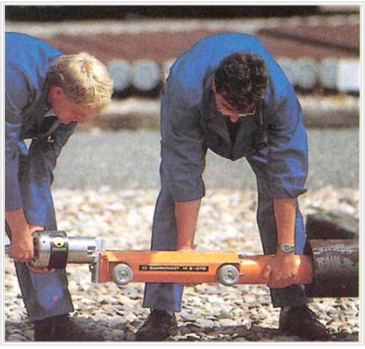
IBC Onshore Pipeline Engineering Training Course London June 2016

Non-destructive testing of onshore pipeline welds



Alan Denney

Contents

This is a brief description of the common NDT methods:

1. Magnetic Particle Inspection
2. Liquid Penetrant Inspection
3. Radiography
4. Manual Ultrasonic Testing

Application of the methods

- Visual Inspection
- Magnetic Particle Inspection (MPI)
- Liquid Penetrant (PT)

To detect surface or surface breaking defects

- Ultrasonic Testing (UT)
- Radiography (RT)

To detect embedded defects

Automatic Ultrasonic Testing (AUT) is a separate presentation

Other methods: Eddy Current, Acoustic Emission, Flux Leakage

Pipeline NDT Codes and specifications - American

Non-destructive Testing (NDT) is covered by API 1104: Welding of pipelines and related facilities

This standard states full requirements for radiography and ultrasonics but also refers to:

- ASTM E709 Standard Practice for Magnetic Particle Examination
- ASTM E165 Standard Practice for Liquid Penetrant Examination
- ASTM E164 Standard Practice for Ultrasonic Contact Examination of Weldments

Non-destructive testing is carried out in accordance with written procedures, which are required to be written by a Level 3 NDT specialist.

European standards for pipeline NDT

EN ISO 17636-1	Non-destructive testing of welds. Radiographic testing. X- and gamma-ray techniques with film
EN ISO 17636-2	Non-destructive testing of welds. Radiographic testing. X- and gamma-ray techniques with digital detectors
EN ISO 17640	Non-destructive testing of welds. Ultrasonic testing. Techniques, testing levels, and assessment
EN ISO 9934-1	Non-destructive testing. Magnetic particle testing. General principles
EN ISO 3452-1	Non-destructive testing. Penetrant testing. General principles
EN ISO 17637	Non-destructive testing of welds. Visual testing of fusion-welded joints
EN ISO 5817	Welding. Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded). Quality levels for imperfections
EN 12732+A1	Gas infrastructure. Welding steel pipework. Functional requirements

The acceptance criteria for NDT are application specific and are stated in separate standards e.g.

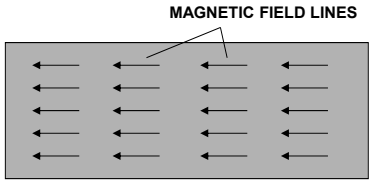
- *Visual inspection: EN ISO 5817 Welding. Fusion-welded joints in steel…Quality levels for imperfections.*
- *NDT: EN 12732 Gas infrastructure. Welding steel pipework. Functional requirements*

Magnetic Particle Inspection (MPI)

- MPI is applied only to steels which can be magnetised
- It can find surface breaking defects, notably cracks
- The ‘ink’ of fine iron filings in a carrier fluid is applied whilst component is magnetised
- The indications show as a black line against the white background
- Alternatively fluorescent coated iron particles are used. These show up as lines under fluorescent light
- Acceptance levels for defects are defined in the application codes.

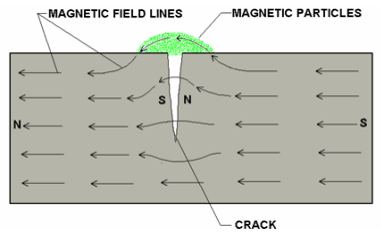
MPI – Examination principle

In a magnetized piece without discontinuities, the magnetic flux remains inside the material

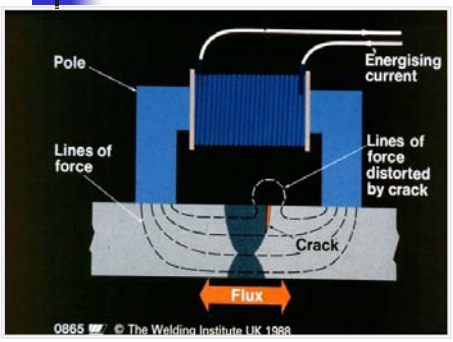


Discontinuity → flux leakage

Flux leakage attracts the examination media (ferromagnetic particles) that cluster to form an indication over the discontinuity



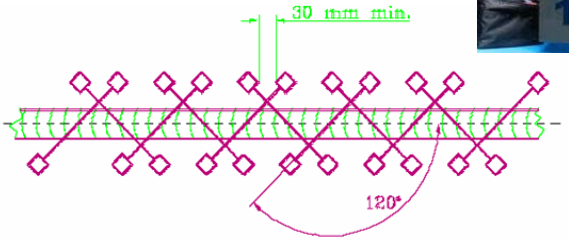
MPI – electromagnetic yoke method



- The magnetisation is by permanent magnetic, electro-magnet, or by current flow to induce a magnetic field between 30 and 50 Oested
- Yoke: Electromagnet composed of jointed sections

MPI – the method in practice

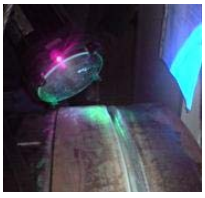
- Equipment is calibrated to ensure that it gives adequate field strength
- A white background paint is first applied to the surface
- The detection medium is either a wet 'ink' or dry powder.
  - → Wet medium Temperature limit is 60° C
  - → Dry medium Temperature limit is 315° C

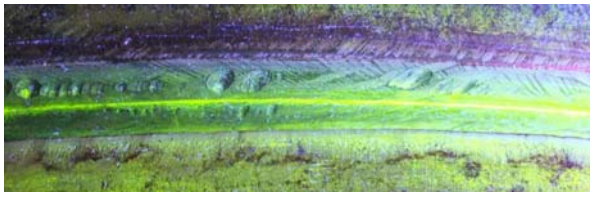


The inspection is done in a criss-cross pattern to detect all the discontinuities – regardless of their alignment

MPI – Electromagnetic yoke method

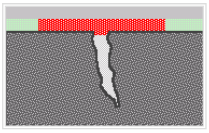
ADVANTAGES	LIMITATIONS
Easy training of technicians	Can be used only with ferromagnetic materials
Inspection method is highly sensitive	Can only detect surface and subsurface (to 2 mm) defects
It can be used with lightly coated pieces	Piece dimensions and geometry can be a limitation
Simple interpretation	



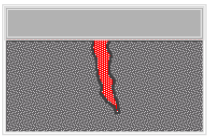


Liquid Penetrant Inspection

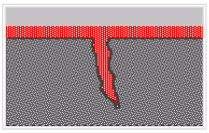
A liquid with high fluidity is sprayed on the surface of the part. Time is allowed for it to soak into surface-breaking defects.



The excess liquid is removed from the surface. No colour is visible.



A developer (powder) is applied and left for some time. This draws the trapped penetrant out of the defect and it can be seen on the surface.



Liquid Penetrant (LP) Inspection

The piece is visually inspected and any cracks show as clear indications in the developer

Where fluorescent dyes are used the visual inspection is done under ultra-violet light

LP Inspection is also commonly applied to fittings, forgings and castings

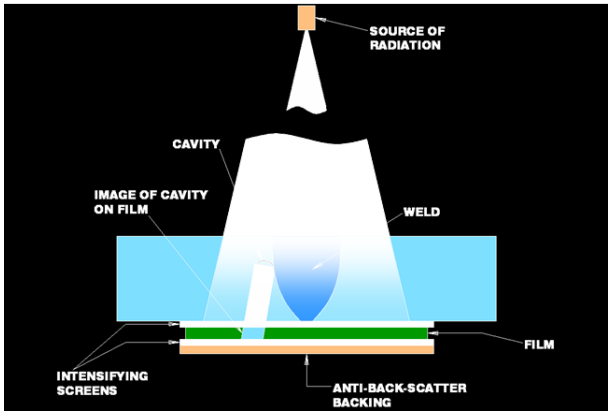
Courtesy: Induction Pipe Bending UK

Advantages and limitations of LPT

ADVANTAGES	LIMITATIONS
Applied to all the materials (ferromagnetic and non-ferromagnetic)	The normal temperature range is 15-52 °C
	Detects only defects which are open to the surface
Simple procedure & Interpretation	Discontinuities filled with dirt, oxides etc. not detected
Can be applied on parts not easily accessible	Requires very good cleaning
Economical equipment	Surface finish is more important than with other methods

- LPT is performed to industry specifications
- Acceptance levels for defects are defined in the application codes.

Radiography - examination principle

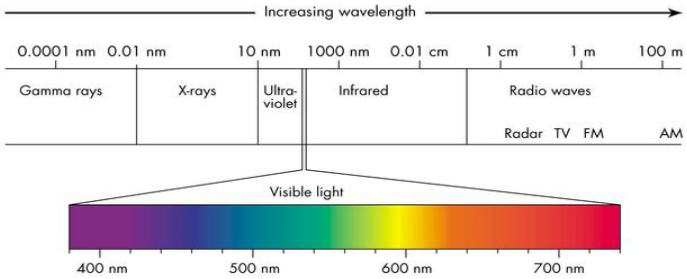


- The film darkness (density) varies with the amount of radiation that reached the film
- Thicker and more dense areas will absorb more radiation.

Radiography – radiation types

The radiation used are High Energy Electromagnetic waves:

- X-Rays (produced by an X-ray Generator)
- Gamma Rays (produced by radioactive materials).

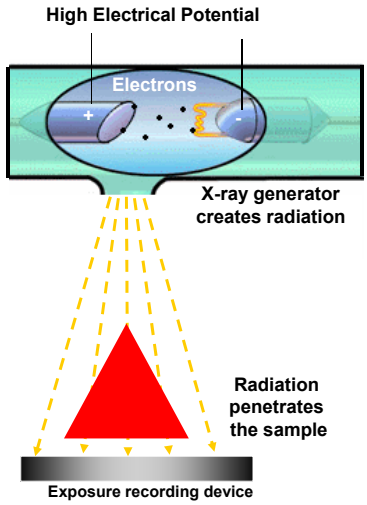


X-ray

Coolidge tube:

The incadescent filament cathode emits electrons. These are accelerated by the strong electric field between the electrodes and bombard the anode target in a limited area (focal spot) producing X-rays.

The target is generally made of tungsten.



Sources of radiation – X-ray

The X-Ray equipment consists of :

- Tubehead
- Control Unit
- Cables.

The X-Ray Tube can be:

- Directional
- Panoramic

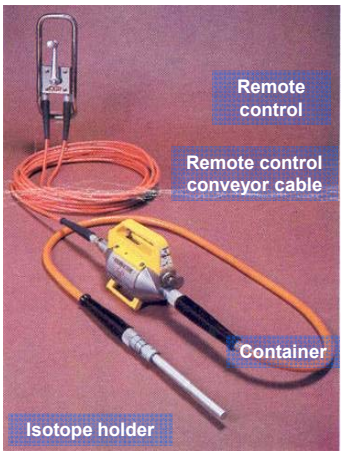
Panoramic crawler units

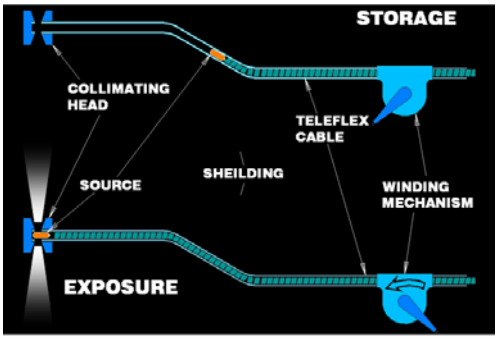
Internal pipeline x-ray unit showing battery tray, control box, and x-ray tube.

Note: the red band at the left end of the x-ray tube is the window

Panoramic gamma ray crawler

Gamma-rays - exposure





Gamma radiography uses:-

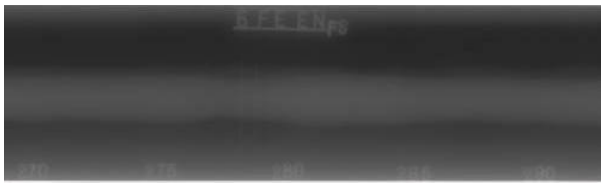
Natural radioactive elements:
U 238, Ra226, Rn222

Artificial radioactive elements:
Ir192 and Co60

X-rays vs gamma rays

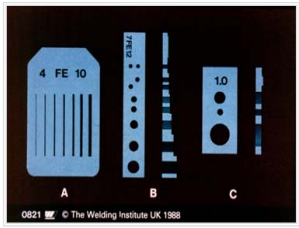
- Gamma rays are easier to handle
  - no electric supply,
  - no cooling system,
- Gamma ray sources can get inside smaller pipes than x-ray tubes
- Greater sensitivity is available with X-rays, giving improved clarity and ease of interpretation
- There are more safety and security issues with Gamma rays, resulting in more regulation and difficulties in obtaining permissions
- Gamma rays are not accepted by some clients.

Radiography



A radiograph of a pipeline weld

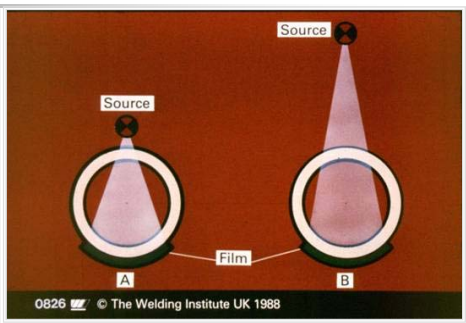
- A radiograph is a negative image, thinner areas appearing darker
- Welds are generally thicker and hence lighter, with volumetric defects showing darker against the weld
- A radiograph should show:
  - The weld identity
  - The index, to locate the defects relative to a datum marked on the item
  - An IQI to show the sensitivity of the image.



IQIs

Pipe radiography techniques

Panoramic shot and local shot - internal source

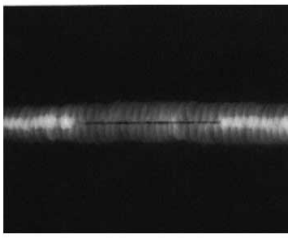


External shots, double wall single image

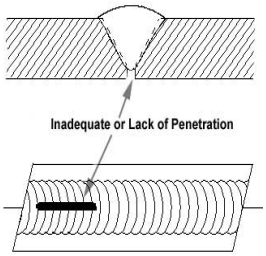
IQIs are to be on source side (where possible) and visible on all radiographs

Radiographic Inspection – defects found

- Radiographic testing is excellent for showing volumetric weld defects in simple joint configurations:
  - Lack of weld penetration
  - Internal concavity
  - Over-penetration or burn-through
  - Slag Inclusions
  - Porosity
  - Undercut



- It is not so good at showing:
  - Cracks
  - Lack of fusion



Limitations of radiography

- Safety considerations are paramount, both in use and for isotope storage – due to the radiation hazards
- Radiography provided no information about defect height, which is the most important defect dimension in welds
- Radiography is better at detecting volumetric defects rather than planar defects (cracks), *but planar defects are the more important category.*

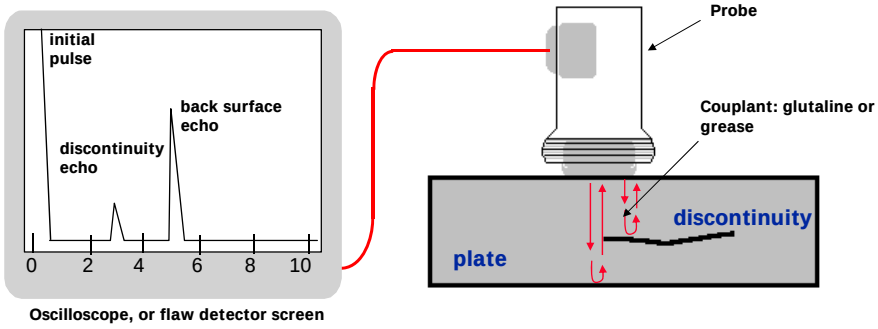
Film based methods of radiography are now giving way to digital methods - particularly in production welding situations. Example: linepipe manufacture.

Manual ultrasonic testing

What is an ultrasonic wave?

- A mechanical vibration with a frequency above 0.02 MHz
- Frequencies generally used in weld and metals inspection are 1-10 MHz.

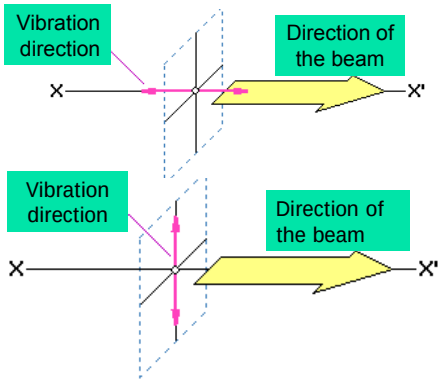
Examination principle



Type of ultrasonic waves

Longitudinal or compression waves:
they vibrate along the line of direction of the wave

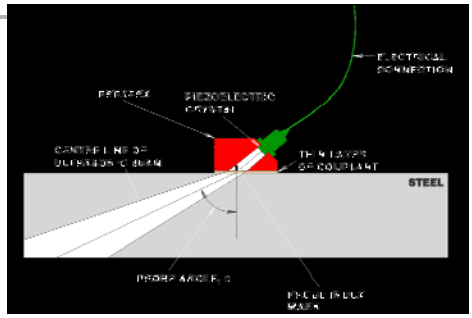
Shear waves:
vibration is perpendicular to the line of direction of the wave



Compression wave probes give a beam which is normal (i.e. perpendicular) to the surface of the test piece.

Shear wave probes are manufactured to give beam angles of 45°, 60° or 70° relative to the test piece.

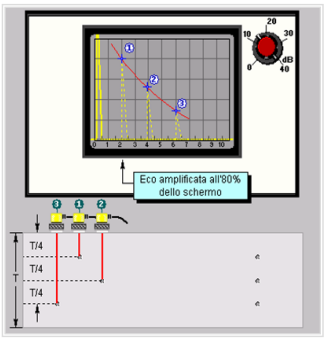
Ultrasonic testing – angle beam examination

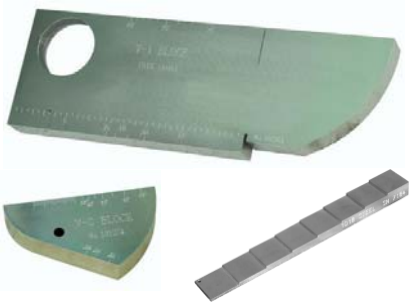


- Angle beam examination is commonly used for weld inspection
- Probes can be either transmit, receive or both
- The probe has a known frequency, angle of entry and beam width
- Defects reflect the beam
- The receiving probe detects the beam, and the signal is shown on the display
- The display has been calibrated to show the distance of the defect from the origin of the beam in the steel

Calibration

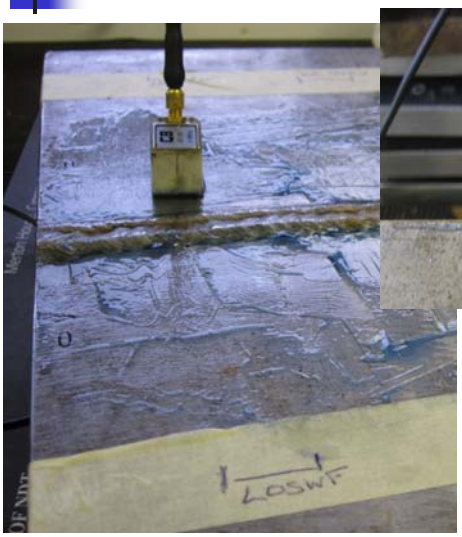
- Verify equipment characteristics
- Calibrate sensitivity of inspection to code requirements
- Develop the DAC (Distance Amplitude Curve)





DAC curve
This models the decrease in amplitude with the distance from the probe.
Its use is intended to ensure that defects of similar size are evaluated the same regardless of distance.

Angle probe UT in progress



Note
- Probe index
- Couplant on the plate

Ultrasonic testing - strengths and weaknesses

Strengths of ultrasonic inspection

- can find critical defects - cracks and lack of fusion
- flexible
- increasingly being automated to de-skill and reduce operator error.

Weaknesses

- requires highly skilled technicians
- slow if there are multiple defects present
- codes generally define acceptability in terms of response signal strength, but this may not relate directly to the size or criticality of the defect
- interpretation of the signals can be an issue
- paper based reporting.

Ultrasonic Testing - defect interpretation

Indications in ultrasonics are generally classified as:

- Planar Imperfections
- Volumetric Imperfections
- Longitudinal or transverse to the weld
- They are classified by *length*, or accumulated length in the case of intermittent defects (including porosity) and by the *amplitude* of the reflected signal
- The technician will attempt to interpret the type of defect from the signals received
- Imperfections that are interpreted as cracks are unacceptable regardless of length.

NDT acceptance criteria - general

- Non-destructive testing is carried out to codes and specifications
- The acceptance criteria are application specific
- Example:
  - For incomplete root penetration API 1104 allows 25 mm in 300 mm of weld
  - EN ISO 5817 Level B states incomplete root penetration is not permitted
- This arises because acceptance standards are ‘workmanship based’ - what is considered good practice. Few are based on actual test performance.

Engineering Critical Assessment

Engineering Critical Assessment (ECA) is the name given to deriving the acceptability of defects by fracture mechanics calculation.

It is used:

- To derive a set of acceptance criteria to be used throughout a project for ultrasonic examination
- To calculate the acceptability of 'out of specification' defects where repair is impracticable or undesireable

ECA is also used for in-service 'Fitness for Purpose' (FFP) assessments of in-service plant and equipment for risks associated with fatigue, fracture and corrosion

ECA is generally used to set defect acceptance criteria when Automatic Ultrasonic Testing (AUT) will be used for pipeline inspection.

THE END