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Non-Destructive Testing on Threaded Connections

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Background

Since the introduction of Non-Destructive Testing (NDT) to industry in the late 1930's many different forms of NDT have been introduced and accepted in the Drilling and Production industry.

Magnetic Particle inspection (MPI), accelerated by the War Effort, it did not come into general industrial use until after the WWII was over, and then did not become generally accepted until the late 1940's when its "Smoke and Mirrors " persona was overcome. Now MPI is the most trusted and accepted form of NDT inspection for Threaded Connections.

Ultrasonic Testing (UT), did not come of age until the original *Sperry Patents* ran out in the early 1960's, and again did not overcome it's Smoke and Mirrors persona until the 1970's, however it has been an 'up-hill battle' until the mid-1980's. UT is now readily accepted for general industrial inspection, due to the low cost Ultrasonic Thickness Gauge (D-meter, T-Mike, etc.).

Electro-Magnetic Inspection (EMI), did not 'come into it's own' until the early 1960's, and because the 'Oil Patch' insisted on the cheapest form of inspection, it did not have any real technology applied to it until an XT-Turbo could be bought for $69.95. Due to the lack of innovative technology, applied to EMI (or a more descriptive – Mechanized MPI), it has certainly fallen far behind UT in it's application to even the most basic workpeices. EMI can now only pay if a high workpiece throughput can be applied, in such cases as Pipe Mills, New/Used Tubing and Casing, or to a less profitable extent in Drill Pipe.

Liquid Penetrant Inspection (LPI), has advanced very little since a mechanic, at the turn of the century, applied 'White Wash' to a cleaned Cast Iron part that had been oil/grease soaked. – Low and Behold, the White Wash *'beaded up'* and did not adhere to the area where a 'light end' was seeping out of a crack. Rocket Science has transformed the *light end* into a Red or Fluorescent 'Penetrating Dye' (although still oil based), and White Wash has been replaced by *Talc* suspended in high Flash Point Alcohol. Any repair facility that does not have an aerosol can of Cleaner, Penetrant, and Remover on hand should have gone out of business 40 years ago!

Eddy Current (ET) inspection is still Smoke and Mirrors unless a tremendous amount of money is spent on Instrumentation and Probe (Sensor) development, to take any guess work or interpretation out of the operator's hands. Ever seen a *Hand Held* Eddy Current tester, less a Gauss Meter, cost under $10.000? – you won't until aircraft sell for less than a Lada! Leave ET in the Primary Steel or Jet Aircraft industry, until we all start producing 10,000 Mud Motors per year or Oil Wells start falling out of the sky!

Now that we have described the most common forms of NDT, lets apply them to our Treaded Connections. – No, I didn't forget X-Ray Inspection, but until a 6 year old can run down to the corner store, to get mom a 100 Curry Cobalt 60 Source and a quart of milk – we'll leave Radiography to Qualified Operators or your cousin the rich Radiologist! I also haven't mentioned ACFM (Alternating Current Field Measurement), due to the high cost and the technique is still in its infancy. Furthermore, I have not covered the 'Art' of Thread Gauging, as we'll leave that topic up to other experts

MPI

The magnetic field required for MPI can be applied in two ways; by the Yoke Method; or via an Encircling Coil. Using a Yoke, while acceptable, is far too time consuming, therefore a coil is used to induce a Longitudinal Field, which is the most common and desirable method. A longitudinal field is required as cracking, normally in the last engaged thread, is caused by torque (simple rotation, bending, or tightening) applied to the connection. Magnetic Particle Inspection Coils are avalible in two forms; a High Amperage *Mobile Power Pack* (3-6000 Amps), with a few (3 to 5) wraps of heavy cable; or a Multi-Turn Coil (1 to 2000 Wraps) with a Low Amperage Power Supply. The accepted *Rule of Thumb* for coils is 1,200 Ampere Turns for every inch of Diameter, with DC fields being the most common due to the need to detect cracking below metal smear in the root of the thread. AC fields are used for surface defects, and will not typically induce a strong enough field into a Box End Thread). Multi-Turn coils are far more suitable due to their modest 115 Volt 15 Amp power requirements (as opposed to 230/460 Volt and over 100 Amps for Mobile Power Packs), as they can be used in the 'Shop' or out on the 'Lease'.

MPI Yoke

MPI Coil

Portable DC Coils are typically equipped with adjustable amperage, which is displayed on a digital meter, to ensure enough magnetism is induced into the work piece. Furthermore, the meter should indicate positive or negative polarity. The +/- Polarity switch allows the operator to Demagnetize the work piece, or to add the correct polarity to a tool that has a small amount or Residual Magnetism. There are many accessories available to the inspector to measure Field Strength (Gauss Meters), and to ensure his selected Field will detect defects (Magnetic Pentrameter or Pie Gauge, Castrol Strips, and QQI's). The rule of thumb for the field intensity, using Wet Fluorescent MPI, is 18 to 24 Gauss.

Either During (Active Field) or After Magnetization (Residual Field), a Fluid Suspension of Fluorescent Magnetic Particles (Iron Oxide) is applied to the work piece. These Wet Method particles migrate to interruptions in the Magnetic Field (Cracks), and the entire threaded area is inspected under Ultraviolet Light (Black Light) which cause the Fluorescent Particles to Glow. Here again, accessories are available to the inspector to measure the Black Light Intensity, and White Light Interference (Radiometers or Light Meters). Radiometers ensure there is enough Black Light to cause the particles to glow, and not too much White Light to 'Mask' Cracks.

Demagnetization after MPI is very important, and is not limited to Mud Motors and BHA's in close proximity to MWD tools. Residual Fields and those induced with a DC Coil require the application of a Reversing and Decaying DC Demagnetization Field. Simply 'waving' a Standard AC Coil over a tool joint will never remove the more intense DC induced field.

MPI can also be performed with *Dry Method* Magnetic Particles, however, these particles are far too large to do meaningful inspection on Threads. However, Dry Method Magnetic Particle Inspection is highly accepted for inspection on other work pieces. Dry Method is commonly used to *Prove-Up* indications found with EMI on Drill Pipe and Tubing/Casing.

UT

Ultrasonic Testing is the most accepted NDT method employed during the manufacture of any type of OCTG (Oil Country Tubular Goods), which encompasses Large or Small, Welded or Seamless Tube and Pipe. Over the years there has been a great continuing debate about the use of *Compression Wave* Ultrasonic Testing on the threads of used Down Hole Assemblies. It is possible to find thread cracks with an Ultrasonic Flaw Detector, and a special probe (10 MHz, Focused, 4° Compression Wave) however it takes far greater care and operator training than Fluorescent MPI. However, 0° Compression Wave UT is a fast and relatively easy method, to reliably find large/deep Thread cracks in a tool joint before any cleaning, inspection, or repairs take place. Furthermore, this same method, with a little more care and training, can be used to find cracking in the Hard Band area of Drill Collars. The following illustration shows the *Sound Paths* of the two techniques discussed above.

Highlighted area shows crack testing with 0° Compression Wave.	Highlighted area shows thread testing with 4° focused probe.
	

Note: This coupling, from a BHA, twisted off due to a fatigue crack. It was determined that the crack had been present for some time, before failure and could have been detected with a simple 0° Compression Wave test.

Probe Assemblies have been introduced, for testing the Upset Area of BHA's, which help overcome alignment difficulties caused by operators handling (and misaligning) the probes. The most common, least expensive, and less sensitive of these End Area Scanners utilize a *Wheel Probe* with a single fixed angle transducer (70°), while more sensitive (and more expensive) units utilize multiple fixed angle transducers (45°, 60°, and 70°). No matter the type of End Area Scanner, many still employ Paper Chart Recorders, while the advanced units, display a Digital Chart Record, that is easily stored, printed, or erased.

The most common type of Ultrasonic Testing however, is the Ultrasonic Thickness Gauge. While limited in use on BHA's to wall thickness tests, these units are an excellent and simple way to confirm Wall Thickness. Furthermore, Thickness Gauges are used to find and measure pit depth, and can easily find *Washouts* on the ID of BHA's.

EMI

Electro Magnetic Inspection is without question the most cost effective way to inspect the body of Tubing/Casing, and Drill Pipe. The work piece is magnetized by an encircling coil, or rotating magnets. Search units (Shoes) detect interruptions in the magnetic field, and through signal processing, the operator is alerted. While this article focuses on Threaded Connections, there won't be any further discussion of this topic, but the wide spread use of EMI merits its mention.

LPI

Liquid Penetrant Inspection (Dye Penetrant, Dye-Check, etc.) is widely used in industry, however on Threaded Connections it is typically limited to the inspection of *Non-Magnetic* Bottom Hole Assemblies, such as Monel Drill Collars. As MPI can only be used on materials with a reasonable level of magnetic permeability, LPI methods are used. As mentioned in the introduction, Dye Penetrant can either be Visible or Fluorescent, with Fluorescent being the more sensitive of the two types.

The benefit of LPI is that it is so simple to use, but several precautions must be followed;

Materials - The operator requires Cleaner, Penetrant, and Developer. Do not mix these between manufacturers.

Pre-Cleaning - The threads must be thoroughly cleaned with a petroleum based cleaner to remove excess oil and dope.

Cleaning - Prior to applying Dye Penetrant, any petroleum products, must be removed with an alcohol based cleaner, often referred to in the operating instructions as *Cleaner/Remover.*

Application - Where large number of work pieces are to be inspected, Dye Penetrants can be applied with a paint brush, however aerosol cans are used for only a few joints.

Dwell Time - Like any other type of penetrating oil, Dye Penetrants are temperature sensitive and require a Dwell Time, which is typically 5 to 10 minutes at 20° Celsius (70° F). As the ambient temperature falls, the Dwell Time must be increased, with an example of 24 hours at -40° C.

Excess Removal - After the Dye has been allowed to penetrate into any potential cracks, the excess must be removed prior to Developer being applied. Two Types of Dye Penetrants exist and support removal by; Solvents; or Water. The only basic difference between the two Types is that Water Washable Penetrants are formulated with an Emulsifier, so it is removed with a Low Volume of Air Charged Water, if you see an inspector using a garden hose and spray nozzle – run him off! If too much volume and/or pressure of water is used, you run a risk of washing the penetrant out of cracks. Furthermore Water Washable Dye Penetrants are not biodegradable, so letting the wash water run into the floor drain is simply not acceptable today.

Solvent Removable Dye Penetrants are first wiped off with a clean rag or towel. Cleaner/Remover is then applied to a rag or towel and the work piece is again wiped down for Final Removal. Where large volumes of tools are being inspected, I like to see the use of 'Saw Dust' rubbed onto the surface, followed by final removal of the Dye. Saw Dust tends to be less wasteful than rags or paper towels and is safely thrown in a landfill.

Drying - After the Final Removal of excess Dye Penetrant, it is extremely important that the work piece is dry. The aircraft industry typically uses warming to ensure dryness and to promote liquidity of Dye contained in cracks.

Developer - In any field application, only Aerosol cans of Developer should be employed, as even application is the most important step in LPI. In high volume applications only Pneumatic Spraying Systems should be used, unless Airless Sprayers have come along way in the last few years, and are used by the body shop on your '46 pick-up! The Aircraft industry again use large 'Air Pots' and powder developers, but that's not practical on even the shortest Collar.

Dye Penetrants can only detect 'Surface Breaking Defects', so threads need to be thoroughly cleaned prior to testing. When inspecting with LPI, Ultrasonic Testing would be highly recommended, to complement it, for finding "large/deep cracks", and it also may merit the use of a *10 MHz, Focused, 4° Compression Wave Probe* for Thread Inspection.

ET

Due to the irregularity and many different types of threads used in our industry, Eddy Current Testing is simply not practical, due to operating training, and the need for detailed procedures and sensor (probe) development. Eddy Current testing is very sensitive to misalignment and elevation (Lift-Off) of the Probe, therefore most industrial applications are mechanized to minimize operator error in aligning the probe to the target area.

Conclusion

All too often we, as an industry, get wound-up in the latest technology but most often the true and trusted technology offers the most effective tests. However, at one point in time the NDT methods that I have called "accepted" were themselves new technology, but pioneers endured the obstacles until the technology became accepted. In the years to come, the methods I have poked fun at, may themselves become accepted, and there will be other technologies to ridicule.