Inspection Technology 101

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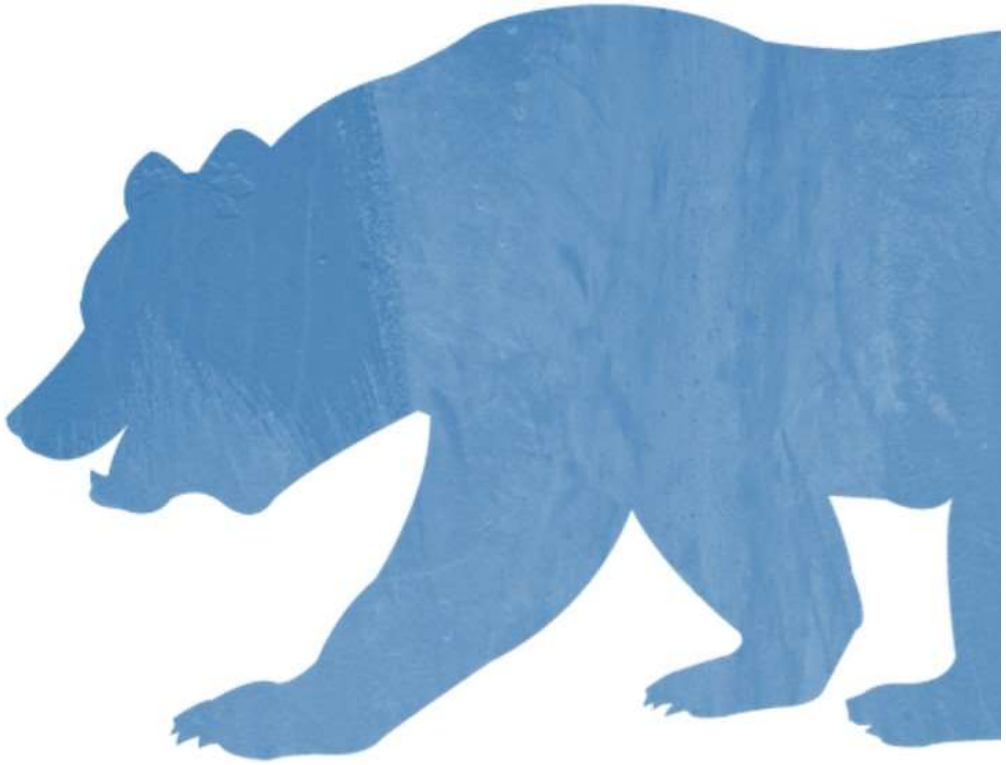
BACKGROUND

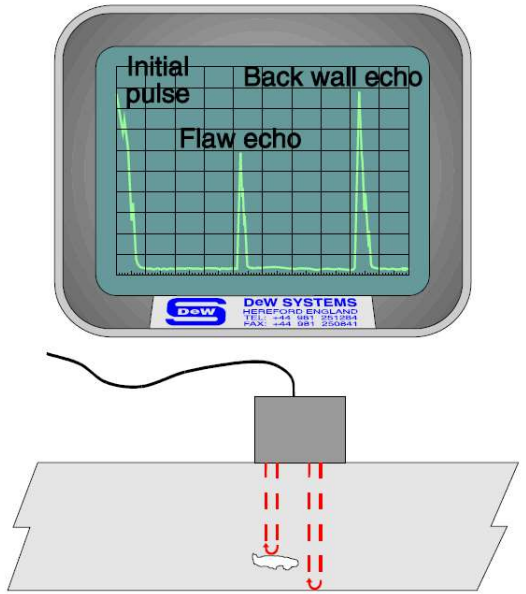
- Mechanical integrity is one of the pillars of safety and responsibility in the oil and gas industry
- NDE operations are usually split two ways
  - Corrosion/Damage Mechanism Detection
  - Quality Control Examination
- Our focus will be on Non-destructive examination techniques and their Pros and Cons
- Not all inspection technologies are created equal nor are they applicable to all situations
- EVERYTHING is technician specific so keep that in mind with all inspection results

Corrosion Detection



CONVENTIONAL ULTRASONIC TESTING (UT)

- A straight beam is directed at the test piece and, utilizing round trip time for the ultrasonic energy, the distance to the flaw is calculated.
- Typically used for detection of corrosion type flaws, laminations, and thickness determination
- Thickness determination helps us predict the useful life of metallic materials



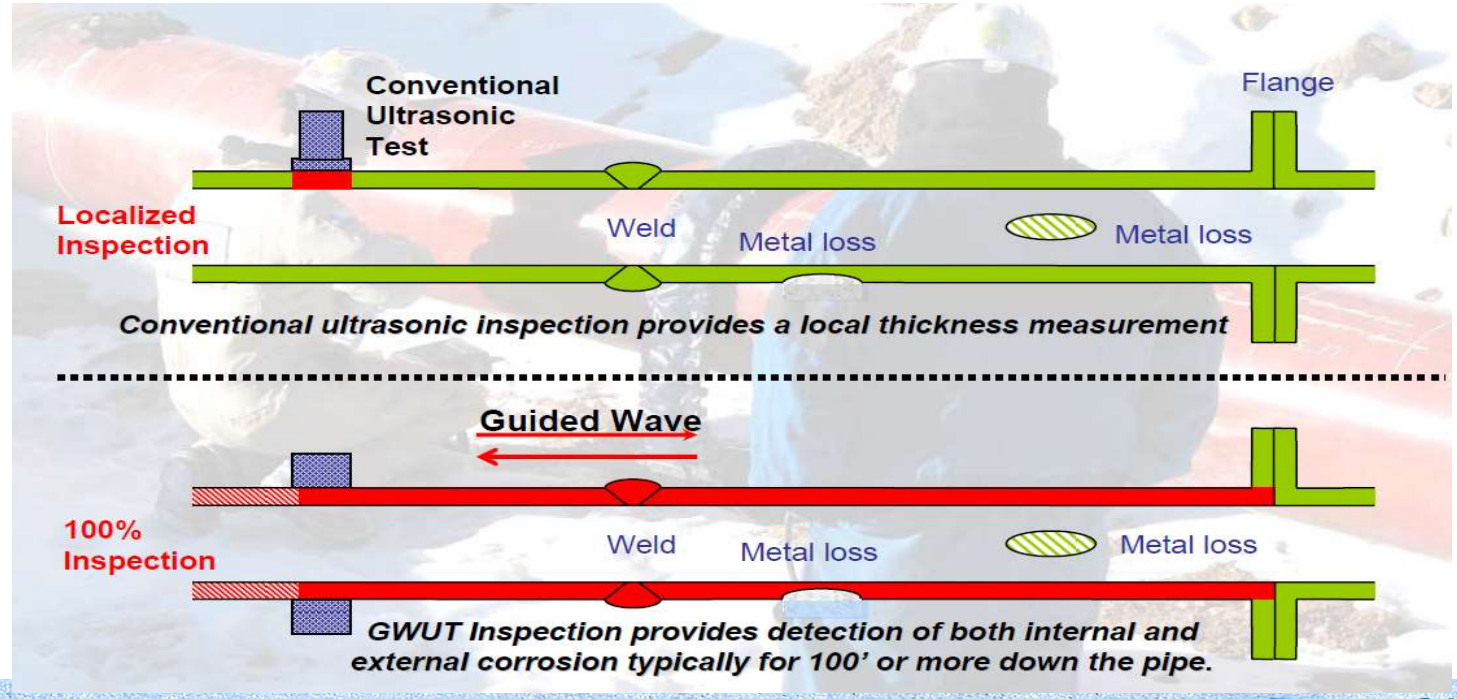
CONVENTIONAL ULTRASONIC TESTING (UT)

- Pros
  - Relatively inexpensive
  - Not overly technical, technician can obtain certification quickly compared to more advanced services
  - Repeatable
  - Good means of obtaining corrosion rates for general corrosion

- Cons
  - Single point inspection. Can miss pitting and isolated corrosion.
  - Data scatter can be a problem since experience levels may vary between technicians.
  - =/- 10 mils difference between UT meters when properly calibrated
  - Not very effective for ID coated materials where general corrosion is not expected

GUIDED WAVE ULTRASONIC TESTING (GUL)

- Same basic theory as conventional UT, but the waves are low frequency bulk waves, entire volume inspected



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GUIDED WAVE ULTRASONIC TESTING (GUL)

- Pros
  - Capable of inspecting long lengths of piping from a single point of access
  - Can detect internal and external corrosion (cannot differentiate)

- Cons
  - Expensive
  - Very technician dependent
  - Measures cross sectional area at a given point so small pits can easily be missed, even if they are through wall
  - Very material dependent (can detect holes on bare pipe much better than coal tar epoxy coated)

LIMITATIONS ON GUL

- Table shows that GUL CANNOT detect a .5” diameter hole under ideal conditions; 2.5” hole under normal conditions in a 10” pipe

(34in diameter - Standard Wall)

			Ratio of	Percent of wall loss										
	Pipe Diameter,in	10.75	Pit Diameter											
	Wall Thickness,in	0.594	versus											
	X-sectional Area	9.75	Pit Depth	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	
“Elliptical Pitting”			1.0	0.0%	0.1%	0.2%	0.3%	0.5%	0.7%	0.9%	1.2%	1.5%	1.8%	< 2%
			2.0	0.0%	0.1%	0.3%	0.6%	0.9%	1.3%	1.8%	2.3%	2.9%	3.6%	
	Pitting Corrosion		3.0	0.1%	0.2%	0.5%	0.9%	1.4%	2.0%	2.7%	3.5%	4.4%	5.4%	2% to 10%
“Shallow Pitting”			4.0	0.1%	0.3%	0.7%	1.2%	1.8%	2.6%	3.5%	4.6%	5.9%	7.2%	
			5.0	0.1%	0.4%	0.8%	1.4%	2.3%	3.3%	4.4%	5.8%	7.3%	9.0%	
			6.0	0.1%	0.4%	1.0%	1.7%	2.7%	3.9%	5.3%	6.9%	8.8%	10.9%	
			7.0	0.1%	0.5%	1.1%	2.0%	3.2%	4.6%	6.2%	8.1%	10.3%	12.7%	
			8.0	0.1%	0.6%	1.3%	2.3%	3.6%	5.2%	7.1%	9.3%	11.7%	14.5%	
			9.0	0.2%	0.7%	1.5%	2.6%	4.1%	5.9%	8.0%	10.4%	13.2%	16.3%	
			10.0	0.2%	0.7%	1.6%	2.9%	4.5%	6.5%	8.9%	11.6%	14.7%	18.1%	
	General Corrosion		12.0	0.2%	0.9%	2.0%	3.5%	5.4%	7.8%	10.6%	13.9%	17.6%	21.7%	
			14.0	0.3%	1.0%	2.3%	4.1%	6.3%	9.1%	12.4%	16.2%	20.5%	25.3%	
			16.0	0.3%	1.2%	2.6%	4.6%	7.2%	10.4%	14.2%	18.5%	23.4%	28.9%	
			18.0	0.3%	1.3%	2.9%	5.2%	8.1%	11.7%	16.0%	20.8%	26.4%	32.6%	> 10%
			20.0	0.4%	1.4%	3.3%	5.8%	9.0%	13.0%	17.7%	23.2%	29.3%	36.2%	
			25.0	0.5%	1.8%	4.1%	7.2%	11.3%	16.3%	22.2%	28.9%	36.6%	45.2%	
			30.0	0.5%	2.2%	4.9%	8.7%	13.6%	19.5%	26.6%	34.7%	44.0%	54.3%	
			40.0	0.7%	2.9%	6.5%	11.6%	18.1%	26.0%	35.5%	46.3%	58.6%	72.4%	
			50.0	0.9%	3.6%	8.1%	14.5%	22.6%	32.6%	44.3%	57.9%	73.3%	90.4%	
			60.0	1.1%	4.3%	9.8%	17.4%	27.1%	39.1%	53.2%	69.5%	87.9%		
			70.0	1.3%	5.1%	11.4%	20.3%	31.7%	45.6%	62.0%	81.0%			
			80.0	1.4%	5.8%	13.0%	23.2%	36.2%	52.1%	70.9%	92.6%			
			90.0	1.6%	6.5%	14.7%	26.0%	40.7%	58.6%	79.8%				
			100.0	1.8%	7.2%	16.3%	28.9%	45.2%	65.1%	88.6%				

Loss in Percent of Cross Section

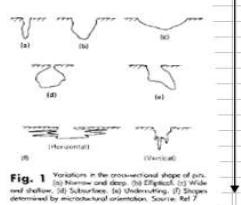
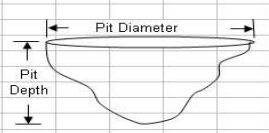


Fig. 1 Variations in the cross-sectional shape of pits. (a) Narrow and deep. (b) Elliptical. (c) Wide and shallow. (d) Subsurface. (e) Undercutting. (f) Shapes determined by microstructural orientation. Source: Ref 7

Source of Fig 1 above - ASM Metals Handbook Volume 13 (Corrosion)	
Diameter / Depth Ratio for :	
Type A - Narrow / deep =	0.3
Type B - Elliptical =	1.0
Type C - Wide / shallow =	3.8



NOTE: GUL and Teletest claim maximum sensitivity of 2% loss of cross-section in ideal conditions, but typically use 10% (refer to wave form)

Green = detectable corrosion in field pipe, yellow = minimum pit detectable in ideal conditions, red = not detectable

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Recent PRCI Test Results

PRCI Test Results for Various LRUT Tools

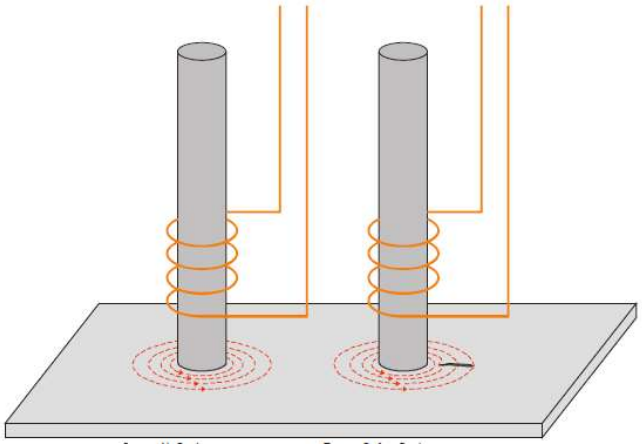
Maximum Distance (Feet) from Collar to Defect for Detecting a 9% Cross Sectional Loss in Pipe Wall (See Note 1)

	Epoxy Coated or	PE Wrapped or	Coal Tar
LRUT Tool	Bare CS	Coated CS	Coated CS
GUL Wavemaker G3	69	43	23
Teletest Focus	79	40	20
Corrfinder	20	13	3
MnS	66	20	5
WiBe	23	16	10

Note 1: A 9% cross sectional loss is equivalent to a ~2.5" diameter through wall hole on a 12" line (big hole!)

EDDY CURRENT (PULSED/NEAR FIELD/CONVENTIONAL)

- Eddy currents are generated in a material by an alternating magnetic field; example wrapping a coil around an iron rod
- The magnitude of the Eddy currents are a function of the geometry, permeability, and conductivity
- Any change in the material or geometry is detected in the coil impedance
- Material changes like cracks, thickness changes, etc can be detected

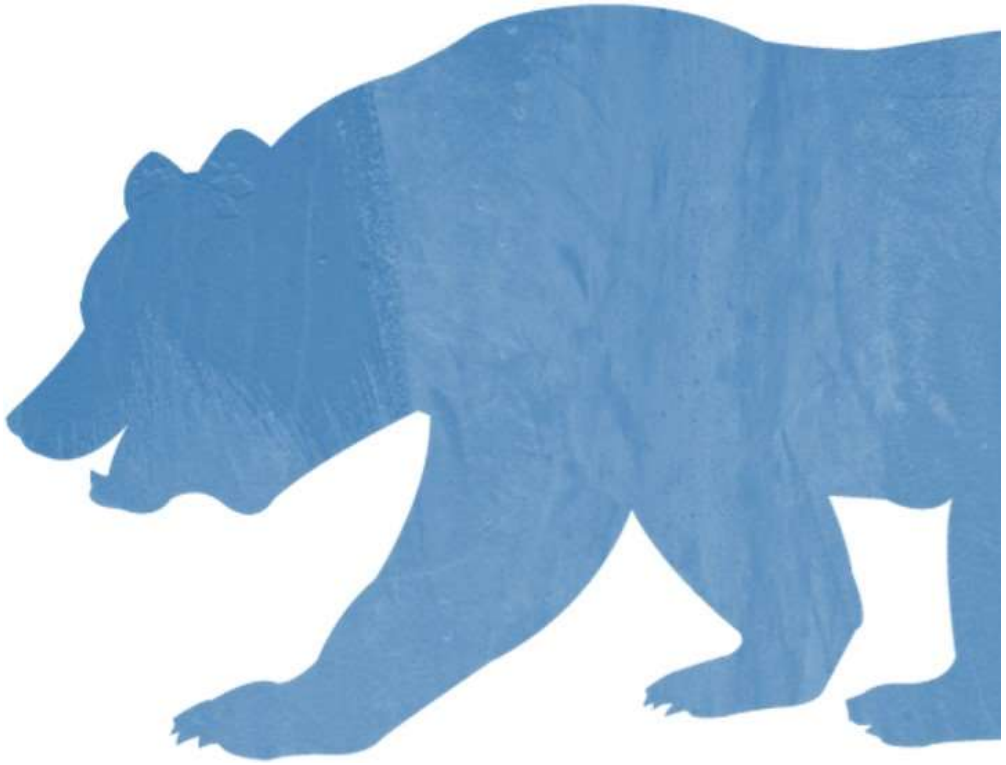


EDDY CURRENT

- Pros
  - Relatively fast tube inspection method for non-ferrous materials
  - Near field can be used for fast inspection of ferrous tubes
  - Can detect small defects/wall loss
  - Pulsed Eddy current can be used to inspect materials that are insulated (direct contact not required)
- Cons
  - Not best method for determining corrosion rate/remaining life, indications are generally reported within a percentage range vs. an actual thickness with Ultrasonic techniques (sensitive but not accurate)
  - Evaluating data takes a long time and can slow the overall process.

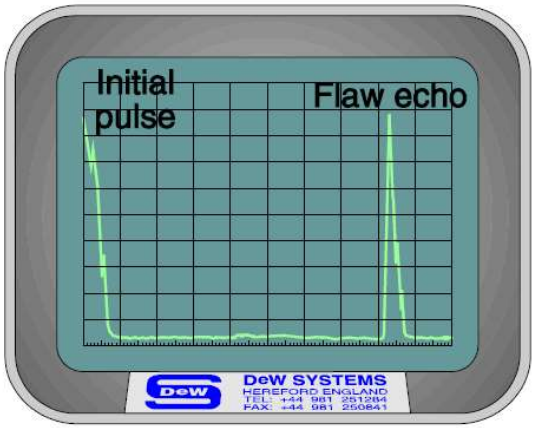

Courtesy of TORNGATS Technical Services

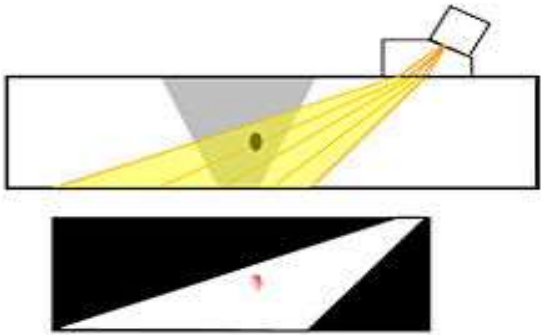
Quality Control

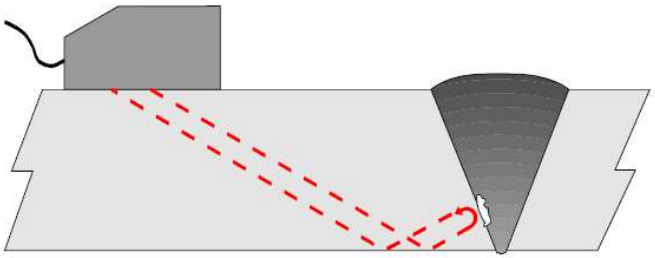


SHEAR WAVE/PHASED ARRAY UT

- An angle beam is directed at the test piece and, utilizing round trip time for the ultrasonic energy, the distance to the flaw is calculated.
- Can be used to size crack like defects particularly in welds
- Also can find voids and other defects







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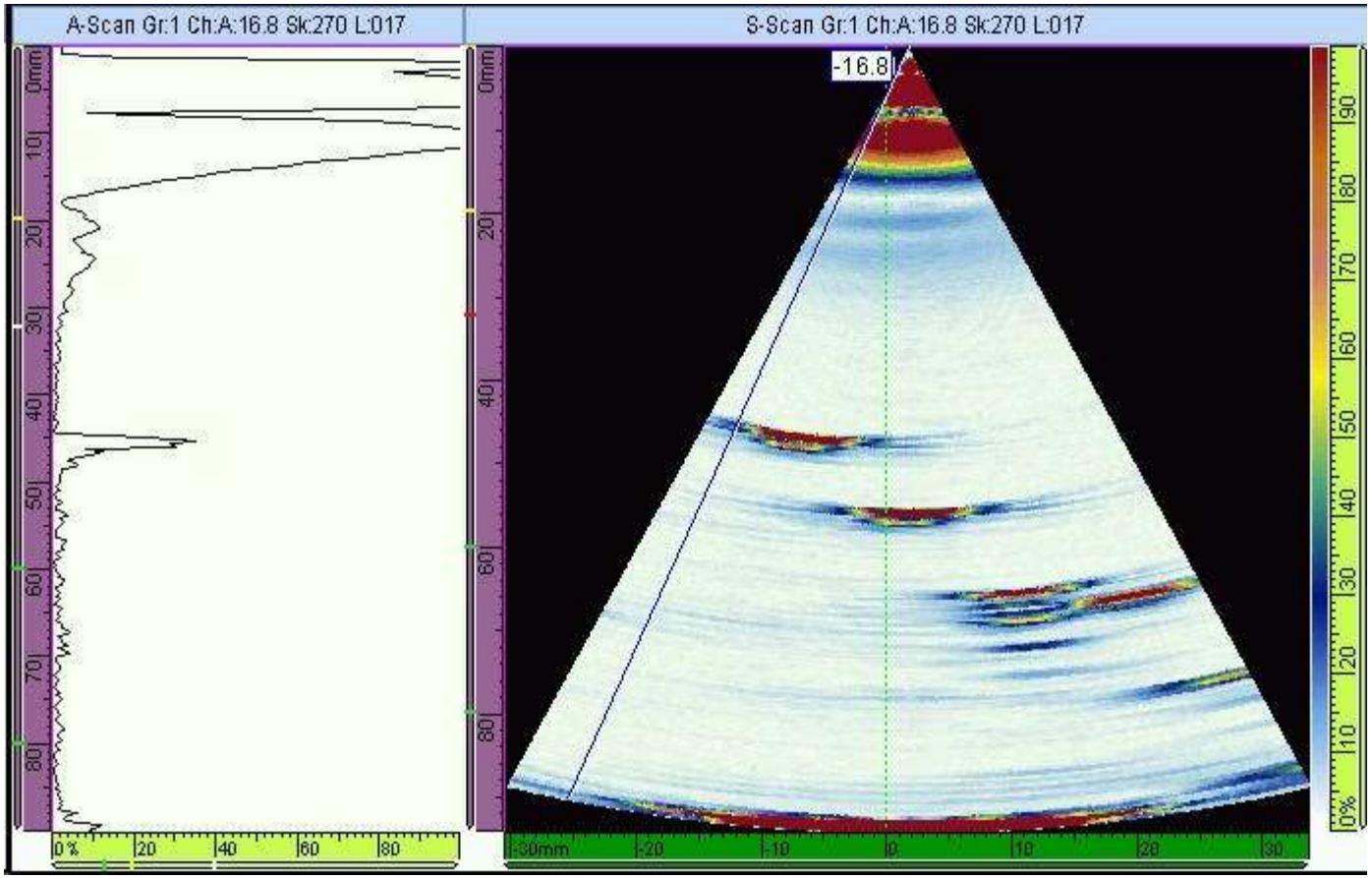

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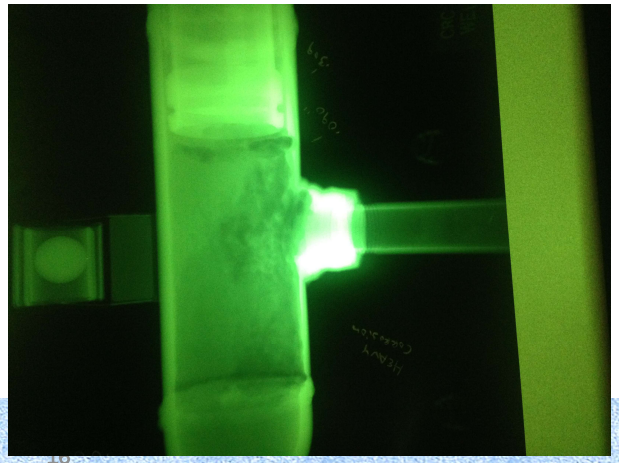
RADIOGRAPHIC TESTING

- X-rays and Gamma Rays are differentially absorbed based on material thickness
- The rays convert silver halide crystals into silver in film (just like light) and this film is developed and viewed like a photograph
- Dark areas are thin and light areas are thick, thus corrosion, weld defects, and voids can be seen

RADIOGRAPHIC TESTING (PROFILE)

- Pros
  - Able to get a picture of what the ID surface of a part looks like. Able to see worst case pitting/corrosion.
  - Can inspect pipe without removing coating/insulation.
  - Good for detecting CUI

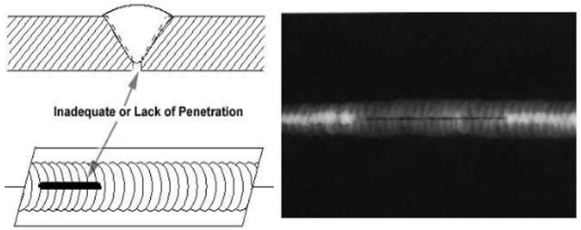


- Cons
  - Repeatability is more difficult since the technique has a lot to do with the shot quality (technician dependent)
  - Potential of “burn off” on pipe edges, not as good as UT for determining actual thicknesses.
  - Size or pipe and type of product inside the pipe can make ineffective.
  - Requires use of radioactive source, exposure potential. Large areas need to be barricaded.
  - Radiation detectors located around the port making radiography difficult in many locations.

RADIOGRAPHIC TESTING (WELD QUALITY)

- Pros
  - Permanent record of the weld. You get a picture vs. just a report.
  - Not overly technical so there are more certified technicians available to choose from. Not as much of an issue to schedule on short notice as some of the advanced NDE methods.

Incomplete penetration (IP) or lack of penetration (LOP) occurs when the weld metal fails to penetrate the joint. It is one of the most objectionable weld discontinuities. Lack of penetration allows a natural stress riser from which a crack may propagate. The appearance on a radiograph is a dark area with well-defined, straight edges that follows the land or root face down the center of the weldment.



- Cons
  - Requires use of radioactive source, exposure potential. Large areas need to be barricaded.
  - Radiation detectors located around the port making radiography difficult in many locations.
  - Film quality can vary between technicians depending on technician skill level.
  - Mistakes (reshoots) require more effort to correct since the area must be barricaded again after discovering the issue.

OTHER TECHNIQUES

- Electromagnetic Acoustic Testing (EMAT)
  - Like UT but electrical waves instead of mechanical; can inspect without direct contact and can send lateral waves
- Internal Rotating Inspection System (IRIS)
  - UT tube inspection; tubes have to be super clean
- Liquid Penetrant and Magnetic Particle Testing (PT/MT)
  - Surface crack/void detection
- Magnetic Flux leakage (MFL)
  - Like Eddy current used mostly on tank floors and smart pigs

THE BEST INSPECTION TECHNIQUE AVAILABLE

- The most sensitive equipment and best inspection technique ever made…YOUR EYES
- Always go look yourself (whenever possible) because all of the above techniques only infer what you can actually do with your eyes.