{\frac{1}{2}} = \Phi^*/\Phi \text{ (magnetic flux)}$$
$$= B^*/B \text{ (magnetic flux density)} = M/M^* \text{ (magnetization)}$$
$$= \gamma/\gamma^* \text{ (gyromagnetic ratio)} = A^*/A \text{ (vector potential)}$$

$$(4\pi\mu_0)^{\frac{1}{2}} = H^*/H \text{ (magnetic field strength)}$$

$$4\pi = \chi_e/\chi_e^* \text{ (electric susceptibility)}$$
$$= \chi/\chi^* \text{ (magnetic susceptibility)}$$

Dimensionless quantities, other than susceptibilities, convert directly. Also, the mechanical quantities convert directly:

$$1 = x^*/x \text{ (length)} = t^*/t \text{ (time)} = v^*/v \text{ (velocity)} = m^*/m \text{ (mass)}$$
$$= F^*/F \text{ (force)} = U^*/U \text{ (energy)} = T^*/T \text{ (torque)}$$
$$= P^*/P \text{ (power)} = S^*/S \text{ (Poynting vector)}$$

Memorization of such a table would be a daunting task. I have written a chapter devoted to the comparison of equations in SI and Gaussian units in a forthcoming book on *Ultrathin Magnetic Structures,* edited by B. Heinrich and J. A. C. Bland (Springer-Verlag, Berlin, 1994).

J. M. D. COEY
Trinity College, Dublin

The current practice regarding units in magnetism is a mess. Advertisements for instruments for magnetic measurements in *Physics Today* exemplify the situation. Large fields are given in teslas, small ones in gausses or oersteds. Magnetic moments and susceptibility are given in emu. The tesla is the only SI unit that seems to have caught on, as often with the symbol H as with B. However, it is common practice everywhere to use SI in undergraduate teaching, which has the powerful advantage that concepts and calculations from one area of the subject can be related to those in another—electricity and magnetism for example! The advantages of a coherent unit system in science and engineering far outweigh minor drawbacks such as the magnitude of μ_0 or the need to employ subscripts on the same symbols used for different quantities (for example, J for polarization, current density, and exchange constant). Nevertheless, CGS units remain widespread in research; more than 80% of the papers in the joint MMM–Intermag Conference use them. Hence the sentiment is that SI is okay for kids, but real scientists use CGS. One might have expected that as older professors retire, and as younger ones exposed to SI as undergraduate students and teachers take over, we would see the gradual adoption of the coherent units system across physics and engineering. This does not seem to be happening. Progress, if any, in the past 20 years has been at a snail's pace. Like domestic metrication in the U.S., converting magnetism to SI seems to have ground to a halt.

Why bother to try to change many people's habits of a lifetime? Is it not acceptable to advocate bilingualism and let everyone do as they please? The reasons for adopting SI in magnetism are the following: advantage of coherence and transparency achieved by using the same units as the rest of science; equations readily checked for dimensional correctness; straightforward calculations without the need to remember conversion factors, which are often misapplied; confidence in results of simple calculations based on the formulas learned at college.

But there is also an urgent reason why it is not in the long-term interests of the magnetism community to persist in the present shambles. Public concern is growing, especially in the U.S. and Germany, about possible harmful effects of weak electromagnetic fields produced by power lines, domestic appliances, video display units, etc. This may be the "green" issue of the decade, costing billions of dollars. The experience of the nuclear industry should be instructive. The public may no longer accept bland assurances from the experts that levels are negligibly small. They may wish to check the elementary calculations for themselves, or buy a teslameter and make their own measurements. It should not require a Ph.D. expert to tell where a 4π or a factor of 10^4 needs to be popped in, or explain why equations like $E = \mathbf{v} \times B$ do not mean what they say. If the elementary physics cannot be made quantitatively transparent, it risks being discredited.

How to proceed? Change for all current practitioners should be made as painless as possible. This may be achieved by exploiting the current acceptability of the tesla as a unit of field, given the symbol B_0 in free space. Its use for smaller fields can be promoted through the use of [mT] and [µT].

Magnetic moment, from the energy relation $W = -\boldsymbol{m} \cdot \boldsymbol{B_0}$, is measured in $[\text{J}\cdot\text{T}^{-1}]$. Magnetic polarization is also measured in teslas. $B = \mu_0 H + J$ and $B = \mu_0(H + M)$ can coexist. For practical measurements the numerical equivalence of mass magnetization σ in $[\text{emu}\cdot\text{g}^{-1}]$ and $[\text{J}\cdot\text{T}^{-1}\cdot\text{kg}^{-1}]$ is a useful reference point. Mass and volume susceptibilities χ_m and χ are in $[\text{J}\cdot\text{T}^{-2}\cdot\text{kg}^{-1}]$ and $[\text{J}\cdot\text{T}^{-2}\cdot\text{m}^{-3}]$. Admittedly, $\mu_0 = 4\pi \times 10^{-7}$ $\text{T}\cdot\text{m}\cdot\text{A}^{-1}$ must be committed to memory, but its magnitude makes it easy to spot if it has been left out of one side or the other of an equation. Equivalent units of M are $[\text{J}\cdot\text{T}^{-1}\cdot\text{m}^{-3}]$ or $[\text{A}\cdot\text{m}^{-1}]$, the same as for H.

Here is an SI tool kit, a summary of what I find I need to function effectively in SI:

$$B\,[\text{T}] = \mu_0(H\,[\text{A}\cdot\text{m}^{-1}] + M\,[\text{A}\cdot\text{m}^{-1}])$$
$$\mu_0 = 4\pi \times 10^{-7}\,\text{T}\cdot\text{m}\cdot\text{A}^{-1}, \quad 1\,\mu_B = 9.27 \times 10^{-24}\,\text{J}\cdot\text{T}^{-1}$$
$$W\,[\text{J}] = -\,\boldsymbol{m}\,[\text{J}\cdot\text{T}^{-1}] \cdot \boldsymbol{B_0}\,[\text{T}]$$
$$H = n\,I\,[\text{A}\cdot\text{m}^{-1}]\ (\text{solenoid})$$
$$m = I\,A\,[\text{A}\cdot\text{m}^2] = [\text{J}\cdot\text{T}^{-1}]\ (\text{current loop})$$

$$M\,[\text{A}\cdot\text{m}^{-1}] = M\,[\text{J}\cdot\text{T}^{-1}\cdot\text{m}^{-3}] = m\,[\text{J}\cdot\text{T}^{-1}]\,/\,V\,[\text{m}^{-3}]$$
$$w\,[\text{J}\cdot\text{m}^{-3}] = \tfrac{1}{2}\,B\,[\text{T}] \cdot H\,[\text{J}\cdot\text{T}^{-1}\cdot\text{m}^{-3}]$$
$$\chi_m = \sigma/B_0\,[\text{J}\cdot\text{T}^{-2}\cdot\text{kg}^{-1}], \quad \chi = M/B_0\,[\text{J}\cdot\text{T}^{-2}\cdot\text{m}^{-3}]$$

Personally, my entire student and professional experience was in CGS until I became a university professor. I made the switch.

MIKE R. J. GIBBS
University of Sheffield

A major issue that must be recognized is that, certainly in the U.K. and mainland Europe, the new generation of scientists coming through schools and universities is being trained exclusively in the SI system. It must be a retrograde step to ask them to work in older unit systems or even to learn cumbersome transformations. The U.K. Institute of Physics Magnetism Group has had a working party looking at the issue of units in magnetism. Its members are J. Crangle, C. D. Graham, Jr., M. R. J. Gibbs, S. Brunt, and P. T. Squire.

Our contribution to the debate is that the H field should be replaced by the free space induction B_0. There is a problem in magnetic circuits containing an air gap, where H and B in the gap can be in opposite directions. Great care would be necessary to distinguish the inductions in the gap from the magnetic material and the free poles. We then turned our attention to the representation of the effect of the free space induction on a magnetically polarizable material. Our main concern as a working party centered around whether or not magnetic susceptibility should be dimensionless. There really is no a priori reason why it should be. If magnetization is used, the volume susceptibility is written as M/B_0, which is not dimensionless. We would prefer to use polarization J, whence the susceptibility is J/B_0, which is dimensionless.

We noted that saturation induction B_s may be a recognized label for a material, but strictly it is not uniquely valued. The B-B_0 loop always has a high-field slope of unity. We therefore consider the use of saturation polarization J_s as an attractive alternative. J_s is uniquely defined, and a J-B_0 plot would

show saturation.

What this amounts to is a development of the Kennelly model, giving us a defining equation $B = B_0 + J$.

RON B. GOLDFARB
National Institute of Standards and Technology

One of the main problems with the CGS Gaussian and EMU systems is the reluctance of researchers to express magnetic moment in units of $[\text{erg}\cdot\text{G}^{-1}]$ or $[\text{erg}\cdot\text{Oe}^{-1}]$. Instead, they use the designation "emu," which is not a unit all, but simply an indicator of electromagnetic units. Thus, rather than expressing magnetic moment per unit volume, that is, volume magnetization, as $[\text{erg}\cdot\text{G}^{-1}\cdot\text{cm}^{-3}]$, they use $[\text{emu}\cdot\text{cm}^{-3}]$; and rather than expressing volume susceptibility as dimensionless, simplified from $[\text{erg}\cdot\text{G}^{-2}\cdot\text{cm}^{-3}]$, many researchers write $[\text{emu}\cdot\text{cm}^{-3}\cdot\text{Oe}^{-1}]$ or $[\text{emu}\cdot\text{cm}^{-3}]$.

Another problem with CGS is that, in electricity, the Gaussian unit of current is the statampere, and the EMU of current is the abampere. When electrical and magnetic quantities are combined, care is required. Many researchers working in CGS are reluctant to abandon the ampere and resort to writing equations in mixed units, typically expressing current in amperes, distances in centimeters, magnetization in gausses, and magnetic field strength in oersteds. Equations with such combinations that do not balance dimensionally can cause trouble when they are used in further derivations.

Yet another problem with CGS is the ambiguity between the units for M $[\text{erg}\cdot\text{G}^{-1}\cdot\text{cm}^{-3}]$ and $4\pi M$ $[\text{G}]$. Dimensionally, they are equivalent (this can be seen by substituting $[\text{cm}^2\cdot\text{g}\cdot\text{s}^{-2}]$ for $[\text{erg}]$ and $[\text{cm}^{-\frac{1}{2}}\cdot\text{g}^{\frac{1}{2}}\cdot\text{s}^{-1}]$ for $[\text{G}]$), but numerically, the quantities differ by the factor 4π.

SI (derived from the MKSA system) unifies magnetic units with the practical electrical units ampere and volt. The dimensional balance of equations is always apparent, if one remembers that $[\text{T}] = [\text{Wb}\cdot\text{m}^{-2}]$, $[\text{Wb}] = [\text{V}\cdot\text{s}]$, and that $[\text{A}\cdot\text{m}^2]$, the unit of magnetic moment, is the same as $[\text{J}\cdot\text{T}^{-1}]$.

One ambiguity of SI is that quantities appearing in both $B = \mu_0(H + M)$ and $B = \mu_0 H + J$ are recognized. Two quantities associated with these equations are magnetic moment m $[\text{A}\cdot\text{m}^2]$ and magnetic dipole moment j $[\text{Wb}\cdot\text{m}]$. The ambiguity is not a problem as long as we explicitly give the names of the quantities (magnetization or magnetic polarization, for example) and indicate their units. Permeability is always defined as B/H, with units $[\text{H}\cdot\text{m}^{-1}]$, and relative permeability is defined as $B/\mu_0 H$ (dimensionless). Volume susceptibility in SI is dimensionless and may be obtained as M/H or $J/\mu_0 H$. As used by the International Organization for Standardization (ISO), volume susceptibility is never defined as M/B, J/B, $M/\mu_0 H$, or J/H. A difficulty that arises in reporting volume susceptibility is that it is also dimensionless in CGS, but its value differs by a factor of 4π. To compensate for the lack of specific units, I recommend that "(SI)" or "(CGS)" follow numerical values of volume susceptibility and that these designations be included on the axis labels of figures.

Further discussion on units can be found in my article, "Magnetic Units and Material Specification," in Concise Encyclopedia of Magnetic and Superconducting Materials, edited by J. Evetts (Pergamon, Oxford, 1992).

IEEE UNITED STATES ACTIVITIES ALLIANCE OF IEEE CONSULTANTS' NETWORKS (AICN)

Who Are We?

The AICN is an organization of networks whose members offer state-of-the-art consulting services. Our network members are technical experts in various specialties, including electronics, computer software, electromechanical hardware, power systems, new product development, quality assurance, reliability, and technology management.

We are affiliated with the IEEE. The men and women of IEEE are technical and scientific professionals who make revolutionary engineering advances to reshape our society.

What can we Do for Industry and our Members?

For industry, our networks furnish referrals and technical specialists. They help industry solve routine as well as difficult and specialized problems. When you have a problem, call us. Someone in our group probably specializes in such solutions and can help you. — For our members, we offer referrals and networking, as well as professional training resources. We provide opportunities for teaming to solve problems that are outside of our expertise.

What is a Consultant?

- An acknowledged expert in one or more technical or organizational fields
- An independent contractor, who can be objective in judgment
- A problem solver who is trained to find solutions quickly
- A seasoned professional with many years of experience in his or her field
- Someone who gets results and can help you now

[Editor's note: The above definitions were prepared by Bill Anderson from the IEEE-USA Staff, 202/285-0017]

Consultants National Referral Service

by Tony Scofield, Chairman
National Referral Subcommittee

An Alliance of IEEE Consultants Networks (AICN) Consultants National Referral Service (CNRS) began operations officially in August 1994. Located at IEEE-USA's Washington Office with a toll-free 800 number, it provides clients access to IEEE's private practitioner member services, with no client cost and a 24-hour turn-around.

The National Referral Subcommittee of the AICN, after receiving two unacceptable responses and a no-bid to their "Request for Quote" established an interim national consultants' referral operation at IEEE-USA's Washington Office. The AICN Coordinating Committee approved starting the service while meeting in conjunction with the National Consultants' Workshop hosted by the Los Angeles Area Consultants' Workshop Network in April.

How to get Listed in the National Referral Database

IEEE consultants will be mailed an offer to join the CNRS, and a detailed Professional Data Input Request Form. We encourage reply via a 3½ inch disk DOS format media to reduce the cost of database entry. The form will contain instructions with examples to help private practitioners to describe their engineering skills without ambiguity.

IEEE members who decide to list their services with the CNRS must agree to: (1) abide by the AICN CNRS code of Ethics; (2) conform to all pertinent State licensing regulations; and (3) keep the service informed of their qualifications and availability.

A modest initial listing fee will be assessed to cover part of the cost of data input and administration. After a few months of monitoring operational costs, we will determine the yearly membership amount. The initial listing fee amount will be credited against the full annual CNRS membership. The CNRS subcommittee is also searching for grant funding to help develop our nationwide service.

How Clients Contact Consultants Now

A potential client calls the IEEE-USA Office (202/785-0017) in Washington, DC and describes the services needed. He or she is given the number of the closest IEEE Consultants' Network. A copy of their directory is mailed, if the client requests it.

The client then calls the closest IEEE consultant network referral service and outlines the problem to the referral specialist. At this point the process varies depending upon which network the client contacts. One group puts the client's request on its bulletin board system or FAX tree (available only to paid-up referral service members). Another network faxes the client's request to potential consultants. Many networks review the consultants' skill list until three or more matching consultants are identified. Some networks have the selected consultants contact the client, while others prefer to have the client call the consultants.

## Interim CNRS Helps Clients and Consultant Get Together

The Consultant referral specialist and the client discuss the scope of the problem, jointly identifying project phase, specific skill, end user, application, and facilities needed. The specialist enters key words through the search menu screen. The consultant database is queried and produces a list of the consultants with profiles that best match the client's requirements.

To meet our goal — a service that will provide 24-hour response to client's query — will require an efficient and cost-effective matching of client need to consultant. The design of an interim system is almost complete, using Dbase IV version 2.0 running on a 386 DOS system, with R&R ReportWriter to create reports. By the end of this year, we should have enough experience and data to begin final definition of the system requirements.

Anyone who has used a search program to match up client and consultant, or wishes information, please contact Anthony H. Scofield, Scofield Consulting Group, Inc., 410/666-5674, or Fax 410/666-3081, 10523 Wil Mar Place, Cockeysville, MD 21030-2423.

DISTINGUISHED LECTURERS FOR 1994

A Magnetics Society Chapter may arrange for a talk directly with a Distinguished Lecturer.
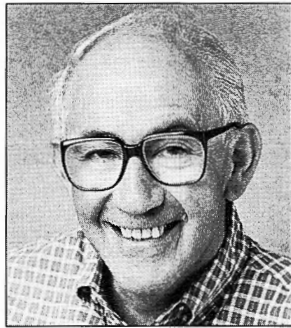
PROF. AMI BERKOWITZ
MAGNETIC STORAGE IN NANOSCALE STRUCTURES

The demands for ever-increasing magnetic storage densities has introduced some fascinating magnetic materials issues whose resolution blurs the distinction between basic and applied research. We are required to understand and control magnetic behavior in structures of dimensions down to the atomic scale. Some topics reflecting this need will be discussed. These include: Magnetic Viscosity, Exchange Anisotropy, Anomalous Finite Size Effects, and Giant Magnetoresistance in Heterogeneous Alloy Films. The talk can be tuned to the interests of specific audiences if the speaker is notified in advance.

Biography: Ami E. Berkowitz, is a Research Professor in the Physics Department and member of the Center for Magnetic Recording Research at the University of California, San Diego. He is Director of the recently established NSF-funded Materials Research Science and Engineering Center at UCSD. His research interests are generally concerned with the synthesis, characterization, and analysis of the behavior of magnetic materials, with particular emphasis on problems associated with magnetic storage. Prior to his current affiliation with UCSD, he was with GE at the research Lab in Schenectady, NY; with IBM at Yorktown Heights, NY and Burlington, VT; and the Franklin Institute Research Labs in Philadelphia, PA. He received a B.S. from Duke University in 1947 and a Ph.D. from the University of Pennsylvania in 1953, both in Physics. He has published about 100 papers, holds about 20 patents, and co-edited, with Eckart Kneller, "Magnetism and Metallurgy". He is a member of the Magnetics Society, the American Physical Society, and the Materials Research Society. This is his second appointment as a Magnetics Society Distinguished Lecturer.

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PROF. MARK H. KRYDER
ULTRAHIGH DENSITY RECORDING TECHNOLOGIES

The areal density of magnetic hard drives is currently advancing at a rate of 60% per year and expected to reach 10 $GBit/in^2$ in about 2001. Advances making this possible include new high-coercivity, low-noise thin film disk media; new high magnetization, corrosion and wear-resistant alloys for write heads, giant magnetoresistive read heads, ultralow flying sliders, maximum likelihood sequence detection methods and improved tracking servos. The areal density in magneto-optic recording remained constant from 1989 to 1993, but this year has doubled. New technologies such as mark edge recording, magnetic super resolution, sector servo and blue wavelength lasers have recently been demonstrated in the laboratory and could put magneto-optical recording on a similar areal density growth curve as magnetic hard drives. This talk will describe the technological advances making the growth in areal densities of magnetic and magneto-optic drives occur and speculate about possible approaches to achieving 100 $GBit/in^2$.

Biography: Mark H. Kryder is Professor of Electrical and Computer Engineering and Director of the Engineering Research Center in Data Storage Systems at Carnegie Mellon University. He has worked for 28 years on magnetic storage technologies including magnetic thin film memories, magnetic bubble memories, magneto-optic recording and magnetic recording. Currently his research includes projects on high magnetization FeAlN thin film write heads and giant magnetoresistive and dual magnetoresistive read heads for magnetic recording, garnet and multilayer media for blue wavelength magneto-optic recording and thin film barium ferrite hard disk media. As Director of the Data Storage Systems Center, he directs the world's largest academic research center directed at data storage technologies. The near-term goals of this center are to demonstrate 10 $GBit/in^2$ recording density in magnetic and magneto-optic recording and 1 $TByte/in^3$ on tape. Professor Kryder has over 225 publications, 13 patents and several patents pending. He is a member of the American Physical Society, a Fellow of the IEEE, and a member of the National Academy of Engineering.

Professor Mark H. Kryder
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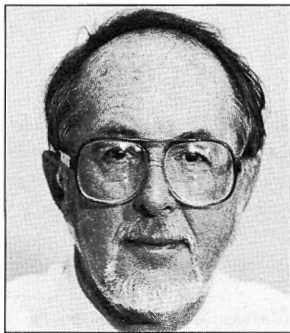
PROF. WILLIAM D. DOYLE

MAGNETIZATION REVERSAL AT HIGH SPEED — AN OLD PROBLEM IN A NEW CONTEXT

The high frequency limit of magnetic recording systems has been set historically by the fall off in permeability of conventional ferrite heads above 10 MHz. The introduction of thin film heads with the potential for frequency-independent performance of > 300 MHz combined with the demands for higher data rates raise an intriguing question: How fast can the magnetization in recording media be switched? Curiously, the possibility that this could be a problem has been ignored despite the clear warning provided in 1975 by Thornley and the painful history of speed-limited performance in ferrite cores and bubble memories. Recent theoretical and experimental studies are beginning to provide a clearer picture of the response of high coercivity media to pulse fields in the nanosecond regime. In this seminar, a historical review of high speed switching will be used to build a framework for interpreting the new results and projecting their implications for magnetic storage systems.

Biography: Bill Doyle was born in Dorchester, Massachusetts on June 5, 1935. He received his B.S. and M.S. degrees from Boston College in 1957 and 1959, respectively and his Ph.D. from Temple University in 1964, all in Physics. He joined the Franklin Institute in 1959 working on magnetic and structural properties of evaporated magnetic films. From 1964 to 1979, he was employed at Sperry Univac where he carried out research on the properties of plated wire memories, magneto-optic memories and bubble devices. In 1970-71, he was a Senior Visiting Fellow at the University of York, England. In 1979, he joined the Motorola Corporation to initiate a new program on bubble memories and was responsible for engineering and production of bubble memory components. In 1984, he moved to Kodak Research Laboratories, San Diego, and as Director, participated in the development of new storage systems using magnetoresistive heads. In 1990, he went to the University of Alabama as the MINT Chair in Physics and Astronomy. He is Director of the University of Alabama's Center for Materials for Information Technology which includes an NSF Materials Research Science and Engineering Center.

Dr. Doyle is a Fellow of the IEEE and a member of the American Physical Society. He has been active in the organization of the major magnetics conferences and has been on the Editorial Board of the *IEEE Transactions on Magnetics* since its inception. In 1987-88, he served as President of the IEEE Magnetics Society and in 1993 received the Society's Achievement Award. He is the author of more than 40 papers in the field of magnetic materials and devices.

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GOVERNMENT RELATIONS INFO ON THE INTERNET

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IEEE MAGNETICS SOCIETY NEWSLETTER CONFERENCE CALENDAR

OCTOBER 20-21, 1994

1st IEEE Workshop on Environmentally Conscious Manufacturing for the Electronics Industry.

IBM, T.J. Watson Research Center
Yorktown Heights, NY, USA.
Jeff Gelorme, IBM, T.J. Watson Reseach Center, P.O. Box 218 (16-204), Yorktown, Heights, NY 10598, TEL: 914 945-3430, FAX: 914 945-4013

OCTOBER 24-25, 1994

Soft Ferrite Users Conference
Chicago, IL.

Magnetics Materials Producers Association, 11 S. LaSalle Street #400, Chicago, IL 60603, TEL: 312 201-0101, FAX: 312 201-0214

APRIL 18-21, 1995

INTERMAG 95
San Antonio, TX.

Diane Suiters, Courtesy Associates, 655 15th Street NW, Suite 300, Washington, DC 20005, TEL: 202 639-5088, FAX: 202 347-6109

JULY 17-19, 1995

6th International Conference on Magnetic Recording Media, (MRM)
Oxford, UK.

MRM 1995, The Institute of Physics 47 Belgrave Square, London SW1X8QX, UK, TEL: +44 71 235 6111, FAX: +44 71 823 1051, E-Mail: IOPCONF@ULCC.AC.UK

SEPTEMBER 17-20, 1995

International Symposium on Non-Linear Electromagnetic Systems (ISEM)
Cardiff, Wales, UK.

ISEM 95 Secretariat, Cardiff School of Engineering, University of Wales College of Cardiff, P.O. Box 917, Newport Road, Cardiff CF2 1XH Wales, UK, TEL: +44-222-874070, FAX: +44-222-874420

NOVEMBER 6-9, 1995

40th Annual Conference on Magnetism and Magnetic Materials (MMM '95)
Philadelphia, Pennyslvania USA

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