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MILITARY HANDBOOK

MAGNETIC PARTICLE TESTING

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

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4.0 SAFETY NOTICE

Magnetic particle testing involves the use of magnetic fields usually produced by electrical currents. The use of electrical currents requires that standard safety practices associated with electrical equipment be observed.

The magnetic forces established can impart motion to loose parts which can result in pinched fingers or other harm to personnel or damage to the parts.

Often chemical dyes which are fluorescent are combined with the magnetic particles. Therefore, standard safety practices associated with the handling of chemical products and the use of ultraviolet light must respectively be considered.

Additional safety comments are found in section 4.8.

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4.1 INTRODUCTION

Magnetic particle testing is used to detect surface and near surface flaws in ferromagnetic (magnetizable) materials. The indications provided by this type of test occur at the surface of the part, directly above the location of the flaws, and the general size, shape, and orientation of the flaws can usually be directly inferred. Magnetic particle testing is used in receiving inspections, in in-process or final inspections, and in in-service inspections. Magnetic particle testing can be used for forgings and castings, for crankshafts and simple plates, for large and small parts and is extensively used for welding inspections. It is one of the best established nondestructive testing methods used on ferromagnetic materials.

This chapter presents the fundamental principles and guidelines associated with magnetic particle testing. This chapter includes descriptions of the basic theory of operation, the equipment and materials used, the advantages and disadvantages of the method, various applications and standards, and guides for specific disciplines.

Chapter 1 contains general NDT information that should be studied along with this chapter for a more complete understanding of magnetic particle testing and its comparison with other methods.

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4.2 BASIC PRINCIPLES

Magnetic particle testing requires the induction of a magnetic field into the part to be tested. If the part has discontinuities in its magnetic permeability, singularities in the magnetic field can exist. These field singularities - or leakage fields - can attract and hold small ferromagnetic particles. Therefore, when a magnetic field is established in a part, and small ferromagnetic particles are applied over the surface, some of these particles will collect at leakage field locations thereby forming indications that can be associated with underlying discontinuities. The basic principles associated with magnetic particle testing involve magnetic properties of materials, magnetic fields, and the visual detection of small particles.

4.2.1 MAGNETIC FIELDS

There are difficulties in studying magnetic fields because historically there has been a large number of magnetic units and concepts utilized. There are some systems that establish relationships with the strength of the magnetic sources in terms of magnetic moments, ampere-turns per meter, or in fictitious magnetic monopoles - all of which are usually constants for any one problem. Then there is the magnetic field intensity due to these magnetic sources in terms of the "H" field - which is also a constant for most problems. Then there is the induced magnetic field, B, inside the part, which often is the magnetic field intensity changed into different units, but can also be modified or affected by the presence of "permeable" matter. This type of magnetic field is seldom linear or constant, but varies with several characteristics of these materials.

In most cases in this handbook, equations are given where the B field is directly calculated from various sources. Usually this "bypassing" of H is accomplished by assuming the absence of, or ignoring the effects of, magnetically permeable materials which might be present.

Although it is not possible to point out all of the relationships between these magnetic variables in this handbook, some of the more important relationships that are generally applicable to magnetic particle testing are presented.

The magnetic fields used in magnetic particle testing are usually created by the flow of current, but permanent magnets can also to be used. Figure 4.2 (1) shows a simple bar magnet with its magnetic field indicated by magnetic flux lines, or lines of force, with direction arrows. All magnets have a north (N) and a south (S) pole, all magnetic flux lines are continuous and form closed loops.

The strength of the magnetic field, at any point, can be measured in terms of the number of lines of force per unit area, the area being at right angles to the lines of force at the point being measured. The direction of the flux lines, shown by the arrows, indicates the direction that an infinitely small north (N) monopole (which exists only theoretically) would move if it were placed at that point in the field. (Inside the magnet, these arrows go from S to N; outside the magnet they follow a path which goes from N to S.)

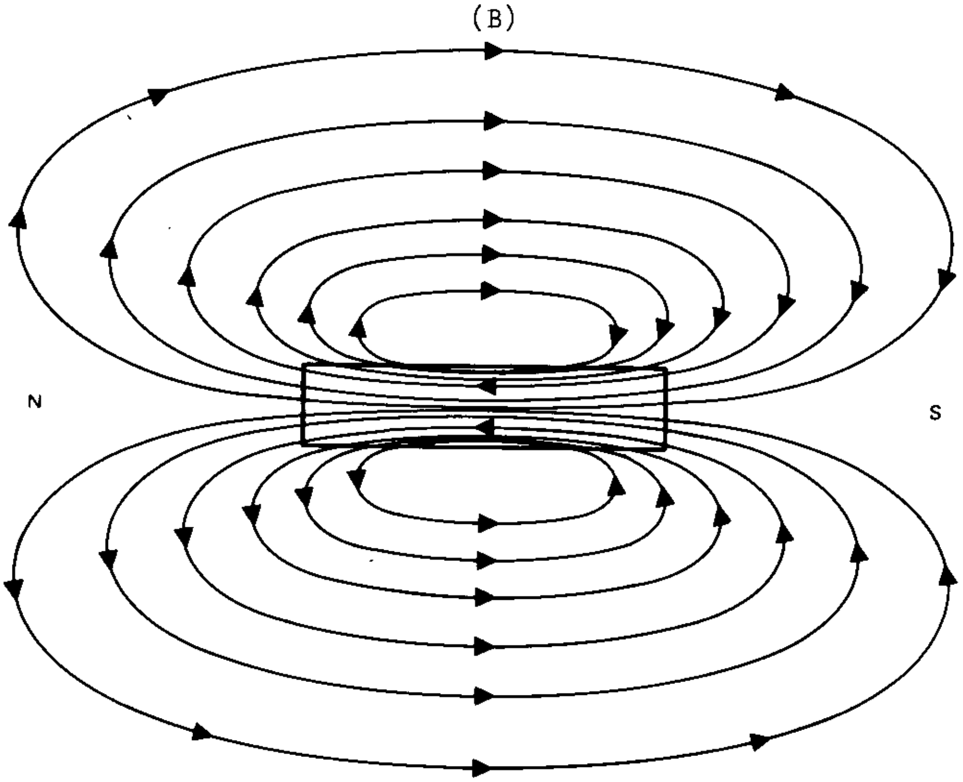
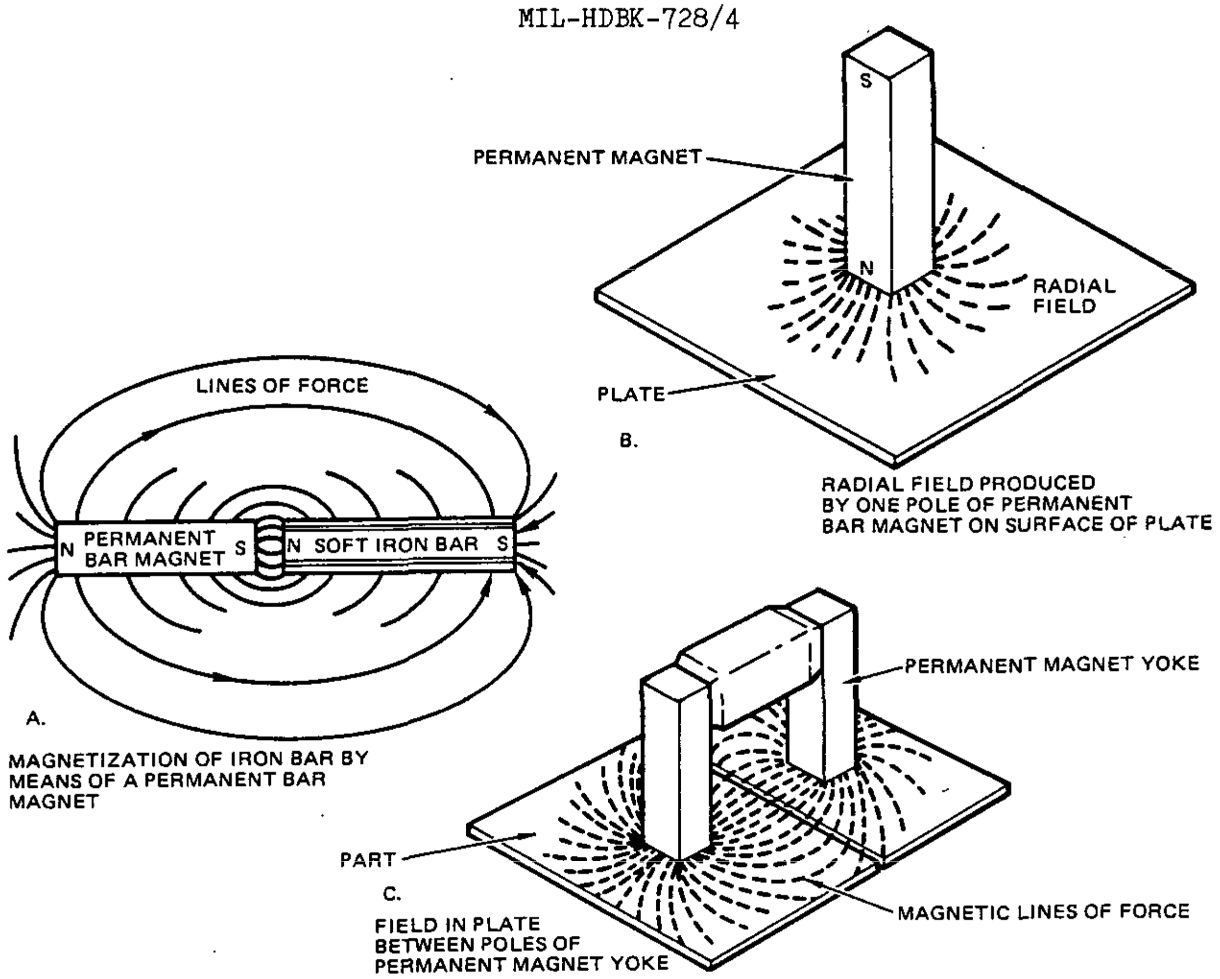


Figure 4.2(1). Magnetic-induction field around a simple bar magnet.

Relationships exist between the strength of the magnet (the source), the strength of the field, and the reluctance of the path of the lines of force, that are similar to the relationships between electromotive force (voltage), current, and resistance in electrical circuits. The magnetic relationships, however, are much more difficult to apply because their effects are not confined to discrete paths - they readily extend through empty space - and the total effects are therefore based upon the combined results of an infinite number of parallel paths. The total effects are therefore nonlinear. Also, results are often affected by previous conditions such that all of the conditions are not always directly repeatable; i.e., hysteresis effects are normally involved. Therefore, exact relationships are not easily established by equations.

As far as working relationships are concerned, the most important thing to understand is that the magnetic field is the strongest at the poles (at corners or edges near the poles), and testing is usually enhanced when the reluctance of the flux paths is reduced by having the magnet in direct contact with the part.

To facilitate this reduction of the reluctance, permanent magnets used for inspecting are sometimes arranged in a "U" shape so that both poles can touch a flat surface close together at the same time. Figure 4.2(2) shows some examples of permanent magnets and their uses.



A.

MAGNETIZATION OF IRON BAR BY MEANS OF A PERMANENT BAR MAGNET

B.

RADIAL FIELD PRODUCED BY ONE POLE OF PERMANENT BAR MAGNET ON SURFACE OF PLATE

C.

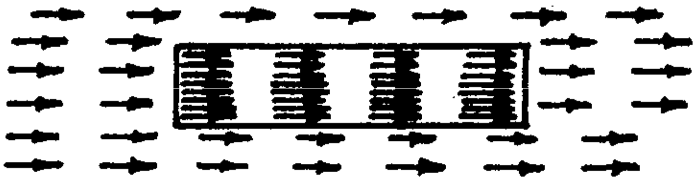
FIELD IN PLATE BETWEEN POLES OF PERMANENT MAGNET YOKE

Figure 4.2(2). Permanent magnet magnetization.

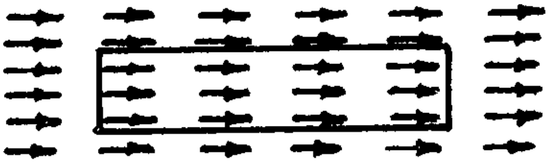
Permanent magnets should not be exposed to mechanical shocks or to high temperatures. They should, when not in use, have a "keeper bar" (usually a soft iron bar) placed between the poles so that the magnetic flux is maintained at a high level.

Note: When a magnetic field is being generated or naturally exists, it is "H". When you place something solid in the magnetic field, then the field inside the solid is "B". The magnetic field inside the solid is induced.

Thus, for iron:



for non-magnetic:



When electrical currents are used to establish magnetic fields, the following relationships are useful: The strength of the induced magnetic field, H, in Wb/m^2, around a long, straight conductor carrying a current, I, in amperes, is given by the equation.

$$H = \frac{\mu o}{2} \frac{I}{x} \tag{1}$$

where

x = distance from conductor, in meters

μo = magnetic permeability of free space (essentially the same as in air), defined to be 4 x 10^{-7} Wb/A-m.

Figure 4.2(3) shows that the direction of this field depends upon the direction of current flow, and can be determined by use of the right-hand rule.

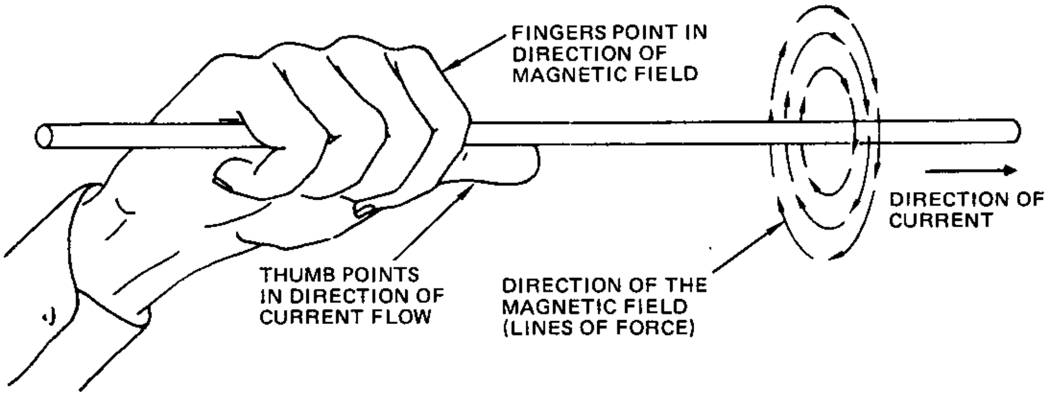


Figure 4.2(3). Right-hand straight conductor.

The strength of the magnetic field, H, at the center of a flat coil of N turns, each carrying I ampers, is:

$$H = \frac{1}{2} \mu o \frac{NI}{r} \tag{2}$$

where

r = radius of the coil in meters

Figure 4.2(4) shows the field distribution of a flat circular coil. The right-hand rule also applies to this type of coil.

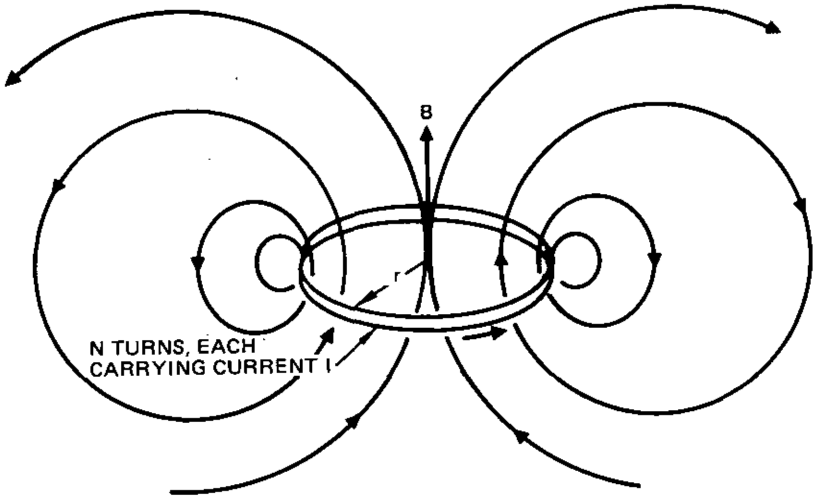


Figure 4.2(4). Magnetic-induction field at the center of a flat circular coil.

The magnetic-induction field in the central region of a long, straight solenoid is essentially uniform and its strength, B, is equal approximately to:

$$H = \mu_o NI \tag{3}$$

where

N = number of turns per meter length of coil
I = current, in amperes, flowing in coil

Figure 4.2(5) shows the right-hand rule for finding the direction of the field.

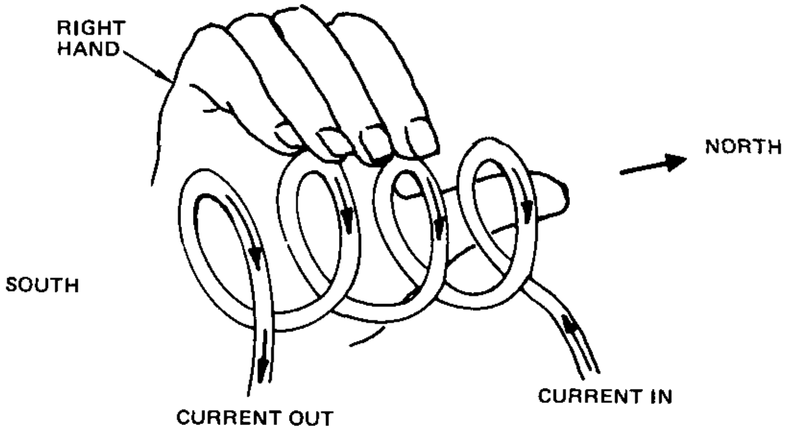


Figure 4.2(5). Direction of a magnetic field in a coil.

In many practical applications current is sometimes carried directly in the test specimen, which may be either a solid bar, a tube, or a flat plate.

Figures 4.2(6) through 4.2(9) indicate the magnetic field distribution produced by these common configurations.

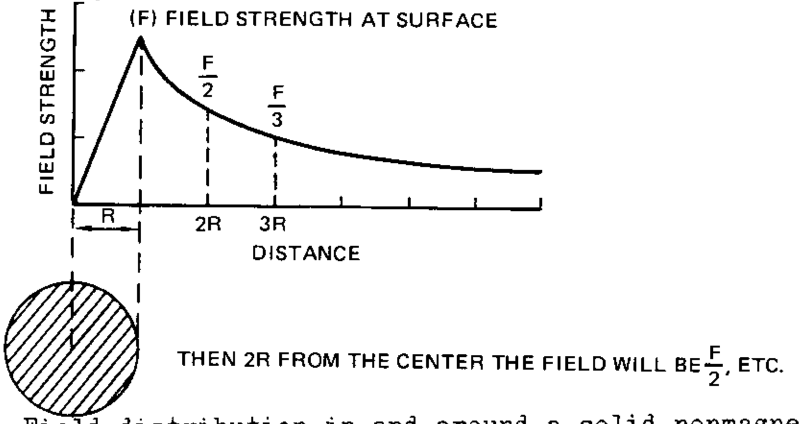


Figure 4.2(6a). Field distribution in and around a solid nonmagnetic conductor carrying direct current.

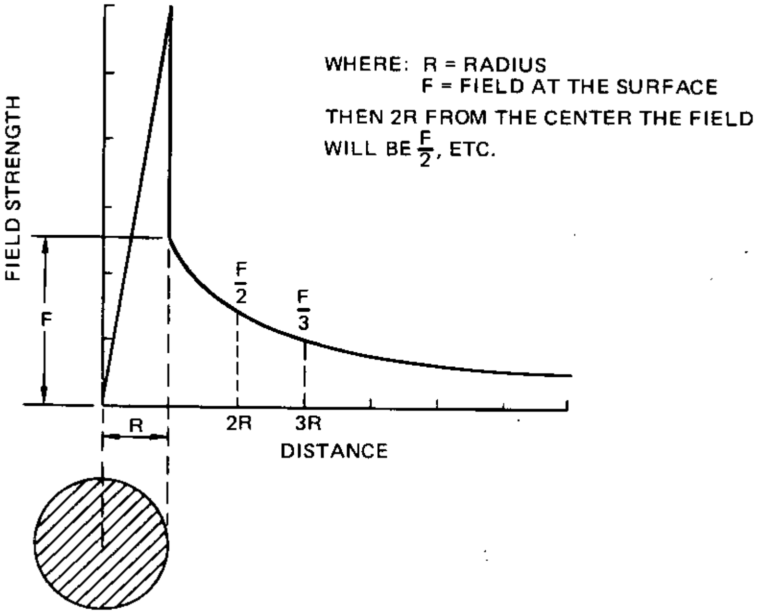


Figure 4.2(6b). Field distribution in and around a solid magnetic conductor carrying direct current.

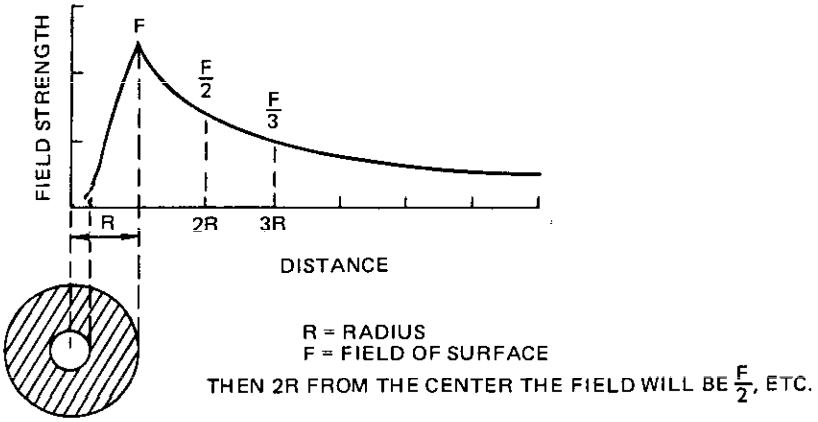


Figure 4.2(7a). Field distribution in and around a hollow nonmagnetic conductor carrying direct current.

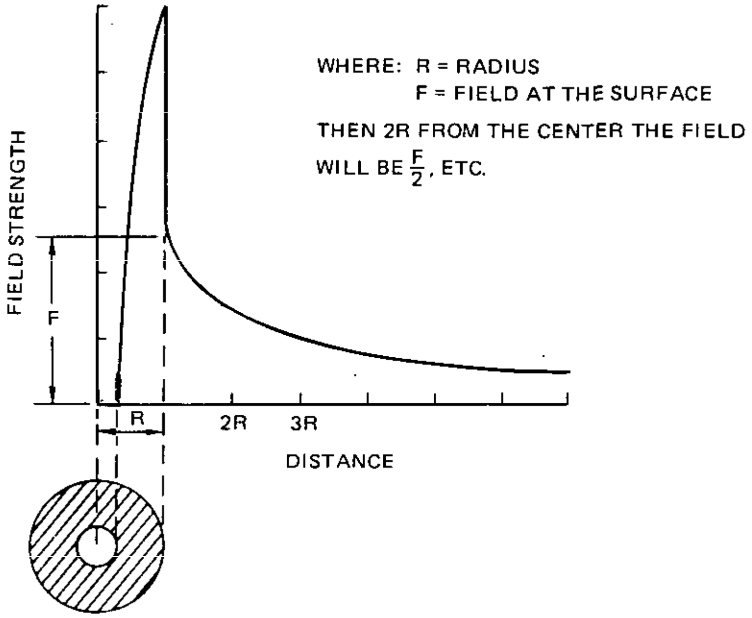


Figure 4.2(7b). Field distribution in and around a hollow magnetic conductor carrying direct current.

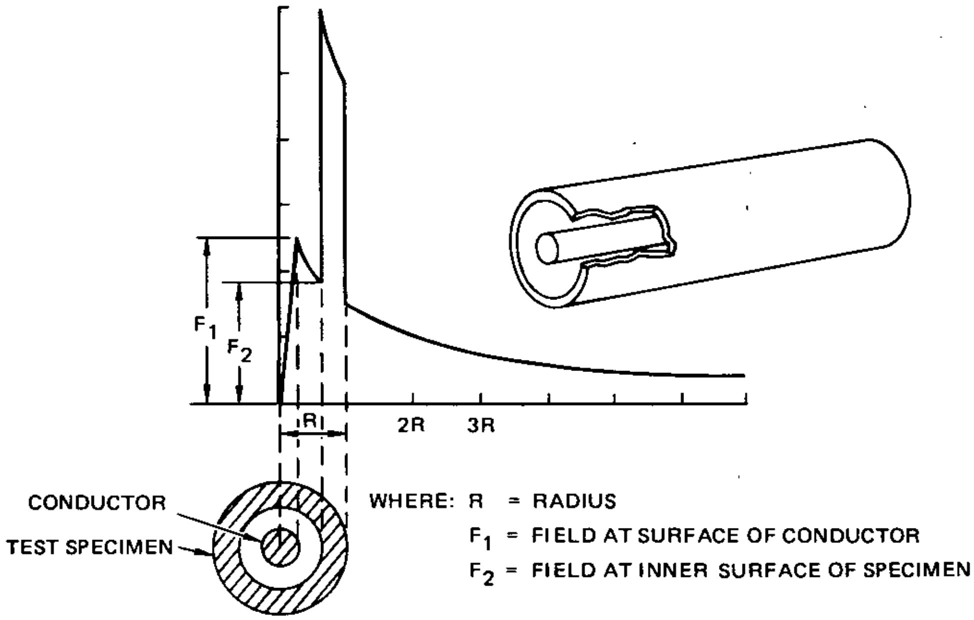
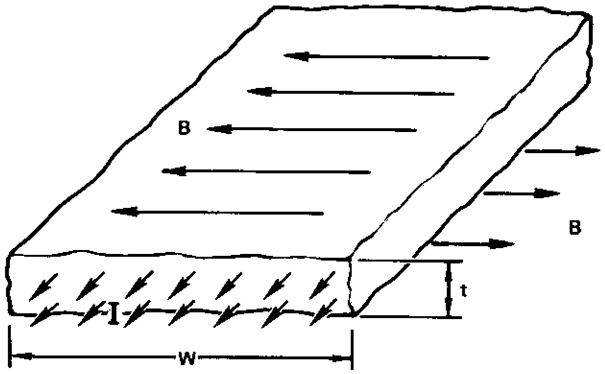


Figure 4.2(8). Field distribution in and around a hollow magnetic cylinder with central conductor carrying direct current.



A LARGE FLAT SLAB BEARING A UNIFORM DISTRIBUTION OF THE CURRENT ESTABLISHES A UNIFORM MAGNETIC-INDUCTION FIELD OUTSIDE THE MATERIAL. THE MAGNITUDE OF THE FIELD AT THE SURFACE IS: $B = \frac{1}{2}\mu_0 I/W$.

Figure 4.2(9). Field distribution in and around a large, flat slab.

Equation 4 shows the relationship between the magnetically-induced field, B, from the "magnetizing" force field, H.

$$B = \mu H. \tag{4}$$

where

μ = the magnetic permeability

When there are no magnetizing materials present (when we are in free space),

$$\mu = \mu_o. \tag{5}$$

When simple magnetizing materials (that form isotropic fields) are present

$$\mu = \mu_o (1 + X_m), \tag{6}$$

where X_m is the magnetic susceptibility of the material. Its value can range from 0, for completely nonmagnetic materials, to very large values, in the thousands, for highly magnetic materials. Although X_m is not a fixed constant even for any one material, it often has common or limited ranges for most materials that allow it to have some utility.

4.2.2 MAGNETIC PROPERTIES OF MATERIALS

The main magnetic property of a material is its susceptibility, normally described in terms of its magnetic permeability. Magnetic permeability is qualitatively the "ease of magnetization of the material." In equation form, it is the ratio of the induced magnetic flux density, B, that occurs from the magnetizing force field, H, that is present. It is the "μ" in Equation 4 of section 4.2.1. The "relative" magnetic permeability and the "effective" magnetic permeability terms are also used. The relative permeability is the permeability divided by the magnetic permeability of free space, μ_o, as defined in the previous section. Thus, it is dimensionless, and has the same value in all unit systems. It is equal to one plus the susceptibility (see Equation 6 in paragraph 4.2.1). The "effective" permeability is the ratio of the existing B field in a material divided by the B field that is present without the material. These two permeabilities, the "effective" and the "relative," are essentially identical when long, bar materials are placed in the direction of the magnetic field. The effective and relative permeabilities are not the same when short length-to-width material shapes are used. The effective permeability includes the geometric factor that recognizes the effects of the poles established at the end boundaries of the material which can reduce the effects of the original external magnetic force field within the material.

For a sphere, the reduced field is as if the relative permeability were less than 3, even if the true relative permeability were a 1000. This field reduction is referred to as a demagnetization effect and, as can be seen with the sphere, it can be a very sizable effect. It is, therefore, the effective permeability that must be considered for magnetic particle testing. Thus geometry of the part being tested is important along with the actual permeability of the material. Each material has its own permeability characteristics. These characteristics can be shown on a B versus H curve. Figure 4.2(10) shows an example of one of these curves from which various definitions can be obtained.

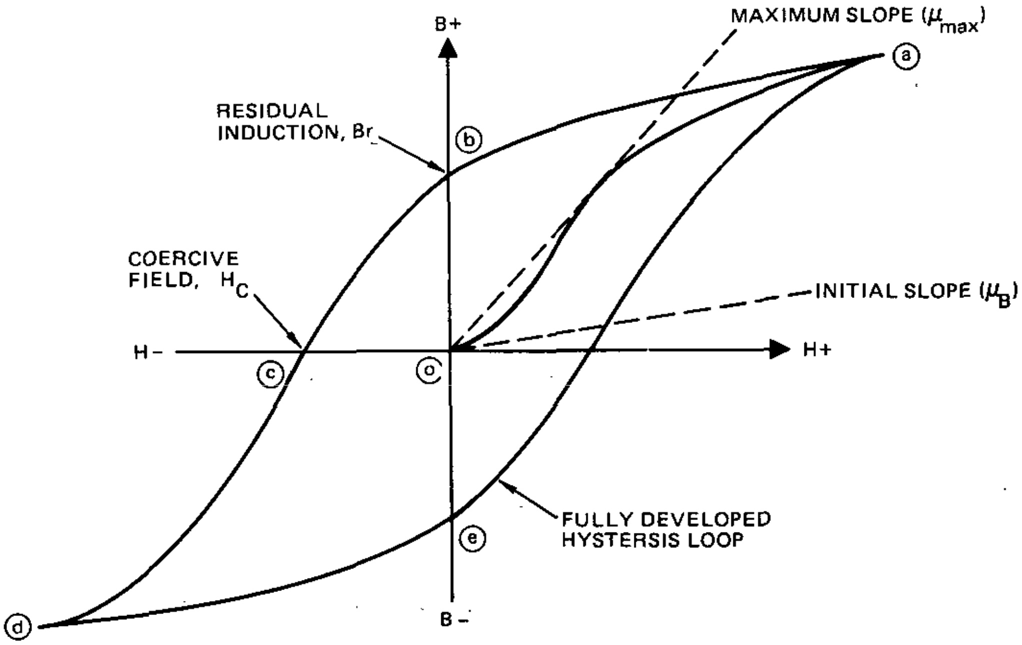


Figure 4.2(10). A generic hysteresis curve for ferromagnetic materials.

The specimen is completely demagnetized at the starting point (0) of the figure. As the magnetic force, H, is increased, the total flux in the specimen increases until it reaches a point beyond which any additional increase in the magnetizing force does not cause significantly further increases in B. This curve, from 0 to a, is defined as the virgin curve. The virgin curve provides the "maximum permeability" of the material, which is the slope of the line from the zero point to the tangent point on the curve. The point at which significant increases in B ceases is known as the "saturation" point. If the magnetizing force is then reduced back to zero, the curve a to b is obtained. The amount of magnetism that the material retains at point b is called residual magnetism. If the magnetizing force is reversed (the current is caused to flow in the opposite direction), the residual magnetism will eventually disappear at point c. The value of "H" at this point represents the "coercive force" for the material, or the magnetizing force required to remove the residual magnetism. As the reversed magnetic force is increased beyond c, the specimen is again saturated as indicated at point d. Returning the magnetizing force back to zero takes the curve to point e. Repeating the start of the cycle for H then takes the curve back up to a where the full hysteresis curve has now been completed. Each material, with its own characteristic curve, exhibits a different amount of saturation, residual magnetism, and coercive force. These variables are all important in magnetic particle testing. The material being tested should be slightly below saturation. If it is too close to saturation, too many field lines will be leaving the surface of the material at arbitrary points, producing false indications. If the material is not near enough to saturation, flux lines, when they meet a discontinuity, can move into the non-saturated middle of the material and not produce visible indications.

If a material shows high residual magnetism, the material can be tested even after it is removed from a magnetic field. Also, demagnetization might be required, and the coercive force will indicate the degree of difficulty in obtaining the demagnetization.

4.2.3 SMALL MAGNETIC PARTICLES AND THEIR VISUAL DETECTION

When a small magnetizable particle (usually with high permeability but low retentivity or low residual magnetism) is placed in a magnetic field, a dipole is formed. That is, opposite magnetic poles, separated by the effective size or length of the particle, are induced on opposite sides of the particle. The strength of these poles multiplied by the effective distance between them (the "size" of the particle) is the magnitude of the dipole moment.

Within a magnetic field, dipoles will tend to move in the direction of the field gradient. The force acting on the particle will be proportional to the strength of the gradient and the strength of the dipole moment. Therefore, the strength of the magnetic field (which determines the strength of the induced poles), and the strength of the gradient of the magnetic field are all important. Magnetic gradients, under normal conditions, increase as the poles of a magnet are approached. The shape of the field gradient is determined by the B field, but the direction of the gradient is not necessarily the direction of the lines of force that make up the B field. The lines of force show the direction of orientation that a dipole particle would tend to assume, but the net force acting upon a dipole particle will include components of forces perpendicular to B in most regions of the field.

Because gradients are large at the poles, or at points where the magnetic lines of force leave the surface of a magnetic material, small magnetic particles, acting as dipoles, will tend to move and attach themselves to these locations. Because these particles form their own poles, they can hang together end-to-end, and not all collect side-by-side at the same concentrated point. This formation effectively extends the size of the gradient, and can actually amplify the indication to a size several hundred times larger than the actual discontinuity. This allows easy observation of flaws or other anomalies.

Additional enhancement of the observations can be accomplished by several means: a contrasting background can be applied over the inspected part before the test begins, and/or the magnetic particles can be dyed a bright color, or the particles can even be made to be fluorescent.

The strength of these magnetic gradients are not always great; therefore the "mobility" of these small magnetic particles is important. Particle size and shape, the medium in which they are carried, if any, and any mechanical vibration or other inducement to move become important considerations. The material the particles are made of, and their size and shape, also affect the magnetic moment that can be induced. Thus, a wide variety of characteristics can be associated with the magnetic particles used, and the expected visual detection capabilities that can be obtained will depend upon several characteristics of the particles used.

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4.3 EQUIPMENT AND MATERIALS

The equipment and materials required to perform a magnetic particle test can be as simple as a strong permanent magnet and a supply of magnetic particle powders. However, sources of electrical currents, with control over the current magnitudes and directions, magnetic coils and yokes, and tanks for holding magnetic powders, either in dry or wet form, can all be considered as necessary facilities for most magnetic particle testing.

4.3.1 COMMERCIAL EQUIPMENT

Today there is commercial equipment available for portable, mobile, or stationary systems.

a. Testing Units. The portable magnetic-particle testing units are available as hand-portable current sources or as hand-held magnetic yokes. A typical portable magnetic-particle unit (current source) is shown in Figure 4.3(1). These portable units are generally designed for operating on 110 or 220 Vac and supplying 500 and 1000 amperes. The output voltage will range from 5 to 25V depending upon the current level being supplied. Portable units are especially desirable for inspecting small items and for inspecting in remote areas.

Except for added features of demagnetizing circuits, the mobile equipment may be best described as heavy-duty portable equipment on wheels. The electrical circuitry is generally designed to provide heavy currents ranging up to 3000 amperes. Since heavier transformer wires and connectors are required to

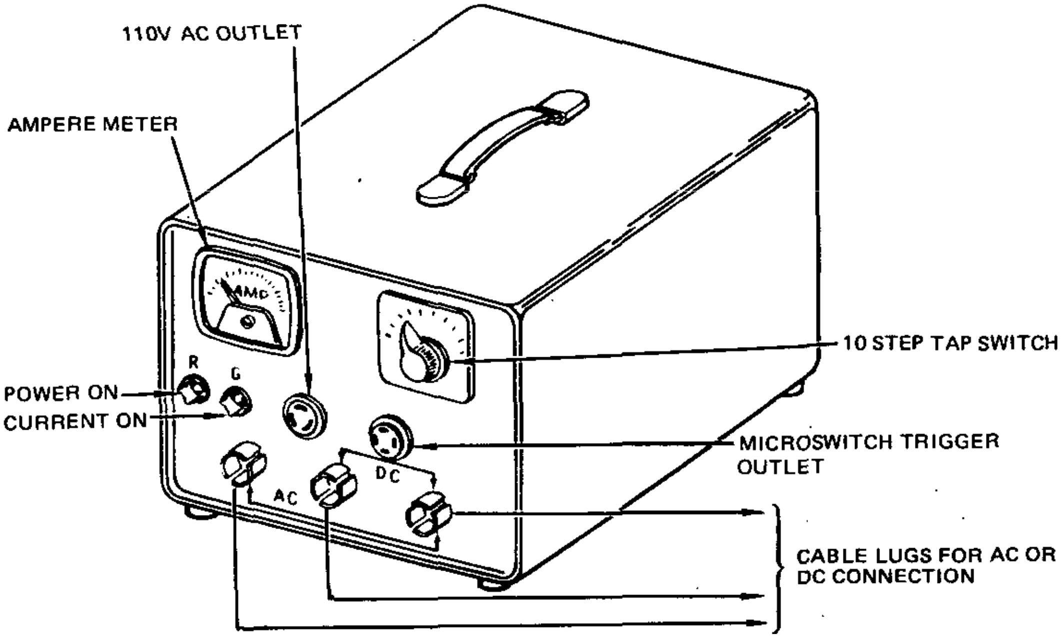
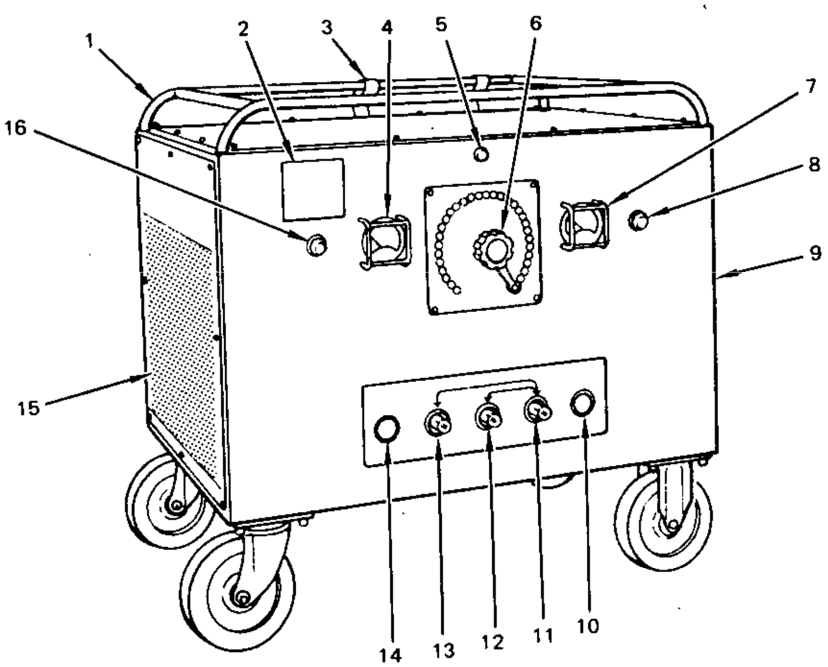


Figure 4.3(1). Portable magnetic particle current source.

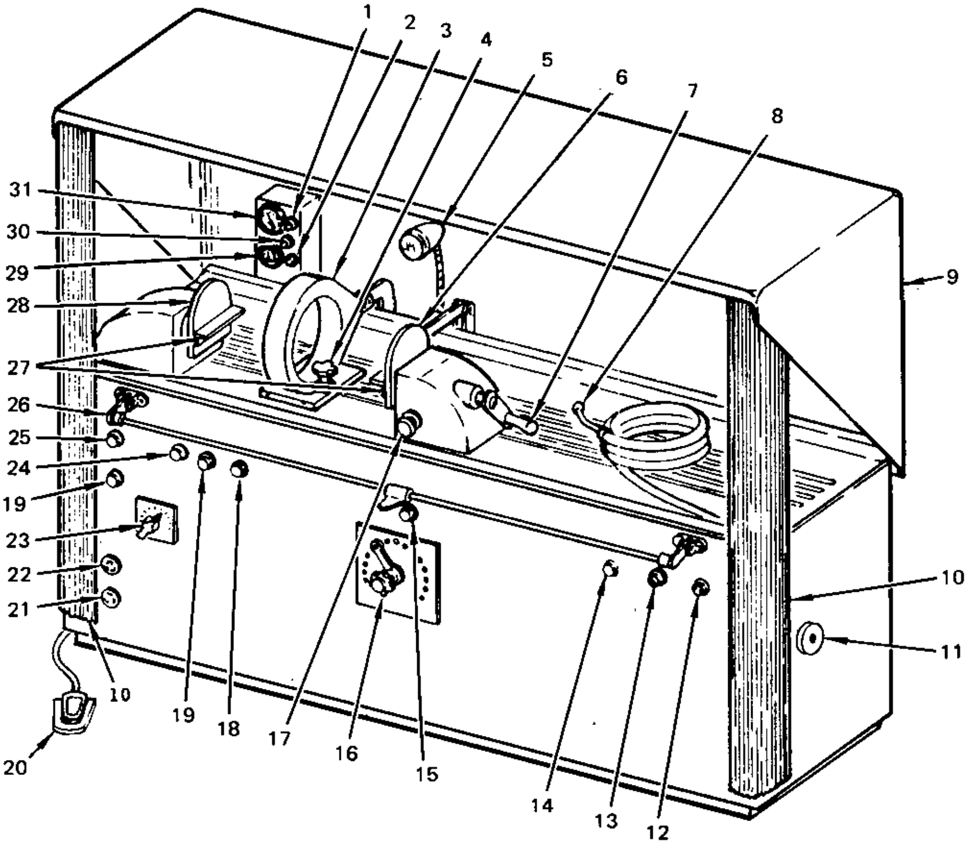
to carry these currents, and cooling fans are added to aid in cooling, the equipment weight becomes excessive. However, such equipment may still be used effectively in many different locations by rolling on wheels. A typical mobile magnetic particle test unit is shown in Figure 4.3(2). Selection of ac or half-wave dc is easily changed by switching cables on cable lugs located in front of the unit. Cables ranging from 15 to 30 feet may be further extended by additional lengths to as much as 90 to 100 feet. When extension cables are used, a decrease in current output can be expected. Although prods are usually used with mobile equipment, solenoid or cable wrapping techniques can be used. Also, use of a central conductor hooked up between the two cables facilitates variation in test techniques. Dry magnetic particle powder is most often used with this type of equipment but the wet technique (with an external tank) or materials in kit form can also be used.



1. CARRYING RACK
2. IDENTIFICATION PLATE
3. CABLE HOOK
4. DC AMMETER (OUTPUT)
5. DEMAGNETIZATION PUSHBUTTON
6. CURRENT VALUE IS SELECTED BY TURNING OF KNOB
7. AC AMMETER (OUTPUT)
8. POWER ON LIGHT (RED)
9. POWER HOOK-UP TO THE TERMINALS IS FACILITATED AND EASILY ACCESSIBLE THROUGH A SMALL DOOR HERE
10. CABLE LEADING TO MICROSWITCH ON THE PROD HANDLE
11. CABLE LUGS (GROUND CABLE)
12. CABLE LUGS
13. CABLE LUGS
14. 110 VOLT AC EXTENSION CABLE
15. COOLING INTAKE
16. CURRENT ON LIGHT (GREEN)

Figure 4.3(2). Mobile magnetic particle test unit.

Stationary magnetic particle test equiment may be obtained as either general-purpose or special-purpose inspection units. The general-purpose unit is primarily for use in the wet method, and has a built-in tank that contains the wet-particle bath pump which continually agitates the bath and forces the fluid through hoses onto the test article. In addition, curtains and an ultraviolet light are provided for inspection whenever fluorescent particles are used. A general-purpose stationary unit is shown in Figure 4.3(3).



1	DC PILOT LIGHT
2	AC PILOT LIGHT
3	COIL
4	COIL LOCKING HANDLE
5	BLACK LIGHT
6	TAILSTOCK CONTACT PLATE
7	TAILSTOCK CRANK HANDLE
8	NOZZLE
9	HOOD
10	CURTAIN
11	FLOW CONTROL VALVE
12	DEMAG CURRENT PILOT LIGHT
13	AC TRANSFER SWITCH
14	MAGNETIZING CURRENT CONTROL
15	30 POINT SWITCH START BUTTON
16	CURRENT REGULATING SWITCH
17	TAILSTOCK LOCKING HANDLE
18	DC TRANSFER SWITCH
19	DC AC SELECTOR SWITCH
20	FOOT SWITCH
21	CONTROL CABLE RECEPTACLE
22	110V AC OUTLET
23	CURRENT CONTROL
24	LINE PILOT LIGHT
25	PUMP SWITCH
26	ACTUATOR
27	HEADSTOCK AND TAILSTOCK LEDGES
28	HEADSTOCK CONTACT PLATE
29	AC AMMETER
30	MAGNETIZING CURRENT PILOT LIGHT
31	DC AMMETER

Figure 4.3(3). General-purpose stationary magnetic particle test bench.

Special-purpose stationary units are designed for handling and inspecting large quantities of similar items. Generally, conveyors, automatic markers, and alarm systems are included in such units to expedite the handling and disposition of parts.

b. Demagnetization Equipment. Most common types of demagnetization equipment consist of an open tunnel-like coil through which alternating current at the incoming frequency (usually 60 cycles) is passed (see Figure 4.3(4)). The larger type of equipment is frequently placed on its own stand and incorporates a track or carriage to facilitate moving large and heavy articles. Smaller demagnetization equipment such as table-top units, yokes, or plug-in cable coils, may be feasible for demagnetization of small test items. The large, stationary equipment is preferable when multidimensional test items are involved.

c. Accessories. The number of accessories used in magetic particle testing are extensive. Some are available from the manufacturers of magnetic particle equipment; others are made up for specific purposes. Accessories usually depend on the type and method or application of the test selected. Such accessories are chosen primarily to facilitate and enhance the quality and performance of a given test or test technique. The following list contains frequently used accessories and their applications.

1. Cables - used to carry the current to prod or solenoid.
2. Prods - used for magnetizing of welds, sheet, or plate.

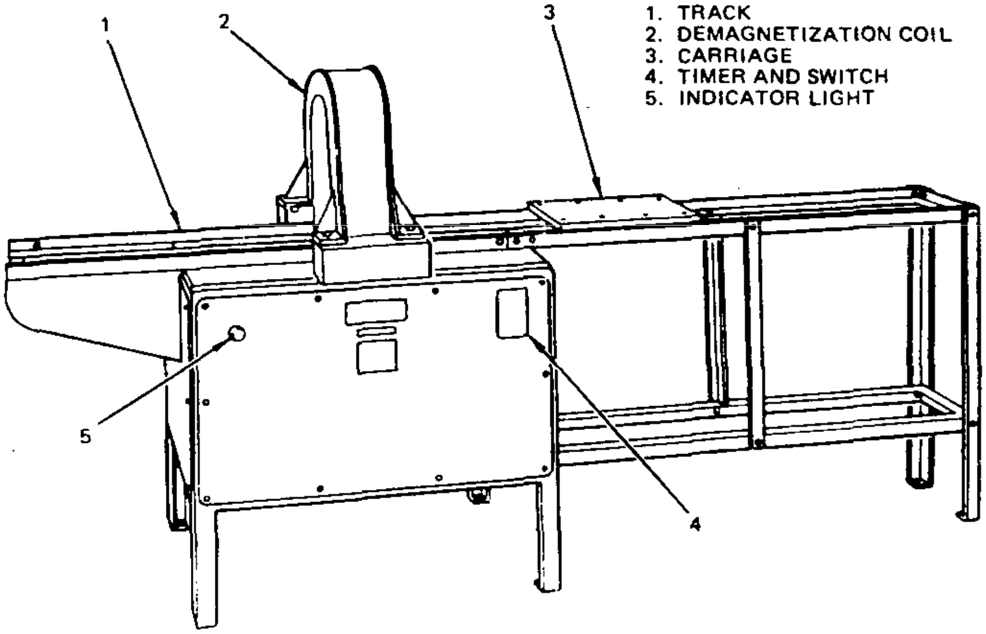


Figure 4.3(4). Demagnetization equipment.

3. Clamps - used instead of prods to facilitate good contact with article or when one-man operation is required.
4. Contact Blocks - used to facilitate cable connection from stationary equipment for external use of prods or coils.
5. Field Indicators - used in measuring residual magnetism in an article.
6. Metal Mesh - used between contact points and article tested to avoid sparking and burns.
7. Liquid Applicators - used in applying fluorescent or nonfluorescent test medium: can be manual, electric, or air operated.
8. Powder Applicators - used to apply magnetic particle powder to the test area: can be a powder-puff or powder blower.
9. Black Light - The use of black light is standard in fluorescent type inspection. In some instances, more than one black light may be desirable. A portable black light may be used with mobile equipment when wet method testing is performed.

4.3.2 MAGNETIC PARTICLE POWDERS

Four properties enter into the selection of satisfactory magnetic particles: magnetic, geometric, mobility, and visibility.

a. Magnetic Properties. It is desirable that the particles of the testing medium possess two important magnetic properties: high permeability and low retentivity. Permeability may be defined as the degree of ease with which a particle is magnetized. Retentivity is that property which enables particles to hold (to a greater or lesser degree) a certain amount of residual magnetism. Particles incorporating high permeability and low retentivity give maximum response in a leakage field, and at the same time do not remain magnetized when they pass out of the influence of the magnetic field.

b. Geometric Properties. The spherical shaped particle offers a high degree of mobility but has low attractive power. The long, slender, jagged particle has a high degree of attractive power and low mobility. A multi-faceted nugget type particle is a good compromise in that it reasonably combines the optimum qualities of the other two types.

Particle size is also an important consideration, and it is desirable to have particles of various sizes. Small particles are required to bridge a tight-lipped crack. Larger sizes are necessary for wider cracks. A weak leakage field is unable to hold a large particle but is able to fix and retain one of smaller size. Thus, dry powder, magnetic particles are usually available in a wide range of sizes - but all are small enough to pass through a 100-mesh screen.

In the wet technique of magnetic particle testing, magnetic oxides of iron are generally used. Although they are extremely fine in size, they are of lower permeability than the metallic, dry particles and have neither the most desirable shape nor variety of sizes available in metallic particles. Fine magnetic oxides are generally used in the technique because they can be suspended in a liquid when a dispersing agent is employed.

c. Mobility. When the particles are brought into the influence of the leakage field of a flaw, they must be free to form a pattern or indication. This freedom is influenced by several conditions, including the shape of the particles and how they are applied to the surface.

In the dry particle technique of magnetic particle testing, particle mobility is obtained by dusting or blowing the particles over the surface of the article. This permits the magnetic field at the flaw to catch and hold some particles as they move by. Mobility is also obtained by vibrating the article after the particles have been applied. Alternating current may be used advantageously because the alternating field causes the particles to "dance" and thus enhances mobility. However, pulsating direct current is sometimes considered superior in other test characteristics.

The principal advantage of the wet technique of magnetic particle testing is the excellent mobility (freedom to move in the three dimensions) of the suspended particles. It is important to use a low viscosity liquid so that the suspended particles are retarded as little as possible by the liquid in which they are suspended.

d. Visibility. So that an indication can be made readily visible, a good light source is essential. Particle color also affects visibility. With various types of part surface finishes (from highly polished to rough castings), no one color of particle is always satisfactory. The choice of particle color is entirely dependent on the test item. The most widely used particles are gray, red, and black. The gray powder has excellent contrast against practically all surfaces (with the exception of certain silver-gray sand-blasted surfaces). Particles coated with fluorescent dye often are used to enhance visibility.

4.4 BASIC PROCEDURES AND TECHNIQUES

Magnetic particle testing can be broken down into five basic steps:

1. Preparation of the test surface
2. Magnetization
3. Application of magnetic particles
4. Inspection
5. Demagnetization and cleaning

Each of these steps are presented with the appropriate test technqiues, where applicable.

4.4.1 PREPARATION OF THE TEST SURFACE

The test surface should be cleaned of grease, heavy coatings of paint, rust, slag, or other materials that would interfere with the mobility of the magnetic particles and the forming of indications. A smooth surface and a uniform color are desired for optimum formation and examination of the magnetic particle pattern. When it is necessary to perform magnetic particle testing on items that have been covered with anti-corrosive protective coatings (such as primers, paints, or cadium-, chromium-, nickel-, or zinc-plating), the coatings do not necessarily have to be removed, since flaw indications are not usually affected. The acceptable thickness limits for such coatings on test items should be checked before conducting a test. In certain cases, coatings are purposely applied to the test item to provide a contrast- ing background for the medium. The acceptable thickness limit of such coat- ings is often up to 0.125-mm (0.005 inch). All holes and openings leading to internal areas where complete removal of magnetic substances or other matter cannot be readily accomplished are plugged. Any material which can be com- pletely removed and is not detrimental to the part may be used for plugging. When necessary, all fraying surfaces or component parts that can be damaged by the bath are masked.

It should be noted that the cleaning of the surface is not necessarily the same thing as cleaning materials out of cracks or flaws that might be on the surface. For liquid penetrant testing (see Chapter 3), the contaminants in the flaws must be removed to allow the entry of the penetrant; but for magnetic particle testing, non-magnetic contaminants do not usually have to be removed from the flaws. This can be an extensive savings in both time and expense. In magnetic particle testing, if current is to be injected into the part, the injection area should also be cleaned to allow good electrical contact.

4.4.2 MAGNETIZATION

To magnetize a specimen, the permeability of the material, the shape and size of the specimen, and the type, size, orientation, and location of the expected discontinuities will all need to be considered. The accessibility of the part, the facilities available, and the required sensitivity of the testing are also parameters that affect the test decisions.

a. Permanent Magnet or Electrical Source. Basically, one has to first decide if the magnetic field source will be established by a permanent magnet or by an electric current. If a permanent magnet is used, then the distance from the poles or distances between inspection points that can be allowed to detect particular discontinuities must be determined for that particular magnet and material. This is usually determined by trial and error. When accessibility, power source, and facilities allow it, fields from current sources will normally be chosen because they provide greater flexibility in terms of the strengths of magnetic fields obtainable and in the shape and direction of those fields. Ability to demagnetize is also increased when electrical currents are available.

b. Alternating, Direct, or Half-Wave Currents. If electric currents are to be used, decisions to use alternating current, direct current, or half-wave or pulsed direct current must be made. It is generally accepted that the best types of magnetizing currents for magnetic particle testing are alternating and half-wave, rectified currents. Alternating current is best suited for locating surface discontinuities (because of skin effect). Half-wave, direct current is best suited for locating below-the-surface discontinuities.

Figure 4.4(1) compares the abilities of various methods to detect subsurface discontinuities. The graph plots amperage against depth of discontinuity. This experiment was performed using the test specimen shown at the lower right in Figure 4.4(1). The lowest amperage that gave a minimum threshold indication at various discontinuity depths was recorded.

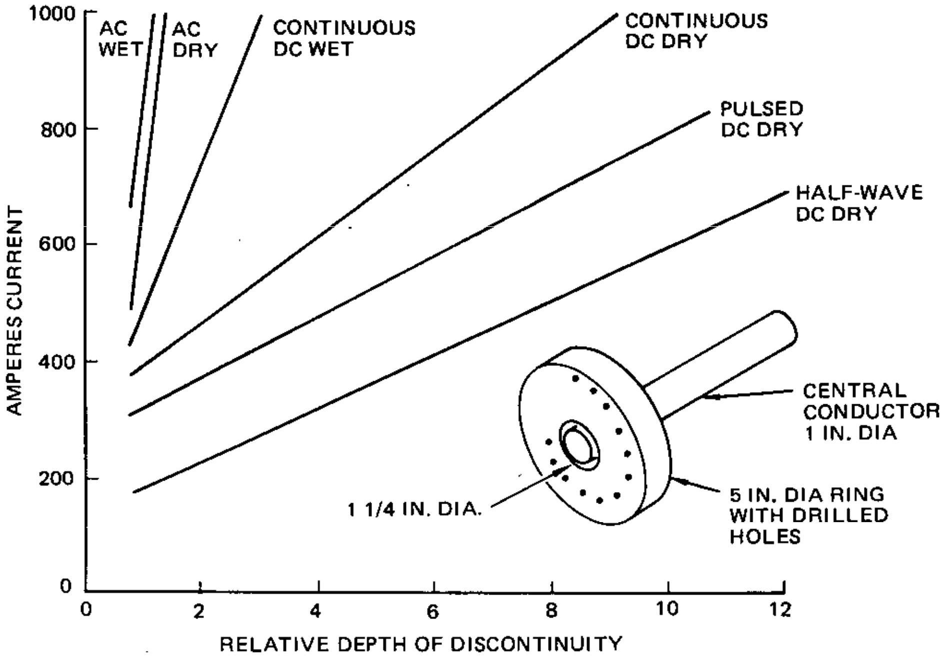


Figure 4.4(1). Threshold sensitivities of various test methods.

The advantage of using alternating current is that the voltage can be stepped up or down by the use of a transformer. Also, the reversal of magnetic fields, due to the alternating current, makes the magnetic particles more mobile, thus facilitating their collection at leakage fields.

The advantage of half-wave direct current is that, by the use of a rectifier, it can be generated from any commercial alternating current source. Penetration is comparable to that of straight direct current with the pulsating effects of the rectified wave being helpful in adding mobility to the magnetic particles.

c. Direction of Current. After the type of current is chosen, the direction of current application must be determined.

Basically, there are two directions usually considered: 1) a "head shot" that establishes a flow of current along the length of the part, resulting in circular magnetization around the part which will locate cracks orientated in the direction of the length of the part, and 2) a "coil shot" that establishes longitudinal magnetization along the length of the part, which will locate cracks oriented perpendicular to the length of the part.

Figure 4.4(2) illustrates a head shot and an alternate version where a central conductor is used. Figure 4.4(3) indicates a coil shot. Figure 4.4(4) indicates other possible current setups.

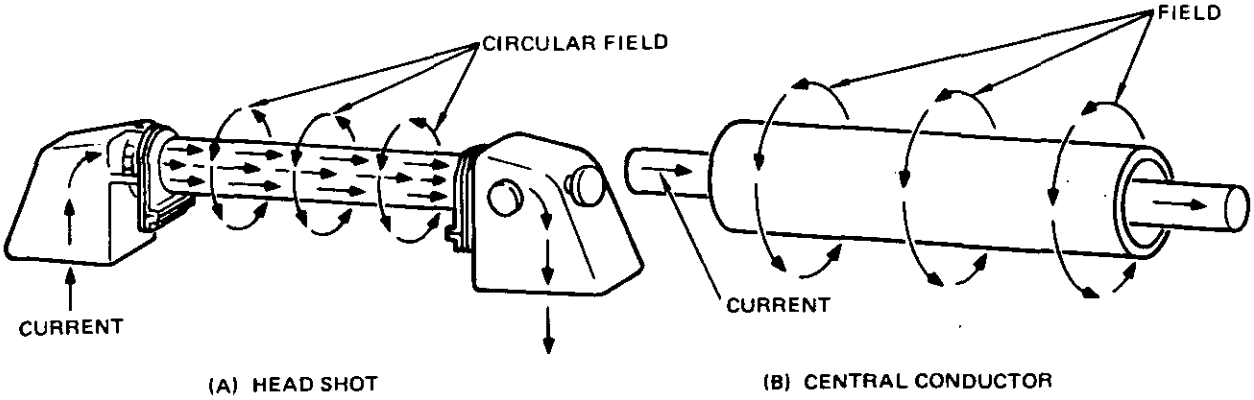


Figure 4.4(2). Circular magnetization by direct and indirect current induction.

Usually setups for more than one direction must be made to ensure that all discontinuities will be seen. It should be noted that in some cases the current may flow through the part, and in other cases through separate conductors or coils.

Magnetization by injecting current into the test item is usually preferred whenever maximum sensitivity to tiny flaws is desired or whenever a magnetic field cannot be conveniently induced in the test item by other methods. However, if the part under inspection is

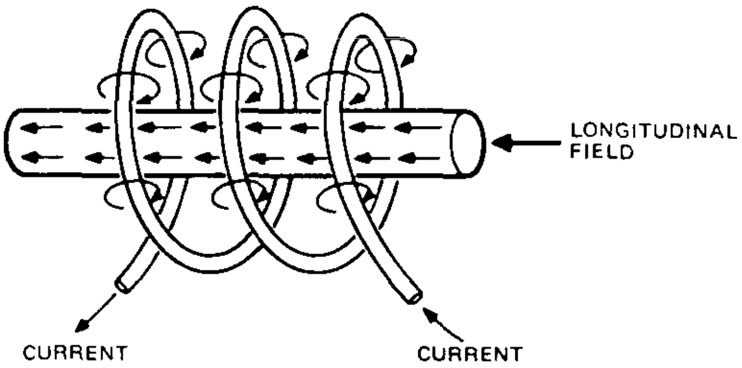


Figure 4.4(3). Longitudinal magnetic fields.

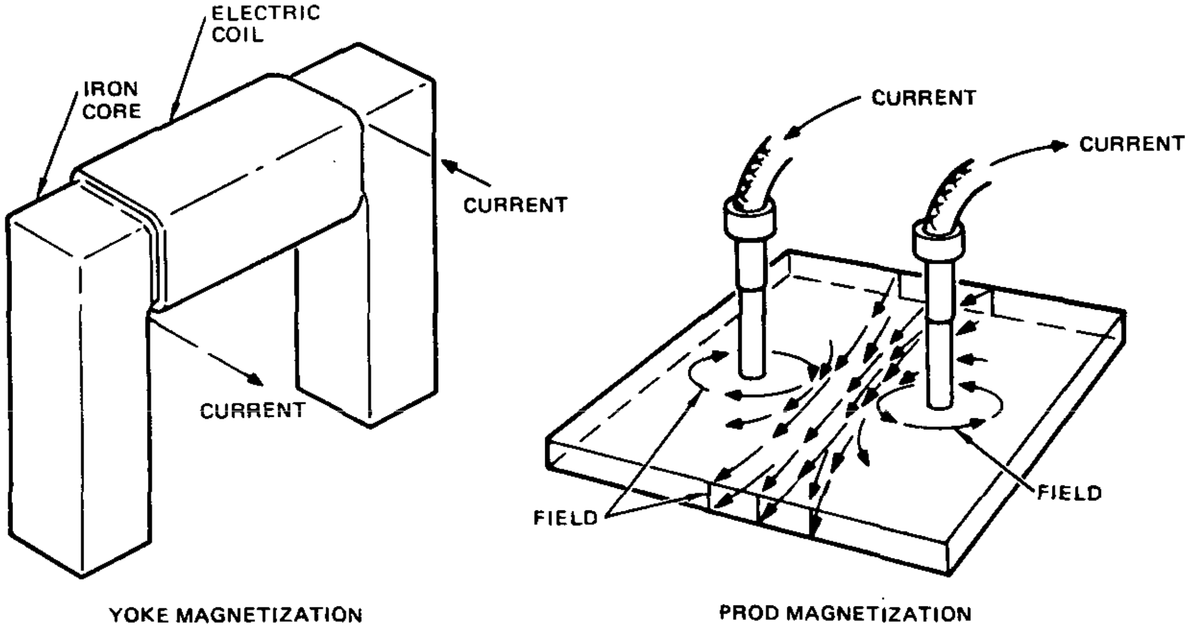


Figure 4.4(4). Magnetization with prods and yokes.

magnetized by injecting current into its surface, care must be taken to avoid arcing as this may severely damage the surface, particularly whenever hand-held prods are used to inject current. Arcing tends to occur whenever the current contacts are dirty or are moved during excitation. A simple way around the arcing problem is to securely clamp the contacts to a clean area. When magnetization is induced by placing the part in an external magnetic field, the arcing problem does not occur.

d. The Amount of Current. The required amount of magnetizing current is affected by the permeability of the material, the shape and thickness of the test specimen, and the type of discontinuity sought. When an article is not uniform in section, it is necessary to use one value of current for the thinner sections and a second, third, or more values of current for heavier sections. In circular magnetization the length of the test specimen does not affect the current requirement. The electrical resistance will, however, increase with length and so will require more electrical energy to develop the required amperage. In longitudinal magnetization, specimen length is a factor to be considered. It is always proper to use the smaller current value first to test the thinner section and then proceed with successively higher currents to test the increasingly larger sections. This procedure avoids overmagnetization of the thinner sections to the point where the residual field is stronger than the field required for that section. Whenever a stronger field has been imposed than is required for a subsequent test, it is necessary to demagnetize the specimen before applying the lower amperage.

For circular magnetization, only enough current to show the indication is normally used. The test gauge of magnetizing current strength is a test specimen with a typical indication. The test specimen is kept and used as a reference and the current required to reproduce the indication is checked from time to time. The recommended values for circular magnetization vary because of the different factors involved. An acceptable rule is to use from 700 to 1200 amperes per inch (280 to 480 amperes per centimeter) diameter or greatest diagonal width of cross section. The amperages shown in Table 4.4(1), therefore, are only suggested averages for various diameters and widths, and may be incorrect for certain alloys and shapes.

Figure 4.4(5) shows test specimens of several sizes and shapes.

1. View A of Figure 4.4(5) shows a multiple diameter, solid specimen, the smaller diameter being 2 inches, and the larger 3 inches. Following Table 4.4(1), and recalling the foregoing discussion, the thinner section is magnetic-particle-tested first, requiring 1400 to 2400 amperes. The second "shot," for the 3-inch diameter section, requires 2100 to 3600 amperes.

2. Views B and C of Figure 4.4(5) illustrate a tubular section first to be tested by a head shot and then by use of a central conductor. It can be seen from Table 4.4(1), that in either case, the current required is the same; i.e., 2800 to 4800 amperes.

3. View D of Figure 4.4(5) illustrates a number of smaller articles (nuts) requiring testing on a central conductor. The maximum outer diameter is 4 centimeters. Table 4.4(1) shows that 1120 to 1920 amperes will be required.

When a coil is used for longitudinal magnetization, the strength of the field is determined by the product of the number of amperes and the number of turns in the coil. For example, a current of 800 amperes through a five-turn coil creates a magnetizing force of 4,000 ampere turns; it is necessary to know how many turns there are in a coil to calculate the magnetizing force. On most stationary equipment, this information is usually shown on the coil; if not,

Table 4.4(1). Magnetizing current for circular magnetization of solid and tubular articles.

Tubular* and Solid Articles		
Greatest Width or Diameter		Magnetizing Current (Approx) In Amperes
In Inches	In Centimeters	
0.4	1.0	280 – 480
0.5	1.3	350 – 600
0.75	1.9	525 – 900
0.8	2.0	560 – 960
1.0	2.5	700 – 1200
1.2	3.0	840 – 1440
1.5	3.8	1050 – 1800
1.6	4.0	1120 – 1920
2.0	5.0	1400 – 2400
2.4	6.0	1680 – 2880
2.5	6.3	1750 – 3000
2.8	7.0	1960 – 3360
3.0	7.6	2100 – 3600
3.2	8.0	2240 – 3840
3.5	8.9	2450 – 4200
3.6	9.0	2520 – 4320
4.0	10.0	2800 – 4800

* With or Without Central Conductor; Measurement Must be Made on the Outside Diameter of the Article.

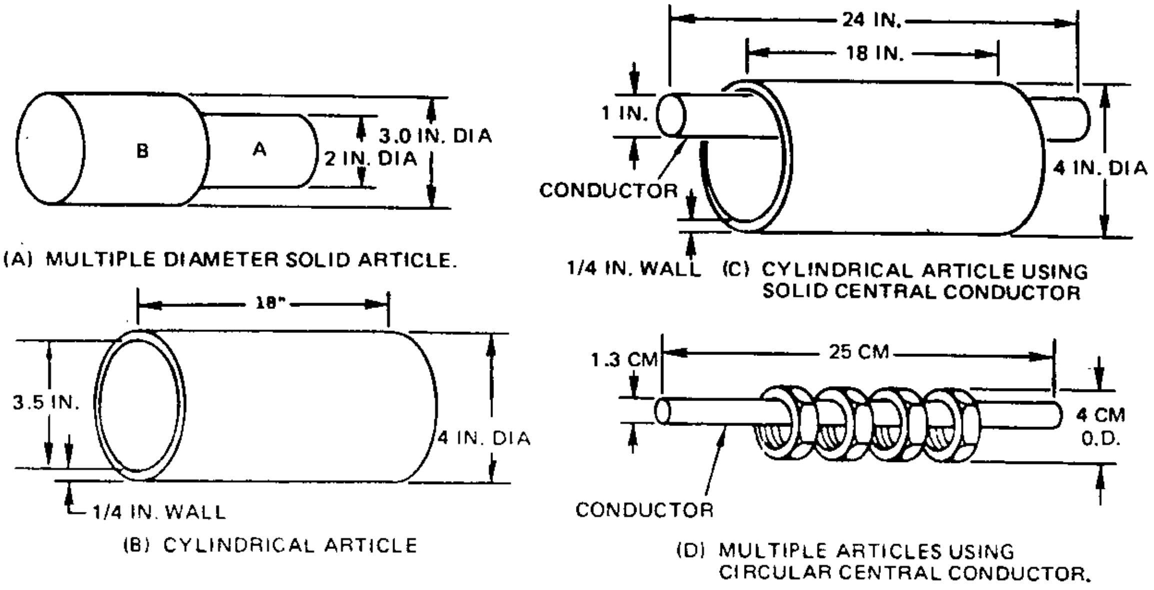


Figure 4.4(5). Circular magnetization of typical specimens using head-shot or central conductor.

it may be obtained from the equipment manufacturer. Another type of coil used is the wrapped cable. This is frequently used when an article is either odd-shaped or too big to handle on the equipment.

For reliable coil magnetization (longitudinal), the article to be magnetized must be at least twice as long as its diameter, or width. This relationship is known as the length-diameter (L/D) ratio. The L/D ratio and the number of turns in a coil determine the required amperage for coil shots, providing the following conditions are met.

1. The article has an L/D ratio of between 2 and 15.
2. The article or section thereof to be magnetized is not greater than 18 inches (46 cm) long.
3. The cross-sectional area of the article is not greater than 1/10 the area of the coil opening.
4. The article is held against the inside wall of the coil and not positioned in the center of the coil.

If the foregoing conditions are met, then the formula for determining a correct amperage is:

$$\text{AMP} = \frac{45{,}000}{L/D} \times \frac{1}{N} \text{ or } \frac{45{,}000\ D}{LN}$$

where:

45,000 = constant
L = length
D = diameter
N = number of turns in coil

Assuming a solid article, 12 inches long (L) by 3 inches in diameter (D), and a coil consisting of 5 turns (N) was available, then the required amperage is determined as follows:

$$\frac{45{,}000\ D}{LN} = \frac{45{,}000 \times 3}{12 \times 5} = 2250 \text{ Amperes}$$

The formula may be used for any number of coil turns. Theoretically, the more turns of cable, the stronger the field though there is a limit to the number of turns (5 when using alternating current) that will increase the flux density. Also, an excessive number of turns will have a heating effect. Since the effective field is limited by the size of the coil, several shots may be required when testing a long article.

The correct flux density is somewhat easier to determine when using prods because it is possible to vary either the current setting on the equipment or the spacing between the prods. If the accumulation of particles between the points of the prods is too heavy, the particles tend to form bands. Banding indicates that the field strength is too great and should be reduced by either lowering the amperage or increasing the space between the prods. Spacing between the prods varies, depending on the size and thickness of the article to be tested; 6- to 8-inch (15 to 20 cm) spacing is found to be most effective on larger articles. American Society for Testing and Materials Standard E709 provides additional guides on magnetization requirements.

4.4.3 APPLICATION OF MAGNETIC PARTICLES

Once the proper level of magnetic flux has been established in a part, magnetic particles are applied. Normally this application is made while the magnetic field source is "on." It is possible, however, where materials exhibit high retentivity, for the residual magnetic field to be adequate for testing, and the magnetizing source can be removed. When the magnetizing source can be removed, the test specimen can be placed in an immersion bath where the magnetic particles are suspended in a liquid. A bath allows maximum particle mobility and usually uniform coverage of the part by the magnetic particles with improved sensitivity and consistency in the test results.

Often the application of particles is by a dry method or by a wet flow. The dry magnetic particles are commonly applied from shaker cans or bulbs. The dry method is probably the simplest application method, but certainly not always the best. Automatic particle-blowing equipment can be used. They are economical in their use of particles and, on most tests, are an acceptable way of "flowing" dry particles over the test surface. A minimum flow velocity is desired in this process.

Wet suspensions can be sprayed or otherwise caused to flow over the surface. Again, velocity of flow is important. The flow should not be so strong that the indications are destroyed.

For the wet flow or bath method the liquid used is usually a light oil. Water, suitably treated with anti-corrosion, anti-foam, or wetting agents may also be used. Ideally, this liquid should not be fluorescent and, for safety purposes, the liquid should be non-toxic and non-volatile and should have a high flashpoint.

The particles are usually obtainable in a dry form, a paste form, or in a highly concentrated liquid form and may be either fluorescent or nonfluorescent. To achieve the required test sensitivity, the degree of particle concentration in the bath must be correct - too light a concentration leads to very light indications of discontinuities; too heavy a concentration results in too much overall surface coverage, which may mask or cause incorrect interpretation of discontinuity indications. Table 4.4(2) lists the preferred particle concentration for wet suspensions. Check applicable specifications for exact allowable concentrations.

While the bath is in use, it must be constantly agitated to maintain the particles in suspension. A short period of agitation prior to use is desirable. Agitation is usually accomplished by electrically driven pumps or by compressed air. Compressed air agitation, while effective, is the less desirable since moisture and foreign matter carried by the air may contaminate

Table 4.4 (2). Concentration for wet suspensions.

Type Particles	Oz. Particles/Gal Suspension	ML or CC Particles/ 100 ML or 100 CC Liquid
Nonfluorescent	See Manufacturer's Instructions	1.0 - 2.4
Fluorescent		0.1 - 0.5

the bath and shorten its useful life. The particle concentration should be checked periodically since the liquid can evaporate and particles are lost as they are removed from the bath on the test specimens.

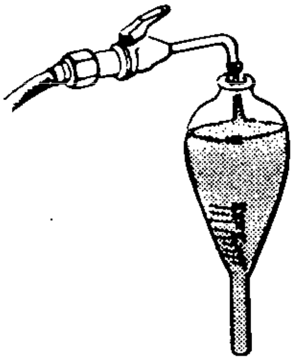
A simple test for particle concentration is the "settling test" shown in Figure 4.4(6). The suspension is agitated for 30 seconds to assure an even distribution of the particles in the liquid. Then, 100 cc (ml) of the bath is pumped through the hose nozzle into the pear-shaped centrifuge tube and allowed to settle for 30 minutes. The amount of particles (measured in cc or ml) settling in the bottom of the centrifuge indicates the concentration of solid matter (particles) in the bath. In measuring the solid matter in the centrifuge, foreign material such as lint and dirt, which settles on top of the particles, is not considered. If the particle reading is high, liquid (vehicle) is added; if low, paste or liquid concentrate containing particles is added. Paste is never directly added to the bath because it might not disperse properly. The paste should be premixed with sufficient bath solution that it can be poured into the holding tank.

When in use, the bath eventually becomes contaminated by dirt, lint, and chips to a degree that efficient formation of discontinuity indications is hindered. Degree of contamination is determined by the amount of foreign matter settling with the paste in the bottom of the centrifuge tube during the settling test. The bath should be checked on a regular schedule depending on the inspection volume: weekly if the volume is high; monthly if the volume is low. When the bath is contaminated beyond usefulness it is discarded, the bath tank and the liquid system is thoroughly cleaned, and a new bath is mixed. Contamination can be minimized by keeping the bath covered when not in use.

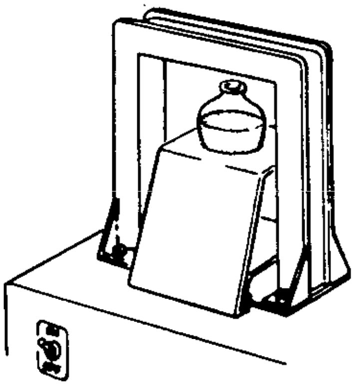
4.4.4 INSPECTION

Indications of discontinuities located on the surface usually appear in sharp distinct lines, whereas discontinuities located below the surface appear as irregular, rough, hazy indications. The width of a subsurface discontinuity indication varies with the depth of its location below the surface. Correct interpretation of indications caused by subsurface discontinuities requires a certain amount of skill and experience on the part of the operator.

1 AGITATE THE SUSPENSION THOROUGHLY TO ASSURE PARTICLE DISTRIBUTION
2 FILL 100cc (100 ML) SAMPLE FROM THE DELIVERY HOSE INTO A 100cc (100 ML) GRADUATED CENTRIFUGE TUBE OR GRADUATE.
3. PLACE CENTRIFUGE IN STAND



4 DEMAGNETIZE, IF NECESSARY (IF CLUMPING OCCURS).



5 ALLOW TO SETTLE FOR 30 MINUTES.
6 TAKE READING AND RECORD IN THE LOG.
7 ADJUST BATH EITHER BY ADDING PARTICLES OR LIQUID AS NECESSARY.

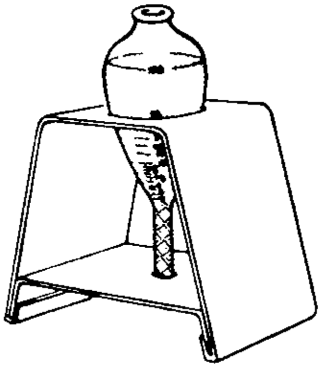


Figure 4.4(6). Settling test procedure.

4.4.5 DEMAGNETIZATION AND CLEANING

Ferrous materials usually retain some residual magnetism after the magnetizing current is shut off. The strength of the residual field depends upon the retentivity of the material, and the strength and direction of the magnetizing force. Complete demagnetization is difficult if not impossible to obtain;

thus, the demagnetization process is limited to reducing the residual field to an acceptable level. The basis for all demagnetization methods is the subjecting of the magnetized article to the influence of a continuously reversing magnetic field that gradually reduces in strength causing a corresponding reversal and reduction of the field in the article. Although some residual magnetization will remain, the method quickly reduces the field to insignificant proportions. Figure 4.4(7) shows graphically how the method works. On the right the graph represents the reversing and reducing magnetic field in the article. On the left are the hysteresis curves corresponding to this action.

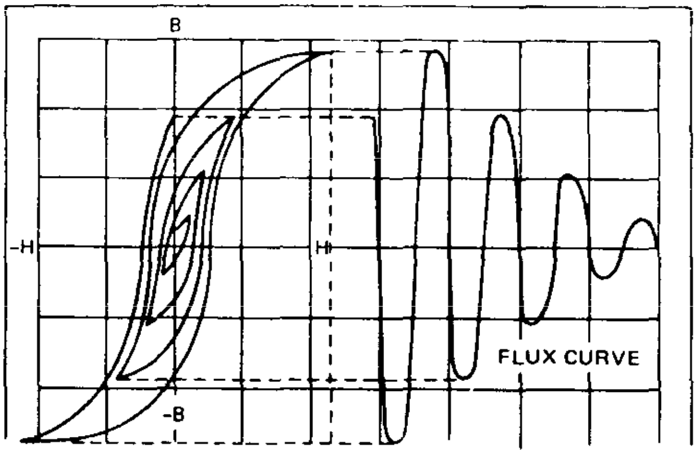


Figure 4.4(7). Demagnetization flux-curve projected from hysteresis curve.

The most convenient method of demagnetization uses a specially built demagnetization coil (see Figures 4.3(4) and 4.4(8)). When such a coil is energized by passing the current through its windings, it induces a magnetic field in the article placed in the coil. Since current direction reverses itself, the polarity of the induced magnetic field also reverses with each reversal of the current. As the article is withdrawn from the coil, the magnetic field becomes weaker the further the article is withdrawn from the coil. Demagnetization is accomplished only if the article is removed from the influence of the demagnetizing coil while the current is flowing; if the current is stopped while the article is still in the influence of the magnetic field the article may still retain some magnetism.

Since the magnetic field produced by alternating current does not penetrate very deeply below the surface of the material, some articles may be difficult to demagnetize completely. This is particularly true with large, heavy, or unusually shaped articles. Direct current can be used to demagnetize if provisions for controlling the amount of current and for reversing the direction of the current are made. Direct current demagnetization is usually more complete and effective than alternating current demagnetization. Some magnetic particle testing equipment is provided with facilities for dc demagnetization. Without such equipment, dc demagnetization is a slow operation. Demagnetization is preferably done on individual articles rather than on groups of articles.

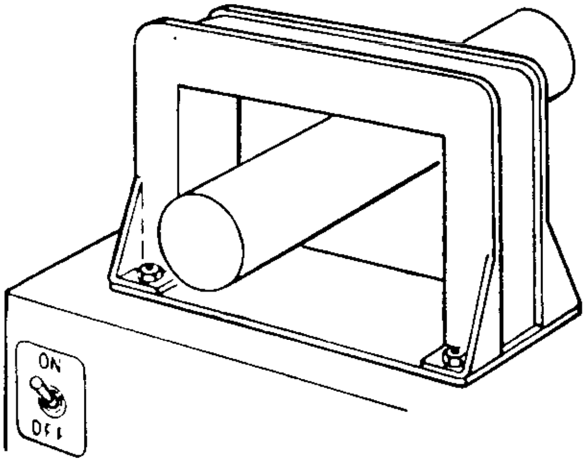


Figure 4.4(8). Demagnetization coil

a. To demagnetize with direct current, the article is placed in a coil connected to a source of direct current. The current is adjusted to a value at least as great (but usually greater) than that initially used to magnetize the article. A magnetizing shot is given at this initial value. The direction of the current is then reversed, the current value reduced, and a magnetizing shot is given at the new value. This process of reversing and reducing the current is continued until the lowest value is reached.

b. For best results in demagnetization, the diameter of the demagnetization coil is just large enough to accommodate the article. If demagnetization of a small article is performed in a large coil, the article is placed close to the inside wall or corner of the coil, since the demagnetization force is strongest in that area.

For practical purposes, it is always correct to utilize a field indicator after performing demagnetization to determine that residual field strength has been reduced to a desired level. The field indicator is a small, pocket-sized device that measures the strength of a field against a set of small, enclosed, permanent magnets which restricts the needle movement on a relative scale. Whether to demagnetize an article or not depends on a number of factors.

a. Demagnetization is usually required if:

1. A strong residual field interferes with subsequent operations, such as welding or machining. Strong fields can "flow" the weld metal as it is deposited, or magnetic chips may cling to the cutting tool and interfere with machining.

2. The article is a moving part of an assembly and a deposit of accumulated magnetized particles might cause wear.

3. Leakage fields interfere with nearby instruments that work on magnetic principles; for example, compasses or indicators of various types.

4. Residual fields interfere with proper cleaning of the article.

5. The article is to be magnetized at a lower magnetizing force in a different direction than the original or previous test.

6. Specified by procedural standards.

b. Demagnetization is usually not required or necessary:

1. On articles of soft steel or iron where retentivity is low.

2. If, after the magnetic particle test, the article is to be heat-treated.

3. On large castings, weldments, or vessels where residual fields will have no material effect.

4. If the article is to be magnetized again in another direction with the same or a greater magnetic force.

5. If the article is likely to become remagnetized during handling by being placed on a magnetic chuck, or lifted with an electromagnetic lifting fixture.

Magnetic particles should be completely removed from the specimen after test and demagnetization. Cleaning is accomplished by use of air, solvents, washes, and wiping equipment suitable to the size and complexity of the task. After cleaning, the article is returned to its original state by the removal of all plugs used to seal holes and cavities during the testing process.

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4.5 STANDARDS

There are several factors that make the need for standards less important for magnetic particle testing methods than for most NDT methods. First, the indications appear directly over the discontinuities and the interpretations are usually fairly direct. The process itself indicates the adequacy of the test in that over or under-saturation conditions can usually be sensed by an experienced operator. Still, standards are desirable. Especially valuable are actual examples of the inspected parts that have known flaws which can be, at any time, tested to confirm the adequacy of any step used in the procedures.

Since magnetic fields cannot be directly seen, a gauss meter can aid in standardizing tests. A gauss meter is especially useful where an inspected part has complicated geometries; e.g., sections with different cross-sectional areas. The gauss meter can ensure that each area has an appropriate field strength for testing. A gauss meter is also useful when demagnetization is required.

Reference photographs may be important if a long-term program is involved, or if a large number of inexperienced inspectors must be used. Reference photographs must be carefully prepared to establish an adequate one-to-one correlation to that being inspected. The color, size, and orientation must all be considered. Distance scales placed on the top or bottom or both sides of each photographed image should be used to establish the true perspective exhibited by the photograph. Reference photographs should show both acceptable and non-acceptable conditions. In addition, reference photographs showing actual limits - indications this large or smaller are acceptable, or indications this small or larger are rejectable - are of great value. ASTM E125, "Reference Photographs for Magnetic Particle Indications on Ferrous Castings," describes a set of reference photographs that are commercially available for ferrous castings. MIL-STD-1949 references MIL-M-47230 for acceptance criteria.

For a production process, magnetic particle test standards are essential. What usually happens is the bath becomes contaminated with use. The build-up in contamination tends to occur slowly. A well designed standard will be sensitive to the build-up in contamination and trigger the time when a change in bath is needed. Picatinny Arsenal (now Army Armament Munitions & Chemical Command) has used magnetic particle test standards for artillery projectiles since 1965. Used are relatively large plugs of identical material that are press-fitted into the wall of the metal part. The plug diameters are finely surface finished as are the receptor holes. The plugs are shrunk by freezing, pressed into place, and contour machined to match the mating surfaces. The criterion for continued magnetic particle testing is a clearly visible continuous circle around each plug. When an indication of a plug breaks down from one complete circle to two half circles, then it is time to dump the bath, clean the tank, and charge a new bath.

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4.6 APPLICATIONS

Magnetic particle testing can be applied to finished articles, billets, hot-rolled bars, castings, and forgings of all ferromagnetic or magnetizable materials. It can also be used to check that processing operations such as heat treat, machining, and grinding did not uncover or cause discontinuities in these materials. Since a large amount of structural parts today are made of magnetizable materials, magnetic particle testing is one of the most widely applied nondestructive test methods.

For ferromagnetic materials, magnetic particle testing is normally better than liquid penetrant testing for two important reasons: the magnetic particle testing can find subsurface flaws that liquid penetrant testing cannot find and, for most cases, the contamination in surface flaws does not have to be removed. Also, the magnetic particle testing can be quicker, since the dwell times required for liquid penetrant are not needed.

There are conditions when the application of magnetic particle testing is inappropriate. There are situations where special demagnetization problems may prevent the use of this method. The presence of residual magnetic forces may interfere with subsequent operations or use of the part. Normally, however, magnetic particle testing can be applied throughout all phases of the manufacturing cycle and service life of production parts that are made from ferromagnetic materials. The flourescent dyes used on the magnetic particles are much less brilliant than the flourescent dyes used in liquid penetrants.

The biggest problem with magnetic particle testing is human error. Visual inspection is the means for segregating cracks from scratches. Magnetic particle testing can become impractical when the signatures of cracks are identical to the signatures of scratches.

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4.7 SPECIFIC GUIDELINES

The following guidelines must be combined with the guidelines given in Chapter 1 to be complete. Chapter 1 includes general guidelines for all NDT methods.

4.7.1 GUIDELINES FOR DESIGNERS

Designers are not always aware of the magnetic properties of their materials. Errors are often made by requiring magnetic particle testing of a nonmagnetic materials (such as austenitic stainless steels) or by overlooking the use of magnetic particle testing on materials that are magnetic.

Magnetic materials include most of the iron, nickel, and cobalt alloys. Some materials are magnetic only after aging (17-4 PH, 17-7 PH, and 15-4 PH stainless steels). All magnetic materials lose their magnetic properties when their temperature is at or above the curie point. For many materials, this is approximately 760°C (1400°F). Materials that are not magnetic include aluminum, magnesium, copper, titanium, and most of their alloys.

4.7.2 GUIDELINES FOR PRODUCTION ENGINEERS

Magnetic particle testing is extensively used by production engineers when components are manufactured from ferromagnetic materials. The fact that magnetic particle testing can also be used to inspect most manufacturing equipment is often overlooked. This inservice testing, checking for developing cracks, etc., can save much time and expense by preventing delays and downtimes due to unexpected failures of the manufacturing equipment itself.

4.7.3 GUIDELINES FOR QUALITY ASSURANCE

Magnetic particle testing, as with most NDT methods, is highly dependent upon the NDT technician for successful operations. Training and proper attitudes are a must, and constant attention should be given to all areas that affect these important parameters. Standards, although not as important in magnetic particle testing as for many of the other NDT methods, are still necessary, and should be a part of any formal program.

4.7.4 GUIDELINES FOR THE NDT ENGINEER

There is great flexibility in magnetic particle testing. New uses and methods are continuously coming forth. Magnetic paints, magnetic rubber, and magnetic printing methods are examples of specialized approaches. Positive or permanent recordings of indications are possible with lacquer or plastic-film sprays. There is a wide range of magnetic sources that produces a variety of shapes and magnitudes of magnetic fields.

Magnetic particles can vary in their shape, size, permeability, color, retentivity, and mobility. There is always room for experimenting and perfecting new methods and procedures. As an engineer in magnetic particle testing, there is no room for complacency. New methods or approaches should be continuously considered.

Magnetic particle testing has great merit when used during the start-up of production. Magnetic particle testing rapidly reveals the locations where flaws occur. This information permits quick modifications in production to reduce the occurence of flaws.

4.7.5 GUIDELINES FOR THE NDT TECHNICIAN

In magnetic particle testing, attention to details, as in all NDT methods, is vital. Magnetic particle testing equipment is subject to breakdowns, magnetic particles can become contaminated or "diluted," and "permanent" magnets are not always permanent. Therefore, if differences in the tests are observed or suspected, they should be noted and discussed with the NDT engineer.

A magnetic particle inspector should be sensitive to the degree of magnetic saturation that is being applied. An inspector should often check this magnetization. Too much magnetization or full saturation causes false indications to appear. These false indications can usually be identified by their shape and location. They usually shift locations as the probes are moved and do not remain at fixed points on the part. Too little magnetization can result in loss of valid indications. An inspector, if he does not have a gauss meter, can change the distances between his probes and/or the amount of current being used to check these saturation limits. He should vary his probe spacing and/or current as often as necessary to remain within an acceptable range. If the material being tested has high retentivity, then the inspector must exercise some care if the same point on the part is to be used to explore for the saturation limits. A complete demagnetization between each check is ideal. If direct current is being used, a change in current direction (or exchanging the positions of the probes) between each test can help reduce the retentivity effect. In no case should a check at a lower current follow a higher current check without appropriate demagnetization.

4.8 SAFETY

Where electrical currents are used to establish magnetic fields and to demagnetize parts, standard safety practices relating to electrical equipment must be observed. This includes the care and handling of electrical cords, observing proper connections and grounding of equipment, and the use of fuses and/or circuit breakers. The magnetic circuit itself is usually a low voltage, high current circuit. Therefore, the greatest danger is from heat or high temperatures usually generated at the points of contact of the circuit.

Where fluorescent magnetic particles or strong chemical dyes are used, some care should be exercised in handling these materials. Spillages are sometimes difficult to clean up. Protective clothing (gloves, aprons, and breathing masks) can be important under some conditions, especially if dry, air-blown particles are escaping into the surrounding atmosphere.

With the use of fluorescent particles, ultraviolet light sources must be used. In using these light sources, special safety precautions must be exercised. The filters used for these lights must be carefully checked to insure that they are not cracked and do not allow harmful rays to escape.

Loose magnetic specimens, or even loose magnetic coils, etc., can be a problem when strong magnetic forces exist. Pinched fingers or damage to parts can occur if loose parts are pulled together or moved out of position due to these magnetic forces.

Dry cleaning solvents which cannot be used for suspending particles in the wet particle technique, because they have an inherently low flash point (below 100 °C 212 °F). Proper safety precautions must be adhered to when they are used. The use of light oils with higher flash points is recommended for safety reasons. Precautions should be taken to prevent inhaling of dry particle materials. The use of suitable face masks is recommended.

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4.9 GLOSSARY

Reference ASTM E-269 "Standard Definitions of Terms Relating to Magnetic Particle Examination.

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