RUHRPUMPEN

Specialist for Pumping Technology







Session 10 –

Non-Destructive Examination (NDE)

Simon Smith December 2021

Presenter Profile – Simon Smith

Simon graduated with an honours degree in Chemical Engineering from the University of Surrey in 1978 and began a long career in the engineered pump industry spanning 40 years (so far!) with Peerless Pump, BW/IP International / Flowserve, SPP Pumps, Ruhrpumpen and Ebara Cryodynamics.

Over his long career he has filled various roles as Applications Engineer / Manager, Project Manager, Key Account Specialist, Vertical Pump Product Specialist, International Sales Engineer / Manager / Director and he has considerable experience in Training & Mentoring young engineers.

RUHRPUMPEN AT A GLANCE

VERTICAL INTEGRATION

SALES OFFICES IN +35 COUNTRIES

MANUFACTURING **FACILITIES** IN 10 COUNTRIES

+70 YEARS OF EXPERIENCE

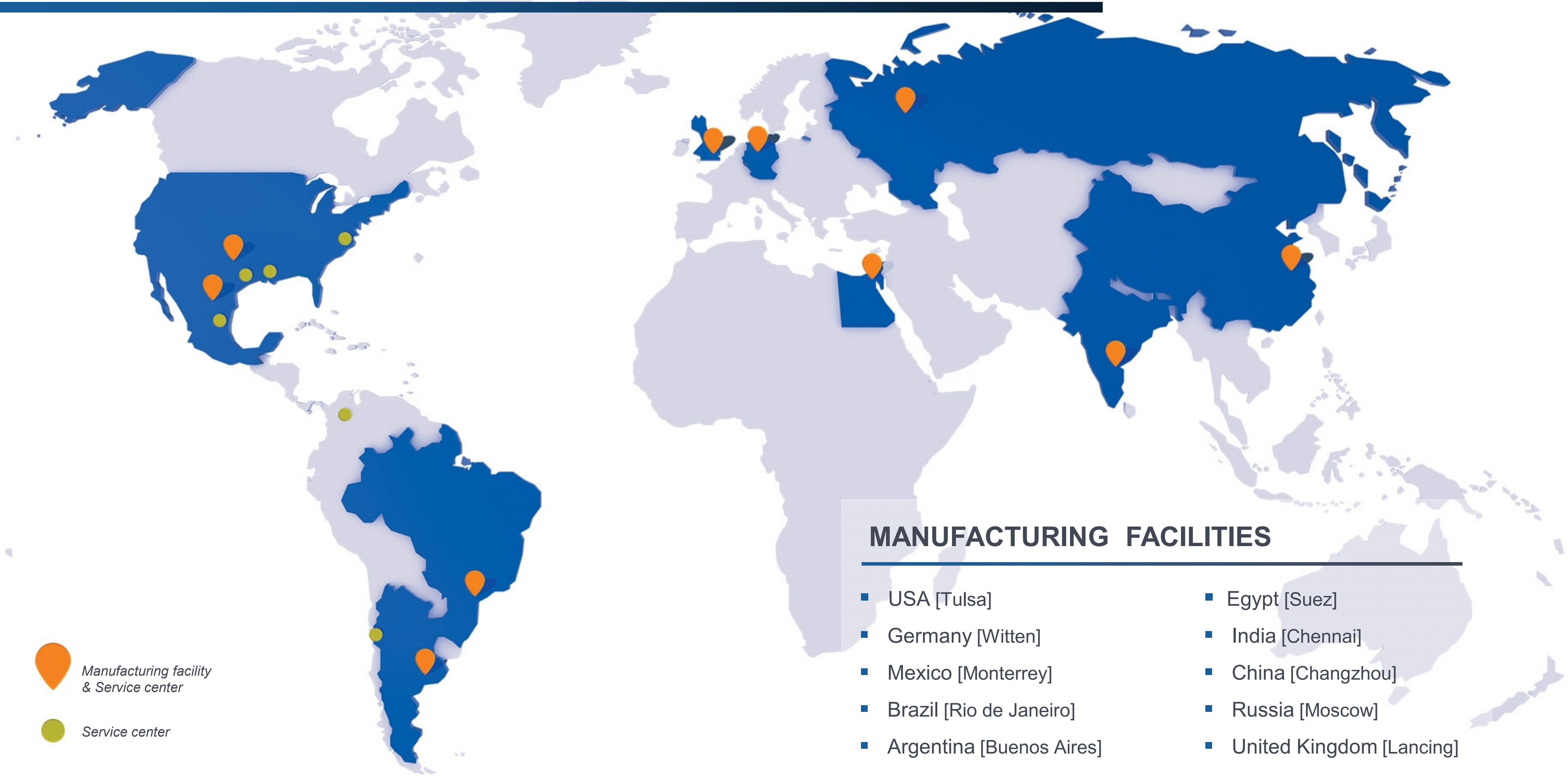
+2,000 EMPLOYEES

15 **SERVICE CENTERS**

+70,000 PUMPING SOLUTIONS INSTALLED WORLDWIDE

A GLOBAL COMPANY

RUHRPUMPEN



MANUFACTURING FACILITIES

- USA [Tulsa]
- Germany [Witten]
- Mexico [Monterrey]
- Brazil [Rio de Janeiro]
- Argentina [Buenos Aires]
- Egypt [Suez]
- India [Chennai]
- China [Changzhou]
- Russia [Moscow]
- United Kingdom [Lancing]

MARKETS WE SERVE

Our commitment to create innovations that offer reliable solutions to our customers allow us to provide a complete range of pump systems to support **core markets** as:

RUHRPUMPEN

OUR PUMP LINES

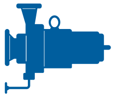
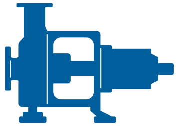
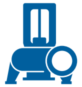
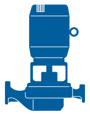
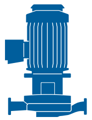
Ruhrpumpen offers a broad range of highly engineered and standard pumping products that meet and exceed the requirements of the most demanding quality specifications and industry standards.

Our pumps can handle head requirements as high as 13,000 ft (4,000 m) and capacities up to 300,000 gpm (68,000 m^3/hr). Moreover, our pump designs cover temperatures from cryogenic temperatures of -310 °F (-196 °C) up to 752 °F (400 °C).

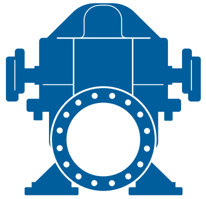
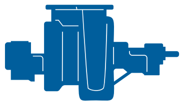
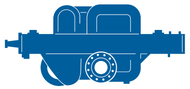
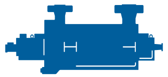
Products include:

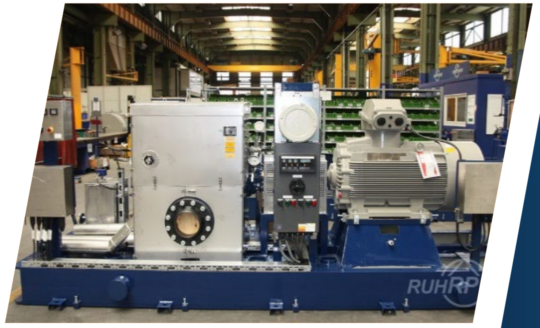
- Single Stage Overhung Pumps
- Between Bearings Pumps
- Horizontal Multi-Stage Pumps
- Vertical Multi-Stage Pumps
- Vertical Mixed Flow & Axial Flow Pumps
- Positive Displacement Pumps
- Full Range of Industrial Pumps
- Submersible Pumps
- Magnetic Drive Pumps
- Decoking Systems
- Packaged Systems
- Fire Systems

OVERHUNG PUMPS

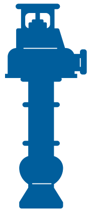
CATEGORY	RP MODEL	DESIGN STANDARD	
Sealless Magnetic Drive Pumps	CRP-M / CRP-M-CC	ISO 2858 & 15783 HI design (OH11)	
	SCE-M	API 685	
Foot Mounted OH1 and General End Suction Pumps	IPP	HI design (OH1)	
	CPP / CPP-L	HI design (OH1) ANSI B73.1	
	CPO / CPO-L	HI design (OH1) ANSI B73.1	
	CRP	HI design (OH1) ISO 2858 & 5199	
	GSD	HI design (OH0)	
	SHD / ESK / SK / SKO SKV / ST / STV	HI design (OH1)	
	SWP	HI design (OH3A)	
Centerline Mounted	SCE	API 610 (OH2)	
Vertical In-Line Pumps	SPI	API 610 (OH3)	
	IVP / IVP-CC	HI design (OH4 / OH5)	
	IIL	HI design (OH5) Dimensionally compliant with ANSI B73.2	
	SPN	API 610 (OH5)	

BETWEEN BEARING PUMPS

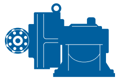
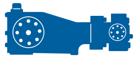
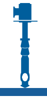
CATEGORY		RP MODEL	DESIGN STANDARD	
1 and 2 stage	Axially split	HSC / HSD / HSL HSR / ZW	HI design (BB1)	
		HSM	HI design (BB3)	
		ZM / ZMS ZLM / ZME	API design (BB1)	
	Radially split	HVN / J	API design (BB2)	
		RON / RON-D	API design (BB2)	
Multi-stage	Axially split	SM / SM-I	API design (BB3)	
		JTN	API design (BB3)	
	Radially split *single casing*	GP	API design (BB4)	
	Radially split *double casing*	A LINE	API design (BB5)	



VERTICAL PUMPS

CATEGORY		RP MODEL	DESIGN STANDARD	
Single casing	Diffuser	**VTP**	HI & API 610 (VS1)	
		VCT	HI & API 610 (VS1)	
		HQ	HI & API 610 (VS1)	
		VLT	HI & API 610 (VS1)	
	Volute	**DSV / DX**	HI & API 610 (VS2)	
	Discharge through column – Axial flow	**VAF**	HI & API 610 (VS3)	
	Separate discharge line	**VSP / VSP-Chem**	HI & API 610 (VS4)	
Double casing	Diffuser	**VLT / VMT**	HI & API 610 (VS6)	
	Volute	**DSV / DX**	HI & API 610 (VS7)	
Submersible pumps		**SMF**	HI design (OH8A)	
		VLT-Sub / VTP-Sub	HI design (VS0)	

SPECIAL SERVICE PUMPS

CATEGORY	RP MODEL	DESIGN STANDARD	
Pitot tube pumps	**COMBITUBE**	HI design	
Reciprocating pumps	**RDP**	API 674 ISO 13710	
Vertical turbine generator	**VTG**	HI design (VS6)	
Barge	**LS BARGE**	HI design	
Floating dock pumps	**ZVZ**	HI design	
	LVZ	HI design	
Cryogenic pumps	**SVNV**	-	
	VTG Cryogenic	-	
	VLT Cryogenic VLTV	-	
Pre-packaged fire pump systems	Fire systems incorporate pumps, drivers, control systems and pipework in a single container. They can be skid mounted, with or without enclosure and supplied with electric motor or diesel engine.	**NFPA-20-850** UL and FM approved components	

Session 10 –
“Non Destructive Examination (NDE)”

Aimed at Process and Mechanical Engineers, and Consultant Engineers who specify pumping equipment as well as Applications & Sales Engineers selecting and quoting them.
This course will look at MPE, LPE, RXE, UTE explaining when they are appropriate for use, how they are carried out and the benefits and limitations of them all.
Get an understanding of what you will be getting when you tick all those boxes on a pump data sheet!

Thanks to Ian James for Source Material

Non Destructive Examination (NDE)

MAIN CHARACTERISTICS OF THE 5 MOST COMMON NDE PROCESSES

NDT METHOD	LIMITATION	DEPTH LIMIT	MATERIAL LIMITATION	COST COMPARISON (1=Low /5= Highest)	CERTIFICATION & PROCEDURES
LIQUID DYE PENETRANT	Surface Cracks Only	Not Applicable	None	1	Level II Operator Certified To SNT-TC-1A, & using Method Detailed in ASME-V, ARTICLE 6.
MAGNETIC PARTICLE	Mainly Surface Cracks	Surface & Minimal Depth	Must be Magnetic	DRY METHOD = 2 WET METHOD = 3	Level II or III Operator, In Accordance with Relevant Parts of ASME SECTION V, ARTICLE 7, ASME VII & ASTM E-709.
ULTRASONIC DETECTION	Below Surface	Good	None, except Surface must be fairly smooth	4	Level II or IIII Operator, in Accordance with Relevant Parts of ASME SECTION V, ARTICLE 7, ASME VII & ASTM E-709.
RADIOGRAPHY (Electronic X-Ray)	Below Surface	X-RAY = Very Good	None	5	X-Ray Examination: Level II Operator, or with Relevant Parts of ASME V-ARTICLE 2, ASME VIII-DIV 1 & ASTM E-94.
RADIOGRAPHY (Gamma Ray Isotope)	Below Surface	Gamma-Ray = Best for thicker materials			Gamma-Ray Examination: Level II or III Operator, in Accordance with Relevant Parts of ASME V, ASME VIII-Div 1, ASTM E-1114 & ASTM E-94.

NOTE:- NDE may also be referred to as NDT.
NDE= Non-Destructive Examination, NDE= Non-Destructive Testing.

Non Destructive Examination (NDE)

LIQUID PENETRANT EXAMINATION or INSPECTION (LPE or LPI)

Non Destructive Examination (NDE)

LIQUID PENETRANT EXAMINATION or INSPECTION (LPE or LPI)

- WHAT IS LPE or LPI:

This is a Non-Destructive Test for detecting surface cracks or other surface problems.

- HOW DOES IT WORK:

1. It works by using two characteristics of a fluid, which are Surface Tension & Capillary action.
2. Basically, if a liquid is thin enough and has a low surface tension & viscosity, when sprayed over a crack, the resulting capillary action will draw the liquid into the crack.
3. Then by removing excess liquid from the surface, the liquid remaining within the crack *is made more visible* by the use of a “developer”, or by the use of “black light” (ultra-violet light), depending on the process.
4. We primarily use the “developer” method, described later in this presentation.

- WHAT INTERPRETATION IS REQUIRED:

Length and shape of the crack is clearly visible, however how it was caused is not.
Since LPE is only used for surface flaw detection, it does not show how deep the crack is, or its extent below the surface. Excavation is required to establish the extent of the problem.

Non Destructive Examination (NDE)

LIQUID PENETRANT EXAMINATION or INSPECTION (LPE or LPI)

PROCESS STEPS REQUIRED FOR LPE:-

1. PRE-CLEANING:

The examined surface must be cleaned to remove any Dirt, Paint, Oil, Grease or any Loose Scales that could either keep penetrant out of a defect/crack, or could cause false indications. Cleaning methods may include solvents or alkaline cleaning processes.

The goal is to clean the examined surface, so that if any defects are present, they will be completely open to the surface, dry, and free from contamination.

2. APPLICATION OF PENETRANT:

The Penetrant is then applied to the surface being tested. The Penetrant is then allowed 10 to 30 minutes time to soak into any flaws by capillary action.

Thinner cracks will require a longer Penetration time, to allow the capillary action to have full effect.

Non Destructive Examination (NDE)

LIQUID PENETRANT EXAMINATION or INSPECTION (LPE or LPI)

PROCESS STEPS REQUIRED FOR LPE:-

3. EXCESS PENETRANT REMOVAL:
The excess Penetrant is then removed from the surface. The removal method is determined by the type of Penetrant used. When using solvent remover and lint-free cloth it is important to not spray the solvent onto the test surface directly, because this can remove the Penetrant from the cracks.
If the excess Penetrant is not properly removed, once the developer is applied, it may leave a background in the developed area that will hide the defects.
Or it will give a false indication because of the excessive liquid Penetrant.

4. APPLICATION OF THE DEVELOPER:
After excess penetrant has been removed, a white developer is applied to the sample. Which draws penetrant from defects out onto the surface to form a visible indication, commonly known as bleed-out.
Any areas that bleed-out can indicate the location and the types of defects on the surface. Interpreting the results and the type of defects from the indications, needs experience.

Non Destructive Examination (NDE)

LIQUID PENETRANT EXAMINATION or INSPECTION (LPE or LPI)

PROCESS STEPS REQUIRED FOR LPE:-

5. INSPECTION:

The inspector will use strong visible light to find the visible dye penetrant. Alternatively, Ultraviolet Light, known as Black Light, will be strong enough for Fluorescent Penetrant examinations.

After 10 Minutes, the inspector will observe the Surface for Cracks & Flaws, after using visible dye.

6. POST CLEANING:

The test surface is often cleaned after inspection and recording the defects. Especially if metallic coating processes or painting will be done after the Inspection has been completed.

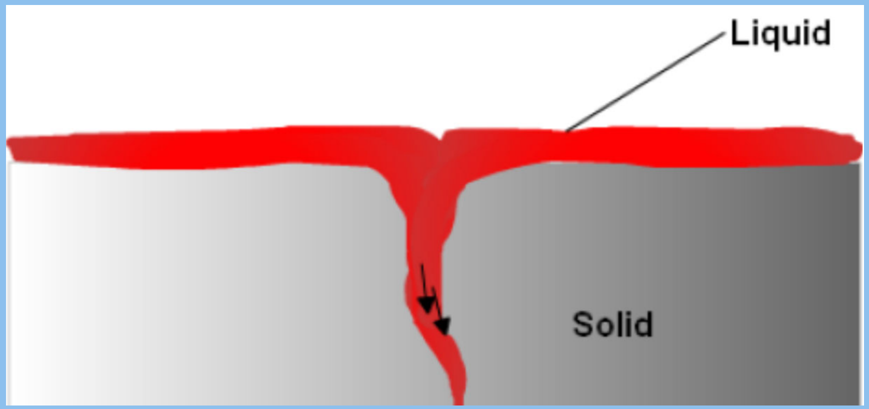
Non Destructive Examination (NDE)

LIQUID PENETRANT EXAMINATION or INSPECTION (LPE or LPI)

VISUAL REPRESENTATION OF THE LPE PROCESS:

PENETRANT APPLICATION:-

Once the surface has been thoroughly cleaned and dried, the Penetrant material is applied by spraying, brushing, or immersing the part in a penetrant bath.



Non Destructive Examination (NDE)

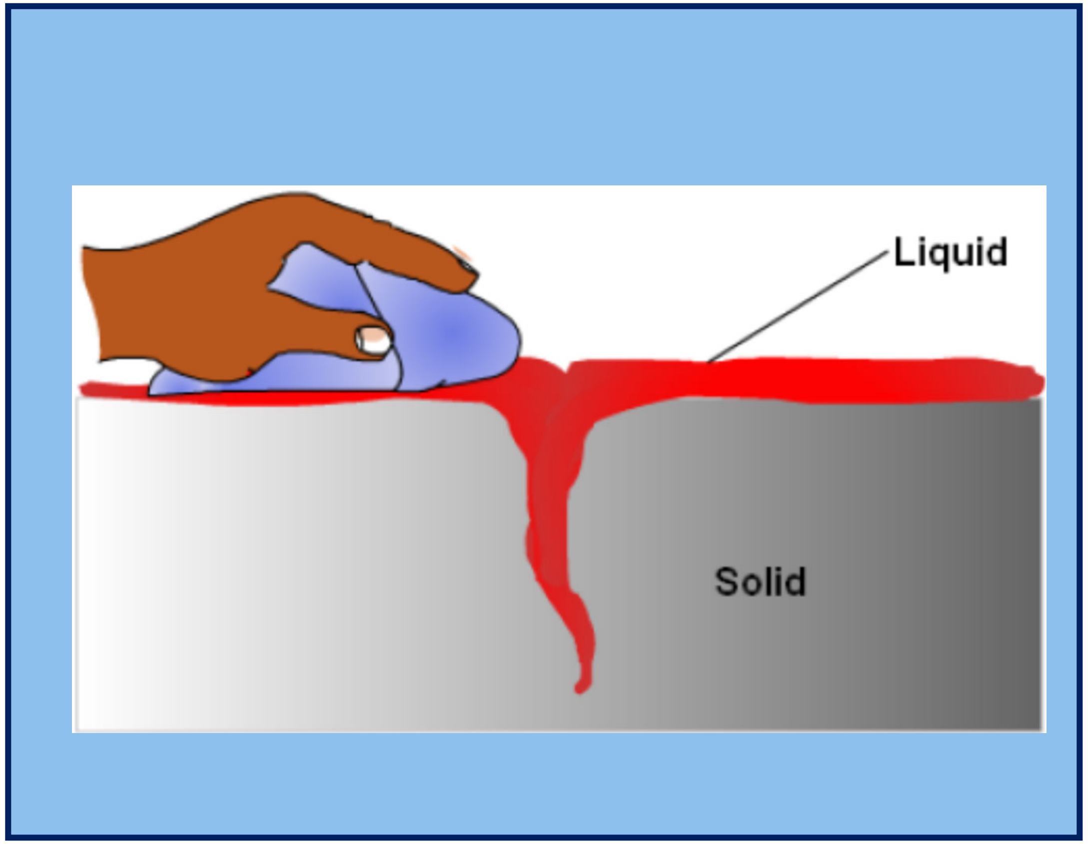
LIQUID PENETRANT EXAMINATION or INSPECTION (LPE or LPI)

VISUAL REPRESENTATION OF THE LPE PROCESS:

<u>EXCESS PENETRANT REMOVAL:</u>

The excessive Penetrant must be removed from the surface of the sample. While removing as little Penetrant as possible from defects.

Depending on the Penetrant system used. This step may involve cleaning with a solvent, direct rinsing with water.



Non Destructive Examination (NDE)

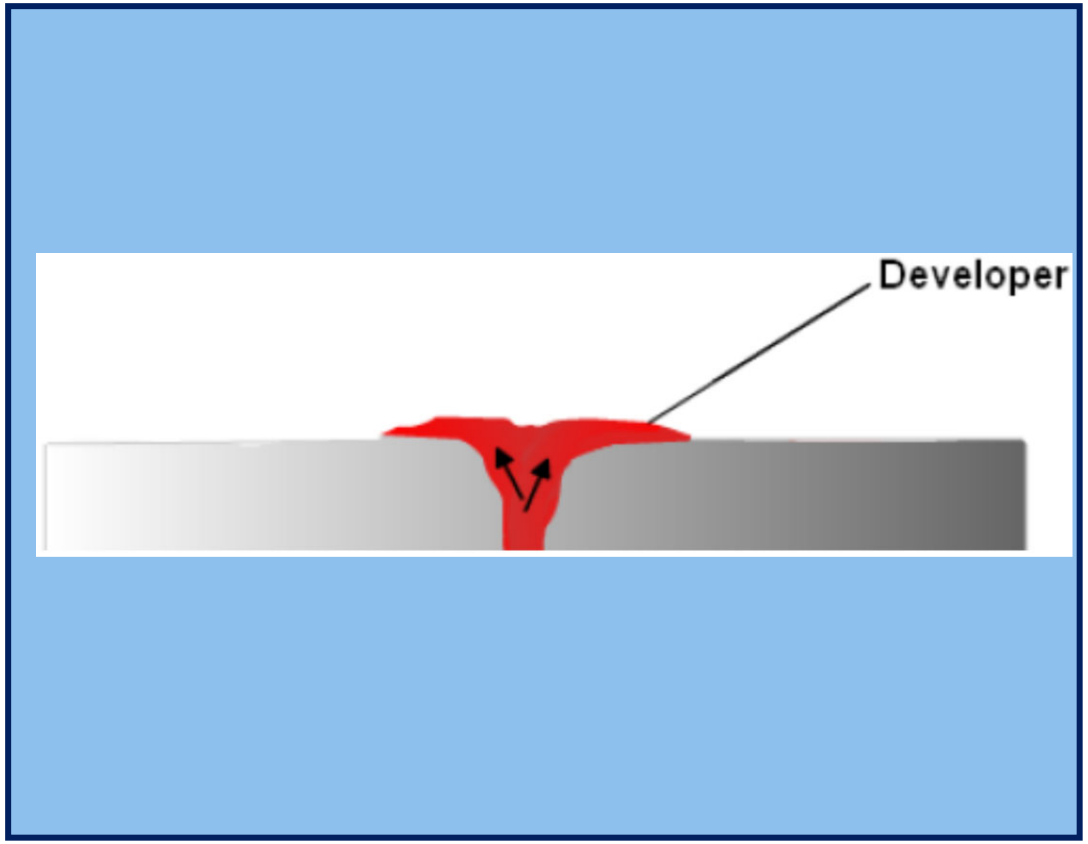
LIQUID PENETRANT EXAMINATION or INSPECTION (LPE or LPI)

VISUAL REPRESENTATION OF THE LPE PROCESS:

<u>DEVELOPER APPLICATION:</u>

A thin layer of developer is then applied to the test sample, to draw penetrant trapped in flaws back to the surface where it will be visible.

The Developers come in a variety of forms, that may be applied by dusting (dry powdered), dipping, or spraying (wet developers).



Non Destructive Examination (NDE)

LIQUID PENETRANT EXAMINATION or INSPECTION (LPE or LPI)

PRIMARY ADVANTAGES:

- LPE has high sensitivity to small surface cracks.
- LPE can be used on many materials, metallic & non-metallic, as long as they are non-absorbent. Also LPE can be used on:- magnetic and nonmagnetic, and conductive and nonconductive materials.
- LPE can cover large areas and large volumes of parts, and can be inspected quite quickly at low costs.
- Even complex shaped parts can be easily LPE inspected.
- Indications are produced directly on the surface of the part and show a visual representation of any Cracks.
- Aerosol spray cans make Penetrant materials very portable.
- Penetrant materials and equipment are relatively inexpensive.
- LPE is easy to use and does not require excessive training.

Non Destructive Examination (NDE)

LIQUID PENETRANT EXAMINATION or INSPECTION (LPE or LPI)

PRIMARY DISADVANTAGES:

- Only surface breaking defects can be detected.
- Only materials with a nonporous surface can be inspected.
- Precleaning is critical since paint or contaminants can hide defects.
- The Inspector must have direct access to the surface being inspected.
- Surface finish and roughness can affect LPE inspection sensitivity.
- Post cleaning of parts or materials is required, especially if welding is to be performed.
- Proper disposal is required.
- Correct Ventilation is required as fumes can be hazardous and flammable from the LPE process.

Non Destructive Examination (NDE)

MAGNETIC PARTICLE EXAMINATION (MPE)

Non Destructive Examination (NDE)

MAGNETIC PARTICLE EXAMINATION (MPE)

- WHAT IS MPE:

This is a Non-Destructive Test for detecting cracks or flaws both on the Surface, or just beneath the Surface for shallow depth flaws.

- HOW DOES IT WORK:

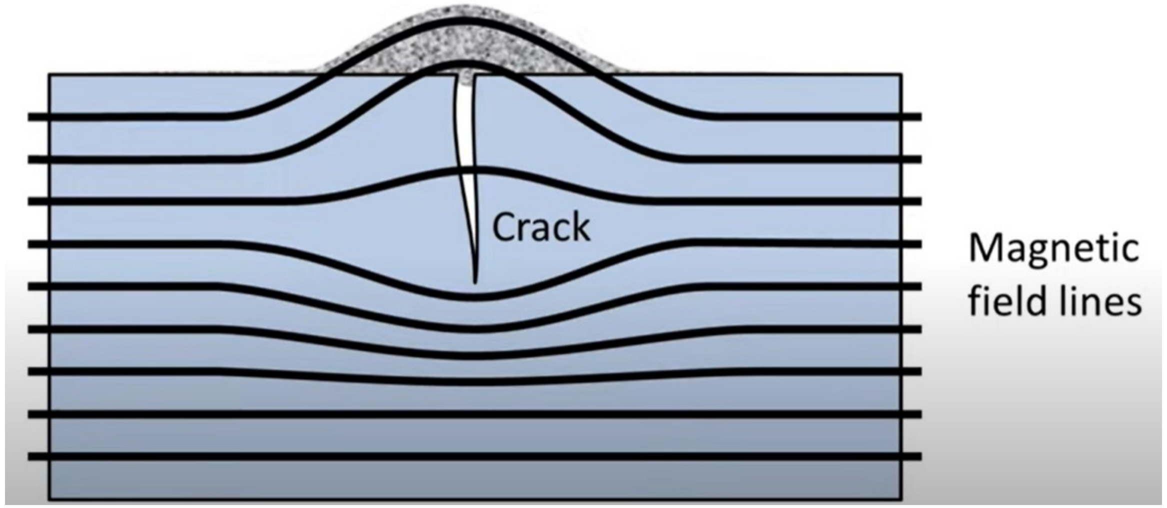
1. It works by magnetizing the part being examined. So it can only be used on Ferromagnetic Materials. (Ferromagnetism refers to materials, such as Steel, Iron or Nickel. Which can retain their magnetic properties when the magnetic field is removed).
2. The magnetic field will change at or near a crack or flaw.
3. This effect is then made visible by the use of iron filings spread over the component.
4. The process can be "wet" or "dry".
5. If required, "wet" testing is carried out by an external inspection authority.

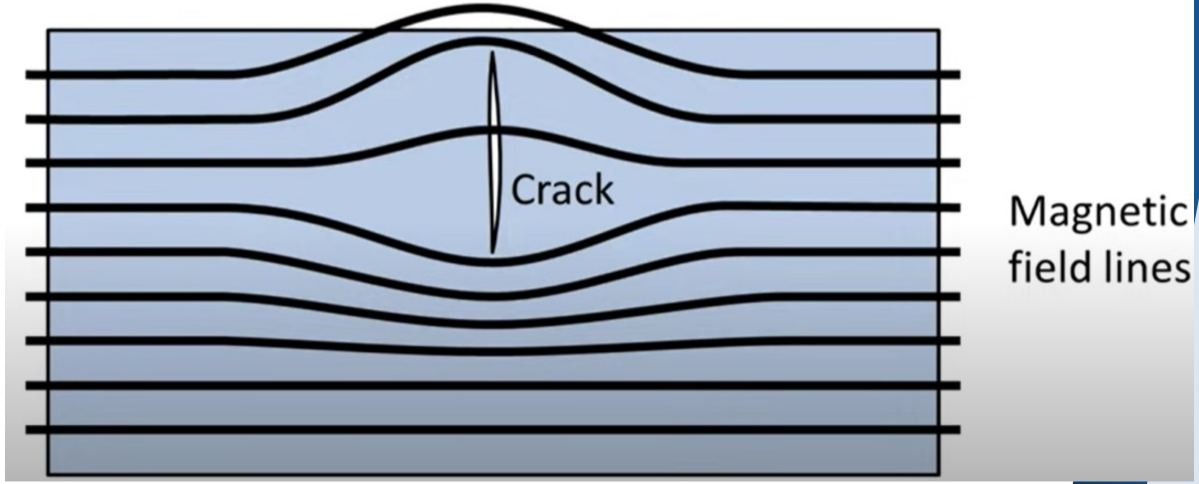
- WHAT INTERPRETATION IS REQUIRED:

The Length and shape of the Crack or Flaw is clearly visible. However interpretation is required, as the Cracks can be at the surface or just below the surface.
MPE cannot determine the depth of a "below surface" Crack, Flaw or Casting Porosity.

Non Destructive Examination (NDE)

MAGNETIC PARTICLE EXAMINATION (MPE)





If the piece is free from flaws the magnetic field lines run within the piece and parallel.
If there is a crack at or near to the surface, the magnetic field lines will locally leave the surface and a local leakage field occurs.
MPE will detect surface defects and those occurring just below the surface

Non Destructive Examination (NDE)

MAGNETIC PARTICLE EXAMINATION (MPE)

Non Destructive Examination (NDE)

MAGNETIC PARTICLE EXAMINATION (MPE)

PROCESS STEPS REQUIRED FOR DRY-PARTICLE MPE METHOD:-

1. PREPARING THE SURFACE OF THE PART:
The surface should be cleaned. The surface must be free of grease, oil or other moisture, which could keep particles from moving freely within the magnetic field.
NOTE: A Thin Layer of Paint, Rust or Scale will reduce MPE sensitivity. Specifications often allow up to a 0.003 inch (0.076 mm) of nonconductive coating, such as paint. Or a 0.001 inch max (0.025 mm) ferromagnetic coating, such as Nickel, to be left on the surface. Any loose dirt, paint, rust or scale must be removed.

2. APPLY THE MAGNETIZING FORCE:
An Electromagnetic Device, can be used to develop the necessary magnetic flux, and cause the Part to be Magnetized. Provided the Magnetic Field is strong enough for MPE.

3. MAGNETIC PARTICLES:- Sprinkle thinly the Dry Metallic Particles on the test area of the Component. Make sure they are in a thin layer, then gently blow away the excess.

Non Destructive Examination (NDE)

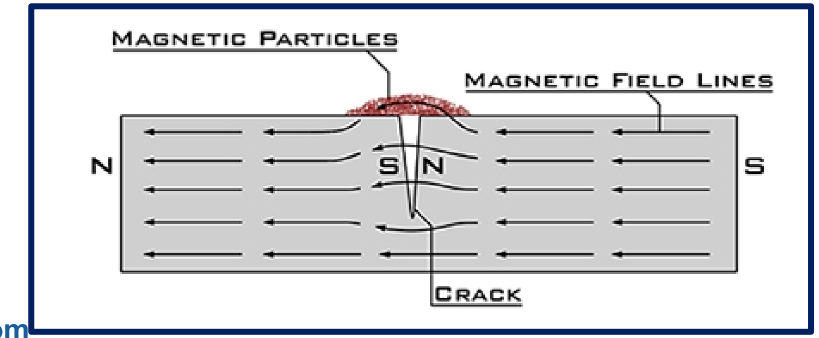
MAGNETIC PARTICLE EXAMINATION (MPE)

PROCESS STEPS REQUIRED FOR DRY-PARTICLE MPE METHOD:-

4. TERMINATE THE MAGNETIZING FORCE:
If the Magnetic Flux is being generated with an Electromagnet or an Electromagnetic Field, the magnetizing force should be terminated.

5. INSPECT FOR INDICATIONS:
Look for areas where the magnetic particles are clustered.

NOTE:- To detect a crack or flaw, the magnetic flux must be TRANSVERSE TO THE FLAW. That is it must be AT RIGHT ANGLES to the flaw, or DIAGONAL to the flaw. Cracks and flaws that are IN-LINE with the magnetic flux WILL NOT BE DETECTED. So in order to check for all possible flaw directions the magnetic field of the next MPE, will need to be changed by 90 degrees.



THE NEXT ESSENTIAL STEP IS DEMAGNETIZATION, BEFORE MAGNETIZING AGAIN AT 90 DEGREES.
This is for Both the WET & DRY PARTICLE MPE Processes, & is described after the next WET-MPE explanation.

Non Destructive Examination (NDE)

MAGNETIC PARTICLE EXAMINATION (MPE)

EXPLANATION OF THE WET-PARTICLE MPE METHOD:-

GENERAL PROCESS DESCRIPTION:-

Wet-Particle MPE, refers to the Smaller Wet-Suspension Particles in a Carrier Liquid. Rather than the previously described DRY-Particle MPE. Wet-Particles are smaller than the Dry-Particles.

THE ADVANTAGES THE WET-PARTICLE MPE HAS OVER THE DRY-PARTICLE MPE:-

1. Wet testing can quickly spray a uniform layer of Particles over the entire surface of the Smooth Component. Even if the area is large. All the Smooth Surfaces of the Component can be easily covered with a uniform layer of Particles.
2. The Liquid Carrier allows the small wet Particles to float to small cracks.
3. Wet-Particle MPE is considered better than Dry Particles for detecting very small cracks on smooth surfaces.
4. Unlike dry particles, Wet Magnetic Particles come in two forms: Non-Fluorescent and Fluorescent When exposed to Ultraviolet Light (Black light), Fluorescent particles shine. Making it easier to detect surface faults in the component. (As shown in a later slide).

Non Destructive Examination (NDE)

MAGNETIC PARTICLE EXAMINATION (MPE)

EXPLANATION OF THE WET-PARTICLE MPE METHOD:-

THE DIS-ADVANTAGE THE WET-PARTICLE MPE HAS OVER THE DRY-PARTICLE MPE:-

On Rougher surfaces, these smaller Wet-Particles, being in suspension within the liquid carrier, will settle in the surface valleys and lose mobility.

Which means they are less effective than Dry Particle MPE at showing surface Cracks, if the Component has a Rough Surface.

Non Destructive Examination (NDE)

MAGNETIC PARTICLE EXAMINATION (MPE)

PROCESS STEPS REQUIRED FOR WET-PARTICLE MPE METHOD::-

1. PREPARING THE SURFACE OF THE PART:
The surface should be relatively smooth & clean. The surface must also be free from grease, oil and other moisture. As this could prevent the Liquid Carrier from wetting the surface. So it would also prevent the particles from moving freely.
NOTE: Just like the Dry-Particle MPE, a thin layer of paint, rust or scale will reduce test sensitivity. Specifications often allow up to 0.003 inch (0.076 mm) of a nonconductive coating (such as paint) and 0.001 inch max (0.025 mm) of a ferromagnetic coating (such as Nickel), to be left on the surface. Any loose dirt, paint, rust or scale must be removed.

2. APPLYING THE LIQUID CARRIER (THE SUSPENSION):
Before the Magnetizing Field is applied to the Component. The suspension of Wet Magnetic Particles in the carrier liquid, is gently sprayed or flowed over the surface of the part.

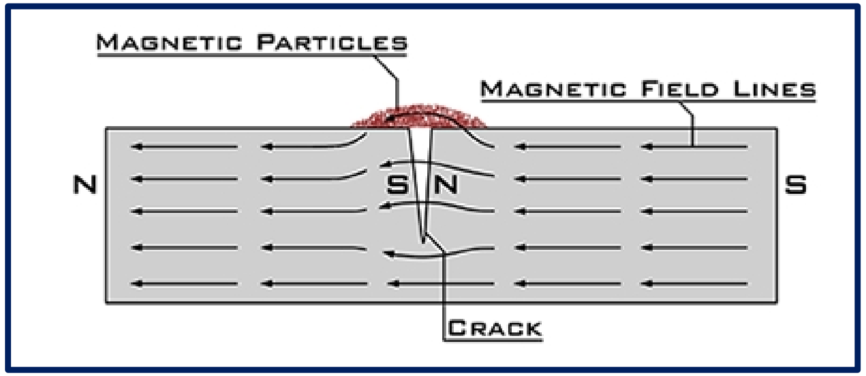
Non Destructive Examination (NDE)

MAGNETIC PARTICLE EXAMINATION (MPE)

PROCESS STEPS REQUIRED FOR WET-PARTICLE MPE METHOD::-

3. APPLY THE MAGNETIZING FORCE:
The Magnetizing Force is applied in two or three short bursts (2 second/bursts). As the resulting Magnetic Kinetic Energy makes the Wet Particles overcome the Suspension Liquids surface tension & viscosity. Which quickly allows the Wet Particles to move.

4. INSPECT FOR INDICATIONS:
Look for areas where the Wet Magnetic Particles are combined. As Surface Cracks will produce a sharp indication Lines. The indications from subsurface Cracks will be less obvious, especially if the Crack is deeply below the Surface



Non Destructive Examination (NDE)

MAGNETIC PARTICLE EXAMINATION (MPE)

PROCESS STEPS REQUIRED FOR WET-PARTICLE MPE METHOD::-

NOTE:- To detect a crack or flaw, the magnetic flux must be TRANSVERSE TO THE FLAW. That is it must be AT RIGHT ANGLES to the flaw, or DIAGONAL to the flaw. Cracks and flaws that are IN-LINE with the magnetic flux WILL NOT BE DETECTED. So in order to check for all possible flaw directions the magnetic field of the next MPE, will need to be changed by 90 degrees.

5. TERMINATE THE MAGNETIZING FORCE:
After completing the MPE Test of the Component, the Electro-Magnetic Field should be De-Magnetized on the Component for reasons shown in the Next Slide.

Non Destructive Examination (NDE)

MAGNETIC PARTICLE EXAMINATION (MPE)

PROCESS STEPS REQUIRED FOR BOTH WET-PARTICLE & DRY PARTICLE MPE METHOD::-

6. DEMAGNETIZING AFTER THE MPE IS COMPLETED (This is critically important)
If Magnetization is left in the Component, the following 5 NEGATIVE EFFECTS CAN OCCUR:-

A. If welding is going to be performed the magnetic field that remains in the Component after the MPE is finished, can create a condition called “ARC-BLOW”.
“ARC-BLOW”, can cause the welding arc to be deflected, and the Molten Filler-Metal may be repelled from the weld.

B. Machining may result in the METAL TURNINGS being Magnetized to the COMPONENT.

C. The Magnetized Component could cause interference with electronic equipment (if eddy current vibration probes (proximitors) are going to be fitted for example).

(Contd)

Non Destructive Examination (NDE)

MAGNETIC PARTICLE EXAMINATION (MPE)

PROCESS STEPS REQUIRED FOR BOTH WET-PARTICLE & DRY PARTICLE MPE METHOD::-

(Contd)

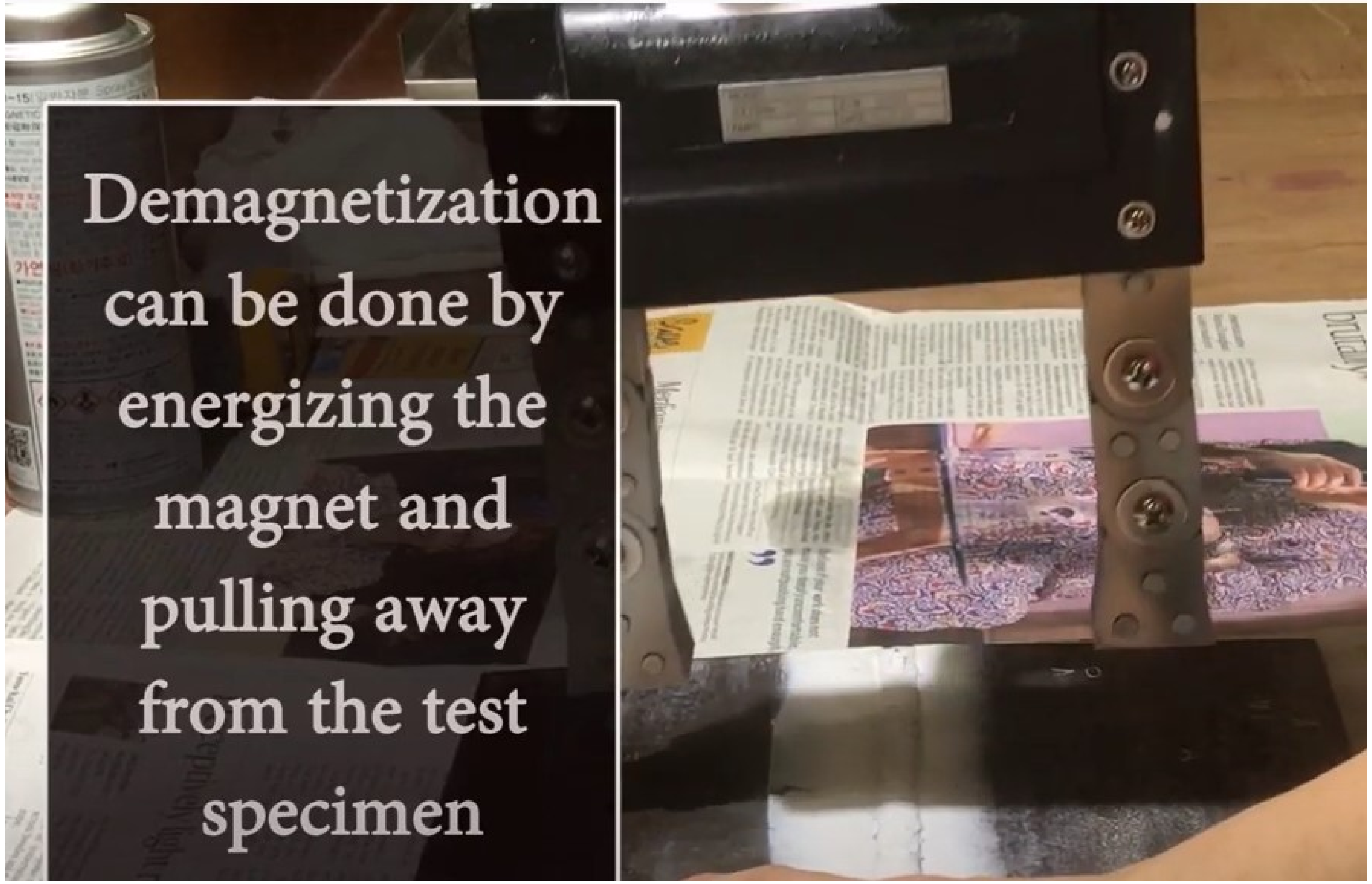
D. Assembly with other Components could be made more difficult. By attracting other Components

E. The Magnetized Component, could also cause ABRASIVE PARTICLES to cling to BEARINGS or the wearing surfaces resulting in increased wear.

Non Destructive Examination (NDE)

MAGNETIC PARTICLE EXAMINATION (MPE)

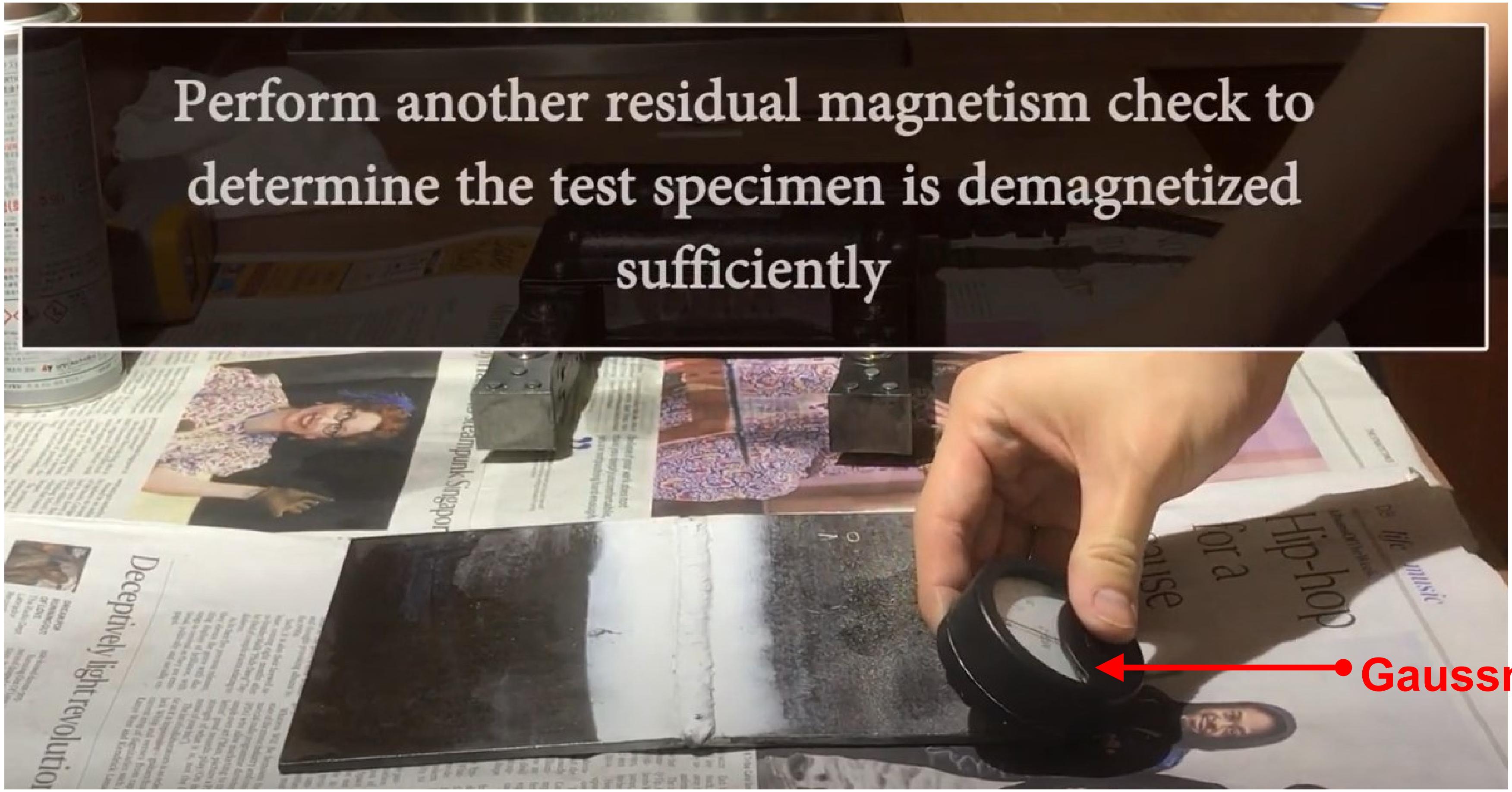
PROCESS STEPS REQUIRED FOR BOTH WET-PARTICLE & DRY PARTICLE MPE METHOD::-



Non Destructive Examination (NDE)

MAGNETIC PARTICLE EXAMINATION (MPE)

PROCESS STEPS REQUIRED FOR BOTH WET-PARTICLE & DRY PARTICLE MPE METHOD::-



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Non Destructive Examination (NDE)

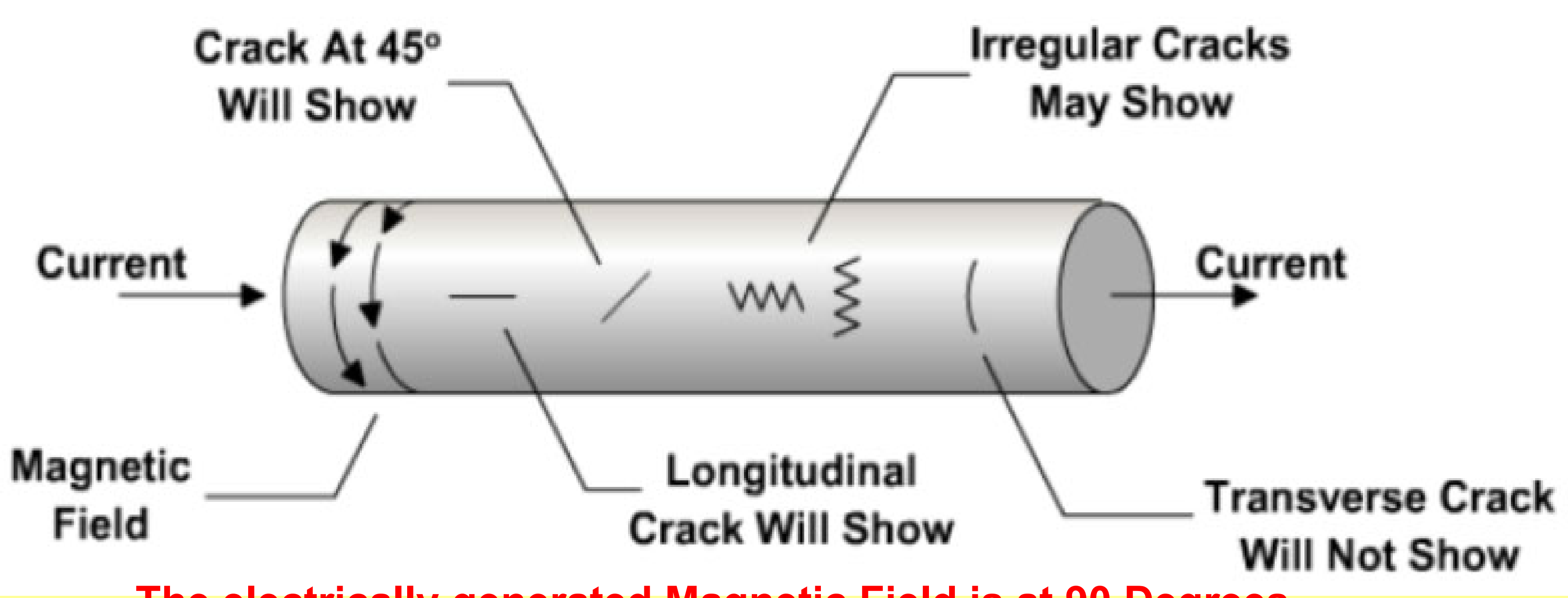
MAGNETIC PARTICLE EXAMINATION (MPE)

PROCESS STEPS REQUIRED FOR BOTH WET-PARTICLE & DRY PARTICLE MPE METHOD::-

Non Destructive Examination (NDE)

MAGNETIC PARTICLE EXAMINATION (MPE)

DRAWING ILLUSTRATING HOW THE FAULT WILL NOT BE VISIBLE, IF IT IS IN THE SAME DIRECTION AS THE MAGNETIC FIELD



The electrically generated Magnetic Field is at 90 Degrees to the Current Flow Direction.

Non Destructive Examination (NDE)

MAGNETIC PARTICLE EXAMINATION (MPE)

EXAMPLES OF VISIBLE DRY MAGNETIC PARTICLE INDICATIONS (Sheet 1 of 4):

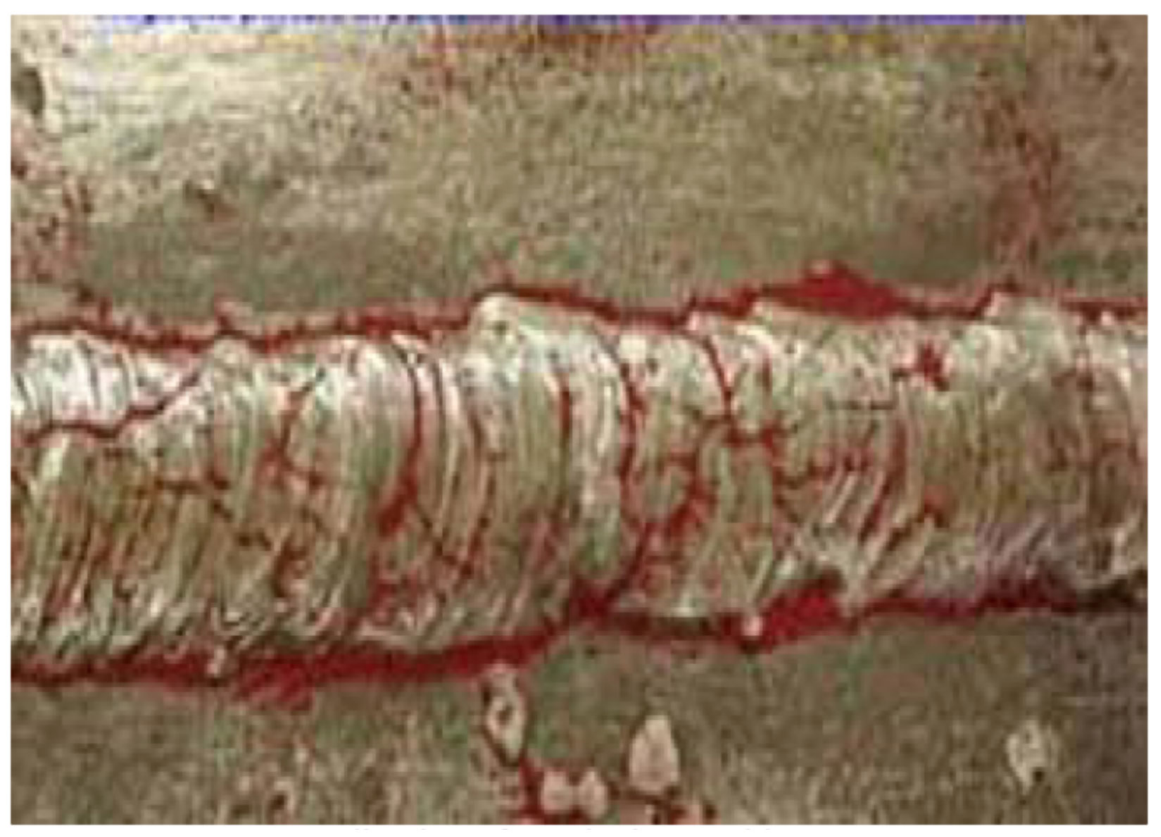
INDICATION OF CRACK IN A SAW BLADE:-

Non Destructive Examination (NDE)

MAGNETIC PARTICLE EXAMINATION (MPE)

EXAMPLES OF VISIBLE DRY MAGNETIC PARTICLE INDICATIONS (Sheet 2 of 4):

INDICATION OF CRACKS IN A WELD:-



Non Destructive Examination (NDE)

MAGNETIC PARTICLE EXAMINATION (MPE)

EXAMPLES OF VISIBLE DRY MAGNETIC PARTICLE INDICATIONS (Sheet 3 of 4):

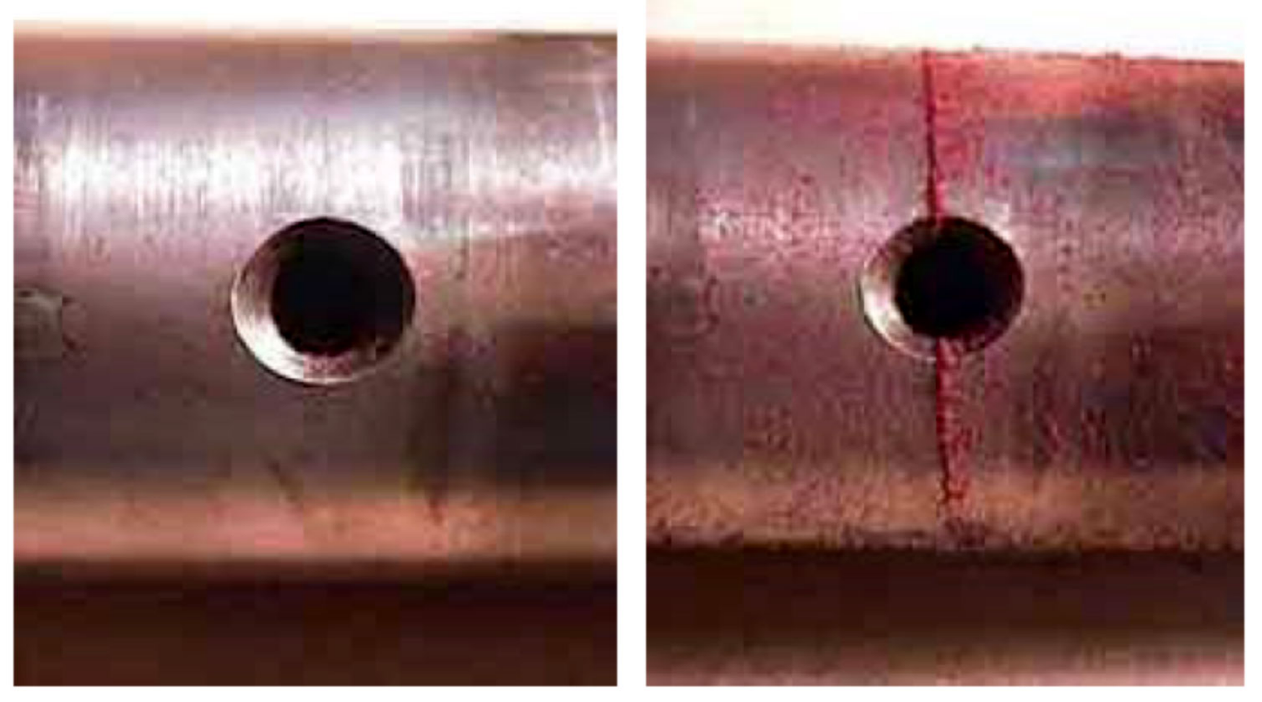
INDICATION OF CRACKS ORIGINATING AT A FASTENER HOLE

Non Destructive Examination (NDE)

MAGNETIC PARTICLE EXAMINATION (MPE)

EXAMPLES OF VISIBLE DRY MAGNETIC PARTICLE INDICATIONS (Sheet 4 of 4):

BEFORE AND AFTER MPE INSPECTION PHOTOS, SHOWING CRACKS EMANATING FROM A HOLE

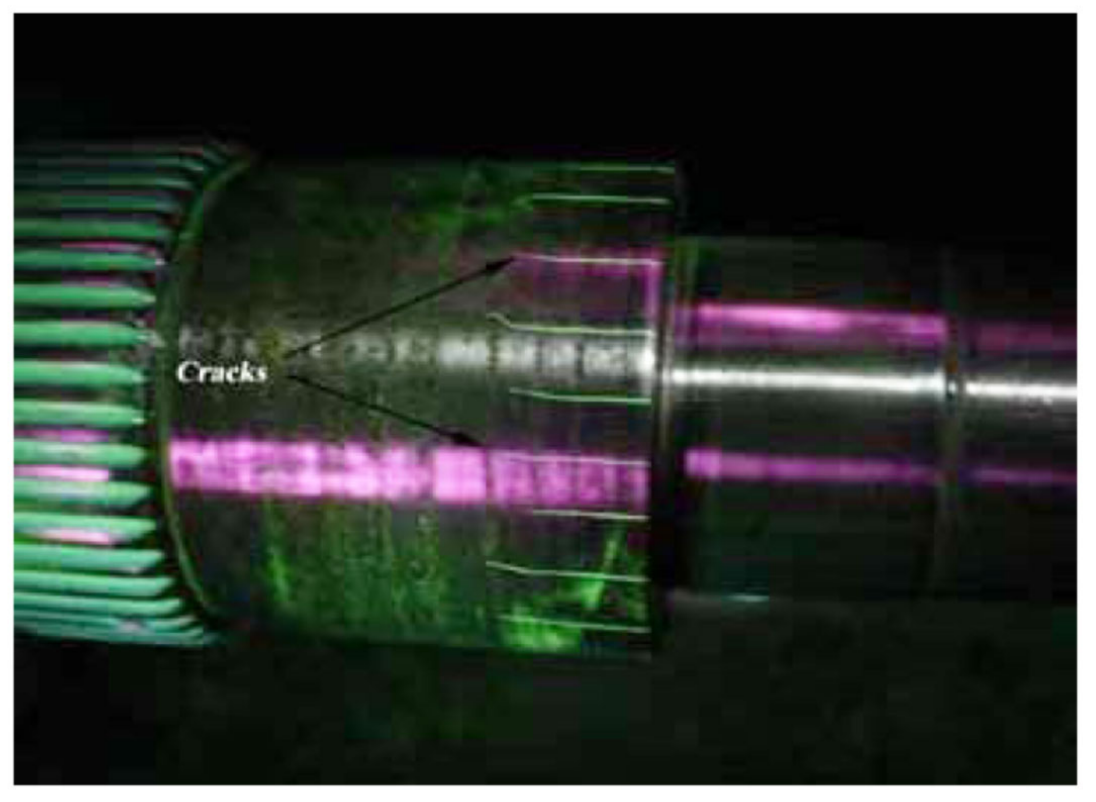


Non Destructive Examination (NDE)

MAGNETIC PARTICLE EXAMINATION (MPE)

EXAMPLES OF FLUORESCENT WET-MAGNETIC PARTICLE INDICATIONS (Sheet 1 of 6):

INDICATION OF FLUORESCENT CRACKS IN A DRIVE-SHAFT



Non Destructive Examination (NDE)

MAGNETIC PARTICLE EXAMINATION (MPE)

EXAMPLES OF FLUORESCENT WET-MAGNETIC PARTICLE INDICATIONS (Sheet 2 of 6):

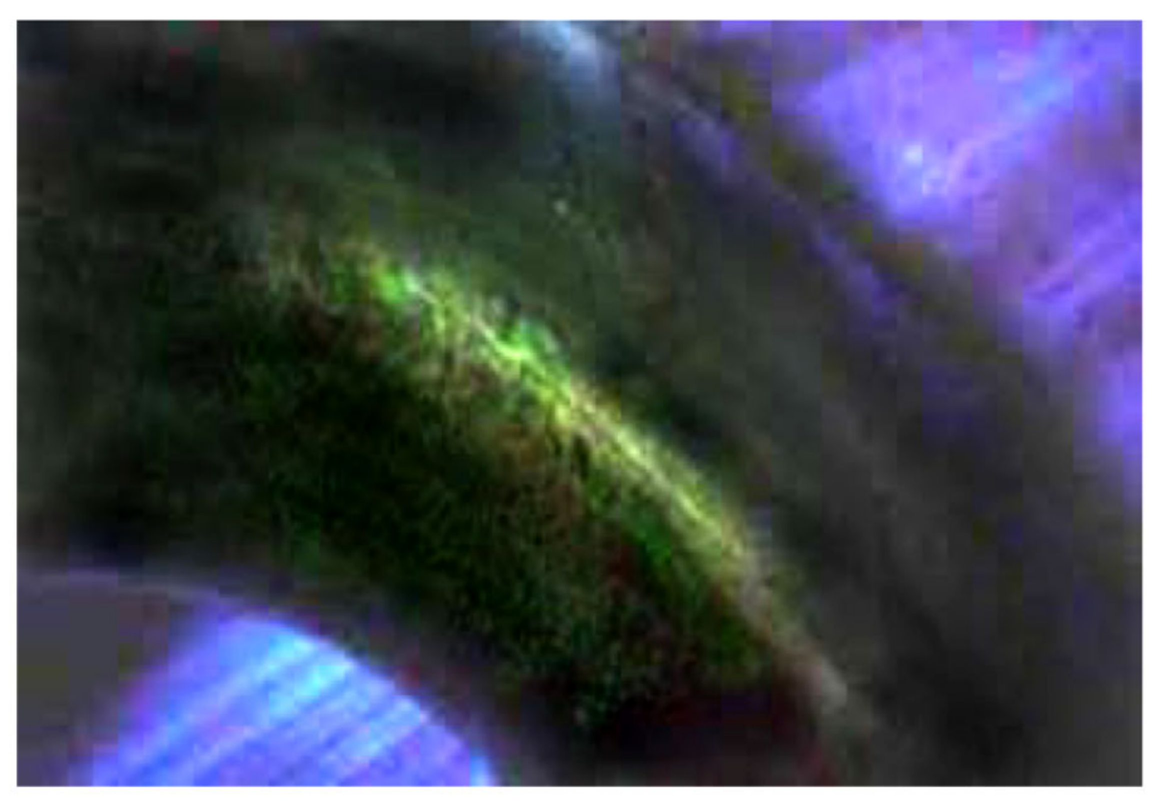
INDICATION OF FLUORESCENT CRACKS IN A BEARING

Non Destructive Examination (NDE)

MAGNETIC PARTICLE EXAMINATION (MPE)

EXAMPLES OF FLUORESCENT WET-MAGNETIC PARTICLE INDICATIONS (Sheet 3 of 6):

INDICATION OF FLUORESCENT CRACKS IN A CRANE HOOK

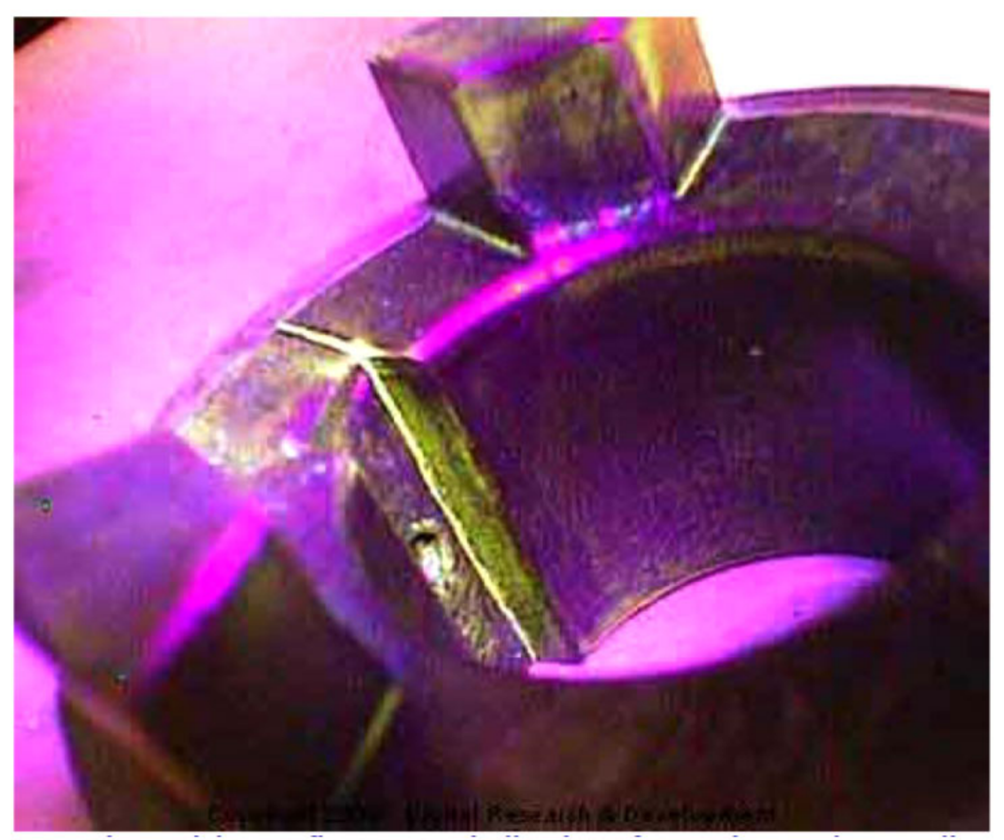


Non Destructive Examination (NDE)

MAGNETIC PARTICLE EXAMINATION (MPE)

EXAMPLES OF FLUORESCENT WET-MAGNETIC PARTICLE INDICATIONS (Sheet 4 of 6):

INDICATION OF FLUORESCENT CRACKS IN SEVERAL SHARP RADII (CORNERS)



Non Destructive Examination (NDE)

MAGNETIC PARTICLE EXAMINATION (MPE)

EXAMPLES OF FLUORESCENT WET-MAGNETIC PARTICLE INDICATIONS (Sheet 5 of 6):

INDICATION OF FLUORESCENT CRACKS IN A CASTING

Non Destructive Examination (NDE)

MAGNETIC PARTICLE EXAMINATION (MPE)

EXAMPLES OF FLUORESCENT WET-MAGNETIC PARTICLE INDICATIONS (Sheet 6 of 6):

INDICATION OF FLUORESCENT CRACKS IN A FASTENER HOLE

Non Destructive Examination (NDE)

ULTRASONIC EXAMINATION (UTE)

Non Destructive Examination (NDE)

ULTRASONIC EXAMINATION (UTE)

- WHAT IS ULTRASONIC EXAMINATION:

This is a Non-Destructive Test for detecting cracks or faults BELOW THE SURFACE OF ANY MATERIAL; and can also determine MATERIAL THICKNESS.

- HOW DOES IT WORK:-

1. ULTRASONIC, is a High-Frequency Sound-Wave signal (beyond human hearing), which is passed into any Metallurgy Component.

2. Any crack or faults within the component will cause a change in the reflection of this Ultrasonic signal.

3. This change is seen on a Display or Diagnostic Machine.

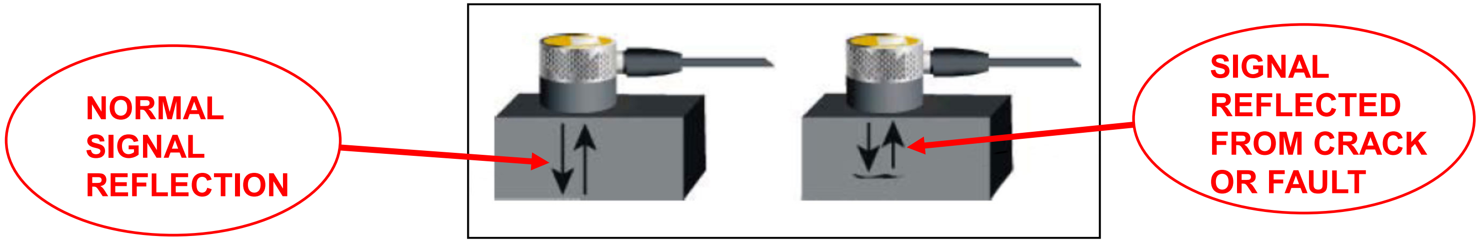
4. This signal reflection & strength can then be used to determine the depth, size and shape of the crack or fault.

Non Destructive Examination (NDE)

ULTRASONIC EXAMINATION (UTE)

- WHAT INTERPRETATION IS REQUIRED:

Interpretation of the Displayed Signal requires Skill & Training.
The strength of the Returned (Reflected) Signal gives an indication of the Size of the Crack.
Also, the Time Taken for the various Signal Returns through the Component, gives an indication of the Depth and Location of the Crack.



Non Destructive Examination (NDE)

ULTRASONIC EXAMINATION (UTE)

DETAILS OF THE TWO ULTRASONIC TECHNIQUES THAT CAN BE USED (Sheet 1 of 5):

MODE 1- THE REFLECTION TECHNIQUE:

In REFLECTION MODE, the single Ultrasonic Transducer performs both the Sending and the Receiving of the pulsed waves, as the "sound" is reflected back to the device.

- For this method a LIQUID COUPLANT such as oil is used on the surface of the part where the ultrasonic transducer is located. The purpose of the Liquid Couplant is to form a layer between the surface of the component and the ultrasonic transmitter/receiver probes to reduce losses in the UT signal.
- Reflected Ultrasound comes from the Back Wall of the Component, or from a Crack or Fault within the Component ,or from a Variation in Density of the material (e.g. Porosity).
- The Ultrasound Diagnostic Machine displays these results in the form of a Signal with an Amplitude representing the Strength of the Reflected Signal.
- THE DEPTH OF THE CRACK OR FAULT, IS DETERMINED BY THE ARRIVAL TIME OF THE ULTRASONIC REFLECTION.

Non Destructive Examination (NDE)

ULTRASONIC EXAMINATION (UTE)

DETAILS OF THE TWO ULTRASONIC TECHNIQUES THAT CAN BE USED (Sheet 2 of 5):

MODE 2- THE ATTENUATION TECHNIQUE:

The ATTENUATION TECHNIQUE, uses 2 probes… a TRANSMITTER & a RECEIVER:

In Attenuation Mode, a TRANSMITTER sends Ultrasound through one surface. Then a separate RECEIVER detects the amount that has reached it on the opposite surface. After traveling through the Component. The "LIQUID COUPLANT" needs to be coated on BOTH SURFACES with this technique.

CRACKS & FAULTS, in the space between the Transmitter and Receiver Probes, allow the Depth of the Cracks and Faults to be detected.

Using the LIQUID COUPLANT between both Probes and the Surfaces of the Component, reduces the Ultrasonic Losses. It makes the Ultrasonic Probes more accurate and more efficient in detecting CRACKS & FAULTS at Depths.

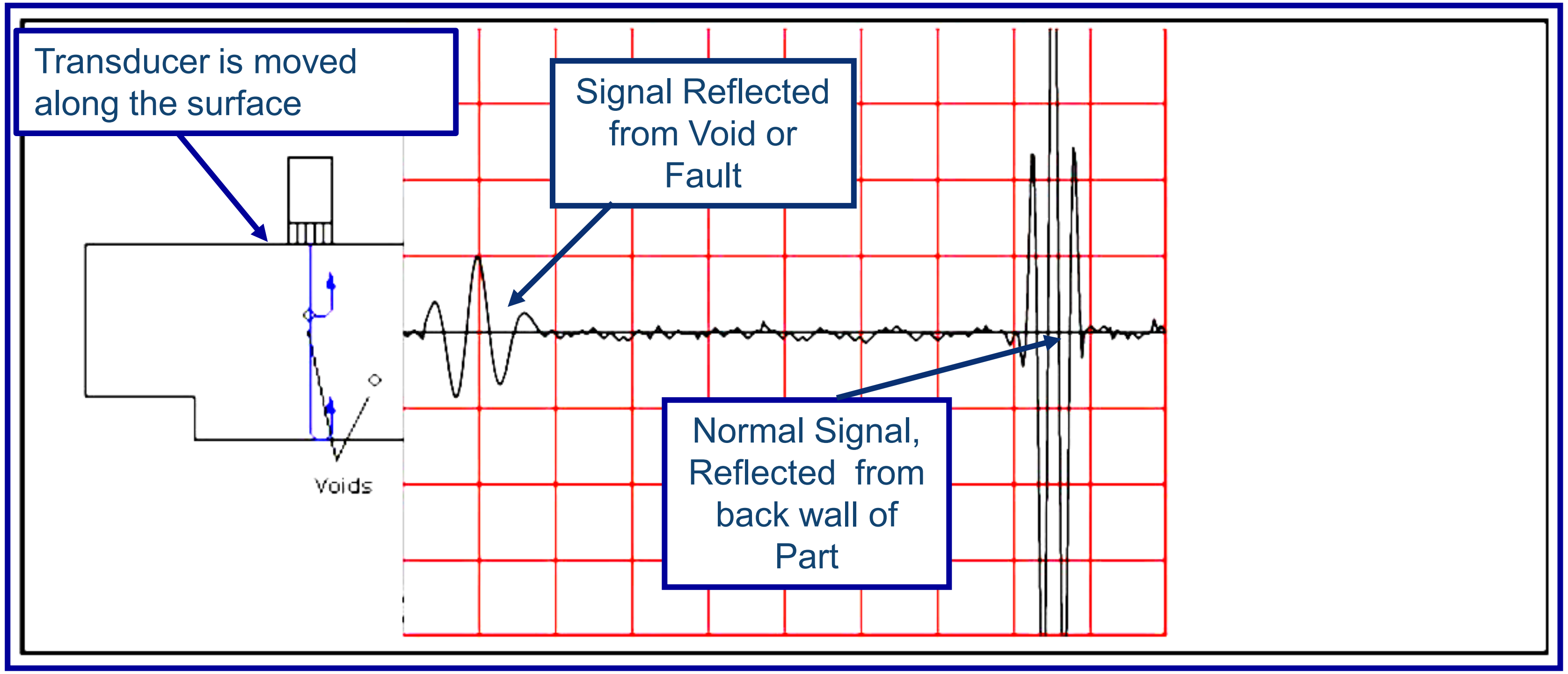
Non Destructive Examination (NDE)

ULTRASONIC EXAMINATION (UTE)

<u>DETAILS OF THE TWO ULTRASONIC TECHNIQUES THAT CAN BE USED (Sheet 3 of 5):</u>

<u>ILLUSTRATION OF THE REFLECTION TECHNIQUE:</u>

The illustration below, shows a typical Ultrasonic Signal from a Casting Porosity Flaw or Crack within the Component. Using the REFLECTION TECHNIQUE.

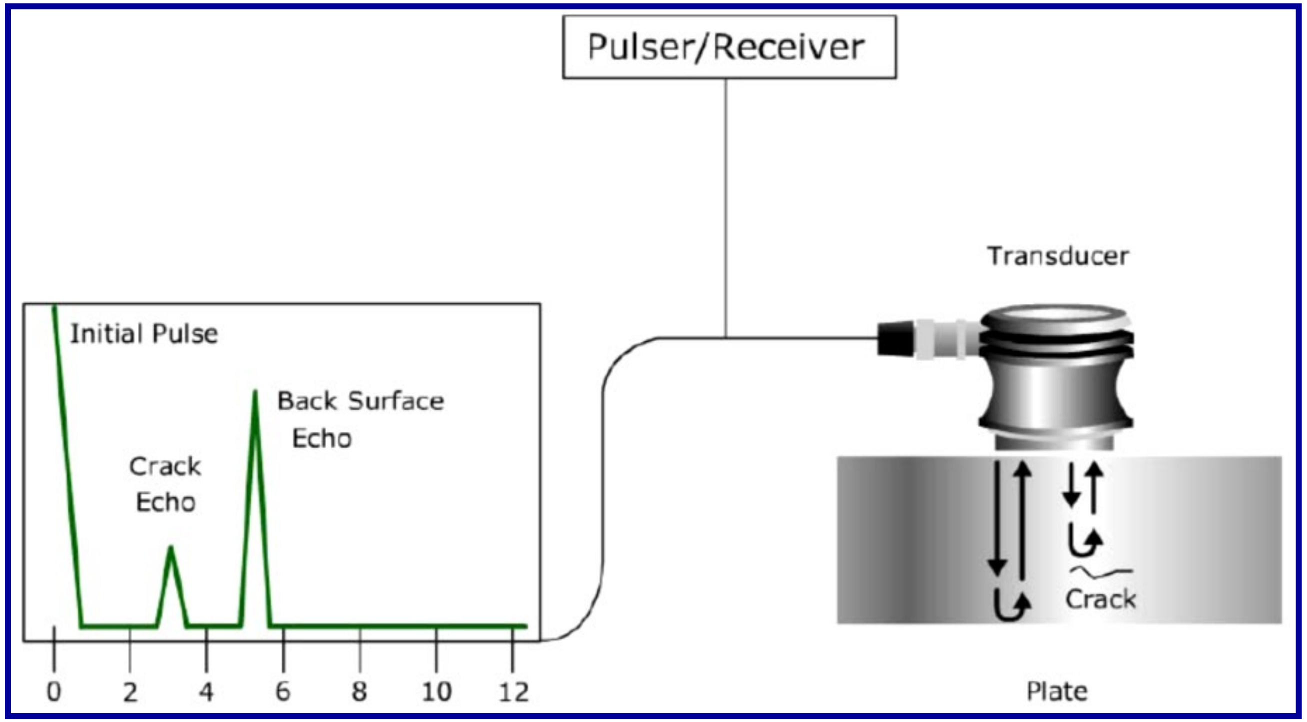


Non Destructive Examination (NDE)

ULTRASONIC EXAMINATION (UTE)

<u>DETAILS OF THE TWO ULTRASONIC TECHNIQUES THAT CAN BE USED (Sheet 4 of 5):</u>

<u>SECOND EXAMPLE OF THE REFLECTION TECHNIQUE:</u>
The illustration below, shows another typical ULTRASONIC REFLECTION SIGNAL from a Crack within a Component. Using the REFLECTION TECHNIQUE.

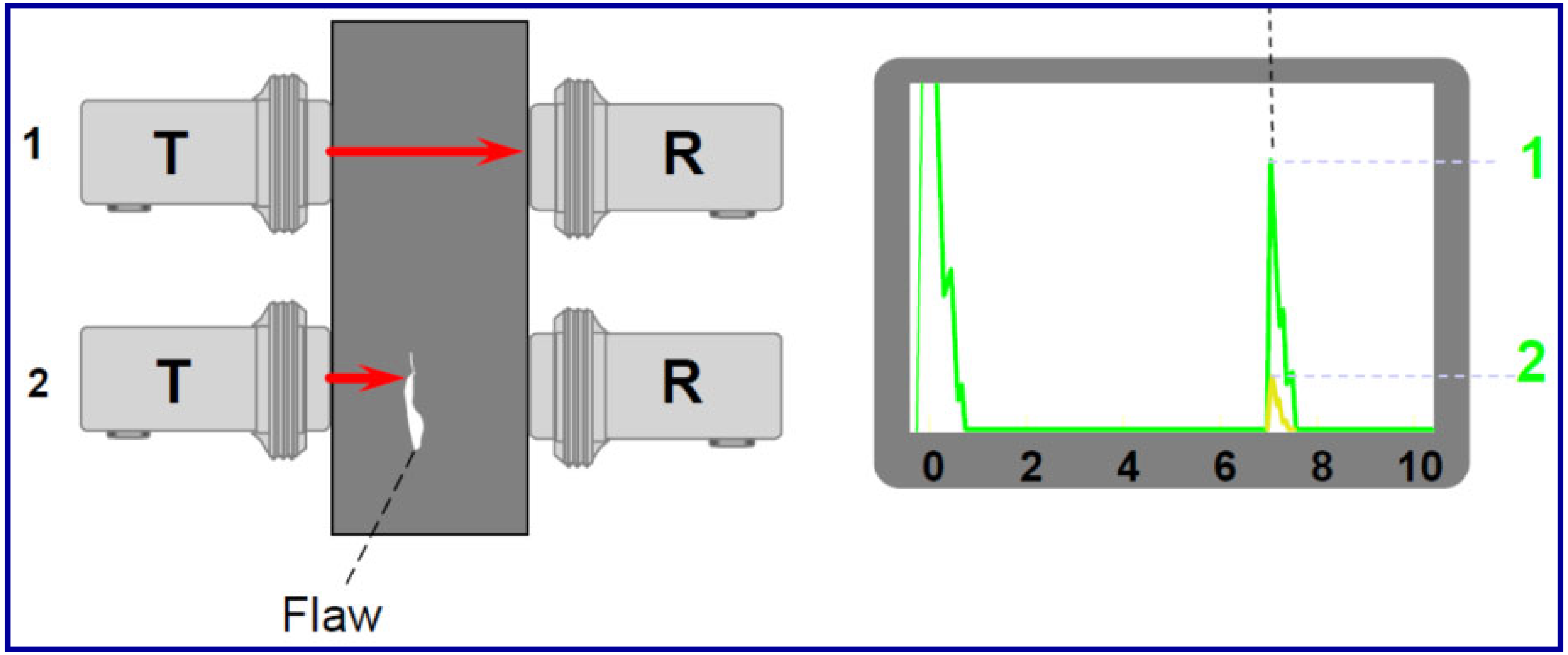


Non Destructive Examination (NDE)

ULTRASONIC EXAMINATION (UTE)

DETAILS OF THE TWO ULTRASONIC TECHNIQUES THAT CAN BE USED (Sheet 5 of 5):

EXAMPLE OF THE ATTENUATION (TWO-PROBES) TECHNIQUE:
The illustration below, shows an example of the detection of a typical Ultrasonic signal from a void or flaw within a part, using the ATTENUATION TECHNIQUE.



Non Destructive Examination (NDE)

ULTRASONIC EXAMINATION (UTE)

)

PROCESS STEPS REQUIRED FOR BOTH ULTRASONIC METHODS (Sheet 1 of 4):

1. PREPARING THE SURFACE OF THE PART:- The surface of the Part should be cleaned. It must also be free of grease, oil or other moisture. Then it should be dried. Also, any loose dirt, paint, rust or scale must be removed.

2. APPLYING THE LIQUID COUPLANT:

The area to be examined should then be coated with an ULTRASONIC "COUPLANT LIQUID", such as oil. The Couplant Liquid ensures that the Ultrasonic signal passes Efficiently from the Probes to the Component through the Couplant Liquid.

If Liquid Couplant was not used, the Air-Gap between the Ultrasonic Probes & the Component would reduce the Ultrasonic Signal Strength & Reduce the Accuracy.

3. NOTE:- If the REFLECTIVE technique is used, only One Surface (One Probe) needs the Couplant to be coated. If the ATTENUATION technique is used (with 2 Probes), then Both Surfaces will need to be coated.

Non Destructive Examination (NDE)

ULTRASONIC EXAMINATION (UTE)

PROCESS STEPS REQUIRED FOR BOTH ULTRASONIC METHODS (Sheet 2 of 4):

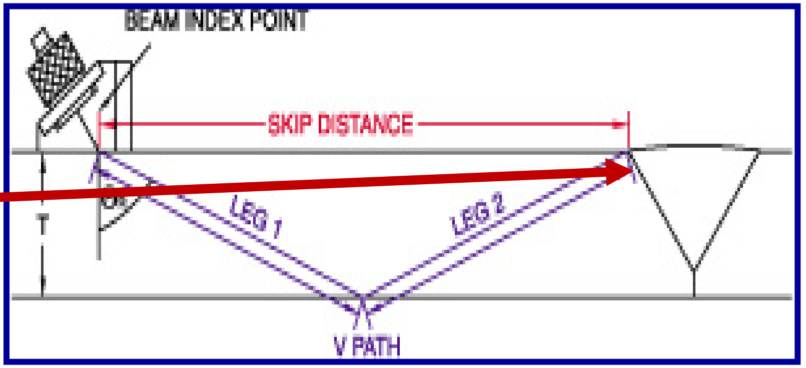
4. CRACK OR FAULT DETECTION:- The Ultrasonic Display Machine will show the plot of the signal reflection, showing the signal strength against time.

NOTE:- The most obvious cracks detected are those that are at 90 DEGREES TO THE PLANE OF THE ULTRASONIC BEAM. Because they stretch across the path of the Ultrasonic Beam to provide the greatest Signal change.

If a crack is IN LINE with the beam, the signal change may be so weak it may be impossible to detect. To protect against this possibility, sometimes angled ultrasonic shots are used.

This is achieved using ULTRASONIC PROBES that are angled at 60 Degrees to the plane of the Component being tested.

AN EXAMPLE OF WHEN THIS IS USED IS SHOWN HERE. WHICH ILLUSTRATES HOW THE ANGLED WALL OF A BUTT-WELD CAN BE EXAMINED, FOR FAULTS.



Non Destructive Examination (NDE)

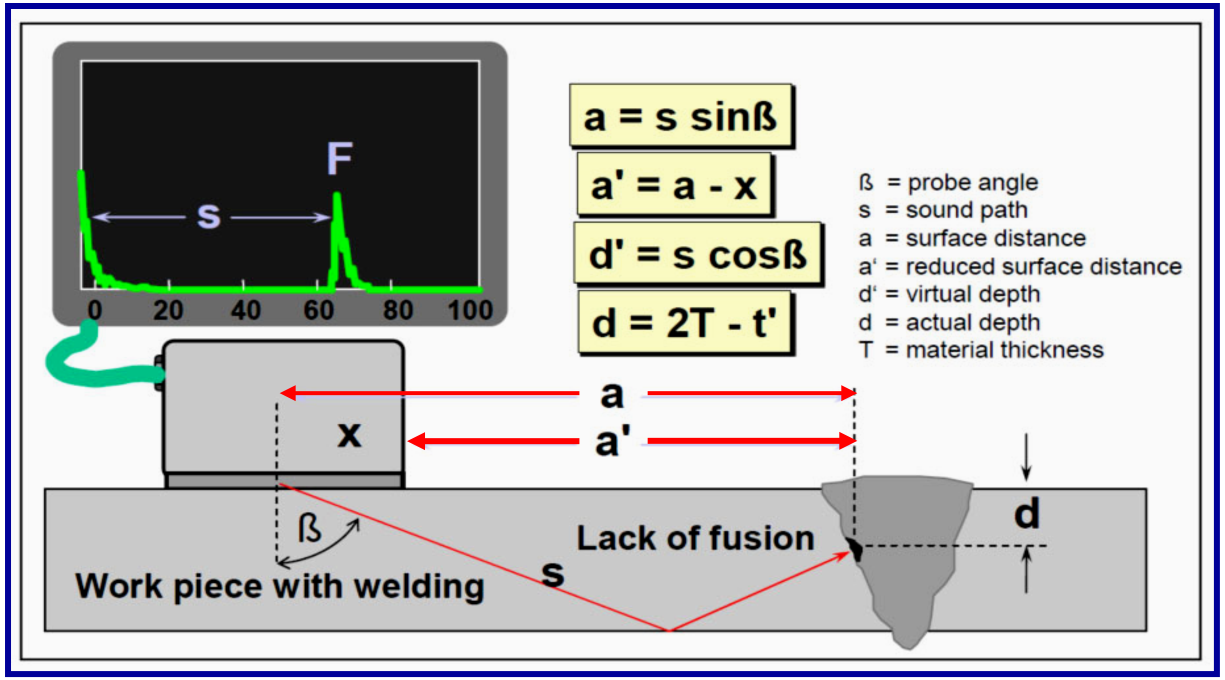
ULTRASONIC EXAMINATION (UTE)

PROCESS STEPS REQUIRED FOR BOTH ULTRASONIC METHODS (Sheet 3 of 4):

4. CRACK OR FAULT DETECTION (CONTINUED):

Here is another example of an Angled shot, with an Ultrasonic Inspection Technique.

Showing how some of the results are calculated: This example is once again used to examine the integrity of the butt weld.



Non Destructive Examination (NDE)

ULTRASONIC EXAMINATION (UTE)

PROCESS STEPS REQUIRED FOR BOTH ULTRASONIC METHODS (Sheet 4 of 4):

5. REMOVAL OF THE LIQUID COUPLANT:

After completion of the Ultrasonic Inspection, the Liquid Couplant must then be removed, and the surface cleaned and dried.

Regularly used Liquid Couplants are oil, or even water.

So it is always beneficial to ensure these liquids are removed, before the Component is further processed.

Non Destructive Examination (NDE)

ULTRASONIC EXAMINATION (UTE)

ADVANTAGES OF USING ULTRASONIC NDE/NDT:

THE FOLLOWING 7 POINTS, SHOW THE ADVANTAGES OF ULTRASONIC NDT TESTING:-

- High Penetrating Power, which allows the detection of Cracks & Flaws Deep in the Component.
- High Sensitivity, permitting the detection of extremely Small Cracks & Flaws.
- Only **One** Surface need be accessible, (for the Single Probe REFLECTIVE method, not the Two Surface & Two Probes ATTENUATION methods).
- Greater Accuracy than other Non-destructive methods, in determining the depth of internal Flaws, and also the Thickness of Components with Parallel Surfaces.
- Ability to assess the Size, Orientation, Shape and Nature of Cracks & Flaws.
- Non-hazardous to nearby Personnel. Also, ULTRASONIC TESTING (UT) has no effect on equipment and materials in the vicinity. Unlike Mag-Particle Inspection.
- UT is also capable of being very Portable or highly Automated Operation.

Non Destructive Examination (NDE)

ULTRASONIC EXAMINATION (UTE)

DISADVANTAGES OF USING ULTRASONIC NDE/NDT:

THE FOLLOWING 5 POINTS, SHOW THE DISADVANTAGES OF ULTRASONIC NDT TESTING:-

- Use of ULTRASONIC TESTING requires Understanding by Skilled, Trained & Experienced Technicians.
- Detailed Technical Knowledge is required to choose the most accurate Ultrasonic Inspection Procedures.
- Components that are Rough, Irregular in shape, Very Small or Thin, or are Not Solid. Are difficult to Inspect using Ultrasonic Techniques.
- Surfaces must be prepared by Cleaning, Removing Loose Scale & Paint.
- Inspected Components must have the Liquid Couplants removed from their surfaces. To prevent the possibility of rust forming on Steel Components, if the Liquid Couplant used was Water.

Non Destructive Examination (NDE)

RADIOGRAPHIC EXAMINATION (RXE)

Non Destructive Examination (NDE)

RADIOGRAPHIC EXAMINATION (RXE)

- WHAT IS RADIOGRAPHIC TESTING (RXE/RT)?:

This is a Non-Destructive Test for detecting CRACKS & FAULTS BELOW THE SURFACE OF ANY MATERIAL, (except lead which is too dense). It is suitable for Thin and very Thick parts.

This method of NDE is the most specialized of all NDE and requires many safeguards and skillsets for safety due to the use of dangerous ionizing radiation.

- HOW DOES IT WORK?:

Industrial radiography uses one of two sources of radiation:

1. ELECTRONICALLY PRODUCED X-RAYS, which are issued by an X-RAY Generator.
2. GAMMA-RAYS:- This Radiation is the Strongest, most Dangerous, & needs More Safeguards & is naturally issued by a Radioactive Isotope. It is also the best for Very Thick & Heavy Metal Components.

(Contd)

Non Destructive Examination (NDE)

RADIOGRAPHIC EXAMINATION (RXE)

- HOW DOES IT WORK?:

(Contd)

- X-RAYS and GAMMA RAYS differ only in their STRENGTHS & Source of Origin.
- Both the X-RAYS & GAMMA RAYS are targeted to pass through the part to be inspected.
- A Photographic Film is then placed at the other side of the part. Ready to be affected by the Ionizing X Rays & GAMMA Rays, after they have passed through the part being inspected.
- Interpretation of the Developed Film is carried out using a “Viewer”. Which requires Skills and Training, to evaluate the Dark Shadows shown on the Developed Film.
- Flaws & Cracks are seen as Dark (Negative) Shadows on the film, after it is exposed & developed.

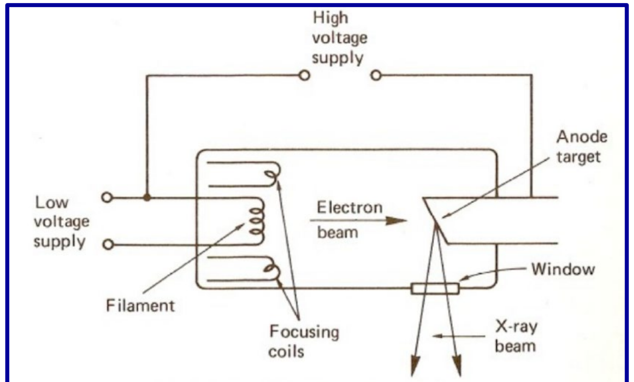
Non Destructive Examination (NDE)

RADIOGRAPHIC EXAMINATION (RXE)

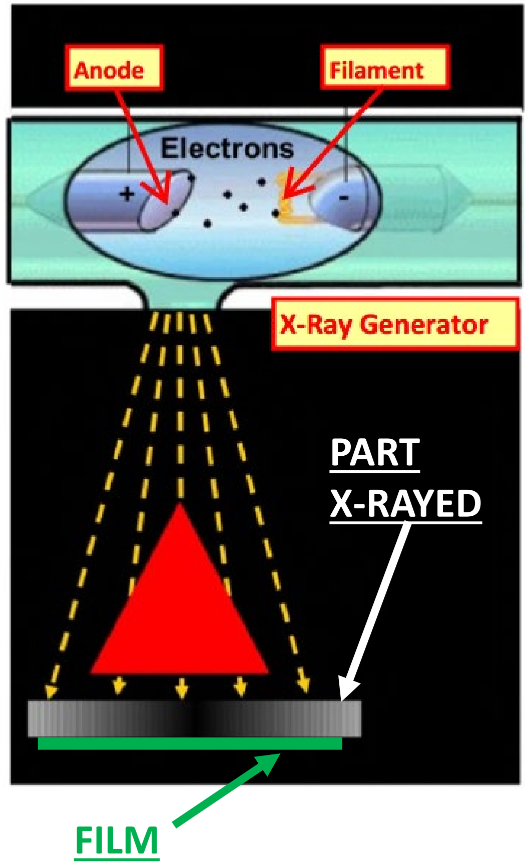
HOW DOES IT WORK?:

X-RAY GENERATION METHOD:

- The Cathode Ray Tube contains a small filament similar to a light bulb.
- The electric current passing through the filament heats it up. This causes electrons to be stripped off.
- Then high-voltage causes this Electron Cloud to be pulled towards the target material called an Anode, which is usually made of Tungsten.
- The Anode has an angled surface so that when the electrons impact onto the anode the impact causes an energy exchange. This results in X-RAYS being generated from the anode in the reflected direction of the angled surface, targeted to pass through the part being examined, onto the film behind the part.



Schematic view of an X-ray tube.

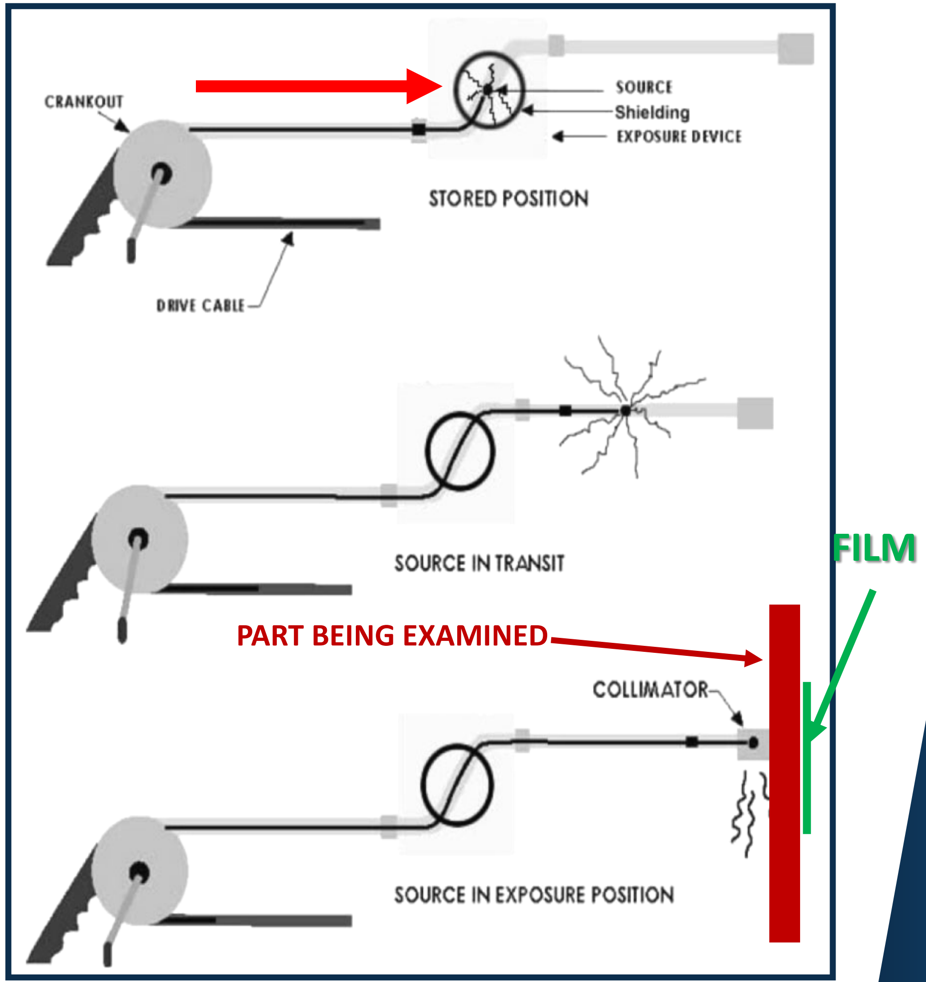


Non Destructive Examination (NDE)

RADIOGRAPHIC EXAMINATION (RXE) HOW DOES IT WORK?:

GAMMA-RAY METHOD & ISOTOPE CONTROL:-

- Gamma-Rays are produced continuously, by the decay of unstable atoms, from a man-made Radio-Active Isotope.
- The Isotope is stored in a heavily LEAD-shielded Container for safe use, as shown.
- The Container has a handle controlling the Drive-Cable attached to one side. With a long shielded Source-Cable on the other side.
- At the end of the Source-Cable is the COLLIMATOR, where the Isotope is fed.
- The intent is to lead the Source-Cable & Collimator to the Part being examined after placing the Film on the other side of the Part.
- The User winds the Drive-Cable handle which pushes the Radio-Active Isotope through the Source-Cable, into the Collimator at the end where the Gamma-Rays pass through the Part & cause an image to form on the Film.



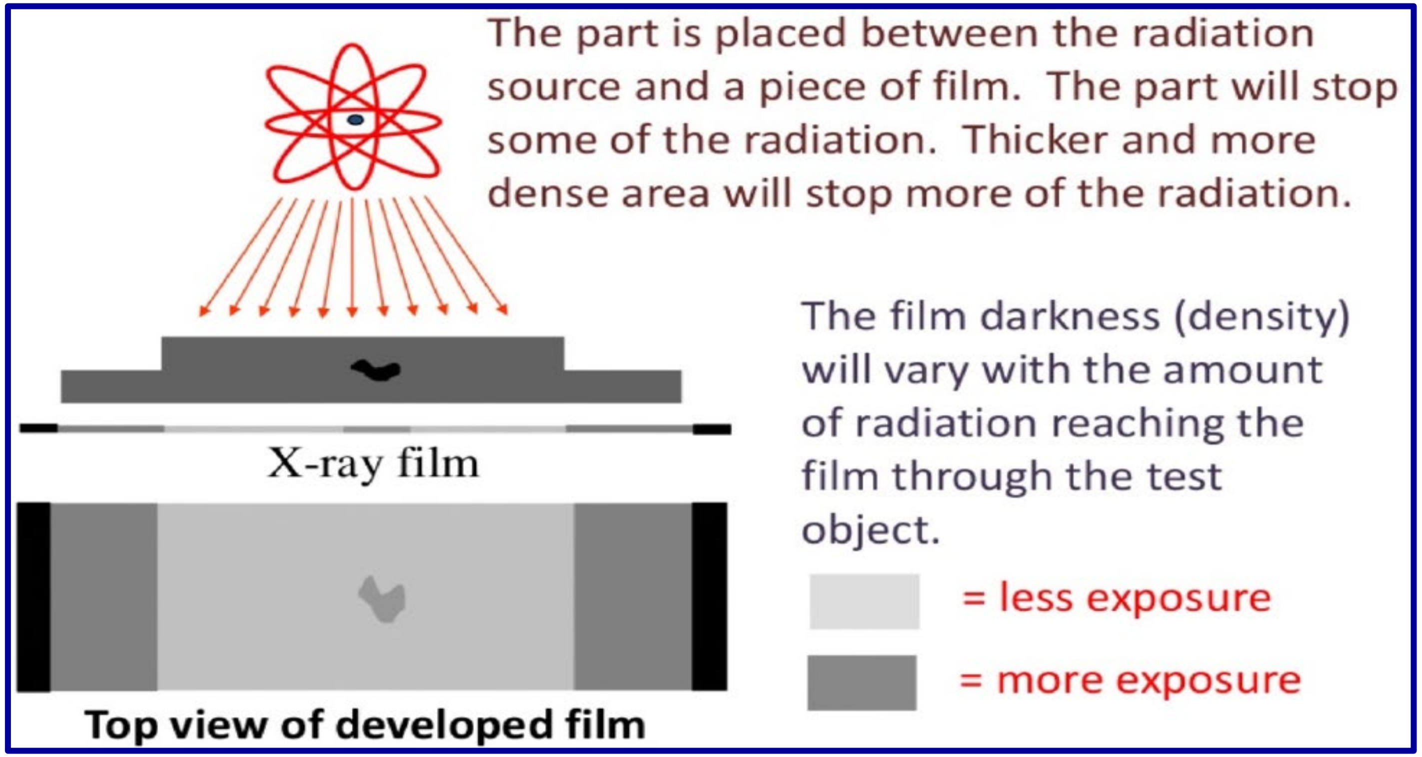
Non Destructive Examination (NDE)

RADIOGRAPHIC EXAMINATION (RXE) HOW DOES IT WORK?:

DETAILS OF FILMED RADIOGRAPHY:-

One of the most widely used & oldest imaging mediums for X-Rays & Gamma Rays, is RADIOGRAPHIC FILM. Which contains microscopic Material called SILVER-BROMIDE.

Once exposed to Radiation & developed in a dark-room, the Silver-Bromide turns to black metallic silver, which forms the image, as shown below.

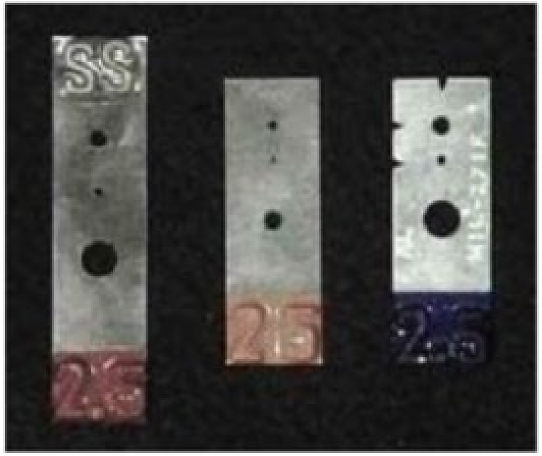


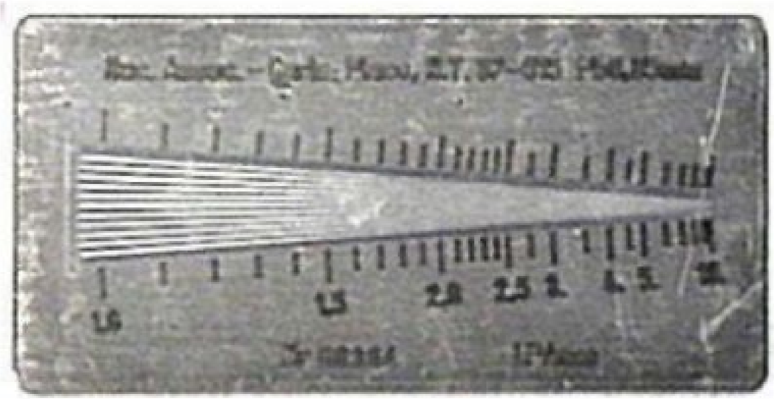
Non Destructive Examination (NDE)

RADIOGRAPHIC EXAMINATION (RXE) HOW DOES IT WORK?:

DETAILS OF FILMED RADIOGRAPHY:-

IMAGE QUALITY INDICATORS (IQI):-
To check that the radiographic Image is clear and accurate. The Image Quality has to be Verified.
Tools called Image Quality Indicators (IQI's), as shown below, are used to verify the image quality.
These are also known as Penetrometers & Comparators, as shown below.
Some IQI's contain Holes Drilled, Wires of Different Diameters & Letters or Numbers. So the sample's Image, Size & Accuracy can be verified when the Film is developed.
The IQI's are usually placed on, or next to the Part being examined.



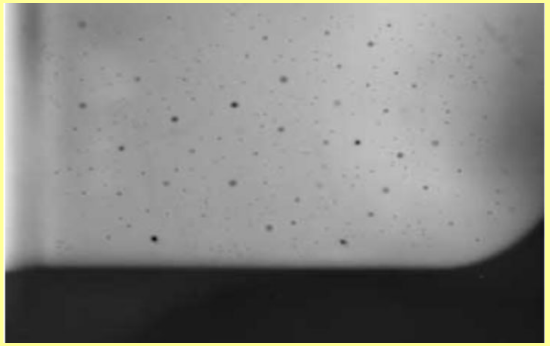


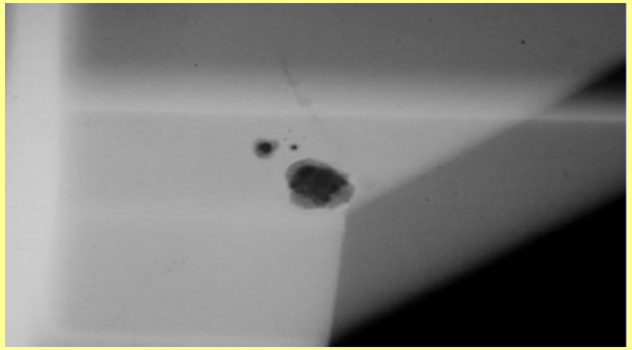
Non Destructive Examination (NDE)

RADIOGRAPHIC EXAMINATION (RXE)

EXAMPLES OF FAULTS DETECTED IN RADIOGRAPHED CASTINGS:-

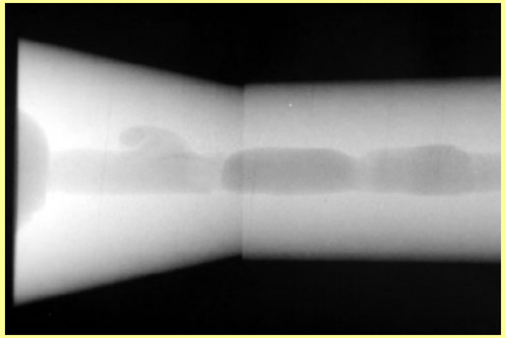
1. **HERE ARE EXAMPLES OF CASTING POROSITY:-**





2. **HERE ARE EXAMPLES OF CASTING SHRINKAGE & HOT TEARS:-**

SHRINKAGE



HOT TEARS

Non Destructive Examination (NDE)

RADIOGRAPHIC EXAMINATION (RXE)

ADVANTAGES OF USING RADIOGRAPHIC NDE/NDT:

- Ability to examine faults and defects below the surfaces components. Even if they are very thick.
- Minimum surface preparation is required.
- Nothing is invisible.
- Most areas can be examined.
- No Limitations on Materials, except LEAD cannot be tested Radiographically.
- Provides a permanent record of the Inspection, with Developed Films.

Non Destructive Examination (NDE)

RADIOGRAPHIC EXAMINATION (RXE)

DISADVANTAGES OF RADIOGRAPHIC EXAMINATION:-

- Relatively high cost.
- Can take much time.
- Specialized skills required.
- Special safeguards to be taken, to minimize the Danger.
- Skilled trained interpretation of film shots required.
- Access to both sides of the Part is required, (unlike Ultrasonic Reflective Examination).
- Determination of depth of the Fault is not possible, without additional angled Radiographic testing.

Non Destructive Examination (NDE)

What Does API 610 Require?

Table 14 — Pressure casing material inspection requirements

Type of component	Requirements by inspection class[a]		
	I	II	III
—	Minimum	> 80 % MAWP and > 200 °C (392 °F)	< 0,5 SG or > 200 °C (392 °F) and < 0,7 SG, or > 260 °C (500 °F) Extremely hazardous services[e]
Casing[b]: cast	VI	VI, plus MT or PT of critical areas	VI, plus MT or PT of critical areas, plus RT or UT of critical areas
Casing[b]: wrought[c]	VI	VI, plus MT or PT of critical areas	VI, plus MT or PT (critical areas), plus UT (critical areas)
Nozzle weld: casing	VI, plus 100 % MT or PT	VI, plus 100 % MT or PT	VI, plus 100 % MT or PT plus RT (100 %)
Auxiliary connection welds[d]	VI	VI, plus MT or PT	VI, plus MT or PT (100 %)
Internals	VI	VI	VI
Auxiliary process piping: socket-welded	VI	VI, plus 100 % MT or PT	VI, plus 100 % MT or PT
Auxiliary process piping: butt-welded	VI, plus 5 % RT	VI, plus 100 % MT or PT and 5 % RT	VI, plus 100 % MT or PT and 10 % RT

= 32 Bar (465 psi)for 300# flange rating process pumps

Non Destructive Examination (NDE)

[a] Definition of abbreviations:

VI: Visual inspection
MT: Magnetic particle inspection
PT: Liquid penetrant inspection
RT: Radiographic inspection
UT: Ultrasonic examination

[b] "Casing" includes all items of the pressure boundary of the finished pump casing (e.g. the casing itself and other parts, such as nozzles, flanges, etc. attached to the casing). "Critical areas" are inlet nozzle locations, outlet nozzle locations and casing wall thickness changes. The manufacturer shall submit details of the critical areas proposed to receive MT/PT/RT/UT inspection for purchaser's approval.

[c] "Wrought" materials include forgings, plate and tubular products.

[d] Due to complex geometry and thickness variations, it is not practical to RT butt-welded auxiliary casing connections.

[e] Extremely hazardous services, as specified by the purchaser.

Non Destructive Examination (NDE)

Table 15 — Materials inspection standards

Type of inspection	Methods	Acceptance criteria	
		For fabrications	For castings
Radiography	ASME BPVC, Section V, Articles 2 and 22	ASME BPVC, Section VIII, Division 1, UW-51 (for 100 % radiography) and UW-52 (for spot radiography)	ASME BPVC, Section VIII, Division 1, Appendix 7
Ultrasonic inspection	ASME BPVC, Section V, Articles 5 and 23	ASME BPVC, Section VIII, Division 1, Appendix 12	ASME BPVC, Section VIII, Division 1, Appendix 7
Liquid-penetrant inspection	ASME BPVC, Section V, Articles 6 and 24	ASME BPVC, Section VIII, Division 1, Appendix 8	ASME BPVC, Section VIII, Division 1, Appendix 7
Magnetic-particle inspection	ASME BPVC, Section V, Articles 7 and 25	ASME BPVC, Section VIII, Division 1, Appendix 6	ASME BPVC, Section VIII, Division 1, Appendix 7
Visual Inspection (all surfaces)	ASME BPVC, Section V, Article 9	In accordance with the material specification and the manufacturer's documented procedures	MSS SP-55

Non Destructive Examination (NDE)

Question

“If a pump casing has a below surface defect that does not reach the surface (either internally or externally) and the pump casing has successfully undergone hydro-test to 1.5x MAWP...... does the defect matter?

I don't KNOW there is a defect as I have done no NDE other than Hydro.

The more NDE you do the more defects you uncover. Is a small defect deep within the casting important? The casting has passed hydro test so arguably the casting is sound.

Or do you feel it is necessary to excavate and weld up every indication?”

Non Destructive Examination (NDE)

Expert Answer No 1

"In most cases no. Defect is a relative term. Many castings have some type of defect such as inclusions, shrinkage, etc. in the casting that will not affect the performance of the casting. I am also assuming this is a standard commercial grade casting and will meet all applicable specifications. The customer always has the right to purchase additional NDE. There are some materials and configurations of casting where it is more or less impossible to get a 100% defect free casting. Castings do not typically fail with these type of defects. Your foundry personnel and metallurgist are aware of these issues and will work with engineering on the configuration of the casting along with the gating and risers to eliminate or minimize this. To do extensive NDE on every casting would make the cost prohibitive and extend lead-times significantly. Also, to your point, how do you repair an unknown defect?"

Buddy Morris – Consultant. Formerly Marketing & Product Mgmt ITT Gould Pumps

Non Destructive Examination (NDE)

Expert Answer No 2

“It depends. One thing to keep in mind is that all castings are to a greater or lesser degree a collection of defects held together with metal.

For non-hazardous service, it doesn't generally matter. The hydrotest has verified that no gross failure will occur regardless of how many subsurface defects exist (and they will).

For more hazardous service it could matter; particularly if the defect became exposed due to corrosion / erosion and then create a leak path in the pressure boundary.

That's exactly why API 610 requires RT or UT for hot or hazardous services (Class 3 inspection). That requirement is specifically to uncover subsurface defects in critical areas.”

Simon Bradshaw – Director of Engineering, Pumps America CIRCOR.

Formerly Director Product Development ITT Gould Pumps

Coming Attractions ☺

"Vertical Pumps (VS1, VS4, VS6)"

Thurs 13th Jan – 08.00 (UK GMT) (Eastern Hemisphere) & 17.00 (UK GMT) (Western Hemisphere)

Aimed at Process and Mechanical Engineers, and Consultant Engineers who specify pumping equipment as well as Applications & Sales Engineers selecting and quoting them.

While engineers generally have a good understanding of horizontal pumps, their exposure to vertical pumps is more limited and as a result they are frequently misunderstood and under-utilised.

This course will look to put that right and explain the features and benefits of vertical pumps and how they can frequently be problem solvers.

Future sessions : Recommencing early next year (13th & 27th January)

– Subject To Be Advised (I haven't decided yet!)

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