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Standard Terminology of Symbols and Definitions Relating to Magnetic Testing¹

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INTRODUCTION

In preparing this glossary of terms, an attempt has been made to avoid, where possible, vector analysis and differential equations so as to make the definitions more intelligible to the average worker in the field of magnetic testing. In some cases, rigorous treatment has been sacrificed to secure simplicity, but it is believed that none of the definitions will prove to be misleading.

It is the intent of this glossary to be consistent in the use of symbols and units with those found in ANSI/IEEE 260-1978 and USA Standard Y 10.5-1968.

Part 1—Symbols Used in Magnetic Testing

| Symbol | Term |
|---------------|--------------------------------------------|
| α | cross-sectional area of B coil |
| A | cross-sectional area of specimen |
| A' | solid area |
| B | magnetic induction |
| | magnetic flux density |
| ΔB | excursion range of induction |
| B_b | biased induction |
| B_d | remanent induction |
| B_{dm} | remanence |
| $B_d H_d$ | energy product |
| $(B_d H_d)_m$ | maximum energy product |
| B_Δ | incremental induction |
| B_i | intrinsic induction |
| B_m | maximum induction in a hysteresis loop |
| B_{max} | maximum induction in a flux current loop |
| B_r | residual induction |
| B_{rs} | retentivity |
| B_s | saturation induction |
| cf | crest factor |
| CM | cyclically magnetized condition |
| d | lamination thickness |
| D_B | demagnetizing coefficient |
| df | distortion factor |
| D_m | magnetic dissipation factor |
| E | exciting voltage |
| E_1 | induced primary voltage |
| E_2 | induced secondary voltage |
| E_f | flux volts |
| f | cyclic frequency in hertz |
| \mathcal{F} | magnetomotive force |
| ff | form factor |
| H | magnetic field strength |
| ΔH | excursion range of magnetic field strength |
| H_b | biasing magnetic field strength |
| H_c | coercive field strength |

¹ This terminology is under the jurisdiction of ASTM Committee A06 on Magnetic Properties and is the direct responsibility of Subcommittee A06.92 on Terminology and Definitions.

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| | |
|-----------------------------------|-----------------------------------------------------------------------------------|
| H_{ci} | intrinsic coercive field strength |
| H_{cs} | coercivity |
| H_d | demagnetizing field strength |
| H_{Δ} | incremental magnetic field strength |
| H_g | air gap magnetic field strength |
| H_L | ac magnetic field strength (from an assumed peak value of magnetizing current) |
| H_m | maximum magnetic field strength in a hysteresis loop |
| H_{max} | maximum magnetic field strength in a flux-current loop |
| H_p | ac magnetic field strength (from a measured peak value of exciting current) |
| H_t | instantaneous magnetic field strength (coincident with B_{max}) |
| H_z | ac magnetic field strength force (from an assumed peak value of exciting current) |
| I | ac exciting current (rms value) |
| I_c | ac core loss current (rms value) |
| I_{dc} | constant current |
| I_m | ac magnetizing current (rms value) |
| J | magnetic polarization |
| K | coupling coefficient |
| ℓ | flux path length |
| ℓ_1 | effective flux path length |
| ℓ_g | gap length |
| \mathcal{L} (also φN) | flux linkage |
| \mathcal{L}_m | mutual flux linkage |
| L | self inductance |
| L_1 | core inductance |
| L_{Δ} | incremental inductance |
| L_i | intrinsic inductance |
| L_m | mutual inductance |
| L_0 | initial inductance |
| L_s | series inductance |
| L_w | winding inductance |
| m | magnetic moment |
| M | magnetization |
| m | total mass of a specimen |
| m_1 | active mass of a specimen |
| N_D | demagnetizing factor |
| N_1 | turns in a primary winding |
| N_2 | turns in a secondary winding |
| $N_1 I \ell_1$ | ac excitation |
| p | magnetic pole strength |
| ρ | permeance |
| P | active (real) power |
| P_a | apparent power |
| $P_a (B:f)$ | specific apparent power |
| P_c | total core loss |
| $P_c (B:f)$ | specific core loss |
| $P_{c\Delta}$ | incremental core loss |
| P_e | normal eddy current core loss |
| $P_{\Delta e}$ | incremental eddy current core loss |
| P_h | normal hysteresis core loss |
| $P_{\Delta h}$ | incremental hysteresis core loss |
| P_q | reactive (quadrature) power |
| P_r | residual core loss |
| P_w | winding loss (copper loss) |
| P_z | exciting power |
| $P_z (B:f)$ | specific exciting power |
| Q_m | magnetic storage factor |
| \mathcal{R} | reluctance |
| R_1 | core resistance |
| R_w | winding resistance |
| S | lamination factor (stacking factor) |
| SCM | symmetrically cyclically magnetized condition |
| T_c | Curie temperature |
| w | lamination width |
| W_h | hysteresis loop loss |
| $\bar{\alpha}$ | linear expansion, coefficient (average) |
| $\Delta\chi$ | incremental tolerance |
| β | hysteretic angle |
| γ | loss angle |
| $\cos \gamma$ | magnetic power factor |
| γ_p | proton gyromagnetic ratio |
| μ_0 | magnetic constant |
| μ_0 | magnetic constant |

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| | |
|----------------------------|-----------------------------------------|
| δ | density |
| κ | susceptibility |
| <i>ac Permeabilities:</i> | |
| μ_a | ideal permeability |
| μ_L | inductance permeability |
| $\mu_{\Delta L}$ | incremental inductance permeability |
| μ_{od} | initial dynamic permeability |
| μ_p | peak permeability |
| $\mu_{\Delta p}$ | incremental peak permeability |
| μ_i | instantaneous permeability |
| μ_z | impedance permeability |
| $\mu_{\Delta z}$ | incremental impedance permeability |
| <i>dc Permeabilities:</i> | |
| μ | normal permeability |
| μ_{abs} | absolute permeability |
| μ_d | differential permeability |
| μ_{Δ} | incremental permeability |
| μ_{eff} | effective circuit permeability |
| μ_i | intrinsic permeability |
| $\mu_{\Delta i}$ | incremental intrinsic permeability |
| μ_m | maximum permeability |
| μ_o | initial permeability |
| μ_r | relative permeability |
| μ_v (also Γ_m) | space permeability |
| μ_x | space permeability |
| μ_{rev} | reversible permeability |
| $\mu'/\cot \gamma$ | figure of merit |
| ν | reluctivity |
| π | the numeric 3.1416 |
| ρ | resistivity |
| Φ | magnetic flux |
| ΦN | flux linkage (see \mathcal{L}) |
| χ | mass susceptibility |
| χ_o | initial susceptibility |
| ω | angular frequency in radians per second |

Part 2—Definition of Terms Used in Magnetic Testing

ac excitation, N_1/I_1 —the ratio of the rms ampere-turns of exciting current in the primary winding of an inductor to the effective flux path length of the inductor.

active (real) power, P —the product of the rms current, I , in an electrical circuit, the rms voltage, E , across the circuit, and the cosine of the angular phase difference, θ between the current and the voltage.

$$P = EI \cos\theta$$

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DISCUSSION—

The portion of the active power that is expended in a magnetic core is the total core loss, P_c .

aging coefficient—the percentage change in a specific magnetic property resulting from a specific aging treatment.

DISCUSSION—

The aging treatments usually specified are:

- (a) 100 h at 150°C or
- (b) 600 h at 100°C.

aging, magnetic—the change in the magnetic properties of a material resulting from metallurgic change due to a normal or specified aging condition.

DISCUSSION—

This term implies a deterioration of the magnetic properties of magnetic materials for electronic and electrical applications, unless otherwise specified.

air-gap magnetic field strength, H_g —the magnetic field strength required to produce the induction existing at some point in a nonmagnetic gap in a magnetic circuit.

DISCUSSION—

In the cgs-emu system of units, H_g is numerically equal to the induction existing at such a point and exceeds the magnetic field strength in the magnetic material.

amorphous alloy—a semiprocessed alloy produced by a rapid quenching, direct casting process resulting in metals with noncrystalline structure.

ampere (turn), A—the unit of magnetomotive force in the SI system of units. The symbol A represents the unit of electric current, ampere, in the SI system of units.

ampere per metre, A/m—the unit of magnetic field strength in the SI system of units.

anisotropic material—a material in which the magnetic properties differ in various directions.

anisotropy of loss—the ratio of the specific core loss measured with flux parallel to the rolling direction to the specific core loss with flux perpendicular to the rolling direction.

$$\text{anisotropy of loss} = \frac{P_{c(B:f) \parallel}}{P_{c(B:f) \perp}}$$

where:

$P_{c(B:f) \parallel}$ = specific core loss value with flux parallel to the rolling direction, W/lb [W/kg], and

$P_{c(B:f) \perp}$ = specific core loss value with flux perpendicular to the rolling direction, W/lb [W/kg].

DISCUSSION—

This definition of anisotropy normally applies to electrical steels with measurements made in an Epstein frame at a flux density of 15 kG [1.5 T] and a frequency of 60 Hz (see Test Method A343).

anisotropy of permeability—the ratio of relative peak permeability measured with flux parallel to the rolling direction to the relative peak permeability measured with flux perpendicular to the rolling direction.

$$\text{anisotropy of permeability} = \frac{\mu_{prl}}{\mu_{prt}}$$

where:

μ_{prl} = relative peak permeability value with flux parallel to the rolling direction, and

μ_{prt} = relative peak permeability value with flux perpendicular to the rolling direction.

DISCUSSION—

This definition of anisotropy normally applies to electrical steels with measurements made in an Epstein frame at a flux density of 15 kG [1.5 T] and a frequency of 60 Hz (see Test Method A343).

antiferromagnetic material—a feebly magnetic material in which almost equal magnetic moments are lined up antiparallel to each other. Its susceptibility increases as the temperature is raised until a critical (Neél) temperature is reached; above this temperature the material becomes paramagnetic.

apparent power, P_a —the product (volt-amperes) of the rms exciting current and the applied rms *terminal* voltage in an *electric* circuit containing inductive impedance. The components of this impedance as a result of the winding will be linear, while the components as a result of the magnetic core will be nonlinear. The unit of apparent power is the volt-ampere, VA.

apparent power, specific, $P_{a(B:f)}$ —the value of the apparent power divided by the active mass of the specimen, that is, volt-amperes per unit mass. The values of voltage and current are those developed at a maximum value of cyclically varying induction B and specified frequency f .

area, A —the geometric cross-sectional area of a magnetic path which is perpendicular to the direction of the induction.

Bloch wall—a domain wall in which the magnetic moment at any point is substantially parallel to the wall surface. See also **domain wall**.

Bohr magneton—a constant that is equal to the magnetic moment of an electron because of its spin. The value of the constant is $(9\ 274\ 078 \times 10^{-21} \text{ erg/gauss or } 9\ 274\ 078 \times 10^{-24} \text{ J/T})$.

cgs-emu system of units—the system for measuring physical quantities in which the base units are the centimetre, gram, and second, and the numerical value of the magnetic constant, $F_{\mu_{m0}}$, is unity.

coercive field strength, H_c —the (dc) magnetic field strength required to restore the magnetic induction to zero after the material has been symmetrically cyclically magnetized.

coercive field strength, intrinsic, H_{ci} —the (dc) magnetic field strength required to restore the intrinsic magnetic induction to zero after the material has been symmetrically cyclically magnetized.

coercivity, H_{cs} —the maximum value of coercive field strength that can be attained when the magnetic material is symmetrically cyclically magnetized to saturation induction, B_S .

core, laminated—a magnetic component constructed by stacking suitably thin pieces of magnetic material which are stamped, sheared, or milled from sheet or strip material. Individual pieces usually have an insulating surface coating to minimize eddy current losses in the assembled core.

core, mated—two or more magnetic core segments assembled with the magnetic flux path perpendicular to the mating surface.

core, powder (dust)—a magnetic core comprised of small particles of electrically insulated metallic ferromagnetic material. These cores are characterized by low hysteresis and eddy current losses.

core, tape-wound—a magnetic component constructed by the spiral winding of strip material onto a suitable mandrel. The strip material usually has an insulating surface coating which reduces interlaminar eddy current losses in the finished core.

core loss, ac eddy current, incremental, $P_{\Delta e}$ —the power loss caused by eddy currents in a magnetic material that is cyclically magnetized.

core loss, ac eddy current, normal, P_e —the power losses as a result of eddy currents in a magnetic material that is symmetrically cyclically magnetized.

DISCUSSION—

The voltage is generally assumed to be across the parallel combination of core inductance, L_1 , and core resistance, R_1 .

core loss, ac, incremental, $P_{c\Delta}$ —the core loss in a magnetic material when the material is subjected simultaneously to a dc biasing magnetizing force and an alternating magnetizing force.

core loss, residual, P_r —the portion of the core loss power, P_c , which is not attributed to hysteresis or eddy current losses from classical assumptions.

core loss, ac, specific, $P_{c(B;f)}$ —the active power (watts) expended per unit mass of magnetic material in which there is a cyclically varying induction of a specified maximum value, B , at a specified frequency, f .

core loss, ac, (total), P_c —the active power (watts) expended in a magnetic circuit in which there is a cyclically alternating induction.

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DISCUSSION—

Measurements of core loss are normally made with sinusoidally alternating induction, or the results are corrected for deviations from the sinusoidal condition.

core loss density—the active power (watts) expended in a magnetic core in which there is a cyclically varying induction of a specified maximum value, B , at a specified frequency, f , divided by the effective volume of the core.

DISCUSSION—

This parameter is normally used only for non-laminated cores such as ferrite and powdered cores.

core plate—a generic term for any insulating material, formed metallurgically or applied externally as a thin surface coating, on sheet or strip stock used in the construction of laminated and tape wound cores.

coupling coefficient, k' —the ratio of the mutual inductance between two windings and the geometric mean of the individual self-inductances of the windings.

crest factor, cf —the ratio of the maximum value of a periodically alternating quantity to its rms value.

DISCUSSION—

For a sinusoidal variation the crest factor is $\sqrt{2}$.

Curie temperature, T_c —the temperature above which a ferromagnetic or ferrimagnetic material becomes paramagnetic.

current, ac core loss, I_c —the rms value of the in-phase component (with respect to the induced voltage) of the exciting current supplied to a coil which is linked with a ferromagnetic core.

current, ac exciting, I —the rms value of the total current supplied to a coil that is linked with a ferromagnetic core.

DISCUSSION—

Exciting current is measured under the condition that any other coil linking the same core carries no current.

current, ac, magnetizing, I_m —the rms value of the magnetizing component (lagging with respect to applied voltage) of the exciting current supplied to a coil that is linked with a ferromagnetic core.

current, dc, I_{dc} —a steady-state dc current. A dc current flowing in an inductor winding will produce a unidirectional magnetic field in the magnetic material.

customary units—a set of industry-unique units from the cgs-emu system of units and U.S. inch-pound systems and units derived from the two systems.

DISCUSSION—

Examples of customary units used in ASTM A06 standards include:

| Quantity Name | Quantity Symbol | Unit Name | Unit Symbol |
|--------------------------------------------|-----------------|------------|-------------|
| Magnetic field strength | H | oersted | Oe |
| Magnetic induction (magnetic flux density) | B | gauss | G |
| Specific core loss | $P_c(B; f)$ | watt/pound | W/lb |

cyclically magnetized condition, CM —a magnetic material is in a cyclically magnetized condition when, after having been subjected to a sufficient number of identical cycles of magnetizing field, it follows identical hysteresis or flux-current loops on successive cycles which are not symmetrical with respect to the origin of the axes.

demagnetization curve—the portion of a flux versus dc current plot (dc hysteresis loop) that lies in the second or fourth quadrant, that is, between the residual induction point, B_r , and the coercive force point, H_c . Points on this curve are designated by the coordinates, B_d and H_d .

demagnetizing coefficient, D_B —is defined by the equation:

$$D_B = [\Gamma_m(H_a - H)]/B_i$$

$$D_B = [\mu_0(H_a - H)]/B_i$$

where:

- H_a = applied magnetic field strength,
- H = magnetic field strength actually existing in the magnetic material,
- B_i = intrinsic induction, and
- Γ_m = 1 in the cgs system and $4\pi \times 10^{-7}$, henry/metre in the SI system.
- μ_0 = 1 in the cgs system and $4\pi \times 10^{-7}$, henry/metre in the SI system.

DISCUSSION—

For a closed, uniform magnetic circuit, the demagnetizing coefficient is zero.

demagnetizing factor, N_D —defined as 4π times the demagnetizing coefficient, D_B .

demagnetizing field strength, H_d —a magnetic field strength applied in such a direction as to reduce the induction in a magnetized body. See **demagnetization curve**.

density, δ —the ratio of mass to volume of a material. In the cgs-emu system of units, g/cm^3 . In SI units, kg/m^3 .

diamagnetic material—a material whose relative permeability is less than unity.

DISCUSSION—

The intrinsic induction, B_i , is oppositely directly to the applied magnetizing force H .

disaccommodation—a time dependent change of magnetic properties, especially the initial permeability, that occurs after demagnetization of a magnetic material. This change is usually due to the motion of point defects such as vacancies and interstitial atoms, occurs over a time period measured in seconds or minutes, and is reversible by demagnetization. It is a different phenomenon than magnetic aging which (a) typically involves the clustering of impurity atoms or precipitation of a new phase, (b) occurs over a much longer time period (normally weeks or months at room temperature), and (c) the changes are not reversible by demagnetization.

dissipation factor, magnetic, D_m —the tangent of the hysteretic angle that is equal to the ratio of the core loss current, I_c , to the magnetizing current, I_m . Thus:

$$D_m = \tan \beta = \cot \gamma = I_c/I_m = \omega L_c/R_1 = I/Q_m$$

DISCUSSION—

This dissipation factor is also given by the ratio of the energy dissipated in the core per cycle of a periodic *SCM* excitation (hysteresis and eddy current heat loss) to 2π times the maximum energy stored in the core.

distortion, harmonic—the departure of any periodically varying waveform from a pure sinusoidal waveform.

DISCUSSION—

The distorted waveform that is symmetrical about the zero amplitude axis and is most frequently encountered in magnetic testing contains only the odd harmonic components, that is fundamental, 3rd harmonic, 5th harmonic, and so forth. Nonsymmetrical distorted waveforms must contain some even harmonic components, in addition to the fundamental and, perhaps, some odd harmonic components.

distortion factor, df —a numerical measure of the distortion in any ac nonsinusoidal waveform. For example, if by Fourier analysis or direct measurement E_1 , E_2 , E_3 , and so forth are the effective values of the pure sinusoidal harmonic components of a distorted voltage waveform, then the distortion factor is the ratio of the root mean square of the second and all higher harmonic components to the fundamental component.

$$df = [E_2^2 + E_3^2 + E_4^2 + \dots]^{1/2} E_1$$

DISCUSSION—

There are no dc components (E_0) in the distortion factor.

domains, ferromagnetic—magnetized regions, either macroscopic or microscopic in size, within ferromagnetic materials. Each domain, in itself, is magnetized to intrinsic saturation at all times, and this saturation induction is unidirectional within the domain.

domain wall—a boundary region between two adjacent domains within which the orientation of the magnetic moment of one domain changes into a different orientation of the magnetic moment in the other domain.

eddy current—an electric current developed in a material as a result of induced voltages developed in the material.

effective circuit permeability, μ_{eff} —when a magnetic circuit consists of two or more components, each individually homogeneous throughout but having different permeability values, the effective (overall) permeability of the circuit is that value computed in terms of the total magnetomotive force, the total resulting flux, and the geometry of the circuit.

electrical steel—a term used commercially to designate strip or sheet used in electrical applications and historically has referred to flat-rolled, low-carbon steels or alloyed steels with silicon or aluminum, or both. Common types of electrical steels used in the industry are grain-oriented electrical steel, nonoriented electrical steel, and magnetic lamination steel.

electrical steel, grain oriented—a flat-rolled silicon-iron alloy usually containing approximately 3 % silicon, having enhanced magnetic properties in the direction of rolling and normally used in transformer cores.

electrical steel, nonoriented—a flat-rolled silicon-iron or silicon-aluminum-iron alloy containing 0.0 to 3.5 % silicon and 0.0 to 1.0 % aluminum and having similar core loss in all directions.

emu—the notation emu is an indicator of electromagnetic units. When used in conjunction with magnetic moment, m , it denotes units of ergs per oersted, erg/Oe. A moment of 1 erg/Oe is produced by a current of 10 amperes (1 abampere) flowing in a loop of area 1 cm². The work done to rotate a moment of 1 erg/Oe from parallel to perpendicular in a uniform field of 1 Oe is 1 erg. The conversion to the SI units of magnetic moment J/T (joule/tesla) or A m² is given by:

$$\frac{\text{erg/Oe (cgs - emu)}}{\text{J/T (SI)}} \equiv \frac{10 \text{ amperes cm}^2 \text{ (cgs - emu)}}{\text{A m}^2 \text{ (SI)}} = 10^{-3} \quad (1)$$

Magnetization, M , the magnetic moment per unit volume, has units erg/(Oe-cm³), often expressed as emu/cm³.

energy product, $B_d H_d$ —the product of the coordinate values of any point on a demagnetization curve.

energy-product curve, magnetic—the curve obtained by plotting the product of the corresponding coordinates, B_d and H_d , of points on the demagnetization curve as abscissa against the induction, B_d , as ordinates.

DISCUSSION—

The maximum value of the energy product, $(B_d H_d)_m$, corresponds to the maximum value of the external energy.

DISCUSSION—

The demagnetization curve is plotted to the left of the vertical axis and usually the energy-product curve to the right.

energy product, maximum $(B_d H_d)_m$ —for a given demagnetization curve, the maximum value of the energy product.

equipment test level accuracy—(1) For a single test equipment, using a large group of test specimens, the average percentage of test deviation from the correct average value. (2) The average percentage deviation from the average value obtained from similar tests, on the same test specimen or specimens, when measured with a number of other test equipments that have previously been proven to have both suitable reproducibility of measurement and test level, and whose calibrations and quality have general acceptance for standardization purposes and where better equipment for establishing the absolute accuracy of test is not available.

exciting current, ac, I—See **current, ac exciting**.

exciting power, rms, P_z —the product of the ac rms exciting current and the rms voltage induced in the exciting (primary) winding on a magnetic core.

DISCUSSION—

This is the apparent volt-amperes required for the excitation of the magnetic core only. When the core has a secondary winding, the induced primary voltage is obtained from the measured open-circuit secondary voltage multiplied by the appropriate turns ratio.

exciting power, specific, $P_{z(B:f)}$ —the value of the ac rms exciting power divided by the active mass of the specimen (volt-amperes/unit mass) taken at a specified maximum value of cyclically varying induction B and at a specified frequency f .

exciting voltage, E —the ac rms voltage across a winding linking the flux of a magnetic core. The voltage across the winding equals that across the assumed parallel combination of core inductance L_1 , and core resistance, R_1 .

feebly magnetic material—a material generally classified as “nonmagnetic,” whose maximum normal permeability is less than 4.

ferrimagnetic material—a material whose atomic magnetic moments are both ordered and anti-parallel but being unequal in magnitude produce a net magnetization in one direction.

ferrite—a term referring to magnetic oxides in general, and especially to material having the formula $M O Fe_2 O_3$, where M is a divalent metal ion or a combination of such ions. Certain ferrites, magnetically “soft” in character, are useful for core applications at radio and higher frequencies because of their advantageous magnetic properties and high volume resistivity. Other ferrites, magnetically “hard” in character, have desirable permanent magnet properties.

ferromagnetic material—a material whose magnetic moments are ordered and parallel producing magnetization in one direction.

figure of merit, magnetic, $\mu'/\cot \gamma$ —the ratio of the real part of the complex relative permeability to the dissipation factor of a ferromagnetic material.

DISCUSSION—

The figure of merit index of the magnetic efficiency of the core in various ac electromagnetic devices.

flux-current loop, incremental (biased)—the curve developed by plotting magnetic induction, B , versus magnetic field strength, H , when the magnetic material is cyclically magnetized while under dc bias condition. This loop will not be symmetrical about the B and H axes.

flux-current loop, normal—the curve developed by plotting magnetic induction, B , versus magnetic field strength, H , when the magnetic material is symmetrically cyclically magnetized.

DISCUSSION—

The area of the loop is proportional to the sum of the static hysteresis loss and all dynamic losses.

flux linkage, \mathcal{L} —the sum of all flux lines in a coil.

$$\mathcal{L} = \varphi_1 + \varphi_2 + \varphi_3 + \dots + \varphi_N$$

where:

- φ_1 = flux linking turn 1;
- φ_2 = flux linking turn 2, and so forth; and
- φ_N = flux linking the N th turn.

DISCUSSION—

When the coupling coefficient, k , is less than unity, the flux linkage equals the product of the average flux linking the turns and the total number of turns. When the coupling coefficient is equal to unity, the flux linkage equals the product of the total flux linking the coil and the total number of turns.

flux linkage, mutual, \mathcal{L}_m —the flux linkage existing between two windings on a magnetic circuit. Mutual linkage is maximum when the coupling coefficient is unity.

flux path length, ℓ —the distance along a flux loop.

flux path length, effective, ℓ_1 —the calculated length of the flux paths in a magnetic core, which is used in the calculations of certain magnetic parameters.

flux volts, E_f —the voltage induced in a winding of a magnetic component when the magnetic material is subjected to repeated magnetization under *SCM* or *CM* conditions.

$$\begin{aligned} E_f &= 4.443 B_{\max} A' N f \times 10^{-8} \text{ V (SCM excitation)} \\ E_f &= 2.221 \Delta B A' N f \times 10^8 \text{ V (CM excitation)} \\ \frac{E_f}{E_{\text{avg}}} &= \frac{2.221 \Delta B A' N f \times 10^8 \text{ V (CM excitation)}}{1.1107 E_{\text{avg}}} \end{aligned}$$

which:

- A' = solid cross-sectional area of the core in cm^2 ,
- N = number of winding turns, and
- f = the frequency in hertz.

form factor, ff —the ratio of the rms value of a periodically alternating quantity to its average absolute value.

DISCUSSION—

For a sinusoidal variation, the form factor is:

$$\pi/2\sqrt{2} = 1.1107$$

frequency, angular, ω —the number of radians per second traversed by a rotating vector that represents any periodically varying quantity.

DISCUSSION—

Angular frequency, ω , is equal to 2π times the cyclic frequency, f .

frequency, cyclic, f —the number of hertz (cycles/second) of a periodic quantity.

gap length, ℓ_g —the distance that the flux transverses in the central region of a gap in a core having an “air” (nonmagnetic) gap in the flux path may be considered unity in the gap.

gauss (plural gauss), G —the unit of magnetic induction in the cgs-emu system of units. The gauss is equal to 1 maxwell per square centimetre of 10^{-4} tesla. See **magnetic induction (flux density)**.

gilbert, Gb—the unit of magnetomotive force in the cgs-emu system of units. The gilbert is a magnetomotive force of $4\pi/10$ ampere-turns. See **magnetomotive force**.

gyromagnetic ratio, proton, γ_p —the ratio of the magnetic moment of a hydrogen nucleus to its angular momentum.

DISCUSSION—

The gyromagnetic ratio is used to calculate the magnetic field from a measured resonance frequency when using the nuclear magnetic resonance technique. The relationship is:

$$B = (2\pi f / \gamma_p) \text{ gauss} = (2 \pi f / \gamma_p) \times 10^{-4} \text{ tesla}$$

where:

f = resonance frequency in cycles per second (hertz) and

γ_p = gyromagnetic ratio (the accepted value at present for water is $2.675 \text{ } 12 \times 10^4 \text{ gauss}^{-1} \text{ s}^{-1}$).

henry (plural henries), H—the unit of self- or mutual inductance. The henry is the inductance of a circuit in which a voltage of 1 V is induced by a uniform rate of change 1 A/s in the circuit. Alternatively, it is the inductance of a circuit in which an electric current of 1 A/s produces a flux linkage of one weber turn (Wb turn) or 10^8 maxwell-turns. See **inductance, mutual, and inductance, self**.

hertz, Hz—the unit of cyclic frequency, f .

hysteresis loop, biased—an incremental hysteresis loop that lies entirely in any one quadrant.

DISCUSSION—

In this case, both of the limiting values of H and B are in the same direction.

hysteresis loop, incremental—the hysteresis loop, nonsymmetrical with respect to the B and H axes, exhibited by a ferromagnetic material in a CM condition.

DISCUSSION—

In this case, both of the limiting values H may have opposite polarity, but definitely have different absolute values of H_m . An incremental loop may be initiated at either some point on a normal hysteresis loop or at some point on the normal induction curve of the specimen.

hysteresis loop, intrinsic—a hysteresis loop obtained with a ferromagnetic material by plotting (usually to rectangular coordinates) corresponding dc values of intrinsic induction, B_i , for ordinates and magnetic field strength H for abscissae.

hysteresis loop, normal—a closed curve obtained with a ferromagnetic material by plotting (usually to rectangular coordinates) corresponding dc values of magnetic induction (B) for ordinates and magnetic field strength (H) for abscissa when the material is passing through a complete cycle between equal definite limits of either magnetic field strength, $\pm H_m$, or magnetic induction, $\pm B_m$. In general, the normal hysteresis loop has mirror symmetry with respect to the origin of the B and H axes, but this may not be true for special materials.

hysteresis loop loss, W_h —the power expended in a single slow excursion around a normal hysteresis loop. The energy is the integrated area enclosed by the loop measured in gauss-oersteds. Using the cgs-emu system of units:

$$W_h = \left(\int H dB / 4\pi \right) \text{ ergs}$$

where the integrated area enclosed by the loop is measured in gauss-oersteds.

hysteresis loss, incremental, $P_{\Delta h}$ —the power (watts) as a result of hysteresis expended in a ferromagnetic material while being driven through an incremental flux-current loop by a CM -type of excitation.

hysteresis loss, normal, P_h —(1) the power expended in a ferromagnetic material, as a result of hysteresis, when the material is subjected to a SCM excitation. (2) The energy loss/cycle in a magnetic material as a result of magnetic hysteresis when the induction is cyclic (but not necessarily periodic).

hysteresis loss, rotational—the hysteresis loss that occurs in a body when subjected to a constant magnetizing force, the direction of which rotates with respect to the body, either in a continuously cyclic or in a repeated oscillatory manner.

hysteresis, magnetic—the property of a ferromagnetic material exhibited by the lack of correspondence between the changes in induction resulting from increasing magnetic field strength and from decreasing magnetic field strength.