# Magnetic Particle Inspection—SAE J420 MAR81

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# ϕ MAGNETIC PARTICLE INSPECTION—SAE J420 MAR81 SAE Information Report

Report of the Iron and Steel Technical Committee, approved June 1952, completely revised March 1981.

*Purpose*—The purpose of this report is to provide general information relative to the nature and use of magnetic particles for nondestructive testing. The report is not intended to provide detailed technical information, but will serve as an introduction to the theory and capabilities of magnetic particle testing, and as a guide to more extensive references.

*General*—Magnetic particle inspection is a nondestructive means of inspecting ferromagnetic materials such as iron and steel for discontinuities (cracks, seams, near surface inclusions) by the detection of leakage fields through the use of magnetic particles.

Magnetic particle inspection is an aid to visual inspection of objects. Surface discontinuities that might not be seen with the aid of optical magnification are often dependably detected in manufacturing operations or maintenance. It is not applicable to nonmagnetic materials. The usual basic steps in magnetic particle inspection of an object are: clean, magnetize, apply magnetic particles, inspect, and demagnetize. Post cleaning is frequently done. Magnetic particle inspection is a relatively simple procedure. It is most effective when the various factors, such as types of magnetization, current, particles, equipment, and method, are properly selected for the application.

*Principle*—The principle of magnetic particle inspection is the accumulation of particles due to magnetic leakage at discontinuities in a magnetized test object. The material subjected to the inspection is magnetized in a fashion which will produce north and south poles on opposite edges of a discontinuity. Finely divided magnetic particles are introduced into the leakage field between the poles, and are held there by the magnetic leakage flux. The visible accumulation of these particles is called an indication.

*Procedure*—A magnetic field is induced in the part to be tested by the application of an electric current through the part, or through a central conductor inserted through a hole in the part, or by means of a yoke, prods, or coil. The type of magnetization selected is determined primarily by the need to establish magnetic flux lines perpendicular to the direction of anticipated surface imperfections. Any discontinuity at or near the surface of the part will interrupt the magnetic flux induced in the part and a leakage field will be formed at the surface of the part. Magnetic particles in the vicinity of this leakage field will be attracted to it, forming a visible indication which, to experienced interpreters, expresses the characteristics of the discontinuity. Following the creation of the indication, the interpretation of the indication, and the evaluation of the discontinuity, the part is suitably demagnetized and, where required, cleaned.

Adequate light must be provided for the quick and sure detection of the indications of discontinuities. Lights should be adjusted to give broad highlights on finish machined parts. If fluorescent lighting is used, the tubes should be located transverse to the long axis of the parts being inspected. A nominal illumination level of 100 ft-c (108 lx) of white light should be present on the part surface in the case of nonfluorescent inspection. Personnel should have eyesight, corrected or uncorrected, capable of distant vision of 20/30 in at least one eye and should be able to read Jaeger Type No. 2 with both eyes at 12 in (305 mm).

An adequate source of long wave ultraviolet light (approximately 3650 Å, colloquially known as *black light*) must be provided for inspection when using the fluorescent magnetic particle inspection method. A filtered high-pressure mercury vapor source is generally recommended. The emitted light should have an intensity of 90 ft-c (97 lx) at a 15 in (380 mm) distance from the source, or no less than 900 $mW/in^2$ (140 $mW/cm^2$) on the part surface. For detection of certain fine indications, illumination at the part surface may need to be as high as 250 ft-c (270 lx). Personnel vision requirements are the same as for nonfluorescent inspection, but in addition, visual acuity in the green-yellow spectrum must be satisfactory.

Demagnetization consists of removing objectionable residual magnetic fields from parts which have been subjected to magnetic particle inspection. This must be done to prevent the deflection of adjacent sensitive instruments and to prevent the attraction of small magnetic chips, or the like, which could cause damage to contacting surfaces. The most common type of demagnetization consists of drawing the magnetized part through a high intensity alternating current solenoid. Another type, often used on heavier parts, consists of passing an alternating current or reversing direct current through the part or through a surrounding solenoid, and then gradually reducing the current value to near zero. Demagnetization is sometimes effected in subsequent processing, such as heat treatment, or hot washing, of a part. Effectiveness of the demagnetizing is usually determined through use of inexpensive meters made for this purpose.

Irons and steels exhibit magnetic characteristics which vary with hardness and composition. Continuous magnetization during particle application is used on relatively soft steels since they usually do not retain sufficient magnetism to allow the use of the residual method. These steels are processed for inspection by introducing the magnetic particles into the leakage fields created at the discontinuities while the magnetizing force is present. Parts processed in this way are said to be processed by the *continuous* method. Use of the continuous method makes possible the successful inspection of irons and steels which do not retain sufficient magnetism for processing by the residual method. In addition to this, certain subsurface discontinuities are easily detected in both hardened and unhardened parts by this method when direct current magnetization is employed.

The residual magnetization test method may be applied to hardened steels, and other highly retentive materials, since they will retain magnetism after the force has been removed. These remaining magnetic fields will produce leakage fields adjacent to discontinuities strong enough to hold magnetic particles and produce indications. Parts processed through the use of these retained fields are said to be processed by the *residual* method. Use of the residual method often eliminates nonrelevant indications. It is especially useful for the detection of surface discontinuities in hardened parts. An adequate level of magnetization is required.

Wet particles used in suspension liquid usually consist of finely ground magnetic oxide of iron. These particles are coated so they can be easily dispersed in a liquid vehicle. They are generally available in powder form having red or black nonfluorescent colors. They are also available coated with a material which fluoresces under long wave ultraviolet (black) light. Wet particles are commonly used in maintenance, process, and finish inspection of machine and engine parts. The wet process offers the advantage of ease of application of the particles, sensitivity in locating the finest discontinuities, and, especially with the fluorescent particle, rapid inspection rates.

Dry particles consist of finely divided magnetic material in powder form. These particles are coated so as to be easily conveyed by air to the part being inspected. They are generally available in many colors for maximum contrast with the test object. Dry particles are commonly used for the maintenance, process, and finish inspection of heavy weldments, heavy castings, and heavy forgings. Dry particles are superior for the inspection of very rough surfaces and for the location of subsurface discontinuities in rough castings, forgings, and weldments.

Circular magnetization consists of inducing a circular magnetic field in a part so that the magnetic lines of force take the form of concentric rings about the axis of the current. This is accomplished by passing the current directly through the part, or by passing the current through a conductor which passes through a hole in the part, sometimes by use of prods. The circular method is used chiefly to indicate discontinuities radiating from and parallel to the axis of the current flow.

Longitudinal magnetization consists of inducing a longitudinal magnetic field in a part by making it the core of a solenoid, such as placing it in a coil or by making it a link in a magnetic circuit through use of a yoke. In a part so magnetized, the lines of force will be parallel to the axis of the solenoid, and the part will exhibit the properties of a bar magnet. The longitudinal method is used to indicate discontinuities transverse or circumferential to the long axis of a part.

Moving field magnetization consists of inducing fields in a part in more than one direction almost simultaneously. The fields induced may be a combination of circular and longitudinal or may be a combination of either type. The moving field method may be used on many parts ordinarily requiring two or more distinct magnetization and inspection operations. The moving field method, because of the rapidly changing field directions, makes possible the location of all detectable discontinuities after only one processing. This may, in some cases, eliminate a great percentage of the time required for the inspection if the parts were processed by more conventional methods.

Alternating current magnetization is commonly used for moderately stressed parts in production and for the detection of fatigue discontinuities due to service. Alternating current magnetization is always equal to, and often superior to, direct current magnetization for the detection of surface discontinuities. Subsurface discontinuities are not revealed when alternating current is used. In moderately stressed parts, this greatly simplifies inspection.



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The ϕ symbol is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. If the symbol is next to the report title, it indicates a complete revision of the report.