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SIMPLE INSPECTION TECHNIQUES & EQUIPMENT

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Introduction.

This presentation discusses Non-Destructive Testing/Examination (NDT/NDE) equipment that is available to the Chief Inspector/Safety Codes Officer, and his staff, for routine inspection, and to provide my audience with just enough information to be dangerous when dealing with their Inspection Contractor. The key here is for "simplicity" of operation, use, and implementation, to ensure only the most basic of training is required. Normally when I define simple, it assumes the user of the equipment will put the operation manual in "the file", and 'fly by the seat of their pants' when they first turn the unit on for its first use out in the field...."What!.....read the manual?....what for!!!!" That's right!, even with all of our written procedures driven by ISO and other quality programs, this is the real world and very little has changed.

The Techniques.

The following NDT/NDE techniques will be discussed, with examples of there corresponding applications;

- Magnetic Particle Inspection (MPI);
  - Dry Method.
  - Wet Method.

- Ultrasonic Inspection (UT);
  - Thickness Gauges.
  - A-Scan.
  - B-Scan.

- Dye Penetrant Inspection (LPI);
  - Visible.
  - Fluorescent.

- Visual Inspection;
  - Remote Visual Testing (RVT);
  - Mechanical Gauges;

Pit Gauges
Welding Gauges
Vacuum Testing;

Coating Inspection
Coating Thickness;
Mechanical (Banana Gauges).
Electronic
Magnetic.
Eddy Current.
Ultrasonic
Holiday Detection (porosity);
Low Voltage
High Voltage

You may note that Radiography didn't make the cut. This time tested NDT/NDE Technique requires the operator to do a little more training than a cursory look at the operators manual, the night before the inspection.

The Equipment and Applications.

NDT/NDE Methods have a very wide application, however, to avoid writing a novel, I have limited the discussions of the applications.

1. **Magnetic Particle Inspection (MPI)**
    - **Affecting the workpiece with a Magnetic field;**
        - AC, surface only (1 mm depth), but excellent particle mobility.
        - Pulse DC, subsurface sensitivity, and reasonable particle mobility.
        - DC, excellent subsurface sensitivity, and poor particle mobility.
    - **Portable Equipment;**
        - Yokes
            - AC (SSC, HIC, Weld Inspection)
            - AC/DC (Pulse DC) (Excellent versatility)
            - Battery Powered DC (Excellent Portability, and particle mobility)
            - Permanent Magnet (Intrinsically Safe, but no particle mobility).
        - Coils
            - AC (excellent for fastener inspection).
            - Battery Powered DC (Excellent Portability, and particle mobility).
            - DC, Pulse and DC (small castings, such as valves).
        - Black Lights (Wet Fluorescent Technique).
            - External Ballast.
                - Rugged, and unaffected by Extension Cord length.
            - Internal Ballast.
                - Powerful, but affected by cord length.
            - Battery Operated.
                - Highly Portable and Instant Light, but lower intensity levels.

- The Techniques;

- Dry Method;

  Applying color contrasted iron powder (White, Red, Yellow, and Black) to a workpiece to find larger defects, as the mean particle size is 180 microns (varies from 30 to 350).

- Wet Method (Water or Oil Base);

  Fluorescent;

  Fluorescent Particles are suspended in a liquid bath, where mean particle size of the Iron Oxide is 5 microns. Wet Fluorescent provides great sensitivity to small defects, however requires a UV Lamp or Black Light to cause the particles to fluoresce.

  Color Contrast;

  'White Contrast Paint' (lacquer) is applied to the workpiece, and in turn Black, (or Red) Iron Oxide Particles are applied. With a mean particle size of 20 microns, they are not quite as sensitive as Wet Fluorescent particles, but no UV Lamp in required.

- Applications;

- Weld Inspection.
- Crack Inspection (SCC, etc.).
- Equipment Inspection.

Magnetic Particle Inspection is a relatively simple inspection technique, but, is subject to operator interpretation. Operators should receive basic training, or formal instruction, and is the reason MPI made the simple list.

2. <u>Ultrasonic Inspection (UT)</u>

Ultrasonic Thickness Gauges send high frequency sound waves into a workpiece, and sense the return signal from the 'back-wall' and most anything in between.

- Standard Thickness Gauges (Provide thickness reading only)

- Precision Thickness Gauges.
- Corrosion Thickness Gauges.
- Data Loggers.

- A-Scan Thickness Gauges (Provides thickness reading and waveform)

- B-Scan Thickness Gauges (Provides thickness reading and 2 dimensional 'picture' of the workpiece).

Standard Thickness Gauges.

Standard thickness gauges are available in two different operational techniques; Precision Thickness Gauges'; and 'Corrosion Gauges'. Precision units utilize 'High Frequency Single Element Probes', and can provide highly accurate readings, however are not acceptable for detecting pitting as they average the signal from the back wall.

Corrosion units provide very respectable accuracy, and utilize ‘Dual Element Probes’ with a smaller crystal size, and are thus very sensitive to pitting.

All Standard Thickness Gauges are available to support, or have built in Data Loggers, for the storage and later down loading of readings. I have seen Internal Data Loggers with up to 4 Meg. of memory, which in many cases is overkill! Data Logging adds a degree of complexity to the operation of a thickness gauge, and furthermore once the data (thickness readings and position) have been stored in the unit, there is the task of transferring it to a data base (I refer this process as - ‘screwing around’). With or without a data logger, a standard ultrasonic thickness gauge is very simple to operate.

A-Scan Thickness Gauges.
A-Scan Thickness Gauges provide the operator with a thickness number and the ultrasonic wave form (similar to the displays of a Ultrasonic Flaw Detector), that provides the operator with the necessary information to determine what the thickness gauge is ‘seeing’ (back wall, pitting, or lamination). When observing an A-Scan, the operator will see a large indication on the right side of the time base, which is the back wall signal, and the indication from a pit will appear to the left of the back wall signal with a lower amplitude. Furthermore, the operator is able to monitor coupling by observing the back wall signal, to ensure its amplitude is at a maximum value. A-Scan units are most often equipped with internal (or onboard) data loggers, but in any case operators can be quickly trained to utilize the benefits of the A-Scan display.

B-Scan Thickness Gauges.
B-Scan is one of the latest ‘buzz words’ used in the Corrosion Survey business, and typically refers to a Computer Based Ultrasonic Flaw Detector, with Graphic Capabilities, that is coupled to a ‘Probe Manipulator’. The experienced operator (CGSB Level II) runs the probe manipulator in a linear fashion, which allows the computer to display cross-sectional pictures (2 dimensions, distance traveled and thickness) on its monitor. Furthermore, some of this equipment is equipped with an X-Y manipulator, which permits a C-Scan display (3 dimensions). In any case, a limited number of hand held thickness gauges, and A-Scan thickness gauges are available with a B-Scan function. These units are typically not equipped with ‘Probe Manipulators’ or encoders to register position, but use a fixed scanning speed of approximately 1 cm/sec. Again, simple to use with a limited amount of training, or amazingly enough by reading the manual.

Referred to above, Ultrasonic Flaw Detectors didn’t make the cut. These highly versatile portable machines are used for both Thickness Testing (Corrosion Surveys), and Weld Inspection. When used for thickness testing (corrosion surveys), they require ‘Tooling’ (in the form of Probes and Calibration Standards) and in depth operator training. That is not to say flaw detectors are out of reach, technically speaking, to the Chief Inspector/Safety Codes Officer, but to be truly effective, they need to be used on a very regular basis to ensure the operator is fully ‘comfortable’ with their operation.

3. **<u>Dye Penetrant Inspection (LPI).</u>**

Dye or Liquid Penetrant Inspection, is without question, the simplest and most accessible NDT/NDE Technique. I have recently trained my dog to inspect it's 'Chain Link Run' with a Level 2 Post Emulsifiable Fluorescent Technique. Three aerosol cans/components (Cleaner/Remover, Penetrant, & Developer), a roll of paper towels, and a lot of time. The disadvantage of LPI is the mess and time required, however this technique can virtually be used anywhere, at anytime.

Dye Penetrants come in two basic forms; Visible (Red); and Fluorescent (requiring a Black Light). Furthermore, these two forms can be either; Solvent Removable; or Water Washable. Each component can be applied by either aerosol cans, or with bulk applicators. First the workpiece must be cleaned, then the penetrant applied and allowed to dwell. Excess penetrant must be removed from the workpiece, with either Cleaner/Remover and towels, or water, and allowed to dry. Developer is applied, as sparingly as possible, allowed to dry and is followed by a visual inspection. Fluorescent Penetrants, depending on Sensitivity Levels, is typically considered more sensitive to small cracks than the Visible Dyes.

To address the time issue, the workpiece should be as clean as possible, and depending on the ambient temperature, the dwell time of the penetrant needs to be adjusted. A typical rule of 'thumb' for dwell times are 5 minutes at 21°C, 2 hours at 0°C, and 24 hours at -30°C. A misnomer of Dye Penetrants, is that Water Washable Penetrants are environmentally friendly, they simply have an emulsifying agent added. Furthermore, Water Base Penetrants, while being safe to use on most plastics, do not break down into constituents elements.

4. **<u>Visual Inspection.</u>**

Visual Inspection covers a wide verity of equipment, but the key is for the inspector to know what he is looking at, and what he is looking for. This section of the presentation is on aids to help the inspector, and will discuss Remote Visual Testing, Mechanical Gauges (Welding and Pit Gauges), and Vacuum Testing.

Remote Visual Testing

Remote Visual Testing utilizes Video Cameras, Borescopes, or Inspection Mirrors to access areas not accessible to the inspector. Inspection Mirrors are very straight forward, and are available in different sizes and shapes. Borescopes (or fiberscopes) utilize lenses attached to a glass fiber bundle, and are available in rigid (straight), or flexible (with articulating tip). The fiber bundles result in the field of view being round, and the image appearing in a 'honeycomb' effect, as groups of bundles make up a single pixel. Depending of the quality of the 'scope', which is cost dependent, the number of pixels will differ. Without question, borescopes are delicate 'instruments', as they have been adapted to industrial use from the medical industry. The length of borescopes is limited to about 15 meters, however the normal diameter is between 6 and 8 mm, and can be equipped with external video cameras.

Video Testing Equipment has become more cost effective with the boom in home video cameras and VCR's, furthermore the cameras employ solid state CCD Chips, which are in the order of 3 mm x 3 mm. As a result of their size, CCD cameras are mounted on the end of multiple conductor cable to produce a 'Video Probe', which tend to be far more robust than fibreoptic borescopes. The length of a Video Probe is less of a limitation, but the greatest benefit is the clarity of the image, as when magnifying lenses are added to the camera, and larger monitors are employed, images become bigger than life, and in living color!

Video Cameras are also mounted on Remote Operated Vehicles, and can be placed in hazardous environments, keeping the inspector out of harms way. All Video Inspection Equipment, and Borescopes for that fact, come at a price, and you guessed it right - its high!

Mechanical Gauges.

My favorite topic! Available in a myriad of shapes and sizes, some with specific uses and others more versatile, some incredibly accurate and others not so accurate. Lets start with the ruler, has yours been calibrated to a NIST traceable standard lately? This discussion will be limited to those our contractors and inspectors use; Welding Gauges; and Pit Gauges.

Welding Gauges.

Welding Gauges are used during fabrication, or subsequent in service inspections, to measure Fit-up, Alignment, and Weld Dimensions. Most inspectors are familiar with Profile Gauges, and Fillet Weld Gauges, that are basically used for 'Comparison' of the Weld to the Gauge, however, other Gauges are Manufactured to Physically Measure characteristics of the Weldment. Some of these Welding Gauges have been available for years, such as the Cambridge Gauge and the AWS Gauge, however, improvements have been made to these existing gauge designs to make them more versatile and repeatable.

New Gauge designs are also available, with specific or versatile functions that merit investigation by the inspector. Gauge Manufacturers are now addressing an international market, so graduations on gauges are typically in Metric or Imperial Measure, if not, buy a calculator!

Pit Gauges.

This is a topic that should have resulted in me receiving an Honorary Ph.D., unfortunately only The Winnipeg College for the Technically Challenged, has come forward. The most common Pit Gauge has been available for 50 years, and was developed by a retired Tulsa area Chevron Inspector, Mr. W. R. Thorpe. Thorpe's Gauge measures on a 0 to 0.500" scale in 1/32" increments and is relatively inexpensive, but in today's world the necessity for higher accuracy exists. Today's inspector requires Dial Indicator accuracy of +/-0.005", with a fixture to mount the Dial Indicator, these have been adapted from machinist tools for several years in the form of 'Dial Depth Gauges'. However Dial Indicators, specifically designed for Pit Gauging, have only been available recently, and when fitted with versatile fixturing, will provide pit measurements on curved and spherical surfaces, as well as ‘Bridging’ into areas of ‘Weight Loss Corrosion’.

Vacuum Testing

Vacuum Testing is nothing more than an aid to ‘soap testing’, and rather than looking for leaks with a soap solution the operator attempts to induce a leak with a vacuum. A clear Plexiglas box is placed over the workpiece (typically a weld) that has been covered in a mild soap solution, and a vacuum is created drawing the ‘Box’ to seal itself. Creating a vacuum is done via a simple vortex, utilizing compressed air, which draws air from the Box, causing a pressure drop which is observed on a vacuum gauge. This pressure differential causes the weld to leak, and creates ‘bubbles’ in the soap solution. Vacuum testing has proven to be the most reliable method for detecting leaks in tank floor plate seams, and floor/shell joints. While not employing the latest high technology, vacuum testing is by far the most reliable and rapid leak detection system.

5. **Coating Inspection.**

Coating Inspection Equipment takes many forms from the simple ‘Wet Film Gauges’ to laboratory based X-Ray Diffraction Systems, but we’re talking portable and simple to use. Therefore, the Wet Film Gauges will make the cut, but are too simple so we’ll discuss Dry Film Gauges (Mechanical and Electronic), and Holiday Detectors.

Dry Film Coating Thickness Gauges.

Two basic forms of Dry Film Coating Thickness Gauges are available; Mechanical, and Electronic Gauges employing Electromagnetic, Eddy Current, and Ultrasonic principles. Mechanical gauges are our trusty old ‘Banana Gauges’, Electromagnetic Gauges measure Non-ferrous coatings on ferrous substrata, and Eddy Current Gauges measure non-ferrous coatings on non-ferrous substrata.

The ‘Banana Gauge’ is still the most reliable, cost effective, and repeatable coating thickness gauge available. However, if there condition and calibration are allowed to slip, they can also be the most unreliable gauge for coating measurements. Mechanical gauges come in a wide variety of forms, to measure the thinnest coatings to those over 25 mm thick.

Electronic Gauges have been available for over 20 years, however ‘have not come into their own’ until recently. Early gauges were delicate and unreliable, but today represent the most robust and accurate of portable electronic equipment. Electronic Gauges typically start with a standard Electromagnetic Platform, that is added to with Data Logging, and Averaging features. The Platform can also have added to it, during manufacture, Eddy Current Capabilities to give the unit dual substrate capabilities.

Ultrasonic Coating thickness gauges are new, and are designed to measure the coating itself without relying on the substrate for a reflective surface. These gauges do work, however are highly operator dependent requiring a high level of care by the operator.

These gauges recognize a sudden change in velocity of very high frequency ultrasound, between the surface and coating/substrate bond, thus the coating itself must have very consistent attenuative properties.

Holiday Detectors

Holiday Detectors utilize either low or high voltage DC current, to determine if porosity is present in coatings. A DC voltage is applied to the grounded workpiece via an insulated ‘Probe’, if porosity is present the circuit is completed and an alarm is activated. Low voltage units (below 100 volts) are used for thin coatings (under 0.25 mm), and High voltage units (up to 30,000 volts) are used for coatings above 0.25 mm). Furthermore, High voltage units can be used to provide a general evaluation of thinner coatings, by simply using a higher than normal voltage and allowing the voltage to ‘jump’ through the coating.

Normally used after a coating has cured, Holiday Detectors can be employed to evaluate the coating after being in service, to ensure it is still free of porosity. Holiday Detectors are an excellent tool for assessing a coating’s continued reliability. These units are easy to use and if the voltage is set too high, for the coating thickness being tested, usually just the operator’s hair stands on end!

SUMMARY

This presentation utilizes extensive overhead illustrations of equipment, and while not presenting this simple to use inspection equipment as the “be all and end all” to the owner’s inspection problems, it is, however, in the final analysis, a ‘stop gap measure’ utilized before your ‘heavy hitters’ arrive.