Fundamentals of Magnetic Particle And Electromagnetic Induction Inspection of Oil Country Tubular Goods

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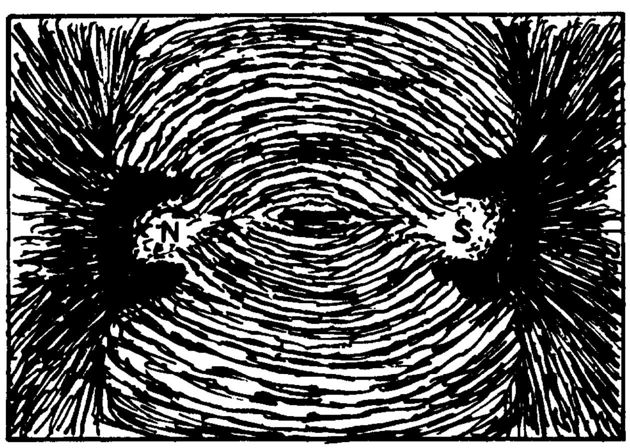
Since a need for the field inspection of oil country tubular goods was recognized many years ago, the application of nondestructive testing of oil country tubular goods has continued to expand. The initial inspection used was an optical inspection with magnetic particle inspection being introduced in the early '40's and the addition of electromagnetic induction inspection in the late '40's. Since that time, the rapid increase of so-called critical pressure and depths of wells have greatly increased along with the introduction of higher and higher yield tubulars for those criteria. These factors coupled with increasingly stringent API specifications make field inspection an important part in the planning and successful completion of today's wells. The steel mills today are producing better and better tubular goods and are employing many very sophisticated inspection devices to comply with API specifications. However, this production line type inspection is limited to its effectiveness and a few defective pieces would ultimately reach the end user if a field inspection were not performed. Recent computations compiled from inspection reports reveal that 1-1/2 to 2 per cent of these tubes above N-80 grade are found not to meet API specifications, and about 4 per cent of lesser grades are found not to meet API specifications when inspected.

Many different types of nondestructive tests are now employed other than those previously mentioned; however, this text will be limited to the discussion of magnetic particle and electromagnetic induction inspection of oil country tubular goods. Magnetic particle inspection and electromagnetic induction inspection are limited to the inspection of ferro-magnetic materials. These inspections detect anomalies which create a discontinuity in the magnetic field created by an external power source. A specimen to be examined is subjected to a direct current magnetizing force in a direction which will create flux lines normal to the plane in which the specimen is to be examined. In other words, a longitudinal field is used to inspect for traverse defects, and conversely, a circular or traverse field is used for the detection of defects in a longitudinal orientation.

Where defects are present, a flux disturbance will be effected and may be detected by two means; one is the use of magnetic particles, and the other is by electronic sensing devices.

The use of magnetic particles is the simplest and, of course, the method in use for the longest time. This type of inspection is based upon a phenomenon of which we are all familiar. If one should overlay a bar magnet with a sheet of paper and dust it with magnetic powder (iron powder), an outline of the flux lines or magnetic lines of force is readily seen (Fig. 1).

If two bar magnets are placed as shown in Fig. 2, the lines of flux take a path as shown. It may be noted that the margin of the two bar magnets is delineated by the disturbance of the flux field so long as there exists physical discon-

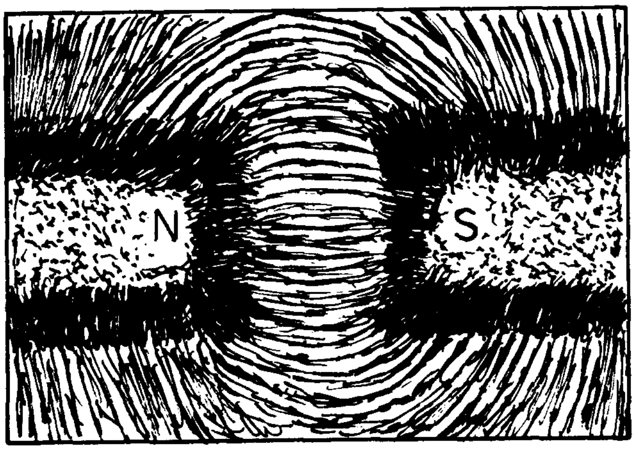


Outline of Flux Lines Subjected to Magnetism of One Bar Magnet.

FIGURE 1

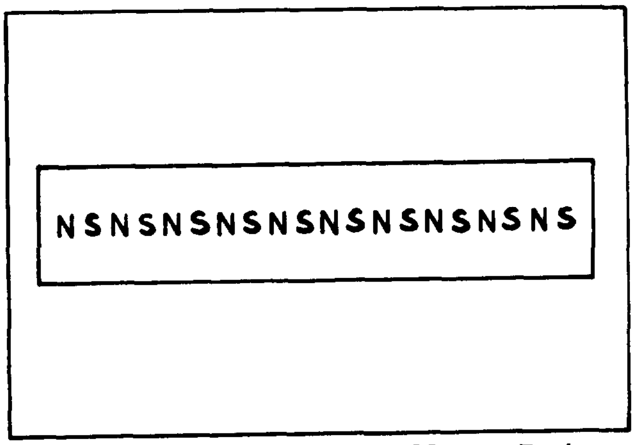
tinuity. This same phenomenon will occur when a simple bar magnet is broken in half since a magnet is made of a series of north and south poles as shown in Fig. 3. This basic magnetic phenomenon is the basis for magnetic particle inspection. When physical anomalies are present in specimens being subjected to magnetic particle inspection, a magnetic pole surface is created which results in an opposite magnetic pole distribution at the opposite surfaces on the discontinuity. This is shown in Fig. 4.

After a sufficient residual magnetic field has been induced into the tube being inspected, the entire surface is then sprinkled with magnetic powder (iron powder). Any anomaly occurring which permeates the surface being inspected will be delineated by concentration of magnetic particles due to the opposite magnetic poles distributed on either side of the discontinuity.



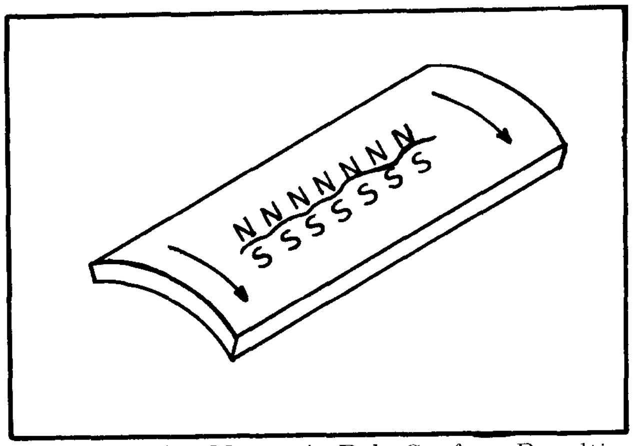
Outline of Flux Lines Subjected to Magnetism of Two Bar Magnets.

FUGURE 2



Polarization of a Simple Bar Magnet Broken In Half (Schematic)

FIGURE 3



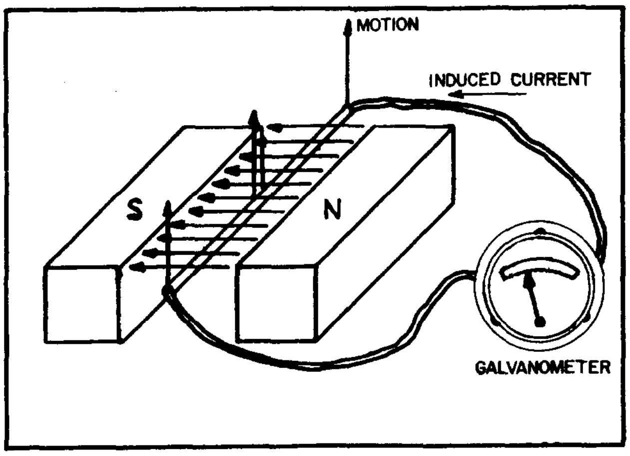
Schematic of a Magnetic Pole Surface Resulting In An Opposite Magnetic Pole Distribution at the Opposite Surfaces of the Discontinuity.

FIGURE 4

Two separate magnetic fields should be employed for the complete inspection of tubes. First, the tube should be energized by passing a DC current from one end to the other. Recalling the right hand rule which states that by grasping a conductor with the right hand in such a manner that the thumb points in the direction of the current flow, the fingers point in the direction of flux flow, this current will then be circular or transverse to the longitudinal axis of the pipe specimen. To energize a tube, a high DC current source is required, and each tube will be pulsed momentarily with a high current discharge. This may be accomplished by the use of prods at the ends of the tube itself; however, this method has been phased out of most inspection companies since a certain amount of arcing by the prod in the pipe will always occur. This arcing has been recognized to create serious defects in the pipe being inspected. The most accepted practice now for energizing pipe with a circular field is the use of an insulated shooting rod through the bore of the pipe. This discharge of current through the shooting rod creates a sufficient residual field without the inherent danger of burning the pipe (so commonly present when prods are employed).

Magnetic particle inspection is generally employed only for the inspection of new tubular goods where the likely defects will be longitudinally oriented in the tube, and a residual longitudinal field is employed only for the inspection of the upset and end areas of the tube. Since a longitudinal field creates, in effect, a bar magnet, the residual for magnetic particle inspection is only at a sufficient level in the end areas. End area inspection for transverse defects is accomplished by an encircling coil around the end and pulsed momentarily with a high current discharge.

In the case of electromagnetic induction inspection, the same flux disturbance is relied upon for the detection and recording of defects present in the pipe. Electromagnetic induction inspection simply replaces the use of magnetic particles with a sensing device which detects those areas of flux leakage or flux disturbance. As may be noted from Fig. 5, when lines of magnetic flux are traversed or cut by a coil an EMF is developed which may be amplified and recorded through the use of a recording galvanometer. This action is no different than that which takes place in a magneto where permanent magnets are used to create a flux field and the armature coils which cut the magnetic lines of force created by the permanent magnets induce current flow.

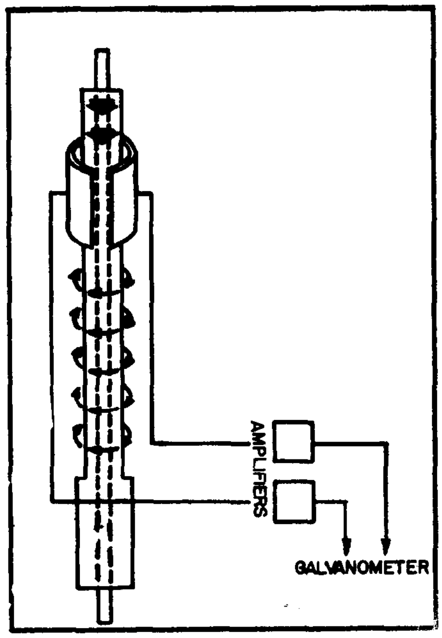


Schematic of Instrumentation That Records EMF Generation Due to Cutting Magnetic Lines of Force

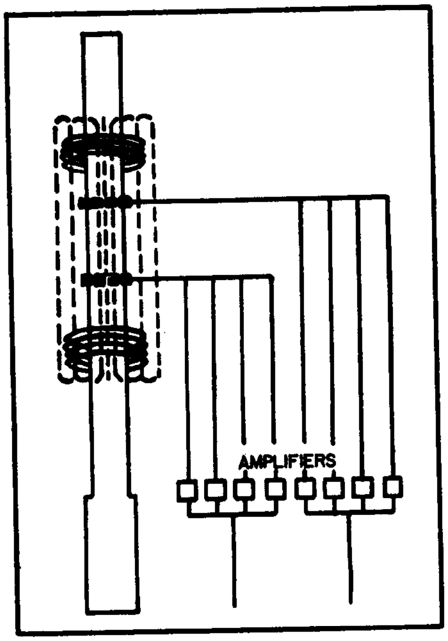
FIGURE 5

Electromagnetic induction inspection is accomplished by two methods—the first by use of a traveling buggy type unit. This method employs a self-driven buggy equipped with a magnetizing coil and detectors. This buggy moves the length of the pipe with power and recording cables extending to a remote console. This unit, as described, will detect defects of a transverse nature. The second type of electromagnetic inspection employs a system to drive the pipe being inspected through a magnetizing coil and an array of detectors to accomplish a full length inspection of the tube for transverse defects. Following the first or transverse inspection, the tube is passed through a degaussing unit to remove the residual polar field left in the tube by the magnetizing coil. The tube is then pulsed momentarily with a high current (DC) discharge thereby inducing a residual circumferential magnetic field in the tube. The tube is then driven through a rotating mechanism containing an array of detectors to record those defects oriented longitudinally in the tube. Figure 6 shows a schematic of the rotating assembly. This type inspection is superior to magnetic particle inspection in the fact that a recording is made of both internal and external defects both longitudinally and transversely throughout the length of the tube. Electromagnetic induction inspection will reveal flaws which are not detectable with magnetic particle inspection. Figure 7 is a typical schematic diagram of the stationary or transverse inspection assembly. This particular schematic shows a single output from the amplifiers. This is accomplished through the use of a limiting circuit which allows only the maximum instantaneous signals from any detector to reach the recording galvanometer. This limiting circuitry is not an essential part of this inspection since each detector could be paneled directly to a recording galvanometer. However, by the constant selection of maximum points, ease of interpretation and less operator fatigue is accomplished.

FIGURE 6



Schematic of Rotating Assembly (Detector)



Schematic Diagram of the Stationary Or Transverse Inspection Assembly.

FIGURE 7

It should be pointed out that the two methods described here, magnetic particle and electromagnetic induction inspection, are two principal inspection techniques. However, many of the field inspection companies employ numerous additional tests and techniques to determine the final classification or usability of these tubes being inspected. Some of the other methods being used today are ultrasonic, radiographic, mechanical gauges, and actual physical tests.