Parto Azmoon Azar

Engineering & Inspection Co.

شرکت مهندسی پرتو آزمون آذر

PARTO AZMOON AZAR

Peyman Rostami

peymanrostami@hotmail.com

Education:

B.Sc. Applied Physics - Nuclear (1989 - 1993)
Amirkabir University of Technology – Tehran
M.Sc. Nuclear Engineering (1995 - 1997)
Amirkabir University of Technology – Tehran

Certification:

1. ASNT NDT Level III – UT
2. ASNT NDT Level III – RT
3. ASNT NDT Level III – MT
4. ASNT NDT Level III – PT
5. Certified as “Radiation Protection Officer - RPO” from Iran Nuclear Regulatory Authority (INRA) as the Iranian Authority for Radiation Protection,

Corrosion Under Insulation (CUI) and Fireproofing (CUF) Inspection Techniques

According to: API Recommended Practice 583
First Edition, May 2014

AMERICAN PETROLEUM INSTITUTE

By: Peyman Rostami
Parto Azoon Azar Engineering & Inspection Co.

Sphere collapse due to Corrosion Under Fireproofing (CUF)

PARTO AZMOON AZAR

Corrosion Under Insulation (CUI)

Introduction to Corrosion Under Insulation (CUI)

Corrosion under insulation (CUI) is one of the most well-known phenomena in the process industries, and yet it still makes up an inordinately large percentage of global maintenance expenditures.

CUI is a subject that is well researched and understood; extensive studies have been commissioned to determine the causes, effects, prevention, and mitigation of CUI.

In the simplest terms, CUI is any type of corrosion that occurs due to moisture buildup on the external surface of insulated equipment.

If undetected, the results of CUI can lead to the shutdown of a process unit or an entire facility, and in rare cases it may lead to a process safety incident.

In almost every manufacturing and process industry, one of the most critical and vulnerable components is the piping system,

External corrosion of carbon steel piping, pressure vessels and structural components resulting from water trapped under insulation in conjunction with other variables that accelerate and drive the corrosion,

PARTO AZMOON AZAR

External Chloride Stress Corrosion Cracking (ECSCC) of austenitic and duplex stainless steel under insulation with other variables present, accelerate the corrosion,

PARTO AZMOON AZAR

Most of the insulation defects are associate with pipelines and vessels occur through poor initial installation or subsequent damage to the insulation material during its lifetime. Damaged insulation will allow water to saturate the materials nearest to the metal where corrosion will eventually begin to occur.

Corrosion Under Fireproofing (CUF):

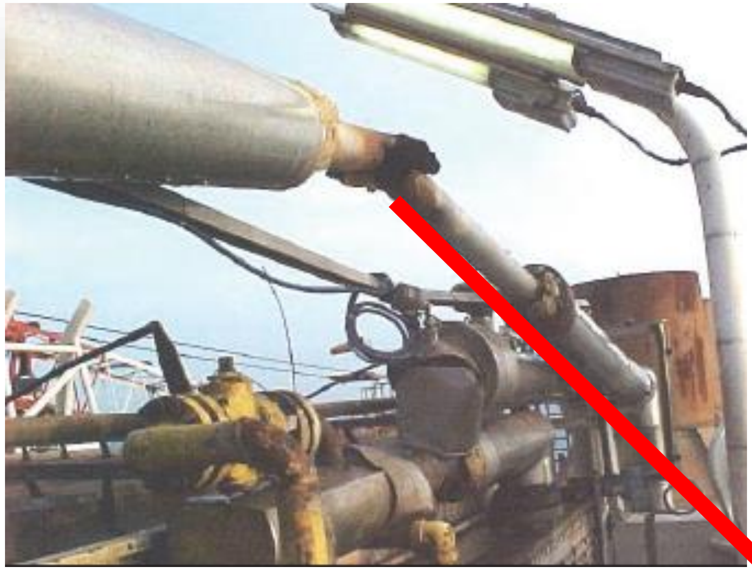
Corrosion of piping, pressure vessels, and structural components resulting from water trapped under fireproofing,

Corrosion Under Insulation (CUI):

External corrosion of carbon steel piping, pressure vessels, and structural components resulting from water trapped under insulation. ECSCC of austenitic and duplex stainless steel under insulation is also classified as CUI damage,

When **moisture** penetrates insulation and fireproofing systems, the surface of the underlying component will be subjected to corrosion,

CUI Failure of 4” Gas Compressor Recycle Line



CUI and **CUF** are phenomenon's that has **plagued** the Oil, Gas and Chemical Industry for years,

Failure of Sphere Legs Due to CUF

CUI at an Insulation Support Ring

Piping system externally maybe subjected to:

- External forces of vibration,
- Pipe support friction and wear,
- Fatigue,
- Climate condition,
- Corrosion Under Insulation (CUI),

Piping system internally maybe subjected to:

- Excessive pressure and/or temperature extremes,
- Liquid or Vapor caused erosion,
- Flow-accelerated corrosion,
- Preferential corrosion in the heat affected zone of welds,
- Localized pitting due to any number of causes,
- Internal blockage,

CUI and CUF can be hard to find, identifying where to start is Key:

- Areas exposed to mist overspray from cooling water towers,
- Areas exposed to steam vents,
- Carbon steel piping systems insulated for personnel protection, operating between -12°C and 175°C,
- Carbon steel piping systems that normally operate in-service above 175°C but are intermittent service,
- CUI is particularly aggressive where operating temperatures cause frequent or continuous condensation and re-evaporation of atmospheric moisture,
- Dead legs and attachments that protrude from insulated piping and operate at a temperature different than the active line,

CUI and CUF can be hard to find, identifying where to start is Key:

- Austenitic stainless steel piping systems operating between 60°C and 205°C (susceptible to ECSCC),
- Vibrating piping systems that have a tendency to inflict damage to insulation jacketing providing a path for water ingress,
- Steam traced piping systems that can experience tracing leaks, especially at tubing fittings beneath the insulation,
- Piping systems with deteriorated insulation, coatings and/or wrappings,
- Piping systems susceptible to physical damage of the coating or insulation, thereby, exposing the piping to the environment,

PARTO AZMOON AZAR

Inspection for CUI and CUF Damages According to API-583 (2014)

PARTO AZMOON AZAR

General:

The purpose of the insulation on equipment and piping should be well understood before performing CUI inspections. This can help:

- To establish priorities,
- Determine what hazards may exist,
- Determine if insulation can be removed while equipment / lines are in operation,
- Determine if insulation can be permanently removed,

In fact, one of the big benefits from this insulation evaluation process is that it can actually discover many areas do not really require insulation so permanent removal results in 100 % elimination of CUI risk.

Inspection Methods and Techniques for CUI and CUF:

There are both **direct inspection methods** and **indirect inspection methods** for detecting **surface corrosion damages** (caused by **CUI** or **CUF**) on equipment or structural supports,

Direct Inspection Methods:

Direct inspection methods are classified as inspection methods conducted **without** the **presence** of a **protective barrier** (insulation or fireproofing system),

In-Direct Inspection Methods:

Indirect inspection methods are classified as inspection methods conducted **with** the **protective barrier** (insulation or fireproofing system) **still in place**,

In-Direct Inspection Methods:

A. Semi-Quantitative Methods:

These are inspection methods that indirectly quantify the relative degree of surface corrosion that has occurred.

B. Qualitative Methods:

These are inspection methods that attempt to assess the quality of the insulation / fireproofing system as an indirect measure of the potential for surface corrosion damage.

These methods are conducted **without removing** the insulation or fireproofing from the equipment or structural support.

1. **Direct Inspection Methods:**
   - A. Visual Examination Method (VT) with Complete Removal of Insulation/Fireproofing
   - B. Liquid Penetrant Examination Method (PT)

2. **In-Direct Inspection Methods:**
   - A. Semi-Quantitative Methods:
     1. Guided Wave Examination Method (GWT)
     2. Radiographic Examination Methods:
        - a) Tangential Radiographic Inspection (Profile radiography)
        - b) Double Wall Radiographic Inspection (Film Density Measurement Technique)
        - c) Radiometric Profiling
        - d) Real-Time Radiographic Examination Method (RTR)
        - e) Computed and Digital Radiography Testing:
          - i. Computed Radiography (CR)
          - ii. Digital Radiography (DR)
     3. Pulsed Eddy Current Method (PEC)
   - B. Qualitative Methods:
     - a) Visual Examination Method (VT) with Partial Removal of Insulation
     - b) Neutron Backscatter Examination Method
     - c) Thermal/Infrared Imaging Examination Method

Visual Inspection (VT)

Visual Inspection (VT):

- Visual Inspection (VT) of Piping / Equipment can serve as a "**Base-Line**" to help establish a plan of action and path forward,

- Two basic types of **Visual Inspection (VT)** examinations:
  1. **Visual Inspection** with **Complete Removal** of Insulation/Fireproofing,
  2. **Visual Inspection** with **Partial Removal** of Insulation/Fireproofing,

Visual Inspection (VT) with Complete Removal of Insulation:

The most reliable method to detect **CUI** and **CUF** on carbon and low alloy steel systems is to physically remove the insulation or fireproofing and visually inspect the surface for damage.

This approach is **costly** since insulation or fireproofing on equipment or structural supports has to be **stripped** and **reinstalled**.

Scaffolding costs to access insulated areas being inspected can be significant especially for large vessels or piping systems on columns or towers.

Scaffolding costs can be reduced in some situations utilizing rope access-qualified inspectors.

Visual Inspection (VT) with Complete Removal of Insulation:

Advantages:

- Only method that can detect 100 % of all surface corrosion damage,
- Eliminates any misinterpretation,

Disadvantages:

- Expensive to remove and reinstallation of insulation on equipment or structural components,
- May require additional funds and time for scaffolds,
- Process problems may occur if the insulation is removed while the piping is in service,
- Inspection personnel need to be careful to avoid contact with surfaces at or above 60 °C,
- Special precautions are necessary on asbestos insulated systems,

Visual Inspection (VT) with Partial Removal of Insulation:

The most reliable technique to detect CUI is to physically remove the insulation and visually inspect the surface of the vessel or piping. This approach is costly since equipment must be de-insulated and re-insulated and frequently requires scaffolding to access areas for inspection.

Removing smaller sections of insulation (windows) is useful for advanced inspections to help prioritize equipment for remediation or more thorough follow-up inspections.

The **placement** and **size** of these inspection **windows** is very important.

Windows should be cut where CUI is most likely as following "key areas":

1. At poorly sealed insulation,
2. At low points in the piping system where water can collect,
3. Damaged areas of insulation,
4. Insulation termination points,
5. Protrusions of Punctures,
6. Damaged seals,
7. At insulation support rings or vessel stiffening rings,
8. At areas where the insulation jacketing is in poor condition and water can penetrate the insulation system,

The areas where insulation is removed (windows) should be large enough to be representative of the condition of the equipment,

It may be necessary to cut several windows in suspect locations because of the difficulty in predicting where CUI damage has occurred,

PARTO AZMOON AZAR

Visual Inspection (VT) with Partial Removal of Insulation:

Advantages:

- Costs associated with insulation removal / reinstallation are significantly reduced compared to complete removal of insulation,
- Limited exposure to hot surfaces for personnel,

Disadvantages:

- CUI damage can be missed since only a limited area of the equipment is inspected,
- Special precautions are necessary on asbestos insulated systems,
- Windows cut in insulation pose a potential leak path for water ingress if insulation not effectively repaired/sealed,

Liquid Penetrant Examination (PT)

PARTO AZMOON AZAR

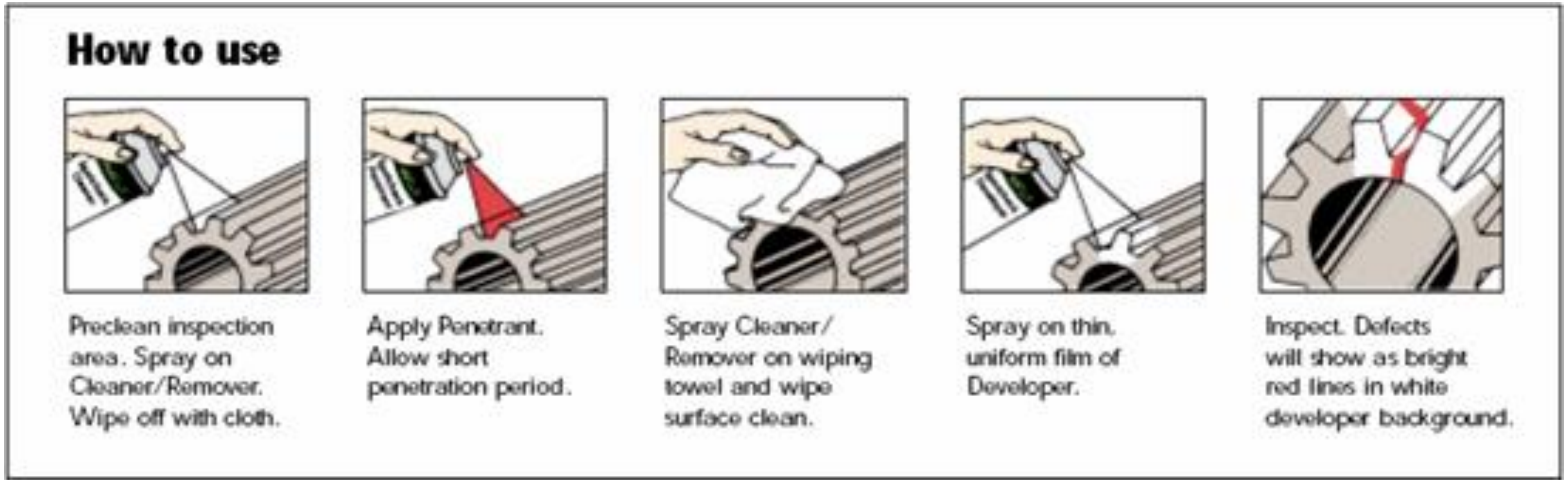
Liquid Penetrant Examination Method (PT):

Typically, ECSCC on insulated stainless steel equipment is not normally detected until leakage occurs,

When this occurs, inspection of the area using PT is an effective way of determining the extent of damage (cracking) on austenitic and duplex stainless steel. Damage is often associated with the weld heat affected zone (HAZ),

Liquid penetrant testing is generally limited to surface temperatures below 49 °C,

Liquid Penetrant Examination Method (PT):



PARTO AZMOON AZAR

Liquid Penetrant Examination Method (PT):

Advantages:

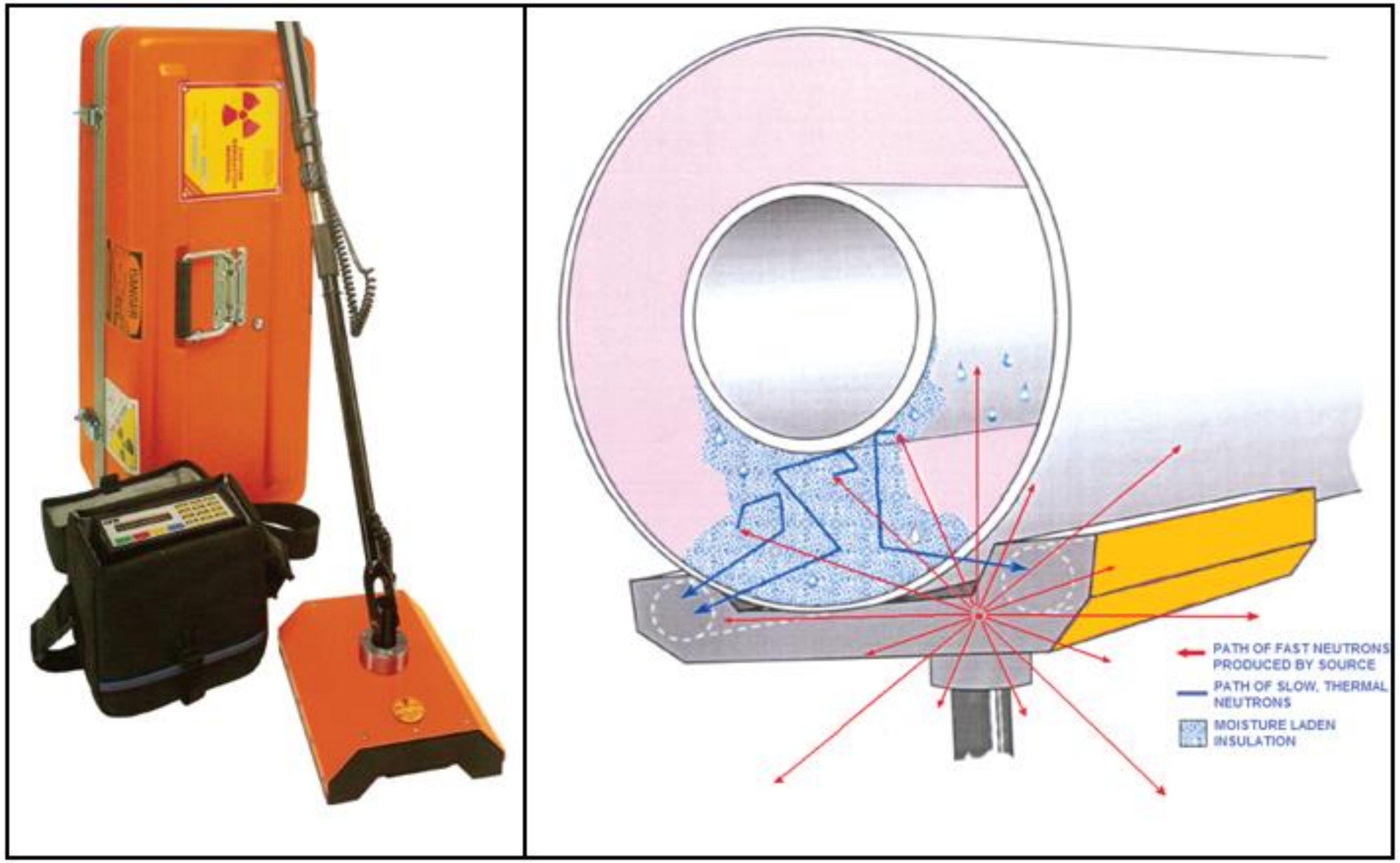
- Capable of detecting very small discontinuities,
- Relatively inexpensive non-sophisticated equipment,

Disadvantages:

- Surfaces have to be clean and free of organic or inorganic contaminants that can impede the action of the penetrating media,
- When sprayed, penetrants are easy to ignite when exposed to ignition sources,
- Cold surfaces require longer dwell times to allow sufficient time for penetrant to be drawn into the crack,

Neutron Backscatter Method

Neutron Backscatter Method:



Am241/Be
Half Life: 432 Years
Primary Emission: Neutron
Primary Energy: 2-10 MeV

Neutron Backscatter Method:

The neutron backscatter technique works because of the interaction of neutrons with hydrogen atoms. The technique utilizes an Am/Be radioactive sealed source to emit fast neutrons with high energies through the insulation jacketing.

When these fast neutrons interact with hydrogen atoms, they release energy and are transformed into slow or thermal neutrons. The thermal neutrons are scattered in all directions, but have a short travel path. Some of these thermal neutrons are scattered back toward the scanning head and counted by a sensitive detector.

The more hydrogen atoms present in a material, the more thermal neutrons produced and counted by the detector.

Neutron Backscatter Method:

It should be noted that this technique detects hydrogen atoms,

Therefore, these devices cannot distinguish between water, hydrocarbons, acids, bases, and organic liquids.

However, the presence of any of these fluids would warrant follow-up inspection,

Effective tool to scan hundreds of feet of insulated pipe to determine wet/saturated insulation in a short amount of time,

Can help pin-point suspect areas for potential CUI, relatively quick and accurate method for identifying suspect areas for the potential of CUI,

PARTO AZMOON AZAR

Neutron Backscatter Method:

Neutron Backscatter:

Advantages:

- Detects the presence of water or hydrocarbon under insulation jacketing,
- Easy-to-use method that can be used to rapidly scan insulated surfaces,
- Can access elevated areas without the need of scaffolding,
- Lightweight and versatile to reach congested areas,
- Effective tool to scan hundreds of feet of insulated pipe to determine wet/saturated insulation in a short amount of time,

Disadvantages:

- Detects the presence of water or hydrocarbon in the insulation system, **not corrosion**,
- Technique is only effective while insulation is wet, technique is not effective if sufficient time has elapsed for insulation to dry out,

Thermal / Infrared Imaging Examination Method

PARTO AZMOON AZAR

Thermal / Infrared Imaging Examination Method:

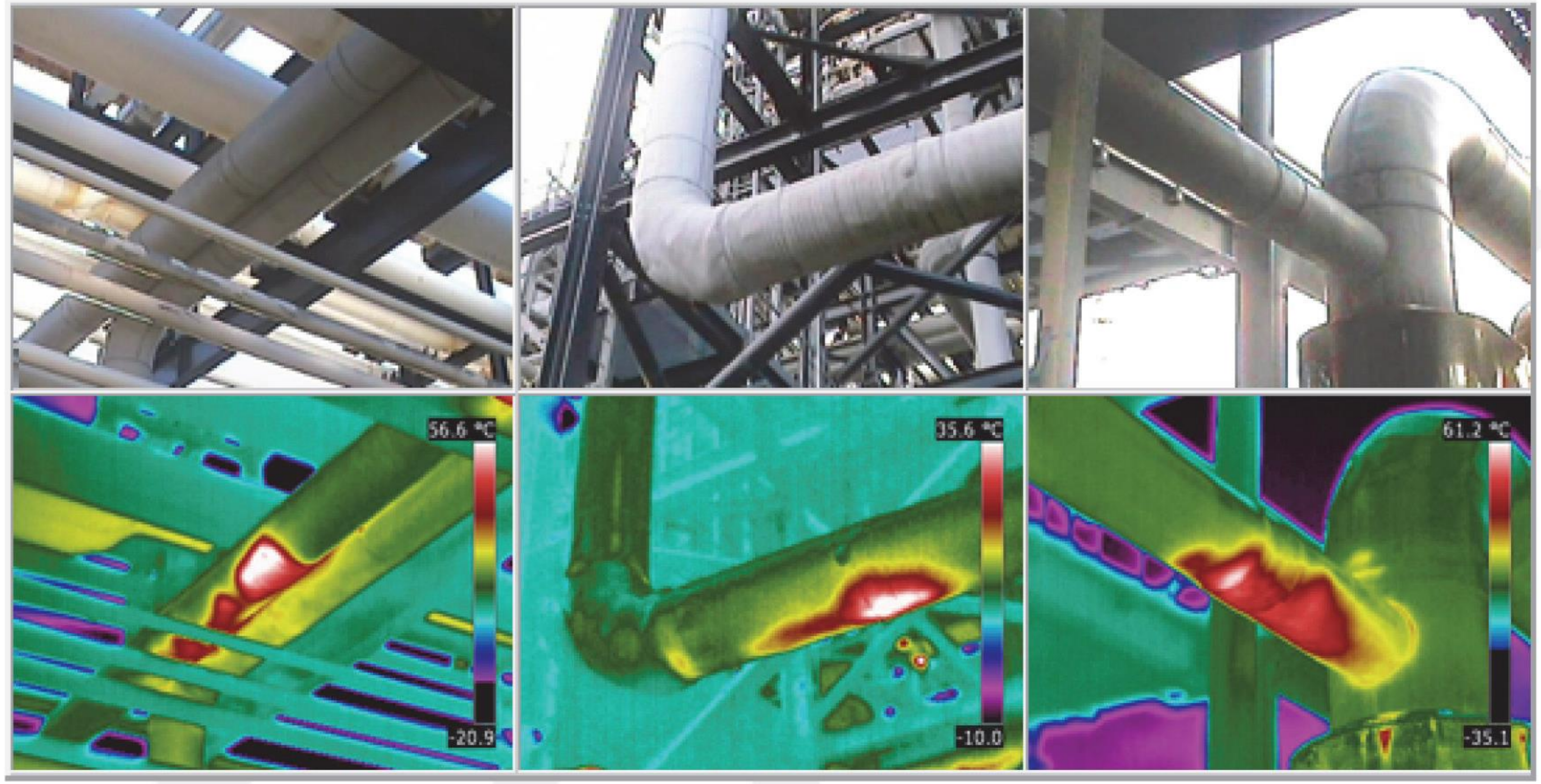
- The thermal/infrared imaging examination method (Thermography) is another approach for assessing the potential for CUI on insulated vessels and piping,

- Thermography is a rapid, passive inspection technique that produces a Heat-Picture of the surface of a component using a thermal imaging infrared (IR) camera,

- IR cameras are used to detect Damp-Spots in the insulation due to a temperature difference between the dry and the wet insulation,

- IR cameras can detect surface temperature variations on the component as small as 0.10°C,

- Temperature variations on the component are displayed as different colors,
- Depending on the temperature of the product contained, “hot-spots” or “cold-spots” on the thermograph show up because of the effect of moisture increasing local conductivity in the component,



Thermal / Infrared Imaging Examination Method:

- Conducting the Thermal / Infrared Imaging Examination IR survey 2 to 3 hours after the sun-set is advantageous since wet insulation holds the heat absorbed from solar rays longer than dry insulation. This can tend to promote more contrast in the thermograph,

- In general, Thermal / Infrared Imaging Inspection for CUI should be done in the absence of strong gusty winds (non-windy conditions),

- It should be noted that while water may be detected with this technique, it does not necessarily mean that CUI is occurring,

Thermal / Infrared Imaging Examination Method:

Advantages:

- Rapid method to detect damaged or wet insulation,
- Non-invasive, Non-contact method that does not require direct access to the insulated surface (can be done from ground level without scaffolding),
- Easy-to-use method to highlight areas requiring inspection follow-up,

Disadvantages:

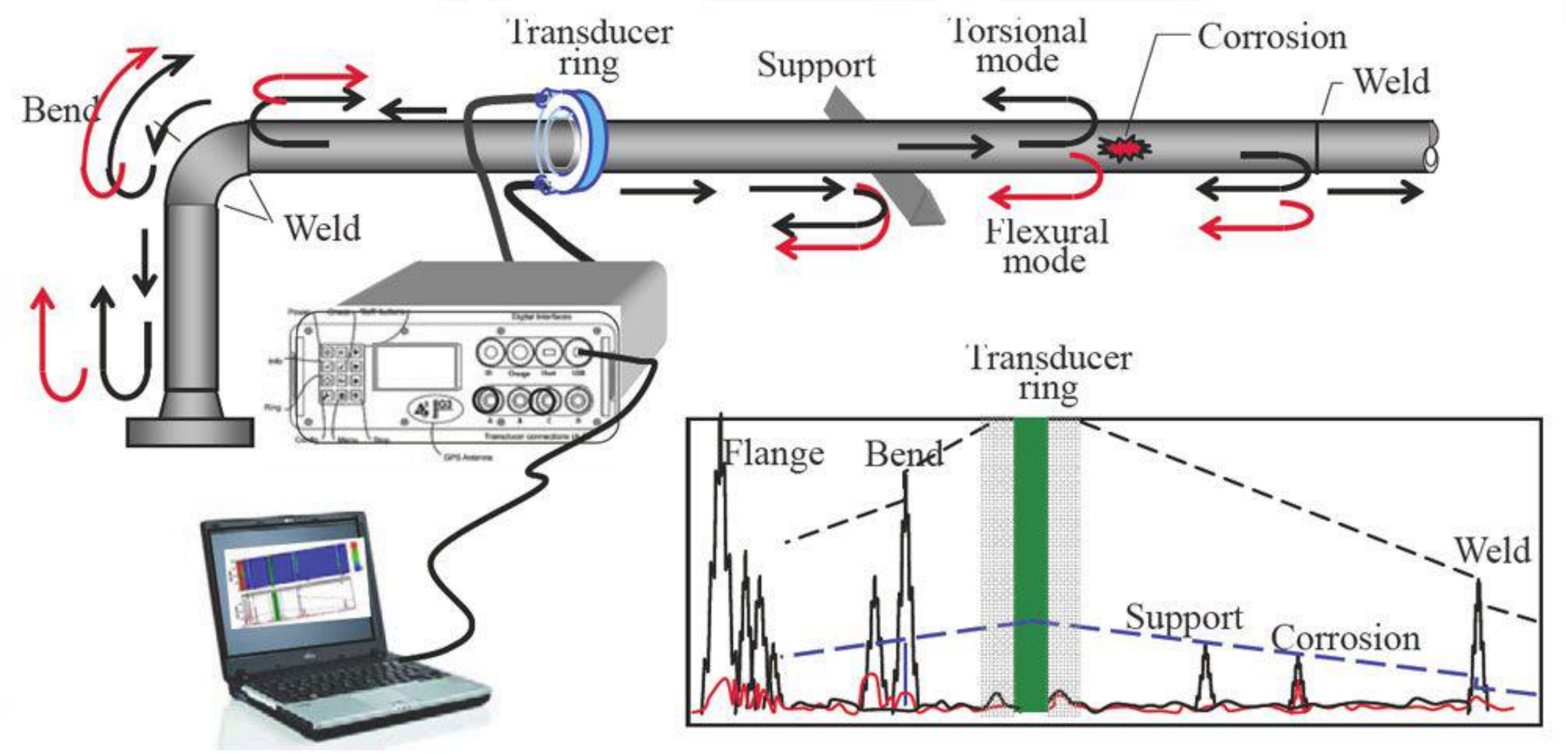
- Does not detect corrosion but only areas where insulation may have been compromised (damaged or wet insulation),
- Not effective method if insulation has had sufficient time to dry out,

PARTO AZMOON AZAR

Guided Wave Examination Method (GWT)
(Long-Range Ultrasonic Testing)

Guided-Wave Examination Method (GWT):

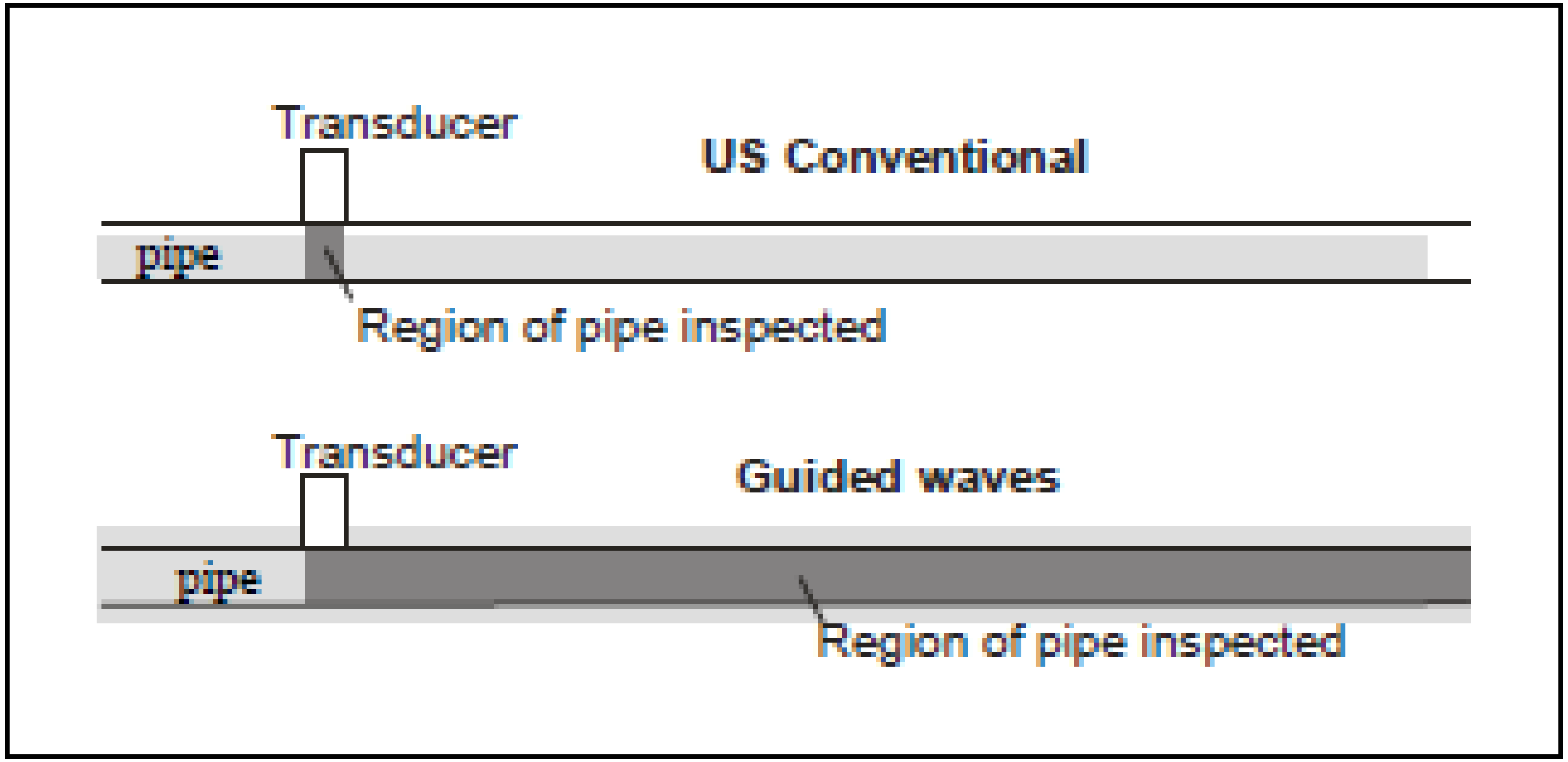
The equipment operates in a pulse-echo configuration where the array of transducers is used for both the excitation and detection of the signals,



Guided-Wave Examination Method (GWT):

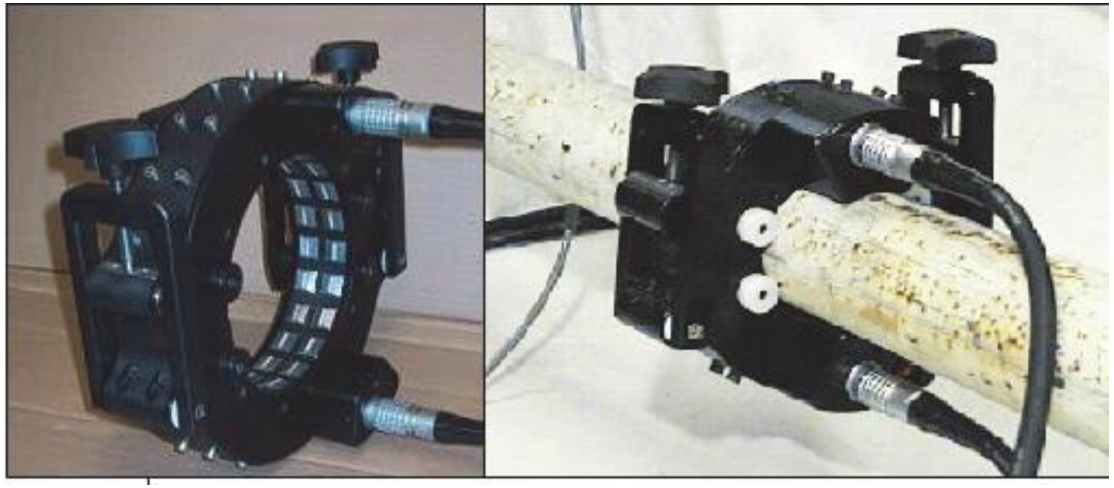
- Guided-Waves are a low frequency and long wavelength mechanical wave which allows a long range of coverage,
- The presence of changes in the pipe cross section due loss of thickness, circumferential welds, pipe features and others of the same magnitude causes a reflection of the Guided-Waves,
- This reflection is detected and recorded at the ring of transducers in pulse echo configuration,
- Each reflector cause a signal in the screen with an amplitude directly proportional to reflector size and decays with the distance from the ring of transducers,
- Guided-Waves Testing can also provide inspection coverage over long distances under the right circumstances,

Guided-Wave Examination Method (GWT):

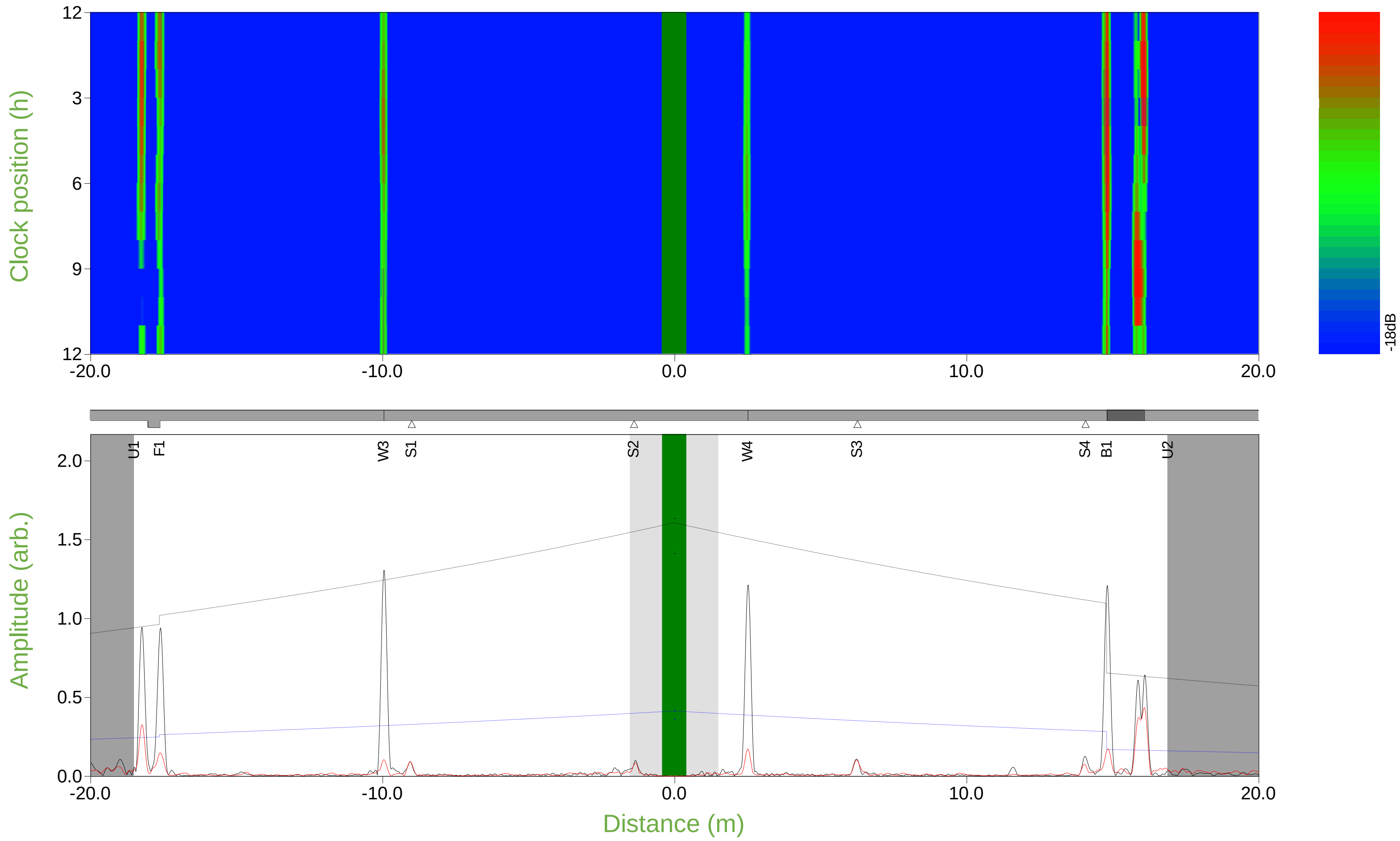


PARTO AZMOON AZAR

Guided-Wave Examination Method (GWT):



Guided-Wave Examination Method (GWT):

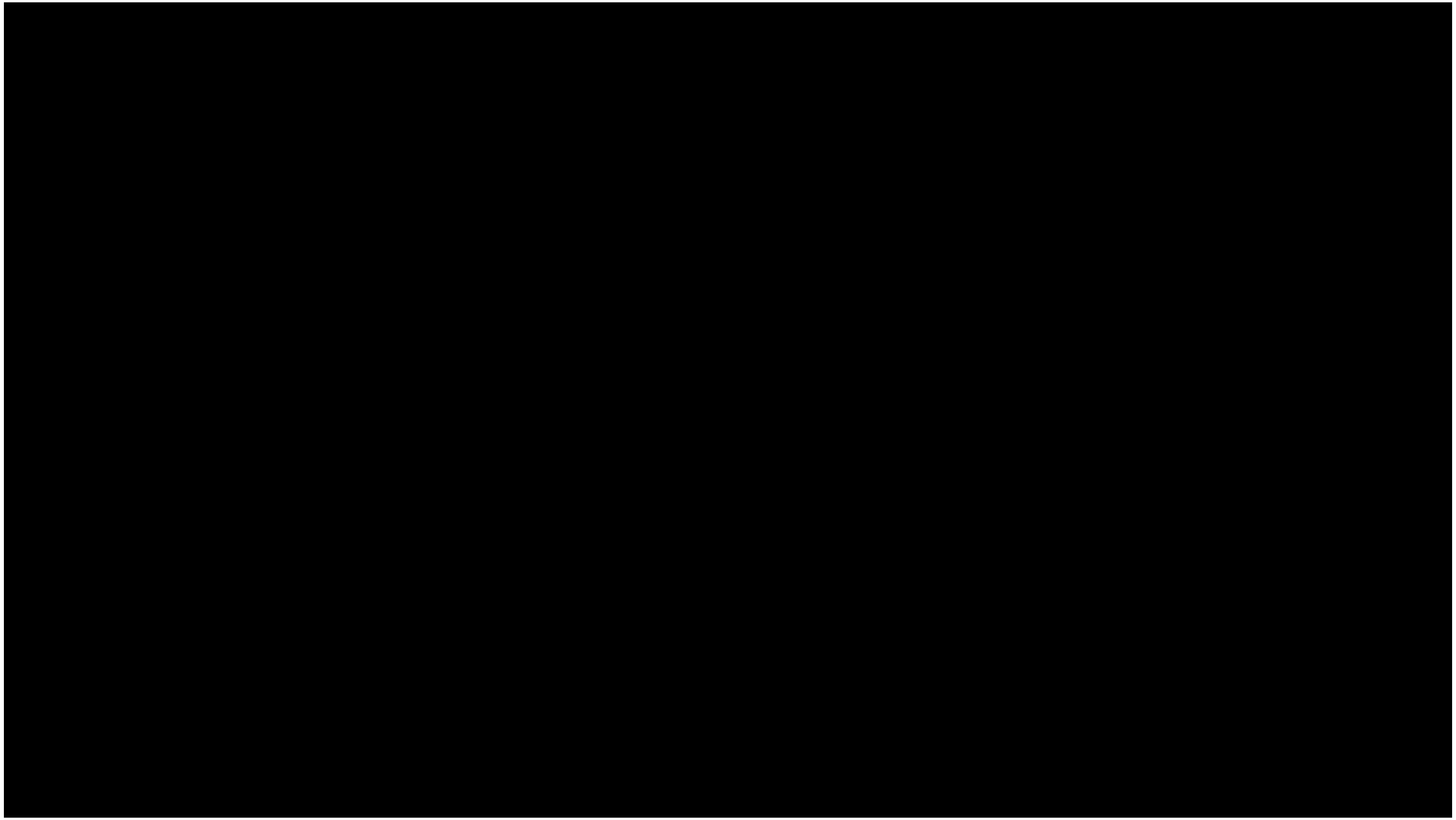


Guided-Wave Examination Method (GWT):

- GWT can be used as a screening method to identify potential areas of CUI damage,

- GWT can be performed without widespread removal of the insulation system (i.e. jacketing and insulation),

- GWT utilizes an array of low-frequency ultrasonic transducers, attached to the pipe circumference of a pipe, to generate an axially symmetric wave in both directions away from the transducer array,



Guided-Wave Examination Method (GWT):

- **Factors that limit the effectiveness of GWT include:**
  - Excessive internal or external surface roughness,
  - Exterior connections such as welded pipe supports, (Inspection coverage is also limited by the number of welds and elbows in the piping system,)
  - High viscosity liquids in the piping,
  - Soil in direct contact with the exterior of the piping system,

Guided-Wave Examination Method (GWT):

- Defects located in the immediate vicinity of welds are difficult to identify because of the strong ultrasonic reflection from the weld itself and could be as much as 6 in. (150mm) on either side of the weld,

- This method cannot detect localized pits,

- This method typically requires corrosion damage be greater than 4 % to 10 % of the pipe cross section to be detected,

- This method of inspection may not be applicable if CUI damage is not extensive,

- In addition to the limitations discussed above, it should be noted that interpretation of data is operator dependent,

Guided-Wave Examination Method (GWT):

- In addition to the limitations discussed above, it should be noted that interpretation of data is operator dependent,
- Owner/users should review the experience of operators performing GWT on piping systems prior to conducting an inspection,
- Some owner/users have required performance demonstration tests prior to initiating an extensive GWT program,
- GWT will identify suspect areas of corrosion in a short period of time, which can then be proved up with other conventional NDT,
- Detects not only **external corrosion** but also **internal corrosion**,
- Can inspect In-Service lines,

PARTO AZMOON AZAR

Guided-Wave Examination Method (GWT) applications:

- Coated Piping,
- Insulated Piping,
- Over-Head piping,
- Above Ground piping,
- Sleeved road cross piping,
- Buried piping,
- Offshore pipe,

Guided-Wave Examination Method (GWT):

Advantages:

- Can inspect up to 100ft (30m) in each direction away from the transducer array,
- Only ~3ft (1m) of insulation need to be removed to attach transducer array,
- Piping from 2” to 48” NPS can be tested,

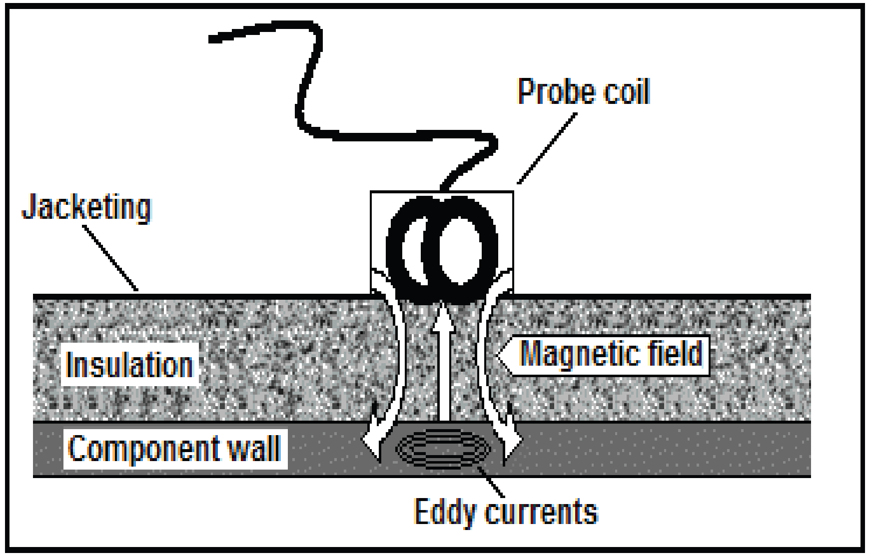
Disadvantages:

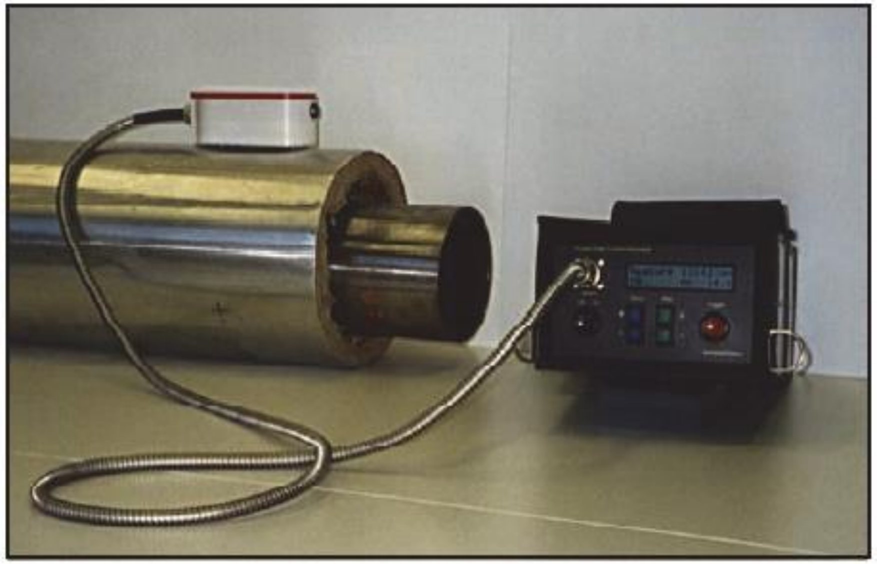
- Limited to applications operating below 125°C,
- Piping containing high-viscosity liquids, heavy external coatings, buried piping, or piping with an excessive number of welds/fittings can reduce the extent of inspection coverage,
- Isolated pitting or corrosion in the immediate vicinity of welds may not be detected,
- Technique is operator dependent,

Pulsed Eddy Current Method (PEC)

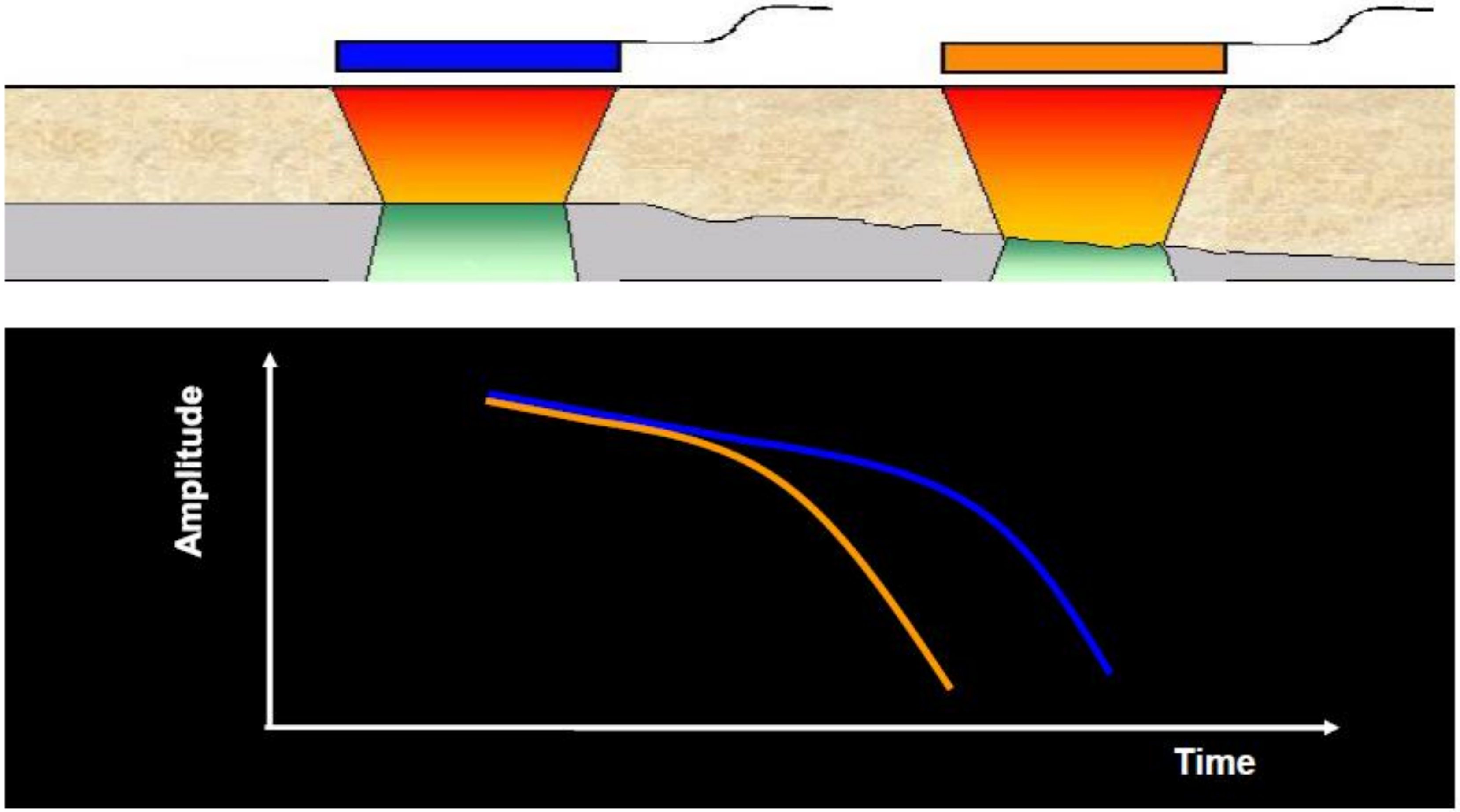
Pulsed Eddy Current Method (PEC):

A magnetic field, created by an electrical current in the probe coil, penetrates the jacketing and magnetizes the pipe wall. Current, in the probe coil, is then switched off to cause a sudden drop in the magnetic field. As a result of the change in the magnetic field, eddy currents are generated in the pipe wall. These eddy currents diffuse inward and decrease in strength. This decrease in the strength of the generated eddy currents is monitored by the probe coil. The thickness of the component is related to the length of time it takes for the eddy currents to show a change of the decay rate when eddy currents reach the back wall of the metal. The greater the wall thickness of the component, the longer it takes for the eddy currents to reach the back-wall.





Pulsed Eddy Current Method (PEC):



Pulsed Eddy Current Method (PEC):

- PEC has been used in recent years to detect areas of wall thinning on insulated piping through aluminum or stainless steel jacketing,
- It is also used to inspect fireproofed legs on storage spheres,
- It is a noncontact, electromagnetic examination method used to detect the average wall loss of carbon and low alloy steel materials,
- PEC can be used on carbon and low alloy steel equipment and piping through up to 8 in. (200mm) of insulation and jacketing,

PARTO AZMOON AZAR

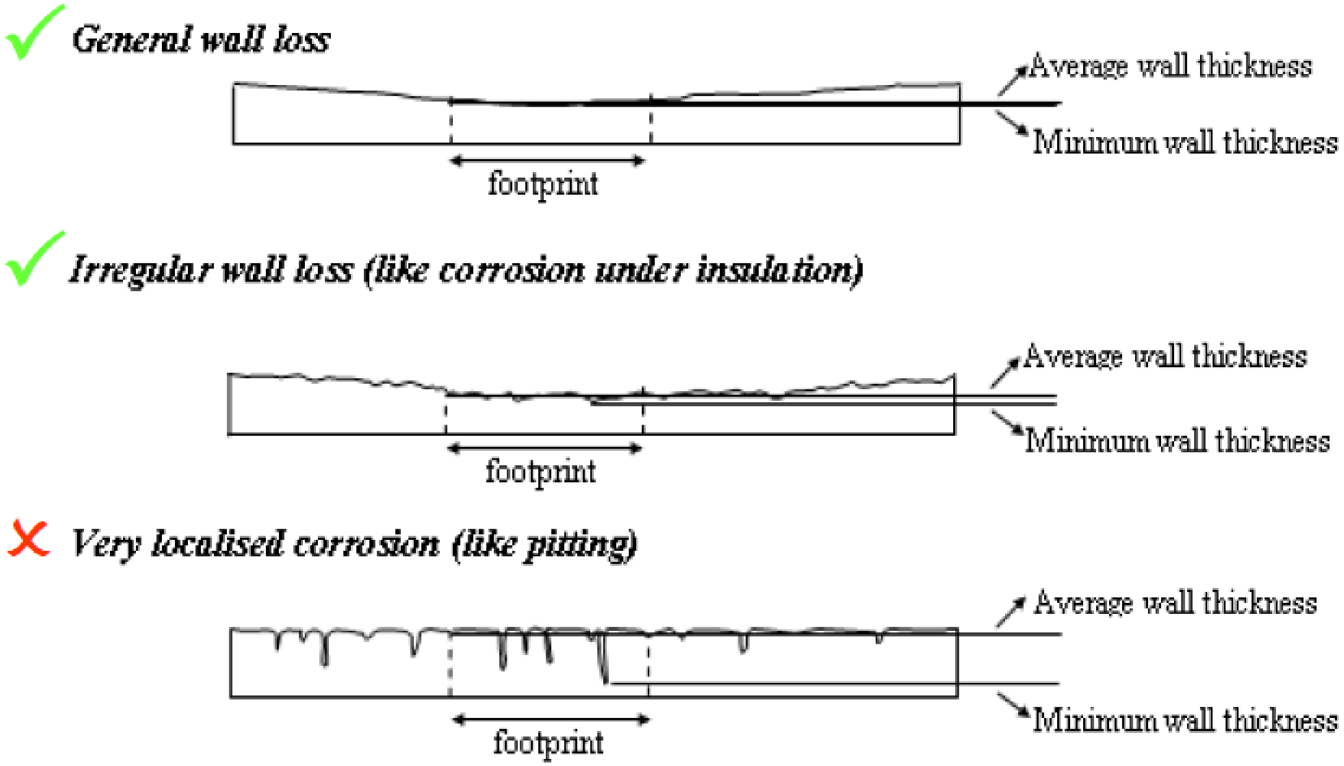
Pulsed Eddy Current Method (PEC):

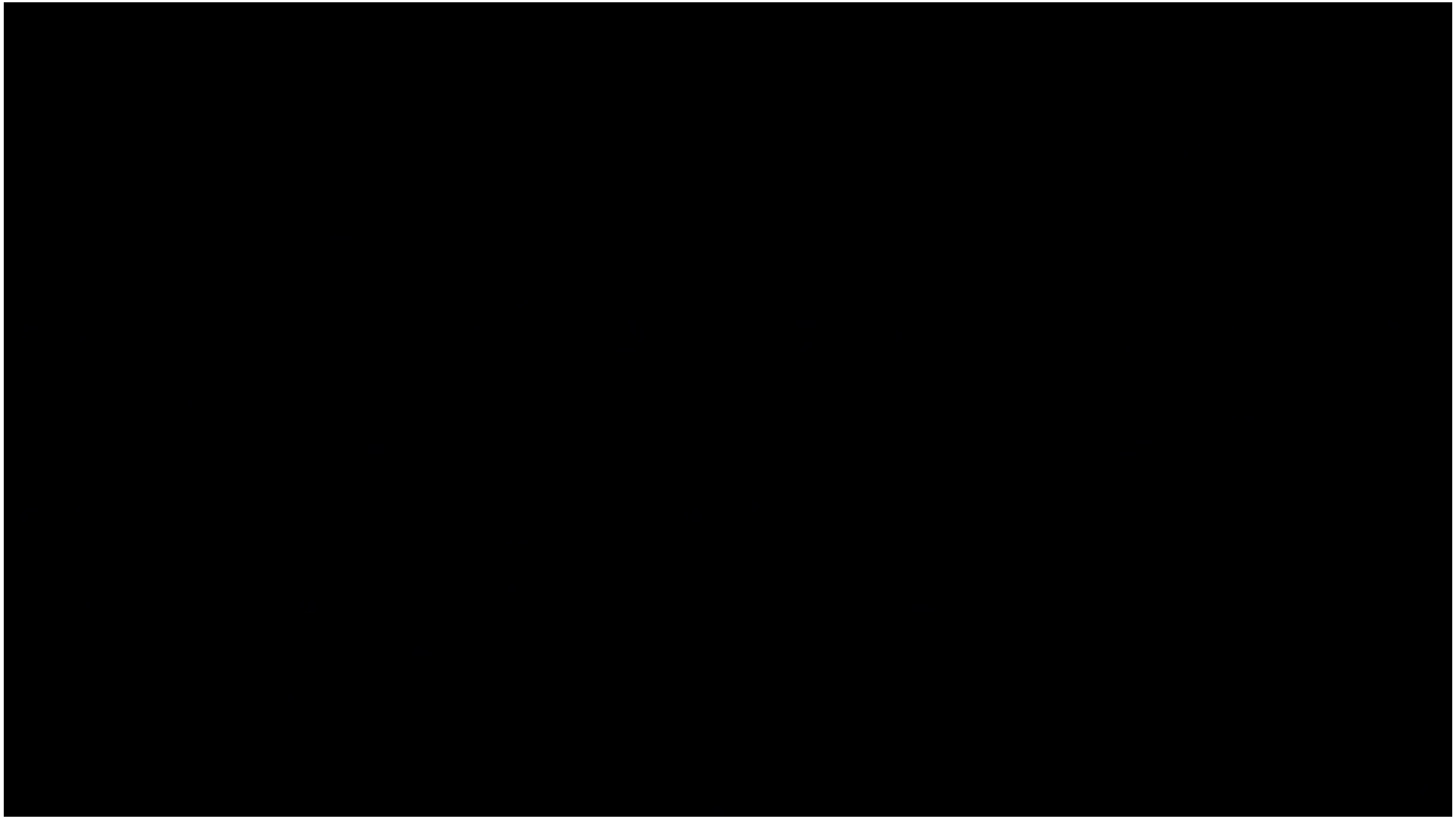
Pulsed Eddy Current Method (PEC):

- The area where the measurement is taken is referred to as the “footprint”,
- The probe is designed in such a way that the magnetic field focuses on an area on the surface of the component,
- The thickness measured by the technique is the Average Wall Thickness “AWT” over the footprint area,
- The size of the area is dependent on the insulation, component thickness, and probe design,
- In general, the footprint can be considered to be on the order of the insulation thickness,
- Since the technique measures the average rather than the minimum component thickness, the technique is not suitable to detect pitting that can be highly localized,

Pulsed Eddy Current Method (PEC):

Difference Between Average and Minimum Wall Thickness Within the Footprint





Pulsed Eddy Current Method (PEC):

Advantages:

- Non-invasive, Non-contact method that does not require surface preparation,
- Can be used between –100°C and 500°C,

Disadvantages:

- Averages corrosion over a 4in. (100mm) diameter area so that isolated pitting may be difficult to detect,
- Affected by ferromagnetic appurtenances such as insulation rings, vents, and drains that can obscure surface damage,
- Technique is operator dependent,

Radiographic Inspection Methods

PARTO AZMOON AZAR

Radiographic Inspection Methods:

- There are a variety of techniques involving radiographic methods that can be used to detect CUI damage,

- Radiography essentially requires a source of radiation opposite a detection medium that records the radiation either as a film or digital image, these include:

    - Tangential Radiographic Inspection (Profile Radiography),
    - Double Wall Radiographic Inspection (Film Density Measurement Technique),
    - Real-time radiography,
    - Computed radiography (CR),
    - Digital radiography (DR),
    - Radiometric profiling,

Radiographic Inspection Methods:

- Radiographic Examination is a very effective method that can be used for the Inspection of CUI,

- Unlike other methods, Radiography cannot only find CUI but also produce accurate wall lose measurements without insulation removal,

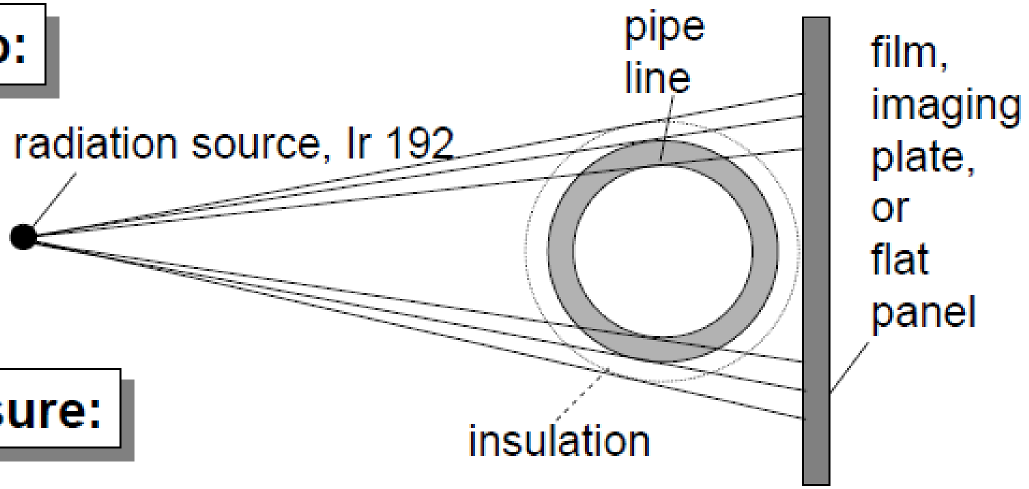
- Can be utilized while Pipe/Equipment is in-service,

Tangential Radiographic Inspection (Profile Radiography)

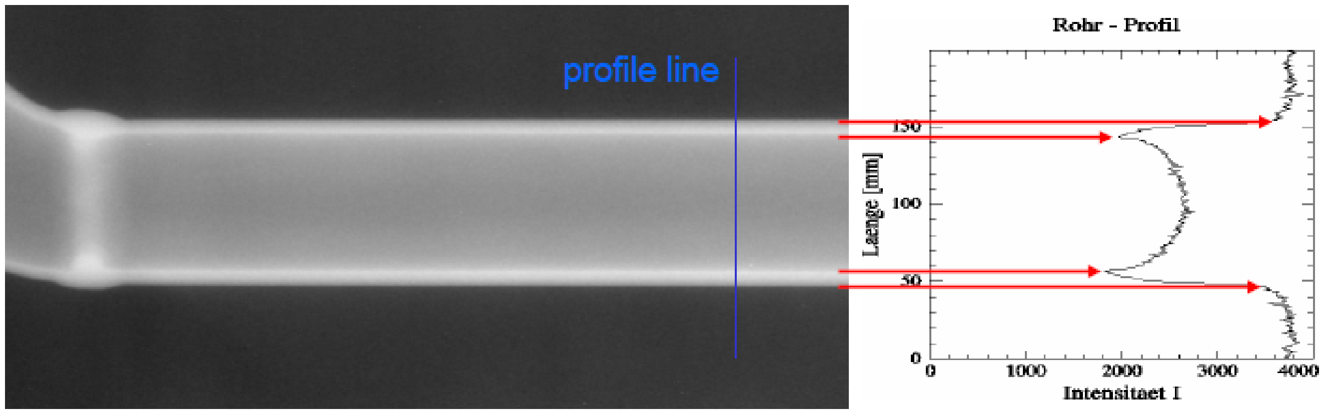
PARTO AZMOON AZAR

Tangential Radiographic Inspection:

classical set-up:

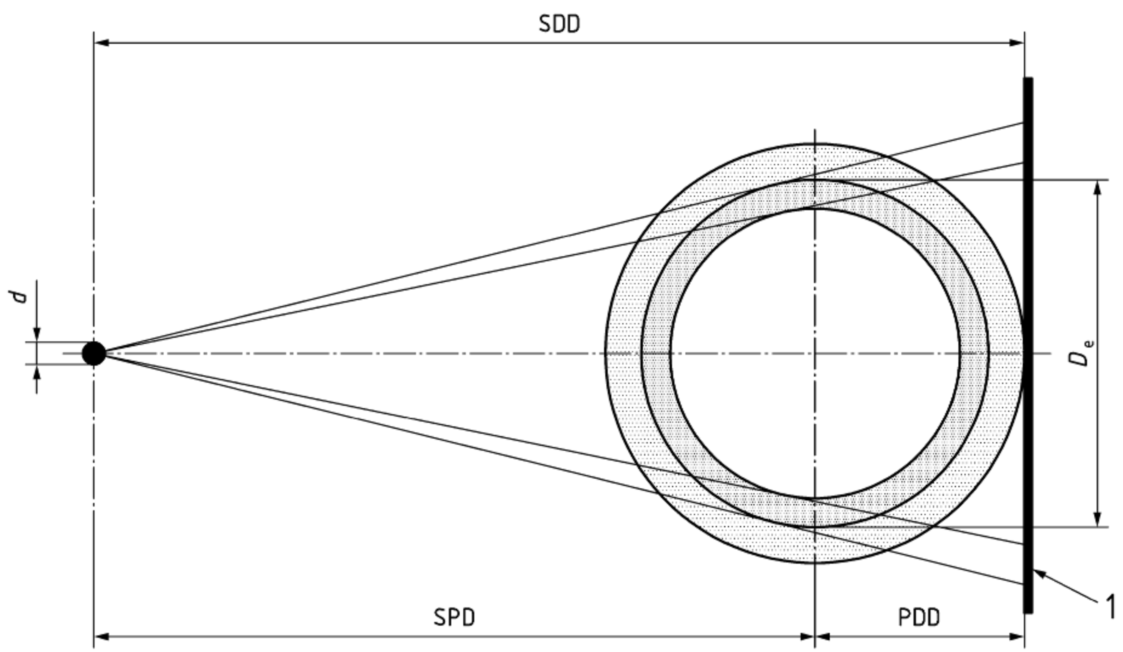


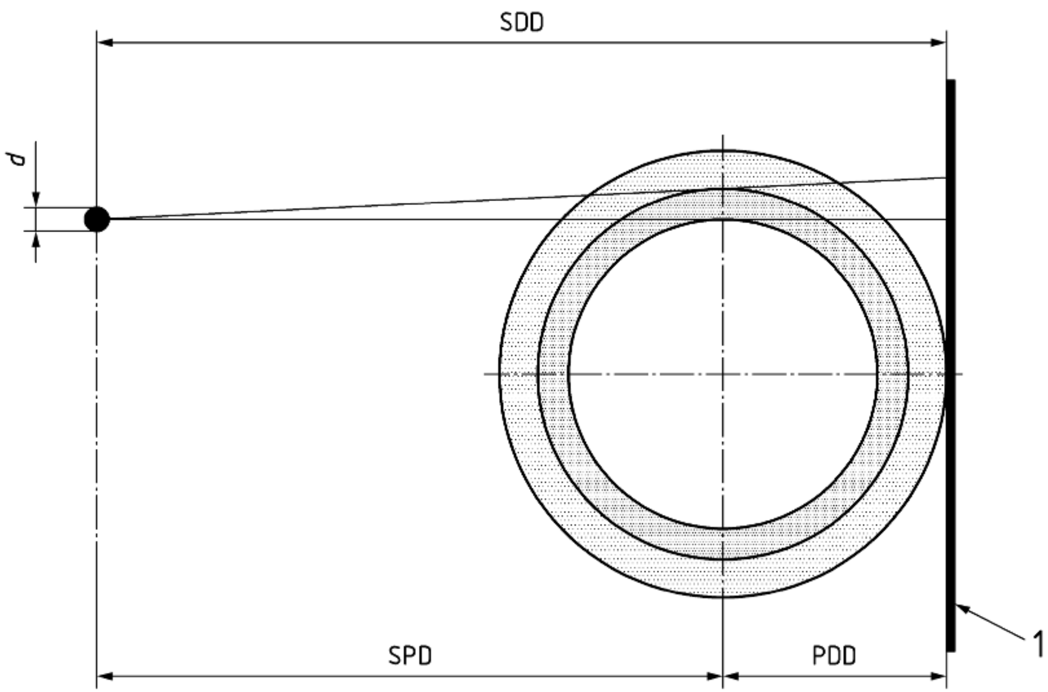
typical exposure:



Tangential Radiographic Inspection:

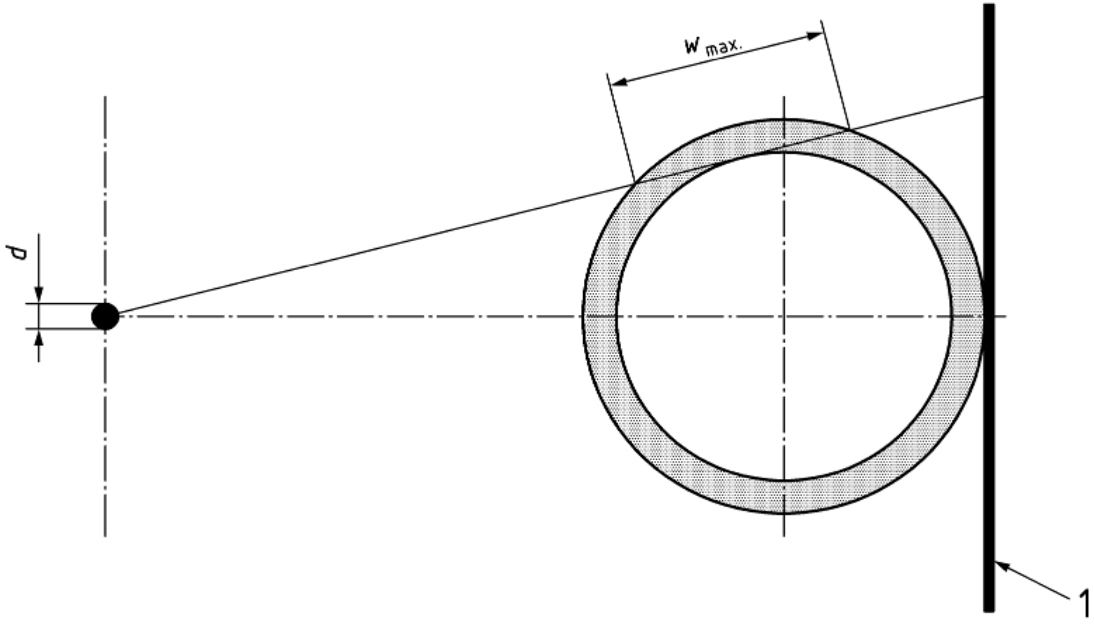
1. Radiation source located on the pipe center-line,
2. Radiation source located offset from the pipe center-line,





Tangential Radiographic Inspection:

- The beam of radiation shall be directed at the center of the area being examined,
- The film or detector should be aligned to be orthogonal to the center of the radiation beam,
- The choice of radiation source should be determined by the maximum penetrated thickness of the pipe, w_{max} which occurs for the path forming a tangent to the pipe inner diameter,



$$w_{max} = 2\sqrt{t(D_e - t)}$$

where

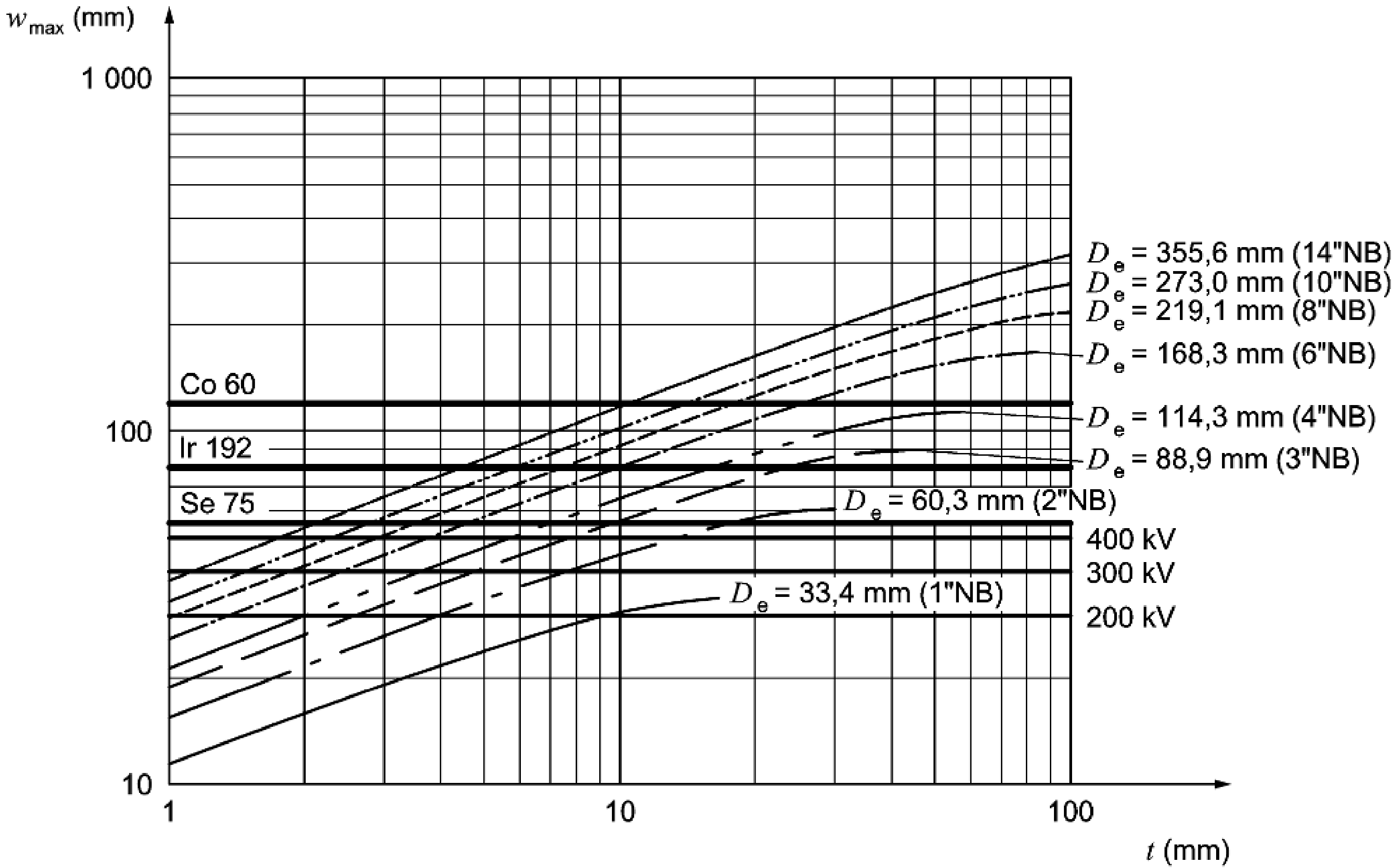
t	is the nominal thickness of the pipe;
D_e	is the outside diameter of the pipe.

Tangential Radiographic Inspection:

- "Tangential Radiographic Inspection" is used to radiograph a small section of the pipe wall,
- "Tangential Radiographic Inspection" can also be done using sealed sources or x-ray machines,

Radiation source	Limits on maximum penetrated thickness w_{max} mm	
	Basic (for generalized wall loss)	Improved (for pitting flaws)
X-ray (100 kV)	≤ 10	≤ 7
X-ray (200 kV)	≤ 30	≤ 20
X-ray (300 kV)	≤ 40	≤ 30
X-ray (400 kV)	≤ 50	≤ 35
Se 75	≤ 55	≤ 40
Ir 192	≤ 80	≤ 60
Co 60	≤ 120	≤ 85

Tangential Radiographic Inspection:

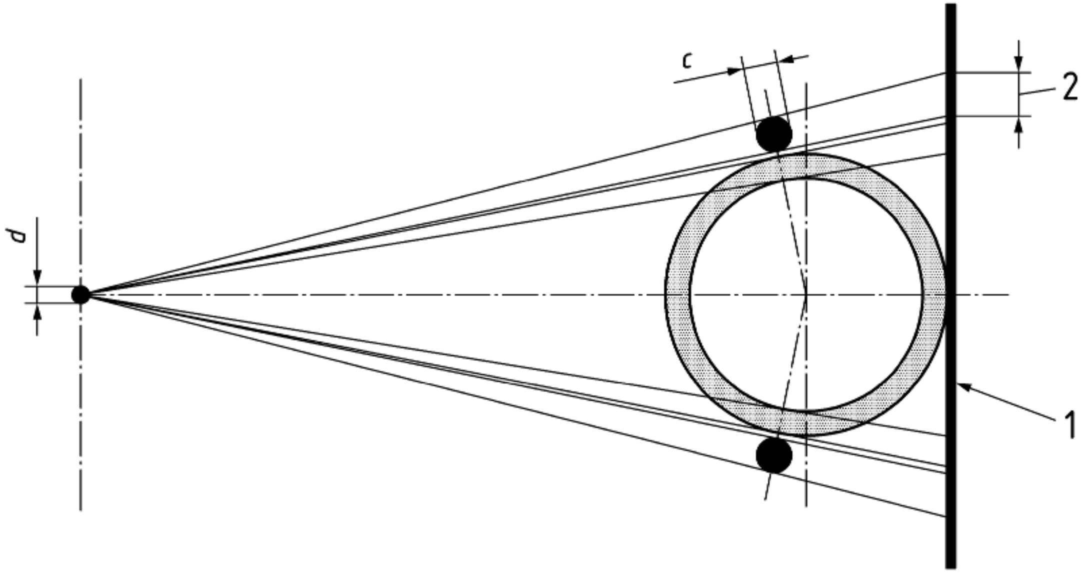


Tangential Radiographic Inspection:

Dimensional comparator:

For measurement of remaining wall thickness, the film radiographs or digital images shall be dimensionally calibrated to correct for the geometric magnification caused by the geometrical arrangement of source, pipe and detector.

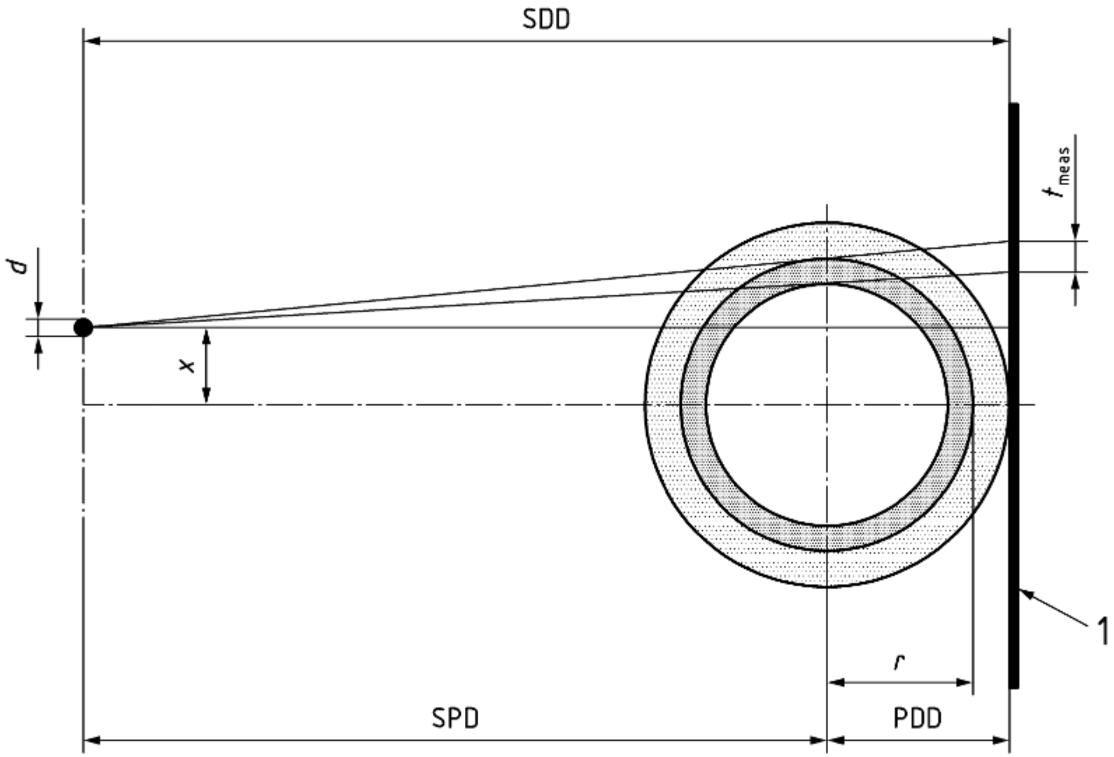
One method for dimensional calibration is the use of a ball bearing or other dimensional comparator. This is an effectively radiation opaque object (usually spherical) with a known diameter, which is placed close to the pipe, and in the same plane as the tangent position on the pipe wall,



Tangential Radiographic Inspection:

For offset tangential radiography (with x approximately r), the true wall thickness t_{act} at the tangential pipe position can be calculated from the measured wall thickness t_{meas} using the approximate formula:

$$t_{act} = \frac{SPD}{SDD} \cdot t_{meas}$$

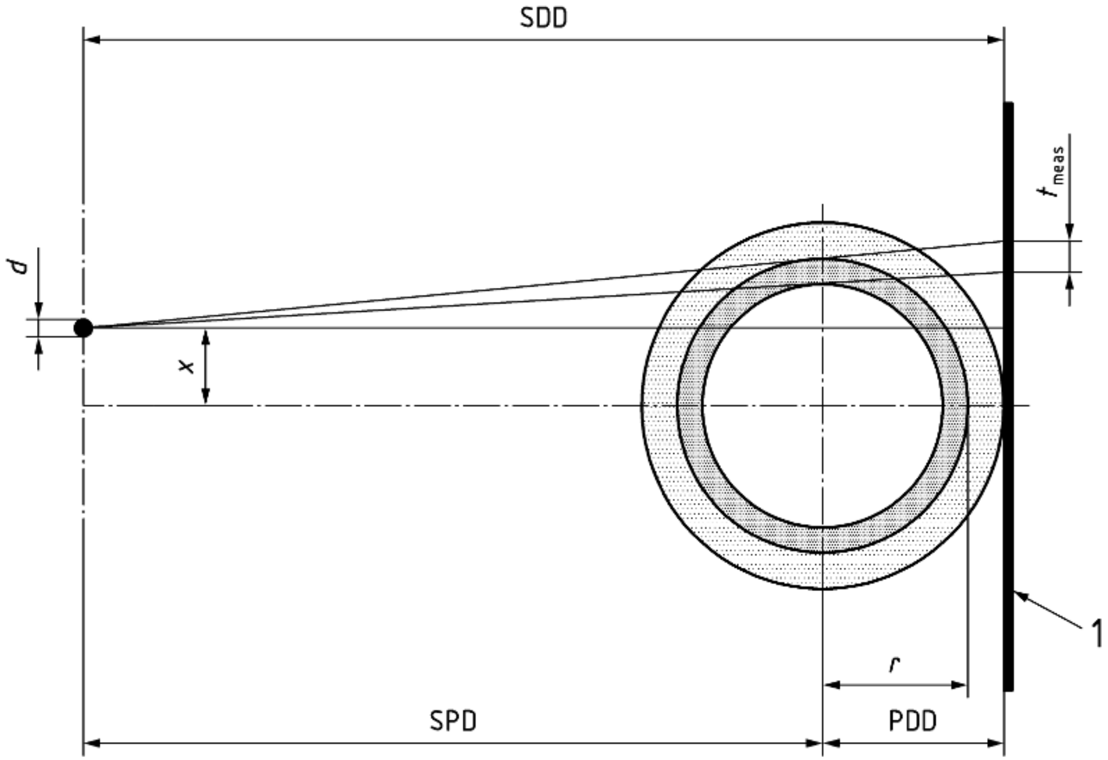


Tangential Radiographic Inspection:

Provided x approximately 0, then the following complex formula can be used to derive the wall thickness t_{act}, from the measured value t_{meas}:

$$t_{act} = r - \frac{SPD\left(\frac{r}{\sqrt{SPD^2 - r^2}} - \frac{t_{meas}}{SDD}\right)}{\sqrt{1 + \left(\frac{r}{\sqrt{SPD^2 - r^2}} - \frac{t_{meas}}{SDD}\right)^2}}$$

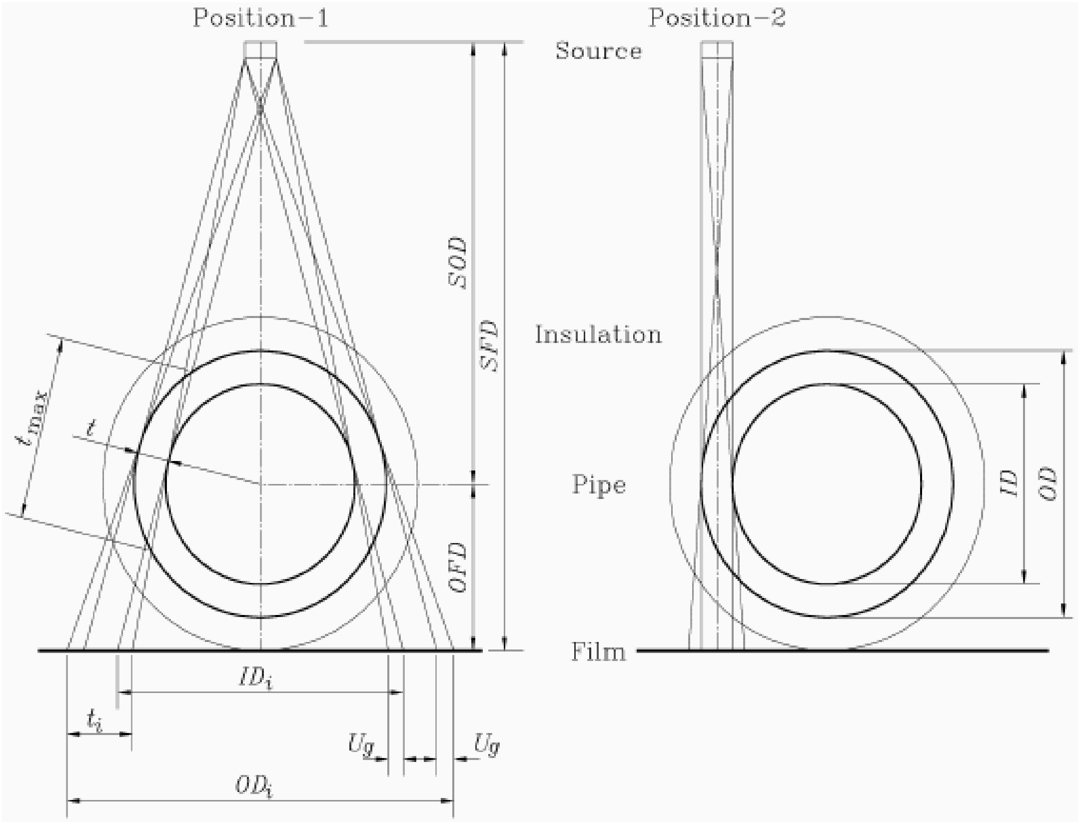
where: $r = \frac{D_e}{2}$



Tangential Radiographic Inspection:

The source is put far from the tube in order to project the two walls of this tube on the film,

Because of dimensions of the radioactive source, an effect of Geometric Unsharpeness appears on the film,



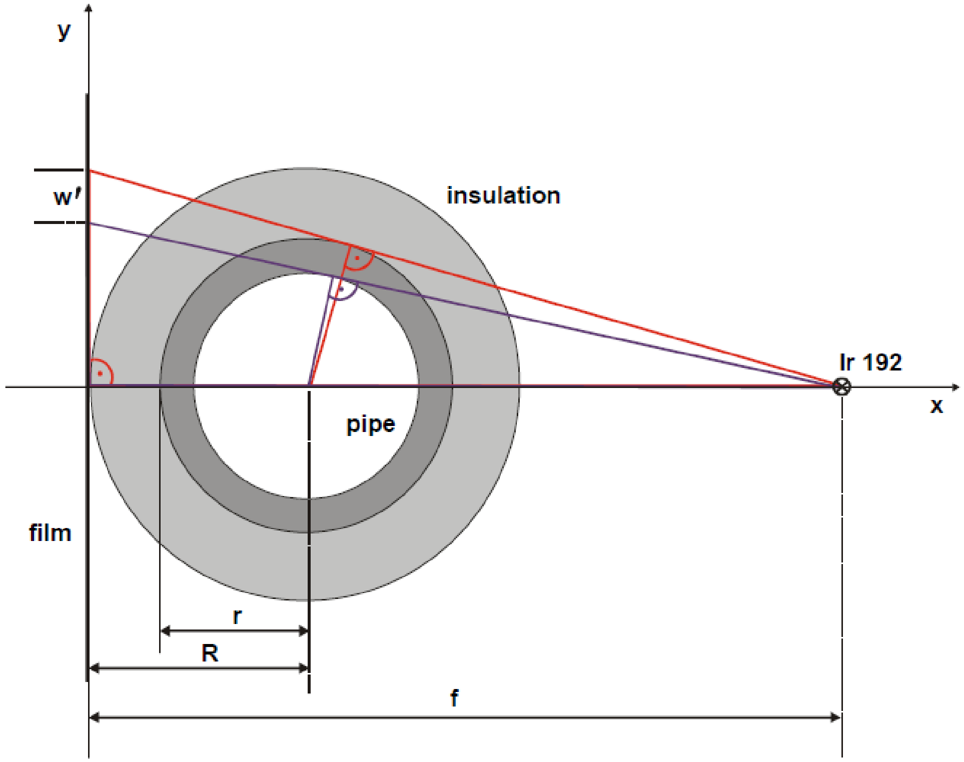
Tangential Radiographic Inspection:

Angle of rotation of tangential point:

$$K = Cos^{-1}\left(\frac{r}{f - R}\right)$$

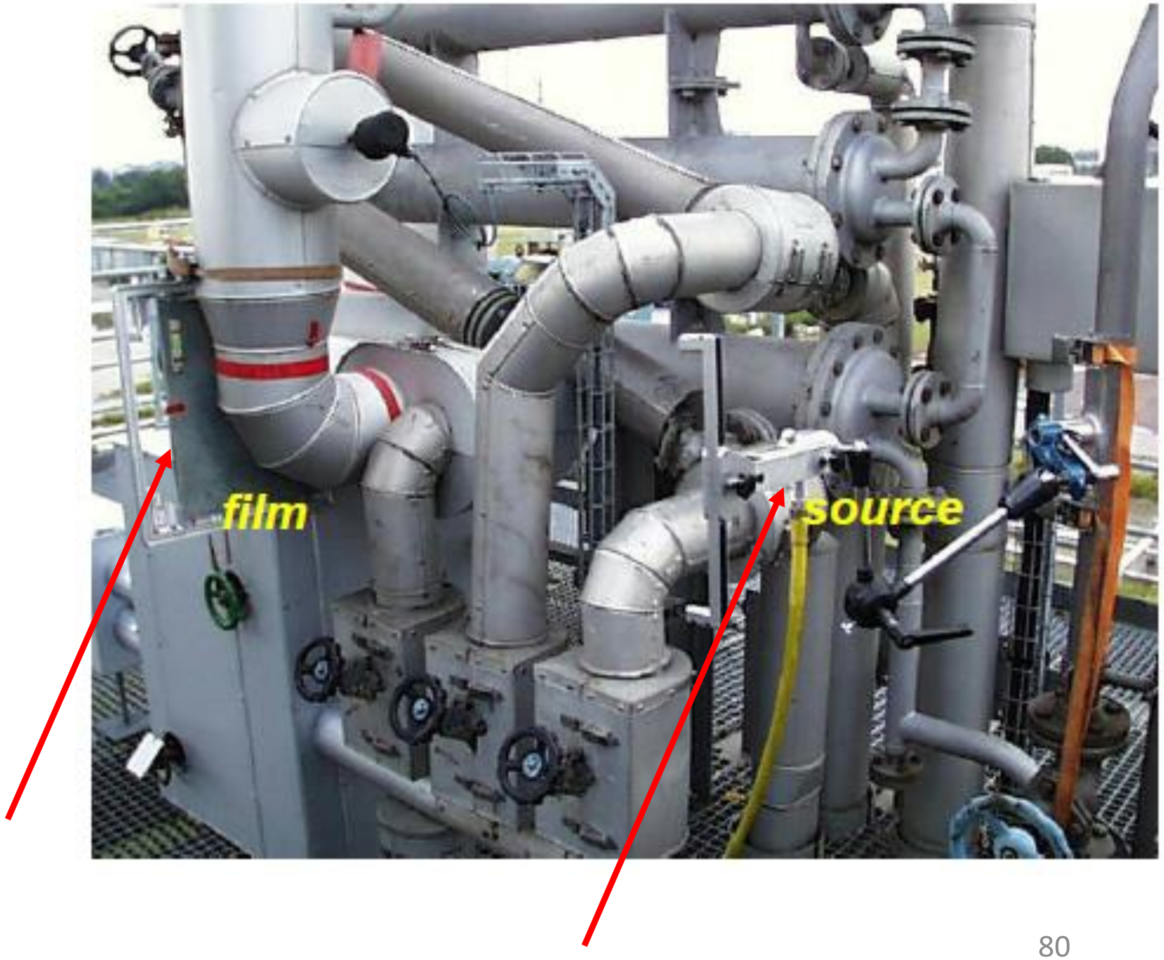
For optimized results, the source to sensor distance should be as large as practical, ratio of source to sensor distance to outside diameter of 6 or more produce low unsharpness values,

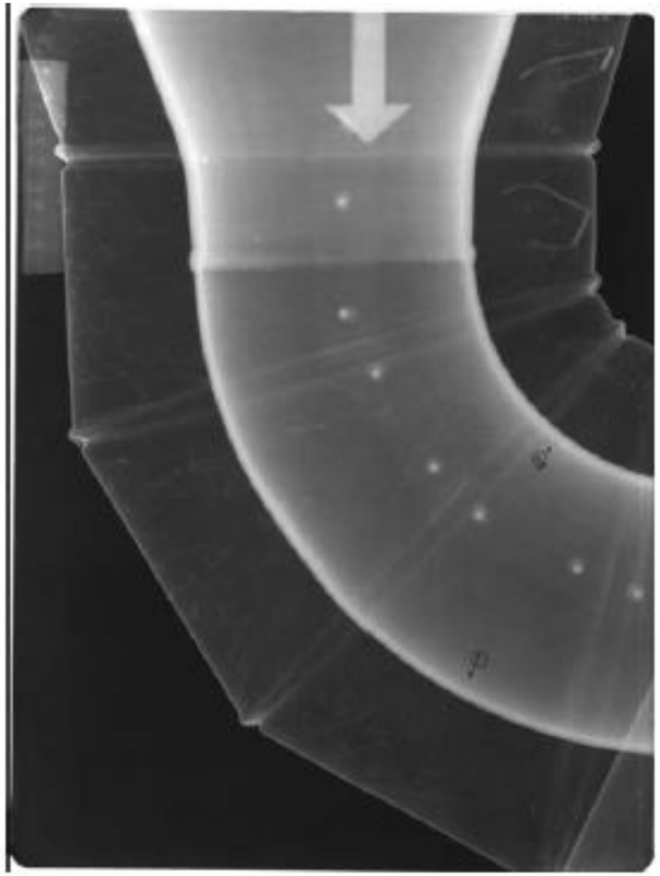
High-contrast and **Fine-grained** films produce more accurate results when developed to medium range film optical densities around 2.0,



PARTO AZMOON AZAR

Tangential Radiographic Inspection:





Tangential Radiographic Inspection:

- "Tangential Radiographic Inspection" is an effective evaluation method but becomes technically challenging in piping systems over 10" in diameter and only offers the limited luxury of verifying relatively small areas,

- This technique is not capable of detecting ECSCC on austenitic or duplex stainless steels,

- Radiation safety can be a real concern, the need to cordon off a large area for radiographic examination can result in downtime and personnel scheduling conflicts,

- "Tangential Radiographic Inspection" is usually preferred to assess insulated piping for **uniform corrosion** damage,

- Great tool for Inspection at Suspect Areas of CUI,

- Can take Profile at multiple different angles to catch Area of interest,

Tangential Radiographic Inspection:

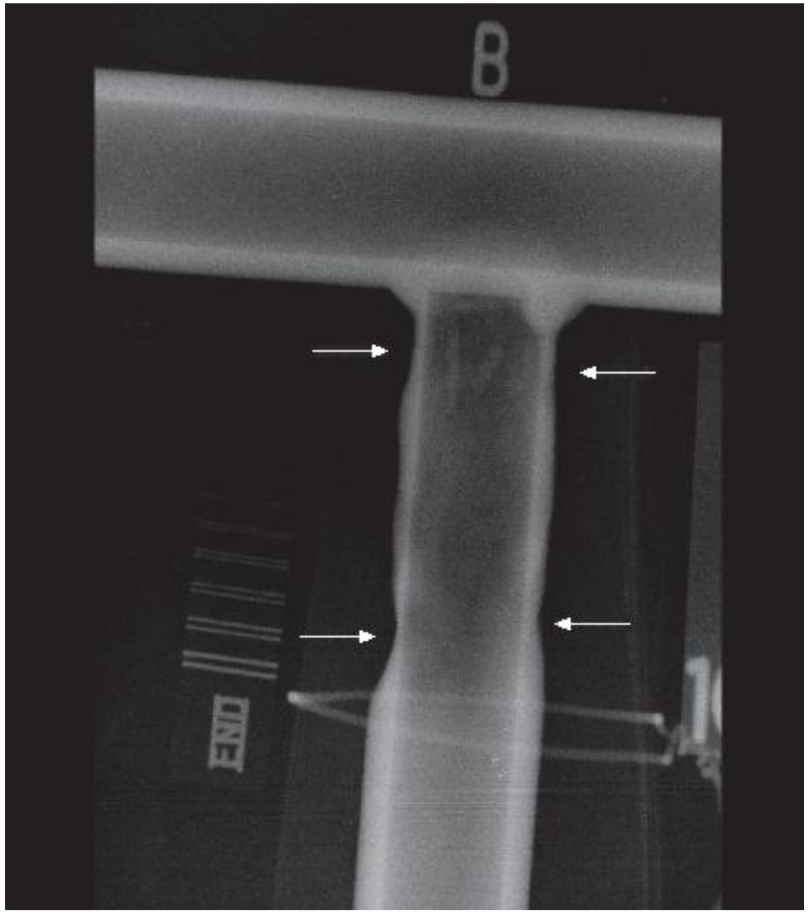
Advantages:

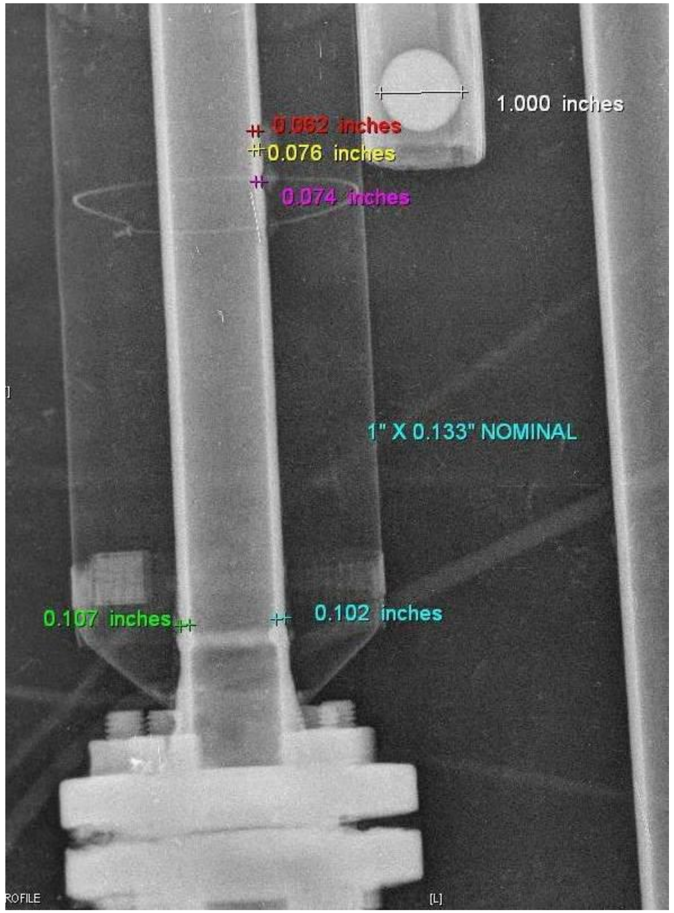
- Provides a permanent record of examined areas,
- Provides a relatively easy scanning method without the need for insulation removal,
- Used routinely on piping 2" NPS and above,
- Determines wall thickness with an accuracy smaller than ±1 mm,
- Not only a Screening Tool but can also Produce Accurate Measurements of Wall Loss,

Disadvantages:

- Limitations on pipe size that can be inspected,
- Piping or equipment would require insulation to protect the film at elevated temperatures,

Tangential Radiographic Inspection:

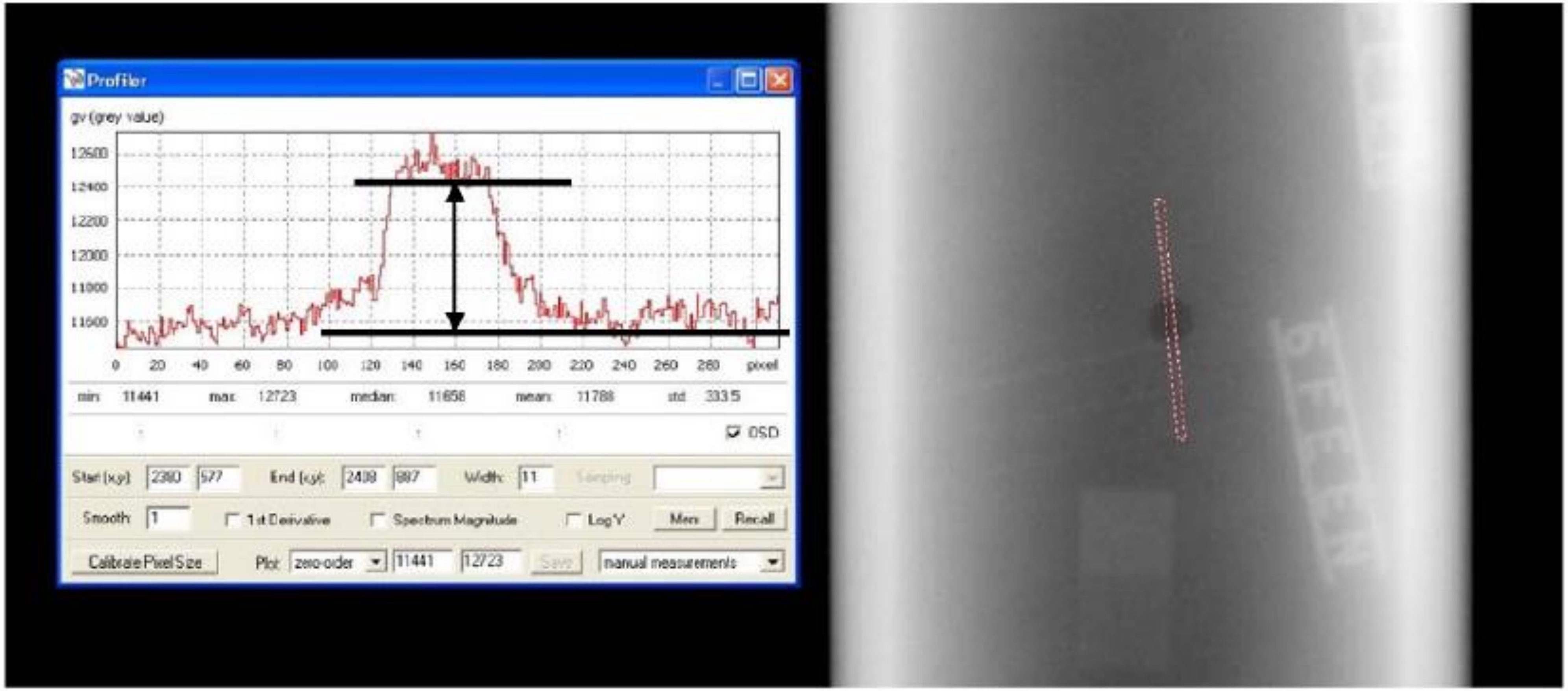




PARTO AZMOON AZAR

Film Density Measurement Technique
(Double Wall Radiographic Inspection)

Film Density Measurement Technique:



PARTO AZMOON AZAR

Film Density Measurement Technique:

- Tangential Radiographic Inspection and Film Density Measurement Technique are complementary methods,

- Film Density Measurement Technique is preferred to assess pitting corrosion damage on insulated piping because of the difficulty of aligning pits perpendicular to the radiographic beam in profile radiography,

- Film Density Measurement Technique only measures the Average Wall Thickness (AWT) of the piping and is often used on small diameter piping [≤6”] however, with some trade-offs, this technique can be used on larger diameter piping,

- The appropriate energy and appropriate film speed should be chosen when the Film Density Measurement Technique is utilized to achieve good image quality,

Film Density Measurement Technique:

- Part 2 of EN-16407 covers "Double Wall Inspection Techniques" for detection of **wall loss**, including double wall single image (**DWSI**) and double wall double image (**DWDI**),

- The "Double Wall Radiographic Techniques" are divided into two classes:

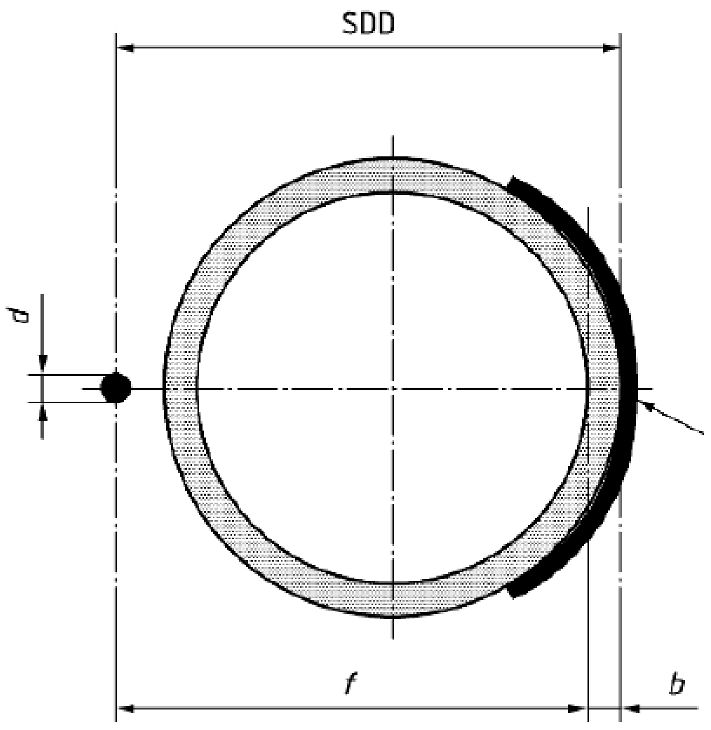
  1) **Basic Techniques "DWA":**
  The " **Basic Techniques**" are intended for double wall radiography of generalized and localized wall loss,

  2) **Improved Techniques "DWB":**
  The "**Improved Techniques**" should be used where higher sensitivity is required such as for radiography of fine, localized corrosion pitting,

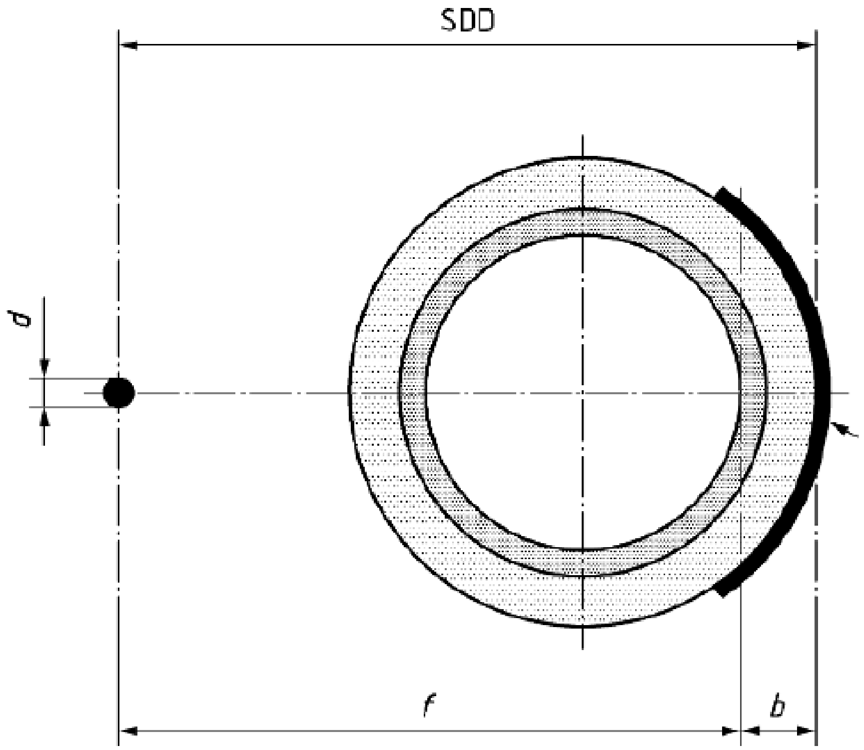
- These techniques can also be used for detection of **deposits inside the pipe**,

Film Density Measurement Technique:

Test arrangement for double wall single image radiography (**DWSI**) using a curved detector,



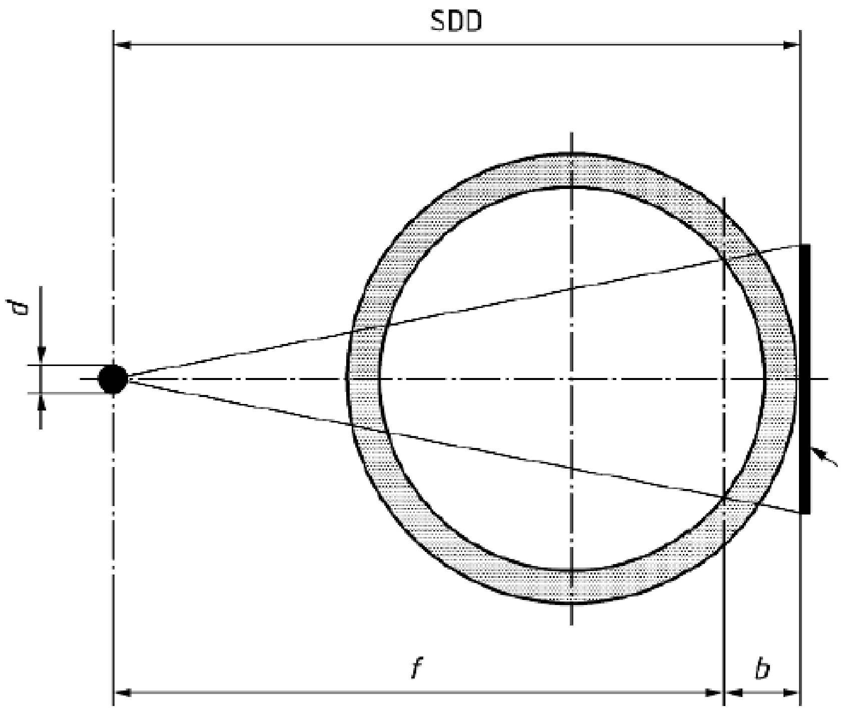
Non insulated pipe



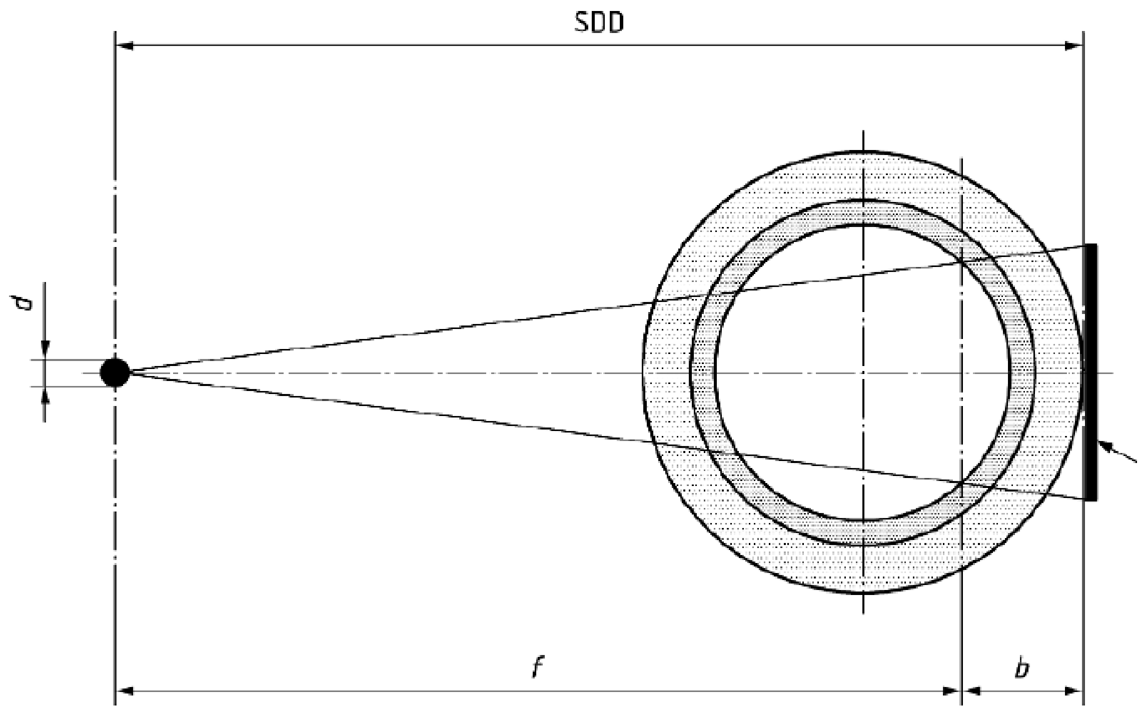
insulated pipe

Film Density Measurement Technique:

Test arrangement for double wall single image radiography (**DWSI**) using a planar detector,



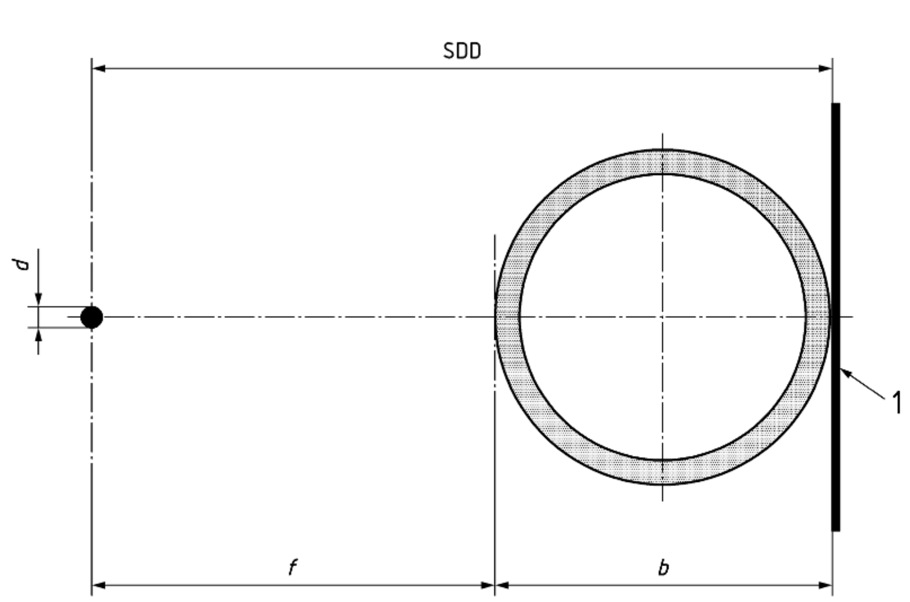
Non insulated pipe



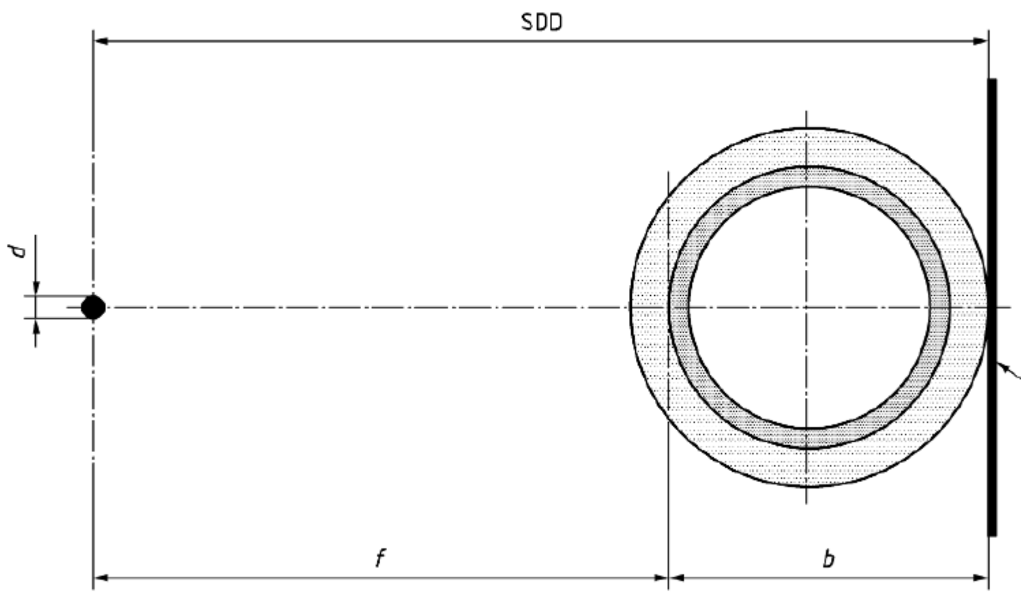
insulated pipe

Film Density Measurement Technique:

Test arrangement for double wall double image radiography (**DWDI**),



Non insulated pipe



insulated pipe

Measurement of differences in penetrated thickness:

To a first approximation, the radiation intensity transmitted through an object is related to penetrated thickness by:

$$I(w) = I(0)\exp(-\mu\, w)$$

Where:

- ***I*(*w*)** is the intensity for penetrated thickness *w*,
- ***I*(0)** is the unimpeded radiation intensity incident on the object,
- ***μ*** is the effective linear attenuation coefficient of the object material,

Consider two different penetrated thickness values w_1 and w_2, Assuming equal incident radiation intensities and attenuation coefficients for these two penetrated thickness values, application of above Formula then gives:

$$w_2 - w_1 = \frac{1}{\mu} \mathrm{Ln}\left(\frac{I(w_1)}{I(w_2)}\right)$$

The ratio of radiation intensities in film radiography shall be determined from the measured optical densities by the following formula:

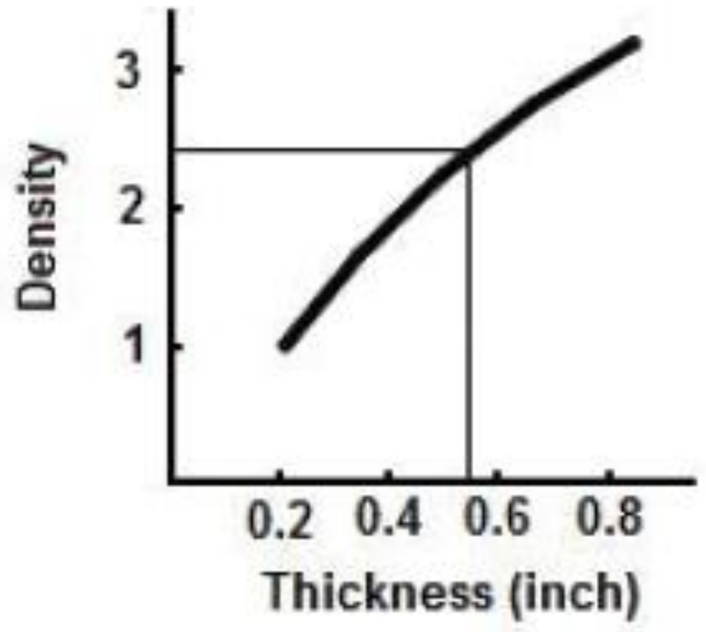
$$\frac{I(w_1)}{I(w_2)} = \frac{D_1 - D_0}{D_2 - D_0}$$

Where: D_0 is the optical density of film base and fog.

Film Density Measurement Technique:

- The density/thickness reference curve should be developed using step wedges that are made from material that is radiographically similar to the piping being evaluated,

- The step wedge thickness should be twice the thickness of the pipe wall being evaluated,

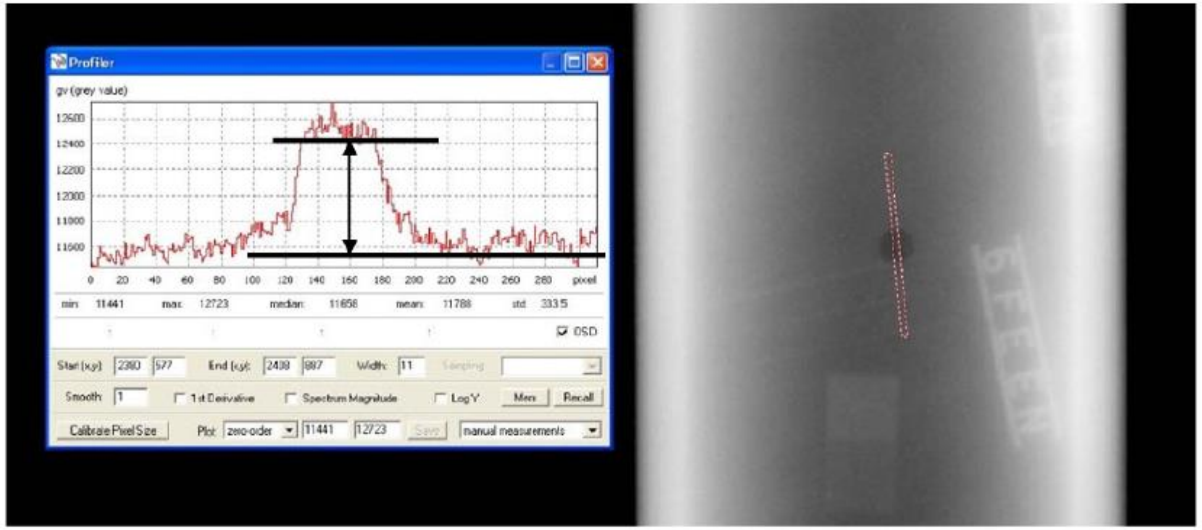


c) Density/Thickness curve

Film Density Measurement Technique:

- It is important to locate the pit or local corrosion area correctly, The pitting should lie on film side during exposure to prevent an underestimation of its depth,

- The depth of the pitting and remaining wall thickness can be determined using the measured optical density of the pit and sound wall and a density/thickness reference curve,



Film Density Measurement Technique:

Advantages:

- Provides a permanent record of examined areas,
- Provides a relatively easy scanning method without the need for insulation removal,
- Technique can locate **irregular** or **scattered** pits,

Disadvantages:

- Corrosion products within pits can decrease film density and result in an incorrect determination of the wall thickness,
- Liquids present in the equipment (piping) will reduce the transmitted radiation,
- An ultrasonic examination will also be required if density curves are not calculated,
- Piping or equipment would require insulation to protect the film at elevated temperatures,

Related Standards:

BS-EN 16407-1 (2014)
Non-destructive testing, Radiographic inspection of corrosion and deposits in pipes by X and gamma rays
Part (1): **Tangential Radiographic Inspection**

BS-EN 16407-2 (2014)
Non-destructive testing, Radiographic inspection of corrosion and deposits in pipes by X and gamma rays
Part (2): **Double Wall Radiographic Inspection**

Computed Radiography (CR)
and
Digital Radiography (DR)

Computed Radiography and Digital Radiography:

- Film radiography is the dominant, volumetric nondestructive testing technique used throughout the world,

- The primary **advantages** of film radiography are that film is:
  - Lightweight,
  - Flexible,
  - Used in a variety of applications for many years with a proven track record,

- Despite this, film does have **disadvantages**:
  - Film processing requires significant amounts of time to develop radiographs (~20 min),
  - Specialized facilities for film processing (i.e. a darkroom),
  - Generates hazardous wastes that require disposal,
  - Film radiographs have a limited shelf life,
  - Require a temperature and humidity-controlled storage environment,

Computed and Digital Radiography:

By contrast:

1. DR requires none of the above,
2. CR requires less exposure time, and no need to chemicals,
3. Digital Images can be generated, optimized, analyzed, stored, and distributed in electronic format,

PARTO AZMOON AZAR

Computed Radiography (CR):

Computed Radiography (CR):

- CR is a transitional technology between film and direct DR.

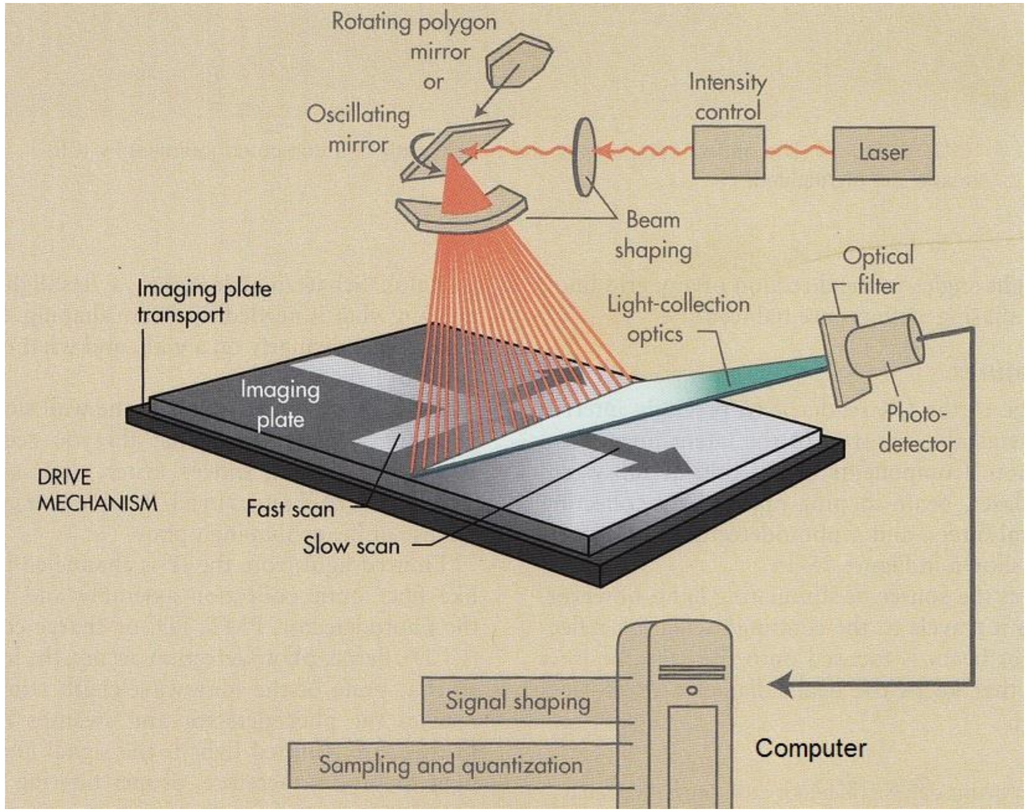
- A re-usable, flexible, Phosphor Image Plate is loaded into a cassette and is exposed in a manner similar to traditional film radiography. The cassette is then placed in a laser reader where it is scanned and translated into a digital image,

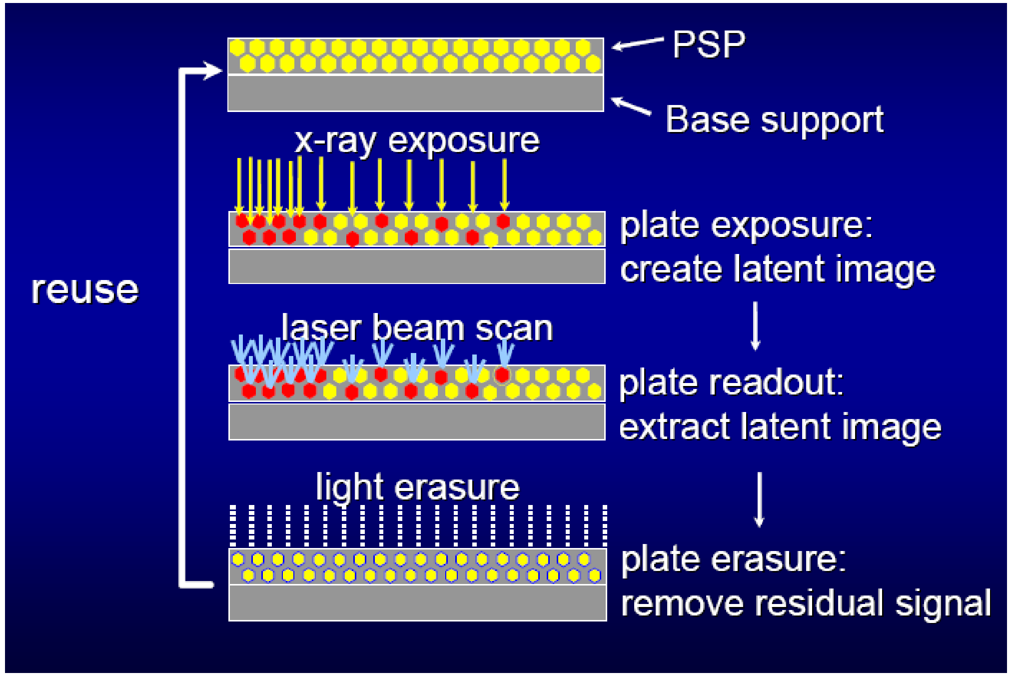
- Depending on the resolution required and image size, the process of digitizing may take from **1 minute** to **5 minutes**,

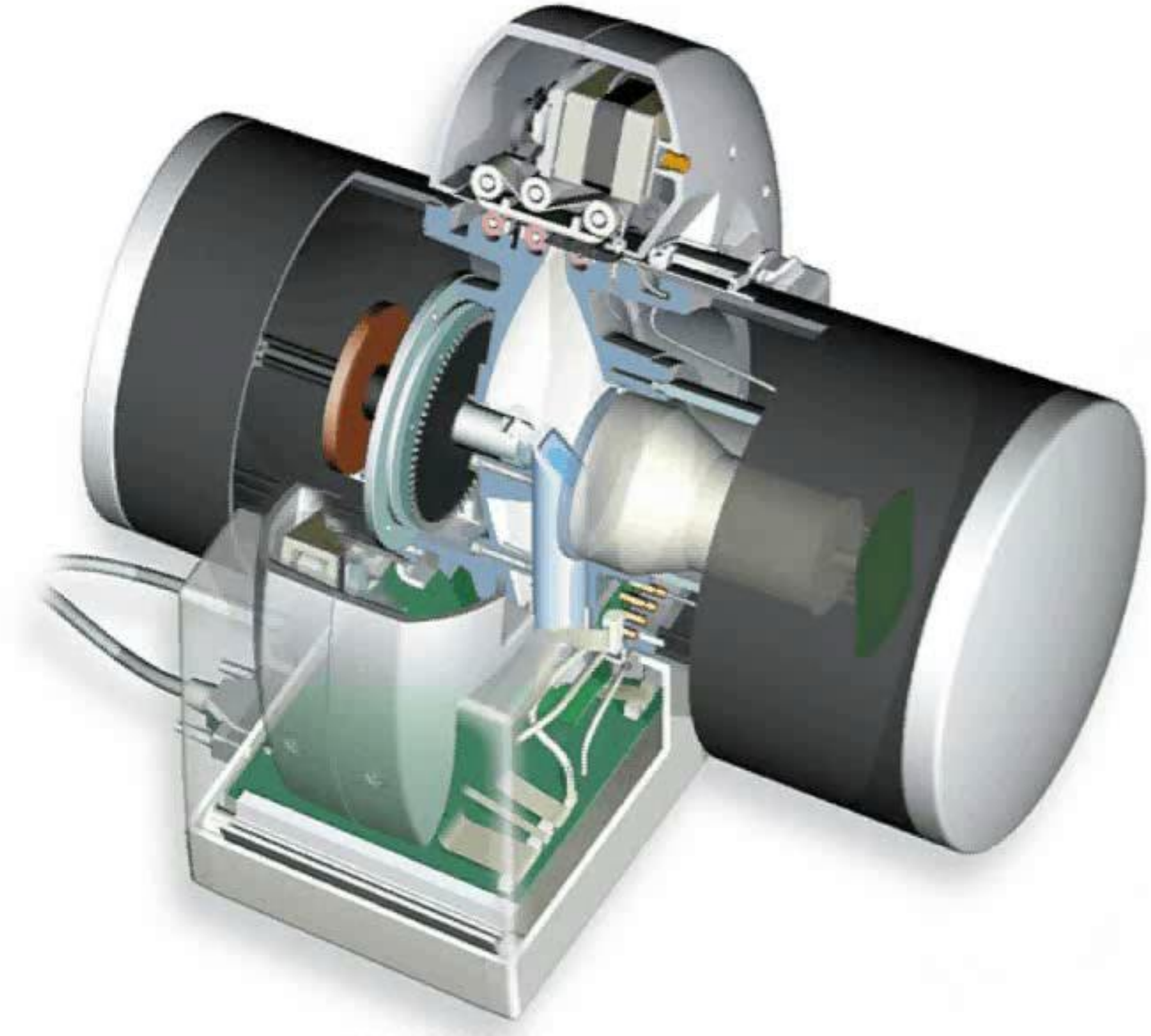
- Once digitally captured, the image may be stored on a computer or other electronic media,

- Archiving is made easier and the images can be electronically distributed to others for viewing,

Computed Radiography (CR):







Computed Radiography (CR):

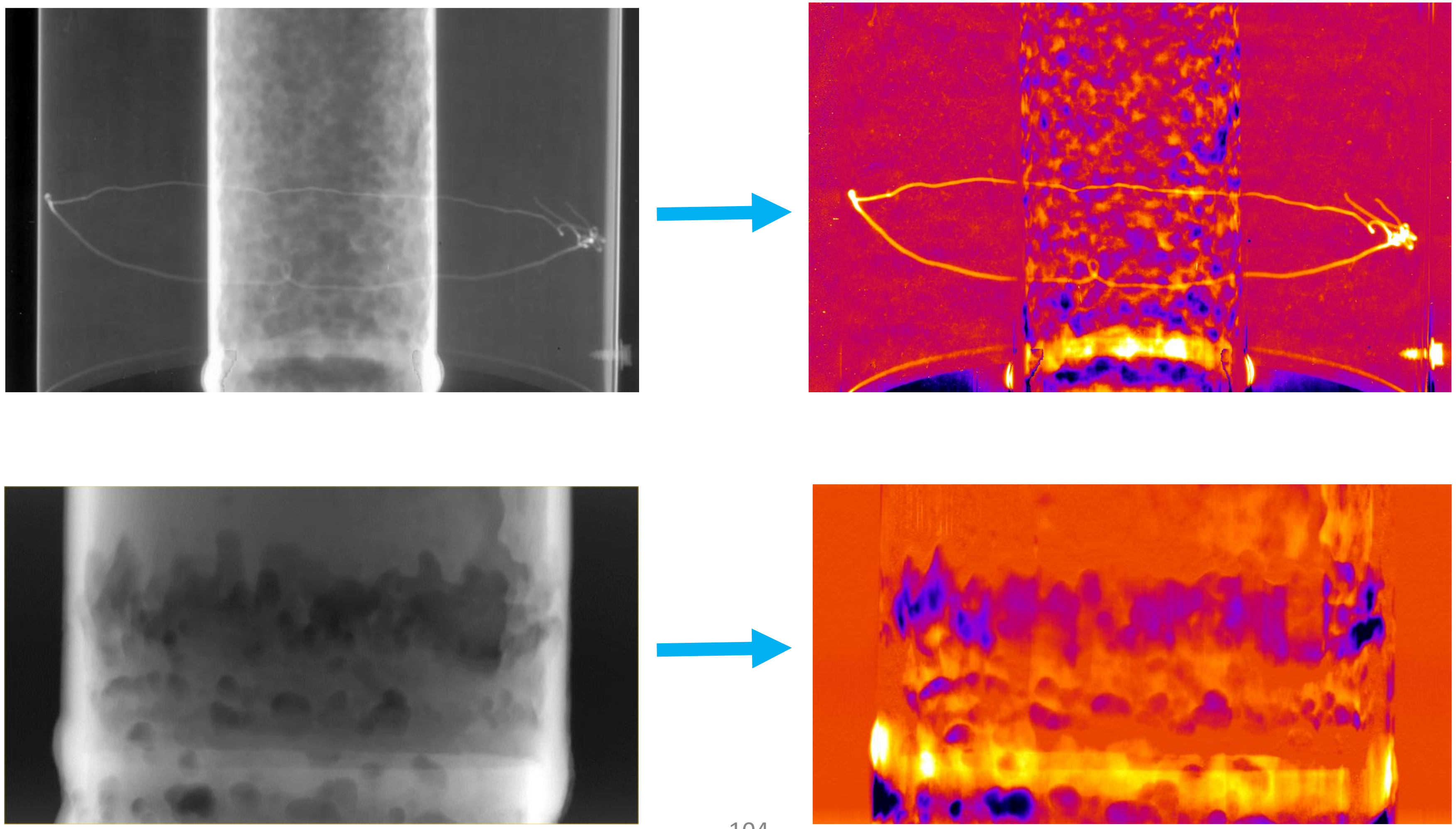
Advantages:

- No silver based film or chemicals are required to process film,
- Reduced film storage costs because images can be stored digitally,
- Requires fewer retakes due to underexposure or overexposure,
- Images can easily be stored and electronically distributed to others,
- Produces a sharper image than conventional film in less time 1-5min vs 10-20 min,

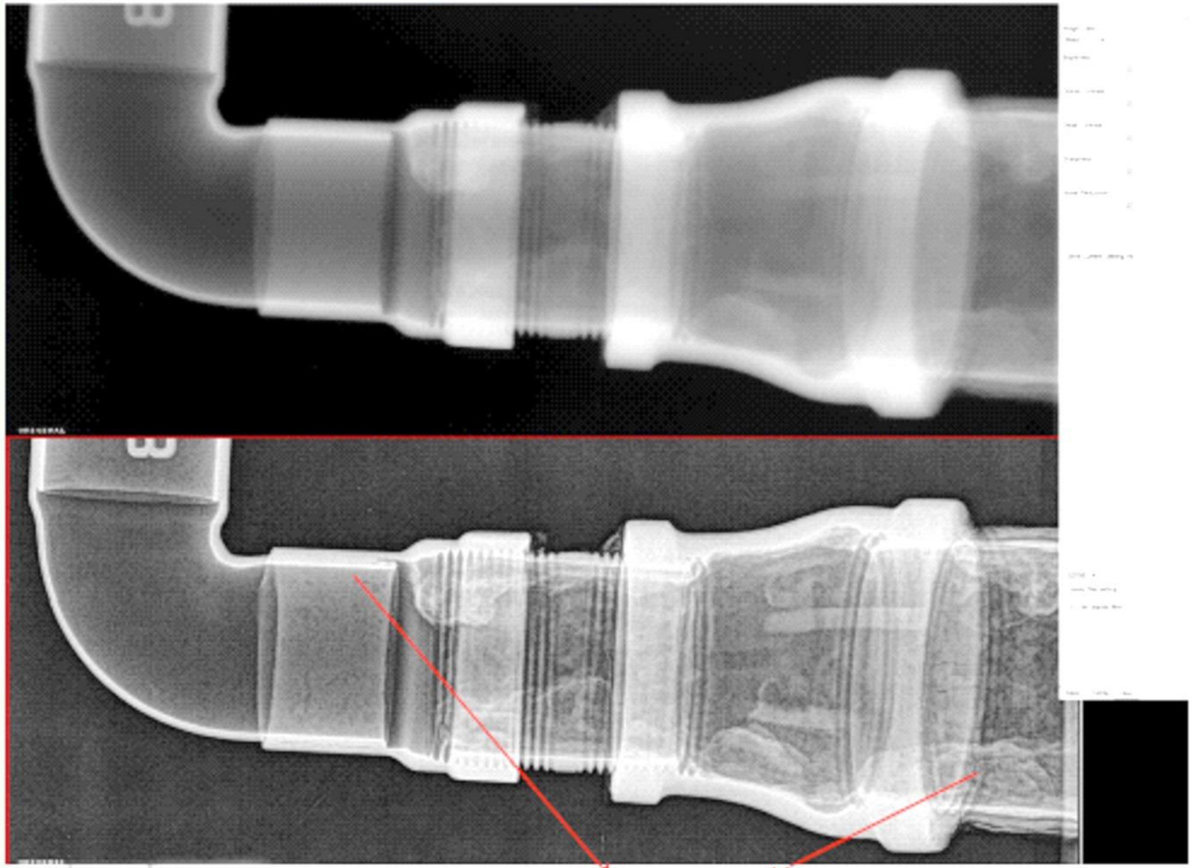
Disadvantages:

- Imaging plates can be damaged by rough handling,

Computed Radiography (CR):



Computed Radiography (CR):



Without AIP

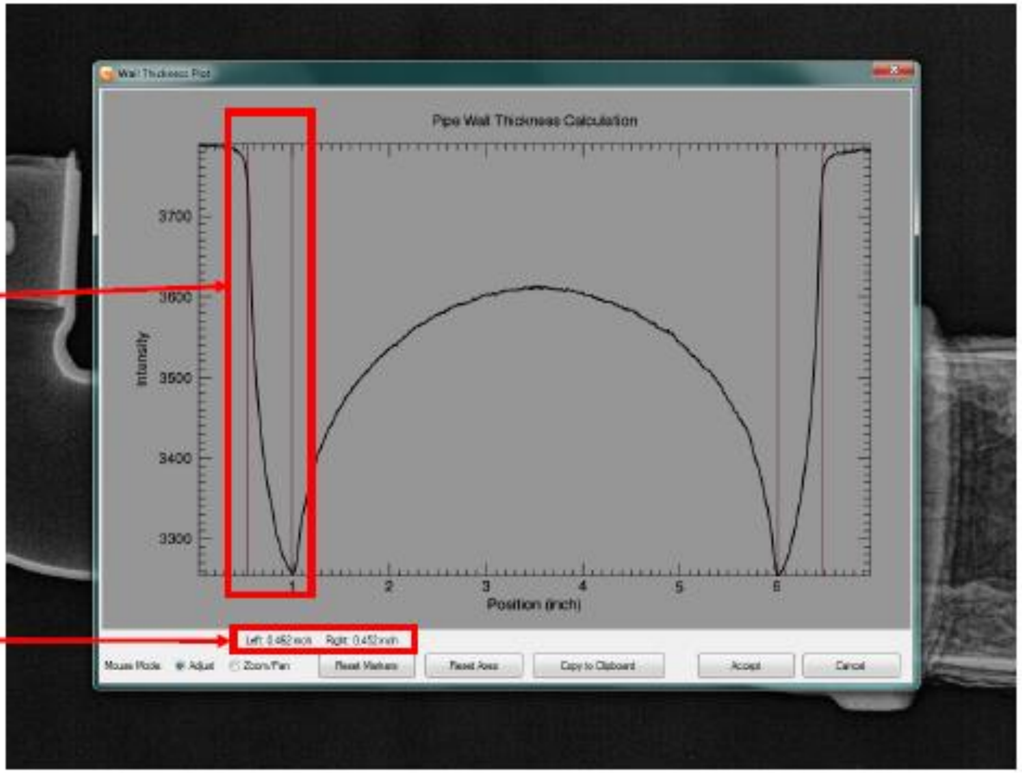
AIP Applied

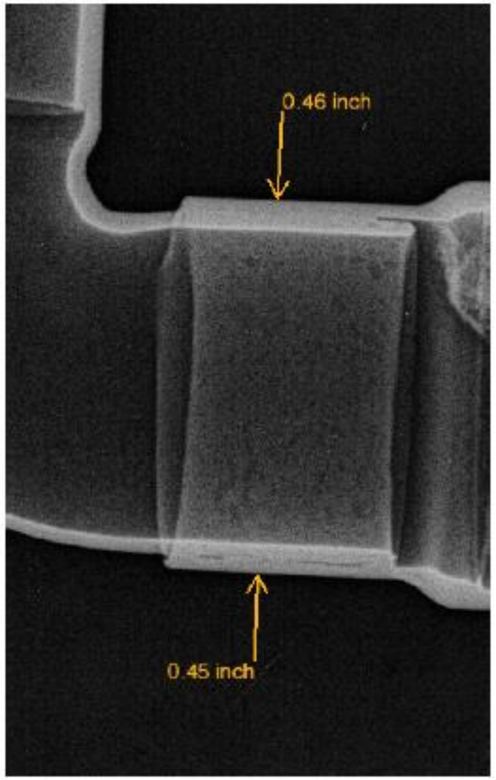
Looking for Corrosion

Computed Radiography (CR) Using the Wall Thickness Tool:

When the wall thickness calculation displays, the user will also now be able to adjust the positioning of the markers by dragging them to optimize the calculation.

Calculation results are displayed here





Computed Radiography (CR) Exposure time:

Diameter	Thickness	Source	Media	Insulation	Time (CR)	Time (film)
4"	8-11 mm	Co60/20Ci	Grey Water	100 mm	1,25 min	13 min
6"	11 mm	Co60/20Ci	Grey Water	100 mm	2,5 min	26 min
8"	11 mm	Co60/20Ci	Grey Water	100 mm	4 min	37 min
10"	18 mm	Co60/20Ci	Grey Water	100 mm	14 min	104 min
12"	22 mm	Co60/20Ci	Grey Water	100 mm	30 min	230 min
16"	9,5 mm	Co60/20Ci	Grey Water	100 mm	4 min	48 min
4"	9 mm	Ir192/24Ci	Water	none	2,5 min	15 min
4"	12 mm	Ir192/24Ci	Water	none	3,5 min	22 min
6"	12 mm	Ir192/24Ci	Water	none	4,2 min	25 min
8"	9 mm	Ir192/13.8Ci	Water	none	4,3 min	24 min
8"	8 mm	Ir192/16.8Ci	Diesel	80 mm	3 min	20 min
10"	8,5 mm	Ir192/13.8Ci	Water	none	6,6 min	not possible
12"	7 mm	Ir192/13.8Ci	Water	none	9,1 min	not possible
20"	20 mm	7.5 MeV	Water	none	2,5 min	not possible

PARTO AZMOON AZAR

Digital Radiography (DR)

Digital Radiography (DR):

Digital Radiography (DR):

A direct DR system is different from CR in that it digitizes the photon radiation that passes through an object directly into an image that can be displayed on a computer monitor,

There are three technologies used in direct digital imaging systems:

1. Amorphous Silicon Devices,
2. Charge Coupled Devices (CCD),
3. Complementary Metal Oxide Semiconductor Devices (CMOS),

Direct digital system images are available for viewing and analysis in seconds as compared to the minutes required in CR systems,

Digital Radiography (DR):

- The increased processing speed is a result of the unique construction of the pixels in a direct digital system,
- The pixels arrangement that also allows an image resolution that is superior to CR and most film applications,
- Produces Superior Quality to other RT forms in a shorter time can produce an image within seconds,
- Less radiation needed to produce image compared to Film RT,
- Requires a computer, monitor and cables for immediate viewing of image,

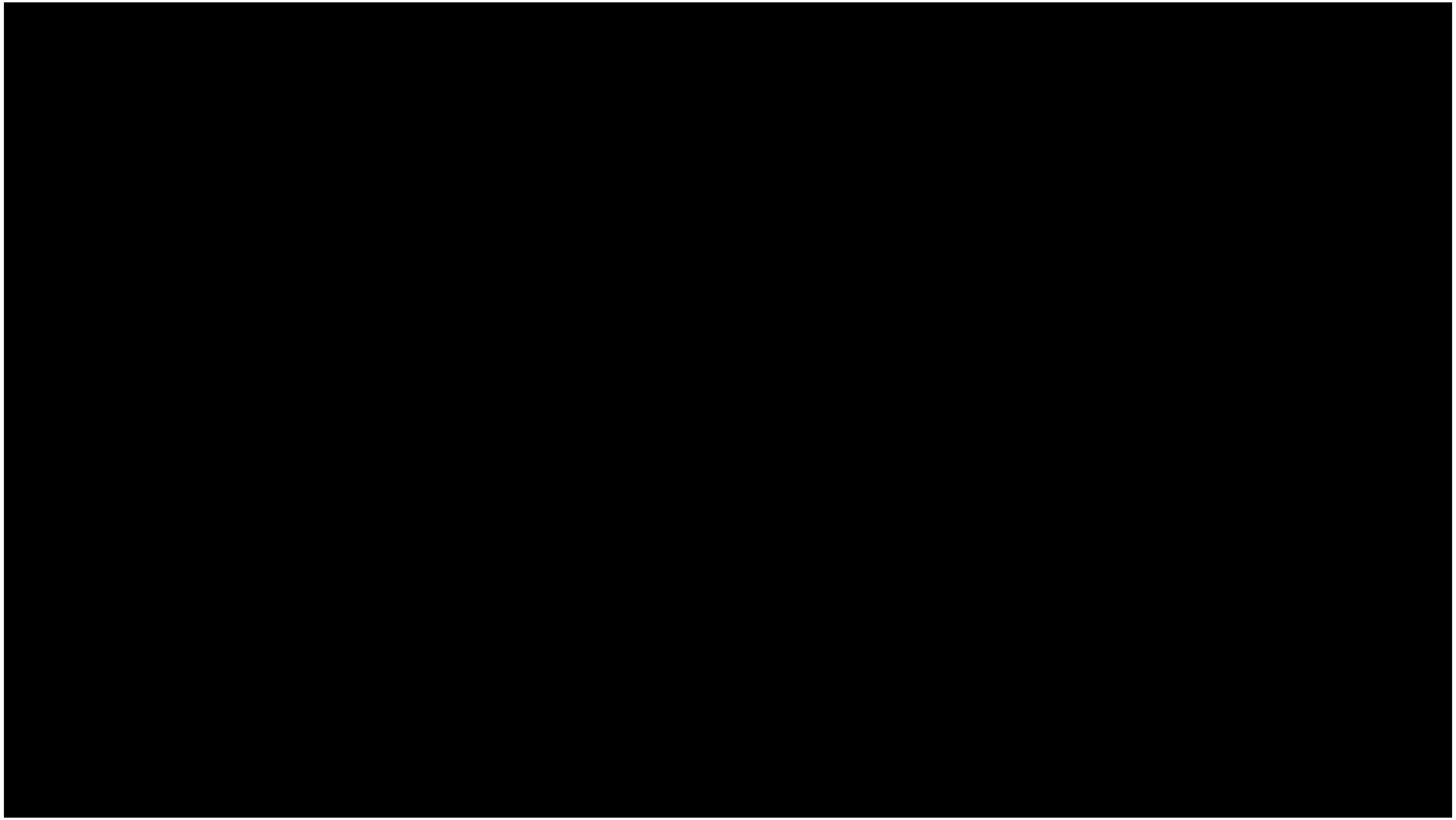
Digital Radiography (DR):

Advantages:

- Requires less radiation to produce an image compared to film radiography,
- The image may be stored, emailed, or processed on a computer,
- Automated Defect Recognition (ADR) systems can be used to analyze the image, replacing the subjective assessment of an inspector,

Disadvantages:

- DR panel detectors require care to avoid damage,
- Lifetime of DR panel detectors dependent on duty cycle / doses applied,
- As a result of manufacturing, every DR panel has some dead pixels,



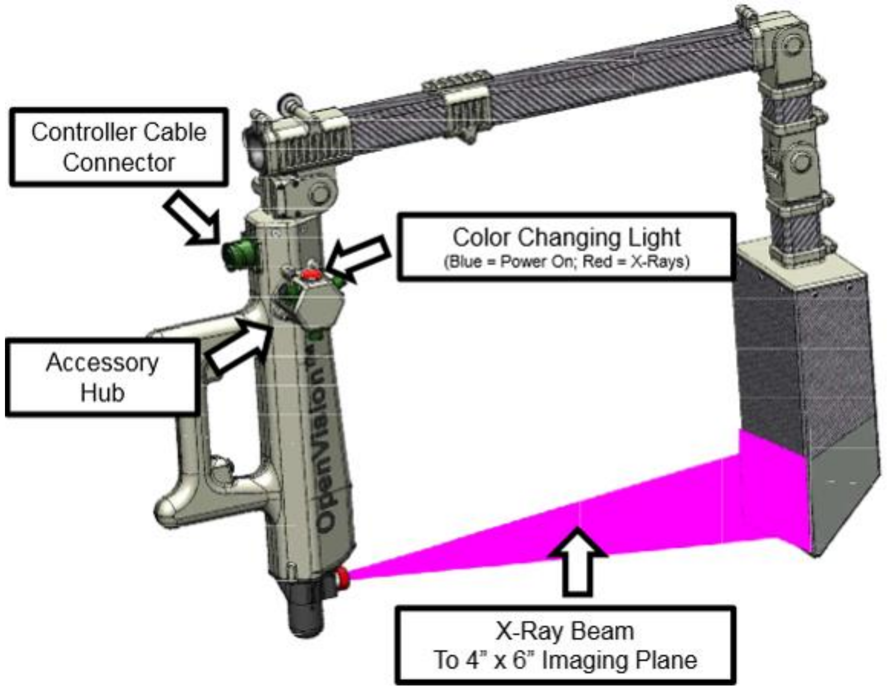
Real-Time Radiographic Examination Method (RTR)

Real-Time Radiographic Examination Method (RTR)

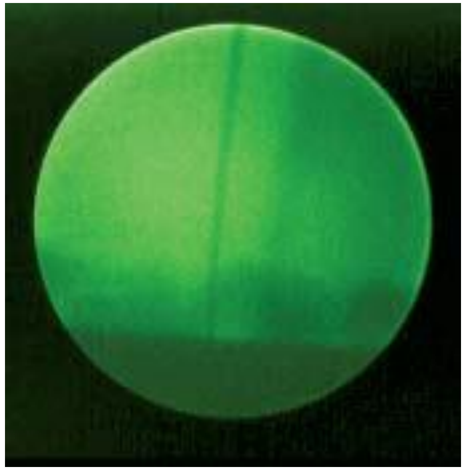
- Real-Time Radiographic Examination Method (RTR), commonly referred to as **fluoroscopy**,
- Provides a clear view of the pipe's OD through the insulation, producing a silhouette of the OD of the pipe on a monitor that is viewed during the inspection,
- No film is used or developed,
- The Real-Time device has a radiation source and image intensifier/detector that are connected to a C-arm,

Real-Time Radiographic Examination Method (RTR)

- There are two categories of real-time radiography devices:
  - One using an x-ray source as radiation source,
  - One using a radioactive isotope (i.e. Gd-153) as radiation source,
- Each has its own advantages and disadvantages; however, the x-ray systems deliver far better resolution than the isotope systems,

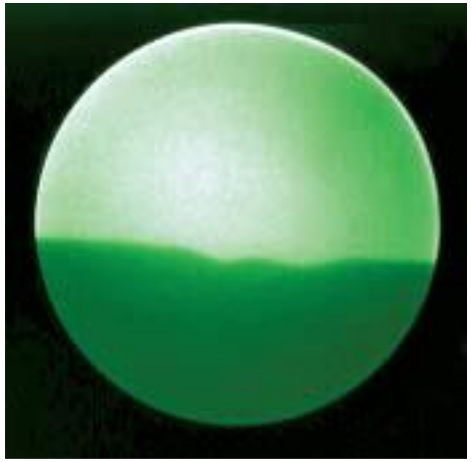


Real-Time Radiographic Examination Method (RTR)



Binding wire holding insulation in place

Weld Location



Corrosion Under Insulation

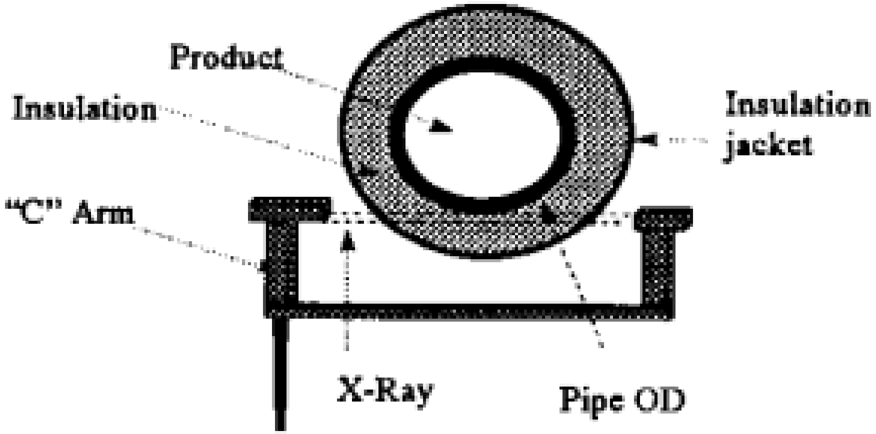
Real-Time Radiographic Examination Method (RTR):

- The x-ray digital fluoroscopy equipment operates using a low-level radiation source (≤75 KV),
- The equipment allows the kV and/or mA of the x-ray tube to be adjusted to obtain the clearest image and allows for safe operation without disruption in operating units or even confined spaces,
- As a result of the low-level radiation, the radiation does not penetrate the pipe wall,
- Instead, the radiation penetrates the insulation, and images the profile of the outer wall of the pipe,

PARTO AZMOON AZAR

Real-Time Radiographic Examination Method (RTR):

- In order for CUI to be detected on insulated pipe, it may be necessary to rotate the fluoroscopy device 360° around a pipe,



- In many instances, the image may indicate a rough surface of the OD of the pipe indicative of corrosion; however, other means should be employed to determine the extent or degree of corrosion present,

Real-Time Radiographic Examination Method (RTR):

- Since the radiation is generated electrically, the instrument is perfectly safe when the power is off,

- Equipment utilizing radioactive material requires additional precautions to ensure the source is shielded when not being used, These precautions extend to transportation and storage of radioactive material in accordance with state mandated regulations,

PARTO AZMOON AZAR

Real-Time Radiographic Examination Method (RTR):

- Most of the fluoroscopy systems come with a heads-up video display,
- A helmet-mounted, visor-type video display frees the system operator's hands to maneuver the C-arm while keeping the image before the operator at all times,
- The heads-up display also improves interpretation by shielding the screen from the sun.

Real-Time Radiographic Examination Method (RTR):

Advantages:

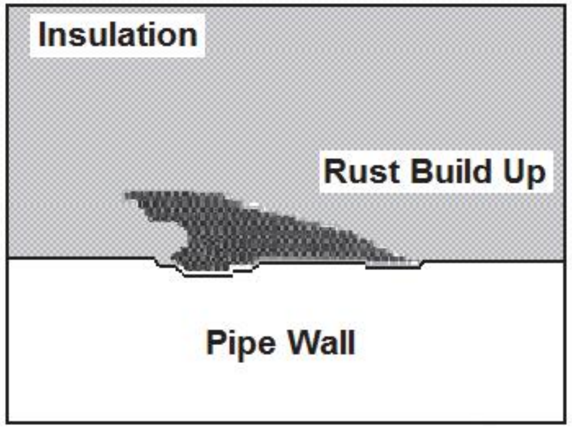
- Images are easily viewed because they are digital and can be electronically stored and retrieved using a computer,
- There is no maximum size limitation since multiple arrays can be assembled to view large areas,

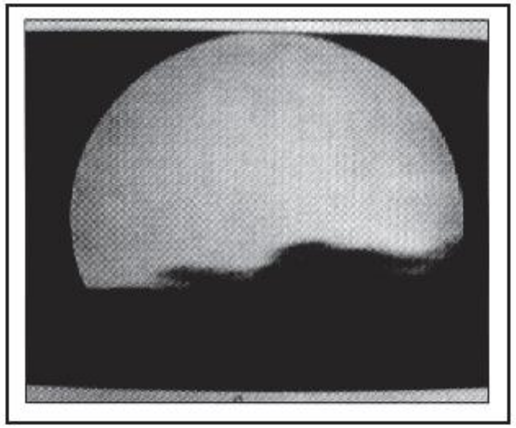
Disadvantages:

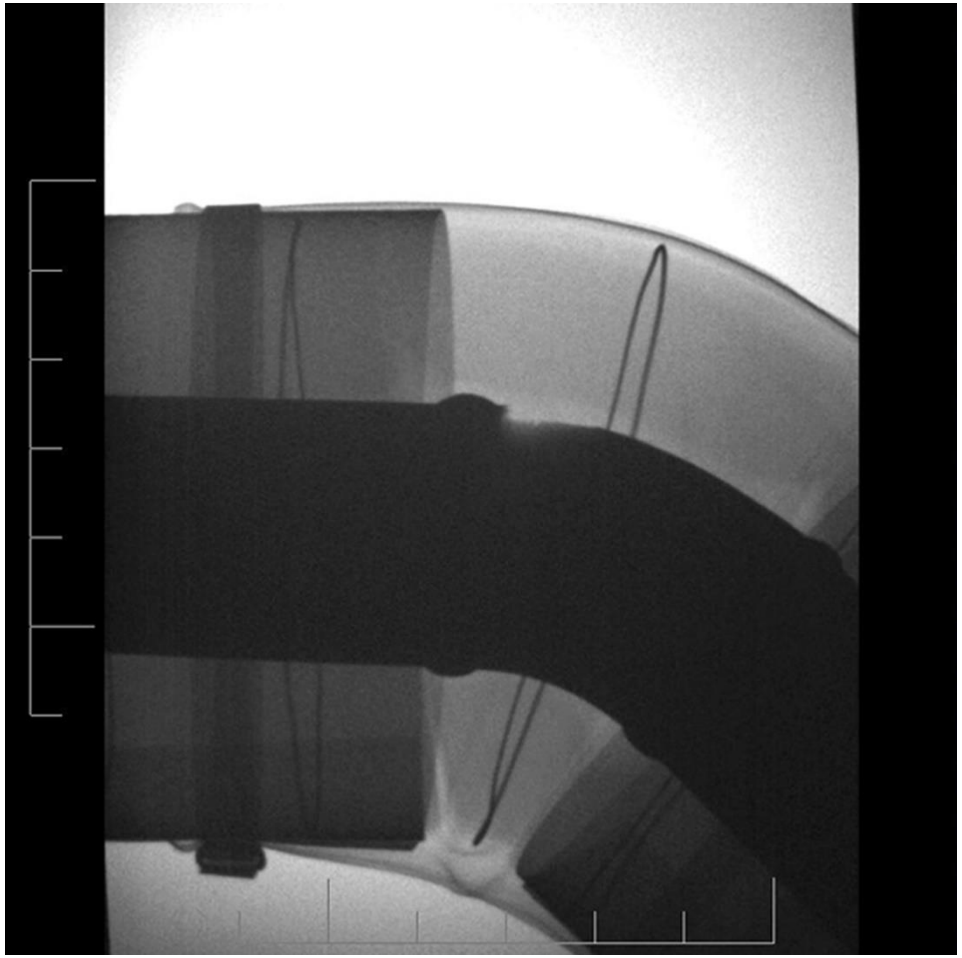
- Adequate clearance [i.e. **30cm**] required on piping in congested areas,
- Wet insulation hampers testing,
- Radioisotope system's image quality deteriorates as isotope decays,

Advancements in Portable Real Time Corrosion Under Insulation (CUI) Inspection Instrument

External Corrosion Inspection



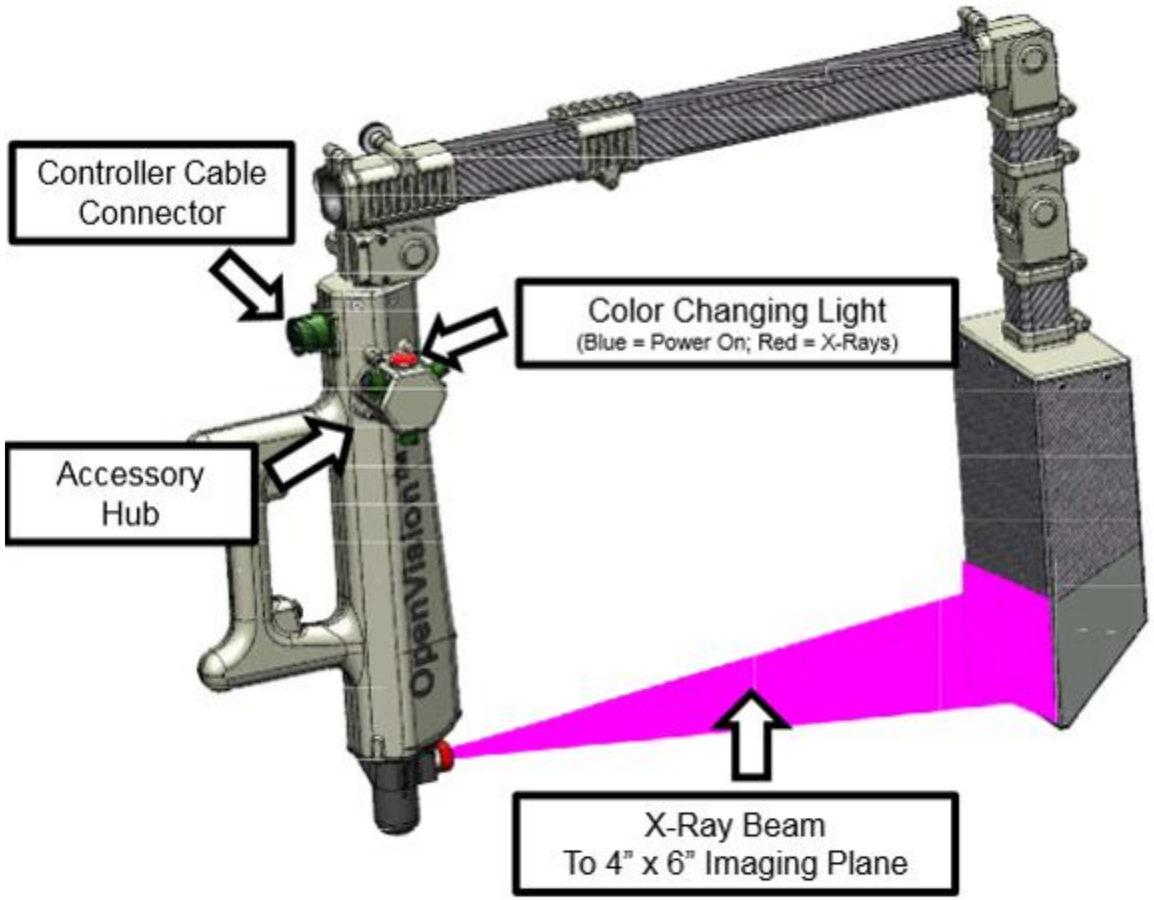




Dimensions (x-ray tube to imager):

Standard:
Adjustable to 19 in (48.26 cm)

Extended:
Adjustable to 25 in (63.5 cm)



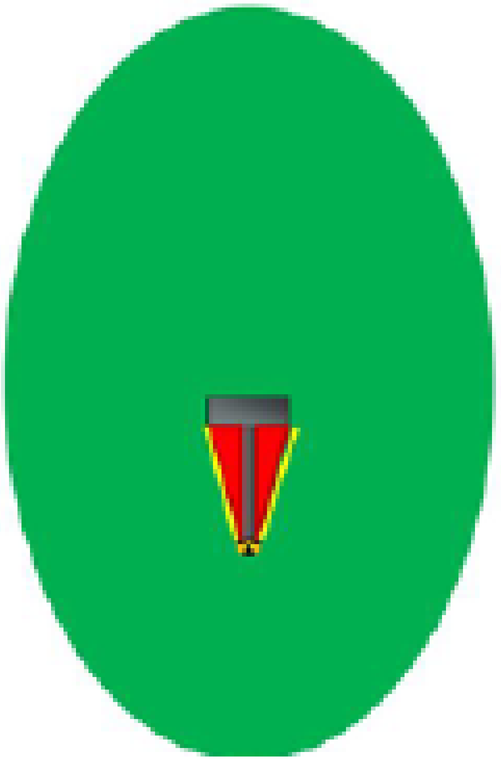
PARTO AZMOON AZAR

X-ray Energy and Intensity:

- High 70kV / 0.3mA
- Medium 70kV / 0.1mA
- Low 40kV / 0.1mA

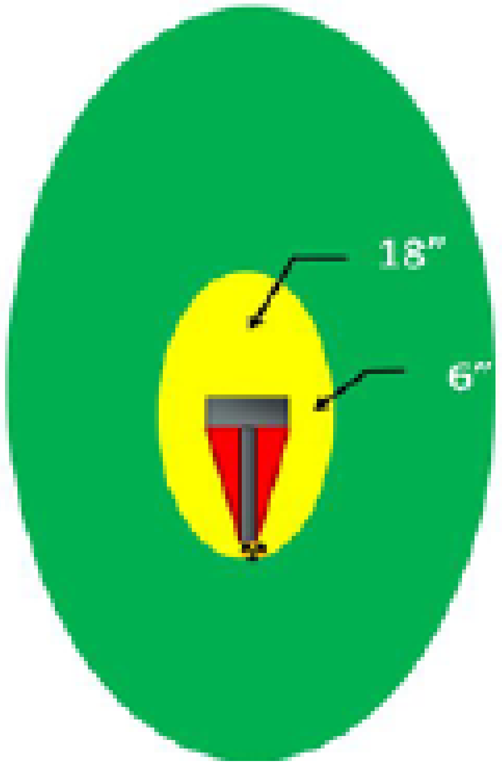
Live Imaging (Detector's Specification):

- Imaging Area: 4" x 6" (10cm x 15cm)
- Spatial Resolution: 250µm



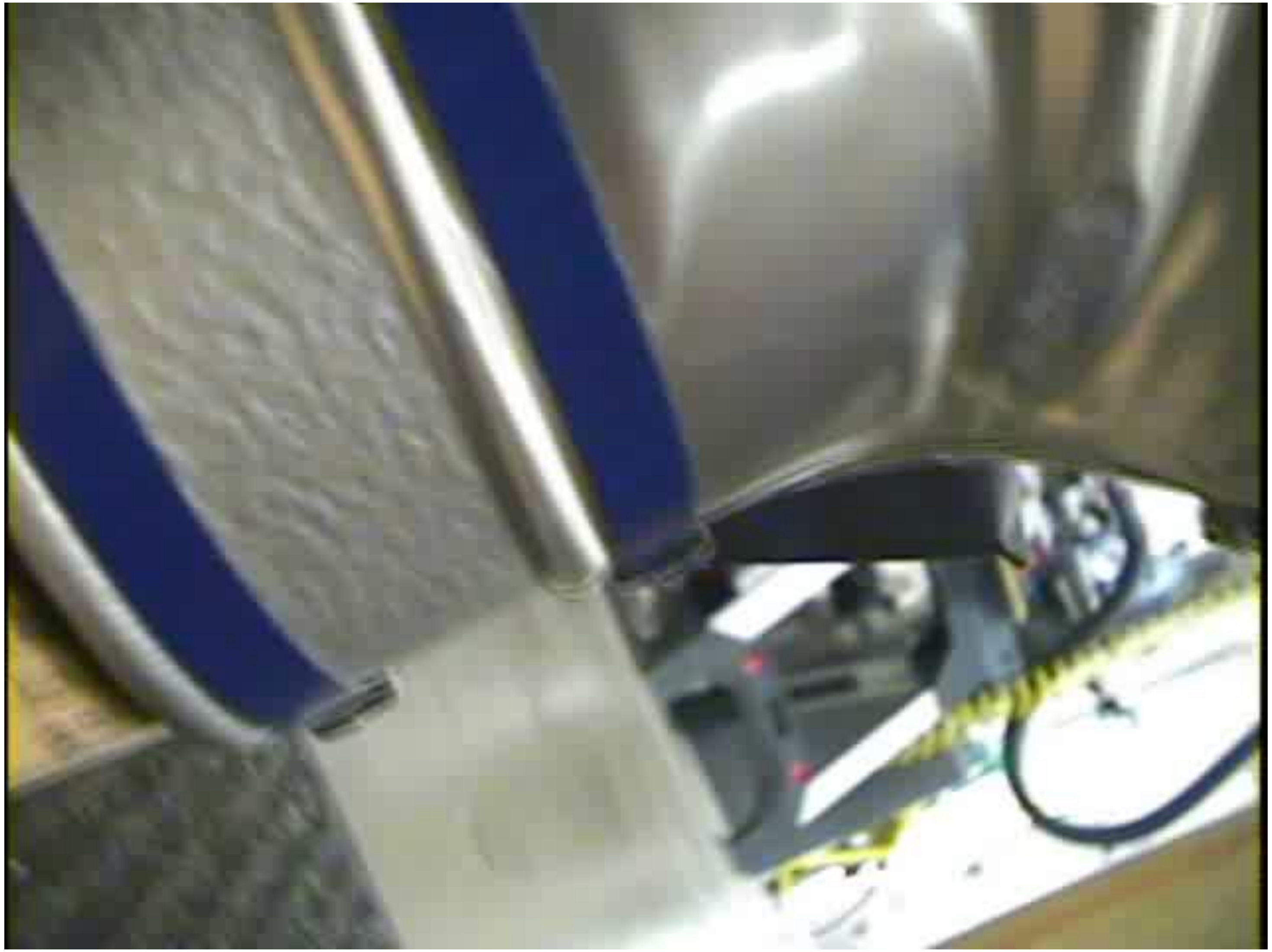
Low kV Low mA

- <0.02mSv/hr exposure
- 0.02mSv exposure in 15 mins
- 0.02mSv exposure in <1 sec



High kV High mA

- <0.02mSv/hr exposure
- 0.02mSv exposure in 15 mins
- 0.02mSv exposure in <1 sec



PARTO AZMOON AZAR

Specification:

- Compact Size,
- Light weight,
- Adaptable,
- Ergonomic (comfort design and user-friendly system),
- Fast Real-Time Inspection,
- Good Resolution,
- Adjustable Power Ranges (kV and mA),
- Low Dose to Operator,
- Battery Operated,
- Durable,

Single Battery Operation:

- 28 volts lithium-ion (max power density),
- State of Charge Indicator,
- 40 minutes continuous x-ray on,
- 4 hours typical use,
- One hour recharge,
- Readily available,

PARTO AZMOON AZAR

Display:

1 - 6.5” (16.51 cm) Hand Held LCD viewer,
2 - Ruggedized Head Mounted Display (HMD),

Recording:

- Digital Video Recorder/Display with 4GB SD card,
- 3.5" Visual image, x-ray image TFT LCD Display (**Thin-Film-Transistor Liquid-Crystal Display**)
- 4 hours on removable 4GB SD card,
- Wireless System,
- wmv Format,

Light-weight & Ergonomic:

C-arm with x-ray tube & imager: 5.7kg
Controller including large battery and shoulder strap: 1.5kg

Durable:
Over 10,000 weld packs inspected
on Alaska’s North Slope with one system,

Operating Temperature:
-29ºC to +49ºC

PARTO AZMOON AZAR

Packaging:

All components housed in a wheeled field case:

- Shipping weight: 24 kg
- Case size: 82cm x 52cm x 32cm

Conclusion:

RTR-CUI as a real-time video x-ray system is available for NDT applications, especially useful for Corrosion Under Insulation surveys (CUI) and weld location,

PARTO AZMOON AZAR

Radiometric Profiling Technique
(Pipe Profiler)

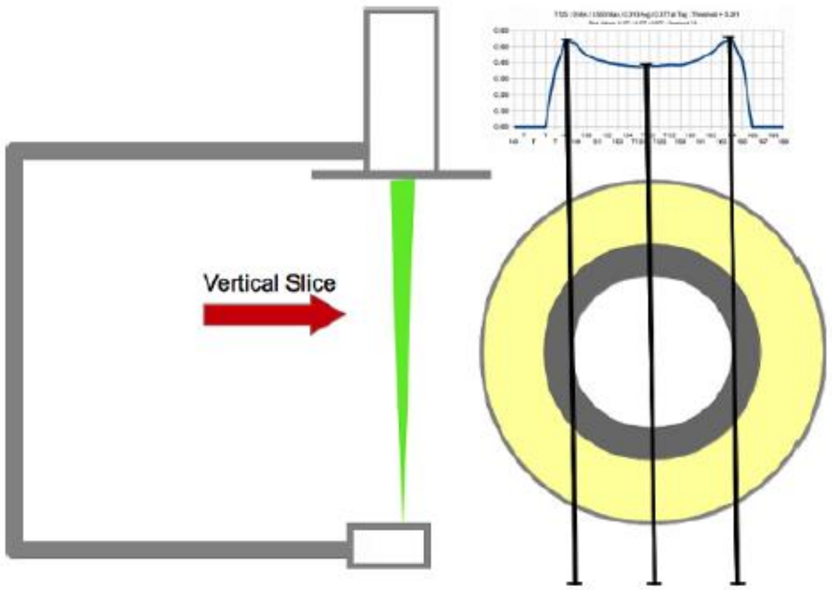
Radiometric Profiling Technique:

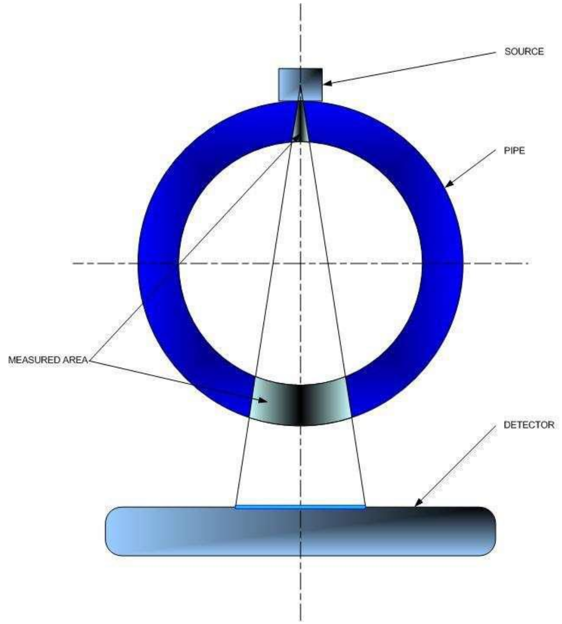
- These handheld radiographic systems use a gadolinium 153 radioactive source in combination with a solid state scintillator that converts γ-rays into photons,
- The activity of the source and the length of the C-arm used determine the maximum density that the equipment can penetrate when looking for CUI,
- This equipment can allow estimation of the pipe wall thickness when shot through the center of the pipe,
- In general, this equipment is capable of inspecting insulated standard wall thickness pipe with an overall OD of up to 18”,

Radiometric Profiling Technique:

The limitations with regard to pipe and insulation diameter depends on:

- The product inside the pipe,
- The density of the pipe material (thickness),
- The type of insulation,
- The type of insulation jacketing being penetrated,





Radiometric Profiling:

Advantages:

- Suitable for piping from ½" to 18" NPS,
- No radiation barricade is required to utilize device,
- Portable and may be operated by a single technician,

Disadvantages:

- Measures the remaining combined double-wall thickness, not the pipe wall thickness of the corroded area,
- Cannot differentiate between ID and OD corrosion,
- Requires a radioactive materials license,

Radiometric Profiling Technique:

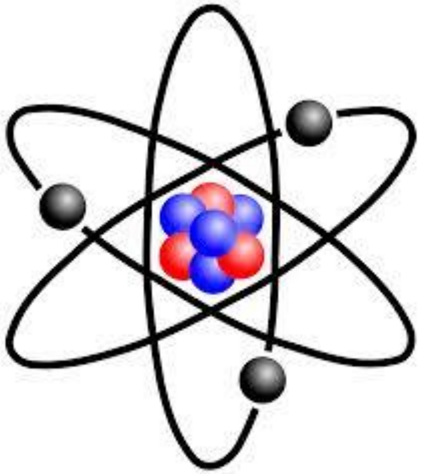
Radiometric Profiling Technique:

The **Pipe Profiler** is comprised of:

- A very low activity gamma radiation source (Gd-153),
- A solid state scintillator photon detector,
- Three arms 6”, 13” and 18”,
- A computer to translate the density of the piping system under test to a relative numerical thickness value,

Physical Characteristics of Gd-153:

Half Life:	241.6 days
Type Decay:	e- capture
Gamma Rays:	0.041 MeV (35.8 %)
	0.042 MeV (64.7 %)
	0.047 MeV (25.3 %)
	0.070 MeV (2.57 %)
	0.084 MeV (0.22 %)
	0.097 MeV (31.3 %)
	0.103 MeV (22.2 %)
• Beta Rays:	0.103 MeV Maximum



Radiometric Profiling Technique:

- The Pipe Profiler is a measurement tool that has been developed to help identify the most deteriorated areas of piping systems in a rapid and economical manner in order to ensure the integrity of a great majority of industrial piping,

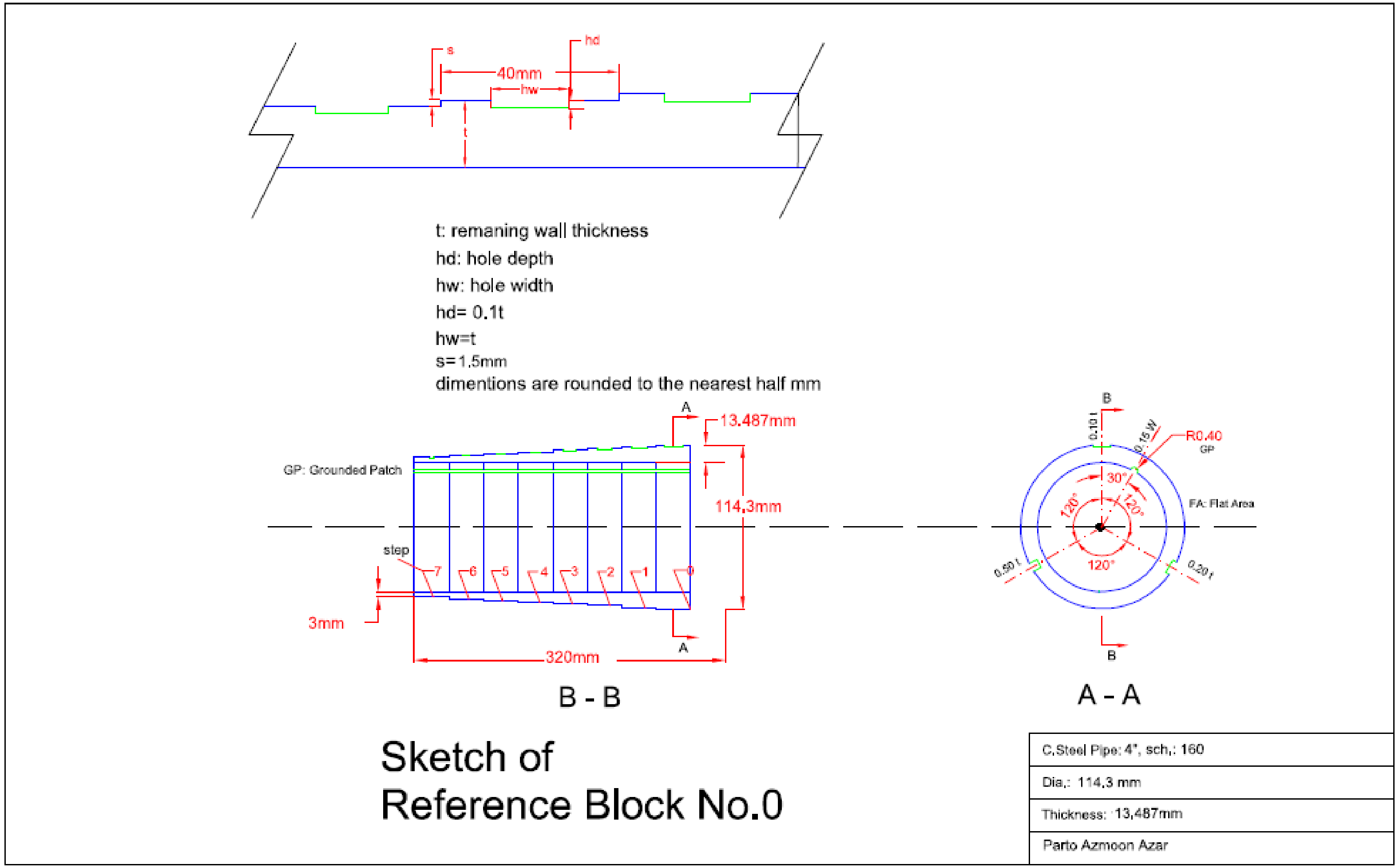
- The Pile Profiler is designed to be a portable, rapid scanning tool for piping systems in order to detect many of defects,

- The Pipe Profiler will report the results in the form of a line graph of thickness,

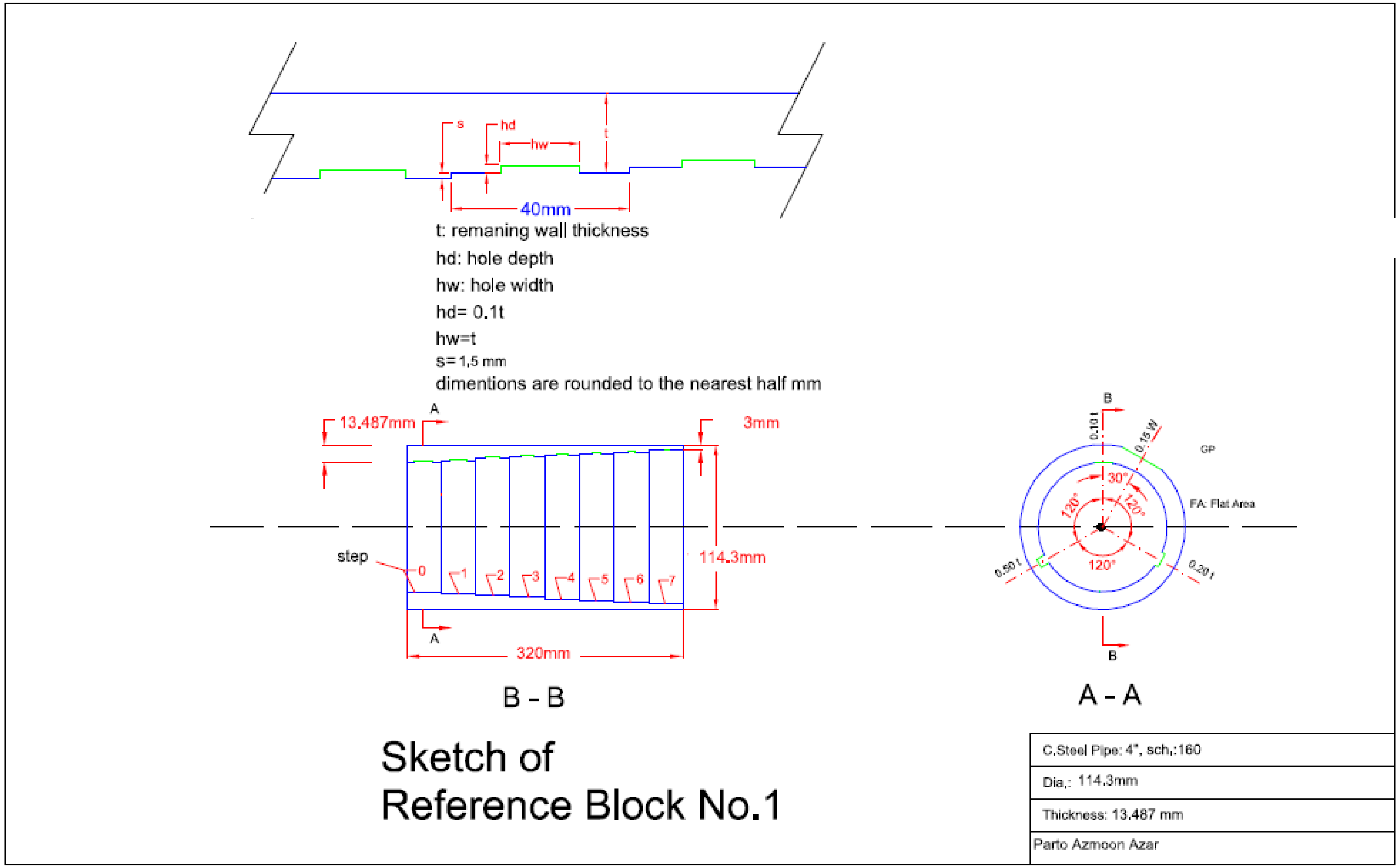
Radiometric Profiling Technique:

The system is easily calibrated utilizing three known thickness values.

Radiometric Profiling Technique:



Radiometric Profiling Technique:



PARTO AZMOON AZAR

PARTO AZMOON AZAR

Radiometric Profiling Technique:

Subsequent scanning of piping will reveal the presence of density variations caused by:

- Internal Corrosion,
- External Corrosion,
- Erosion,
- Welds location,
- Wet insulation,
- Product buildup on the walls of the pipe,
- Any other cause for density changes,

Radiometric Profiling Technique:

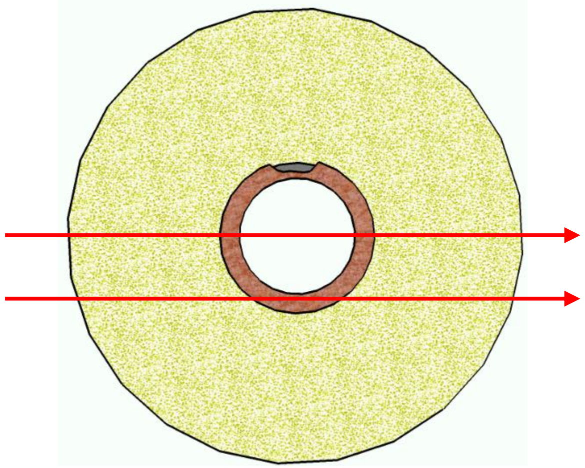
- The portability of the Pipe Profiler is because of the use of Gd-153 limited to a maximum value of 1Ci,

- The Pipe Profiler also limited to penetrating a maximum of 2” of steel with a new source, and an average of 1.5”of steel or steel equivalent for the remaining useful life of the source,

- Fortunately, most of the piping systems utilized in industrial and process environments fall well within the range of operability for the Pipe Profiler to be utilized in an effective and economical fashion for the inspection of these piping systems,

Radiometric Profiling Technique:

If the beam of the radiation is not centered along the diameter of the pipe, the thickness values will increase due to chord length effects,



This fact may seem obvious at first, but when inspecting insulated pipe, the insulation jacket is not always oriented concentrically to the pipe underneath and the radiation beam will not be passing through the pipe coincidentally with the true diameter of the pipe. This may result in higher than actual thickness values,

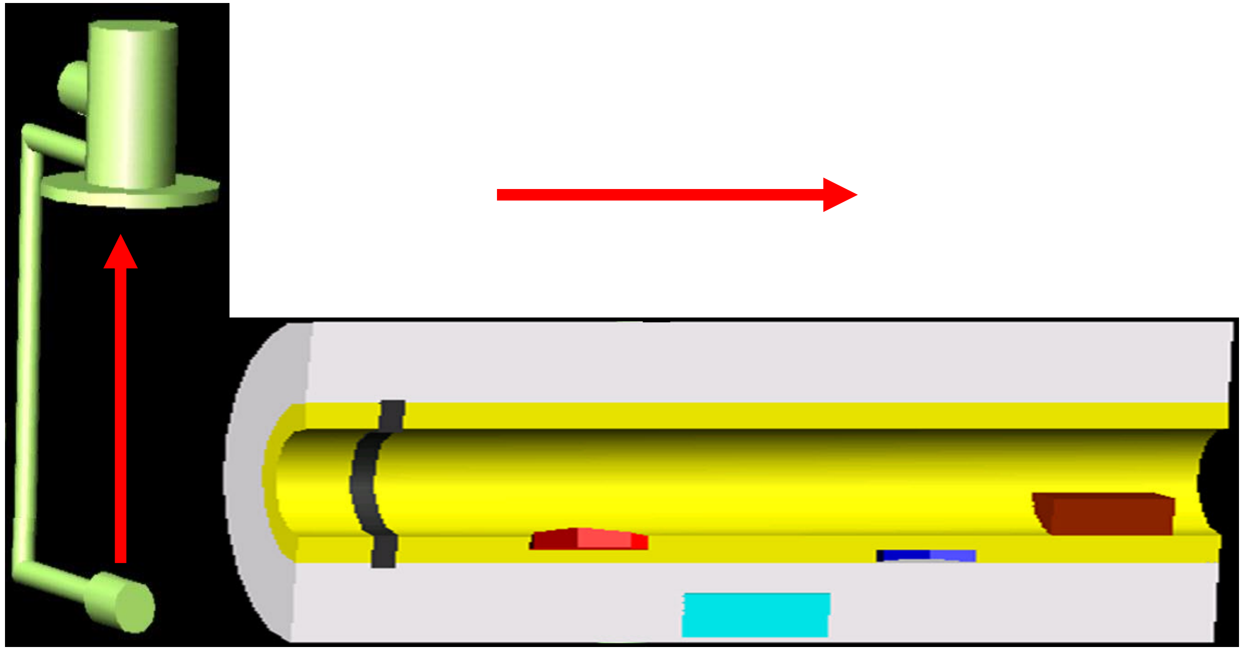
Radiometric Profiling Test Procedure:

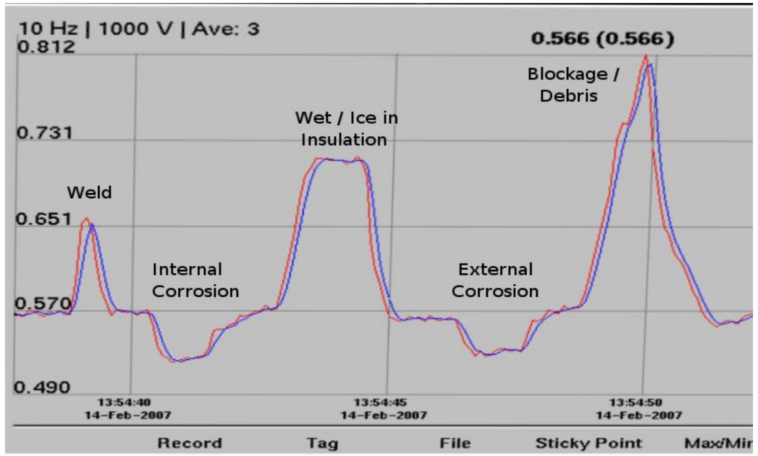
The Pipe Profiler is operated in 2 distinct ways:

1. To “axial scan” along the length of the pipe,
2. To “slice scan” through the pipe at 90 degrees,

Radiometric Profiling Test Procedure:

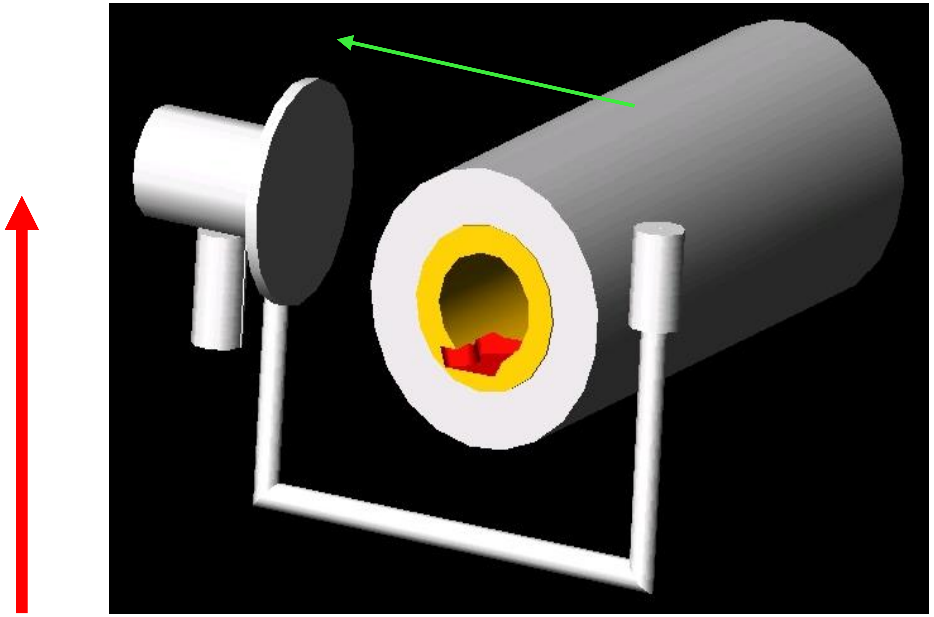
Axial scans are carried out at various orientations (primarily at 6 / 12 O'clock), depending on the pipe process, corrosion expectations and inspection requirements,

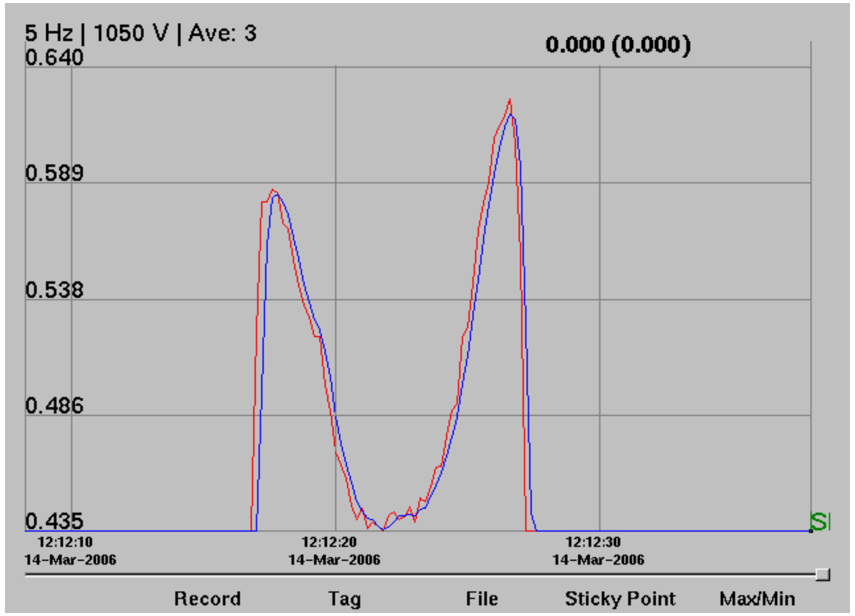




Radiometric Profiling Test Procedure:

Slices scans can also be taken at different angles to help clarify areas of concern,





Applications of Radiometric Profiling Technique :

- Wall thickness measurement on insulated or bare pipes with or without product,
- Wall thickness measurement on very hot pipes while in service,
- Pipe wall thinning,
- Detection of internal & external corrosion,
- Detecting of Pipe blockages,
- Detecting water and ice in insulation,
- Detecting of cluster of internal and external pitting,
- Weld identification on insulated piping systems,
- Assessing product levels,
- Can be used to ensure that valves are open and lines are clear,

Benefits of the Radiometric Profiling Technique:

PARTO AZMOON AZAR

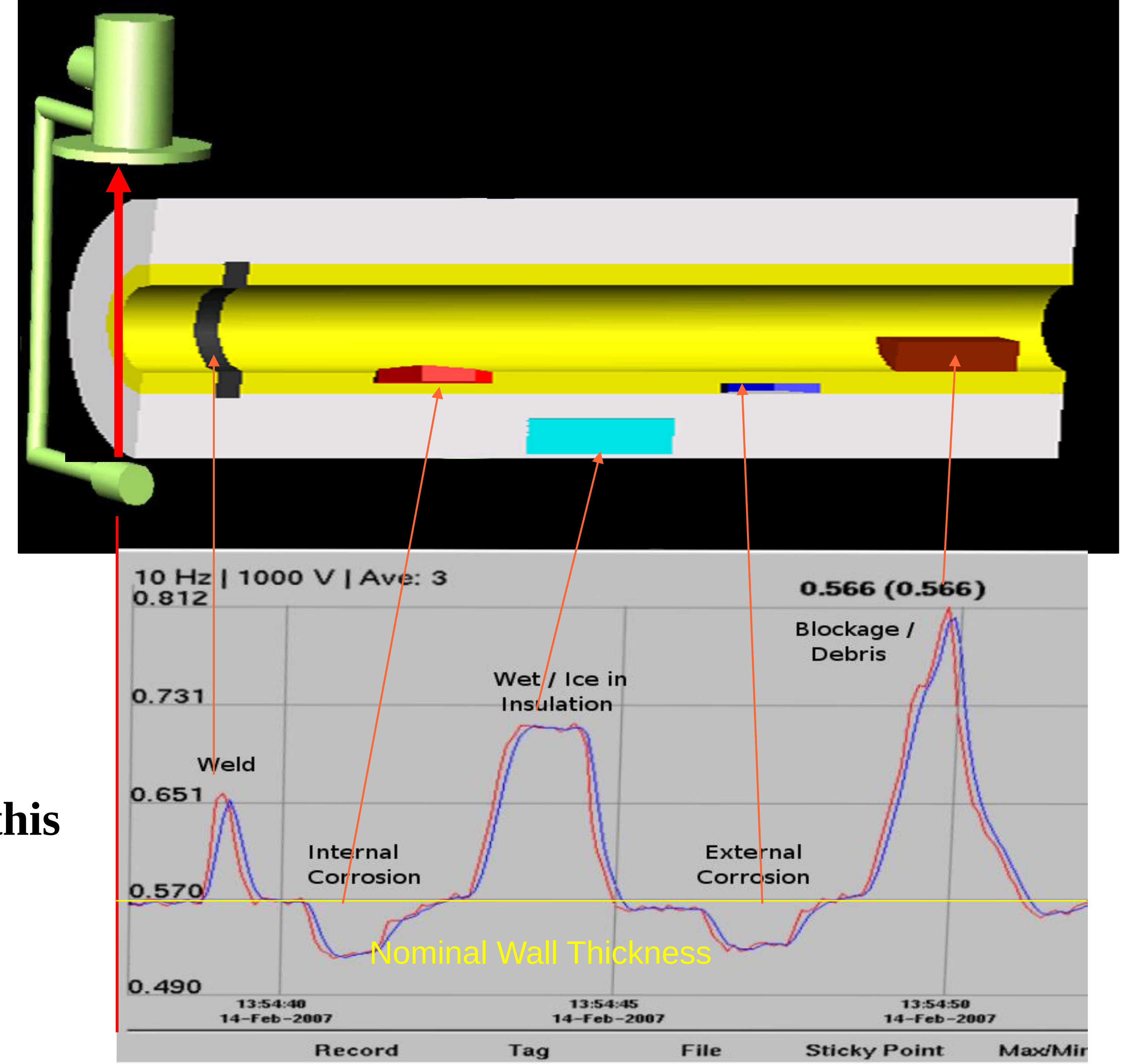
- Fast: No surface preparation,
- Safe: Low dose radiation (1Ci of Gd-153) therefore, No need to rope off an area while testing,
- Instant: Real-Time results (on site reporting),
- Contactless: No contact is needed with piping therefore can be used on high temperature pipes,
- The entire pipeline can be scanned rather than a spot measurement,
- Complete (100% coverage) inspection,
- Can be used on metallic and non-metallic piping,
- Compared to other NDT techniques, is very rapid and allows for much more pipe to be inspected in a given day,
- Quick Analysis,
- Lightweight & battery operated allows Hand-Held, easy to move,
- Easy to use and easy operation device,
- Lower inspection cost,
- Reduce Downtime,

Limitation of the Radiometric Profiling Technique:

- Maximum diameter piping of 18” (external),
- Maximum pipe wall thickness of 25mm (1”),
- Access is needed on both sides of the pipe for the C-arm,
- Not recommended for detection of pinholes / cracks,
- Extensive training and experience necessary for operation and data interpretation,
- Accurate information required from client to allow adequate calculations,

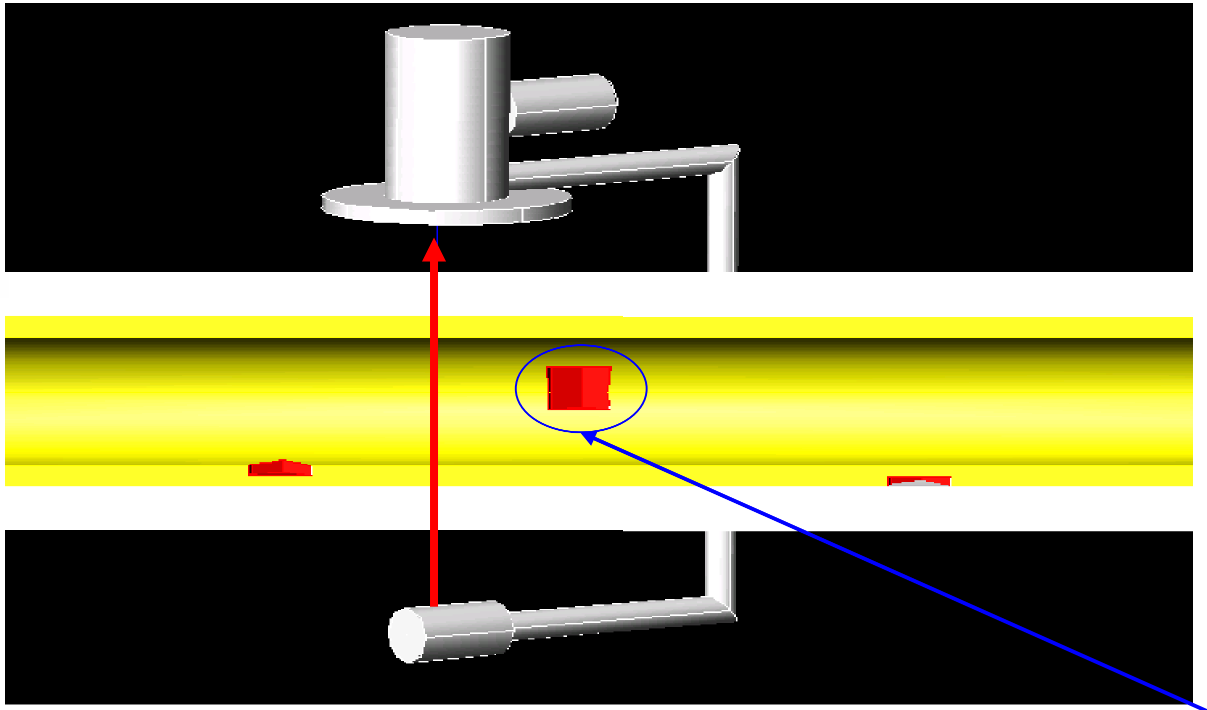
Pipe Size	Up to 18” including Insulation
Wall Thickness	Up to 25mm
Couplant	None
Surface Preparation	None
Material	All
Temperature Range of Pipe	All
Sensitivity	Greater than 1mm
C-arm Size,	6”, 13” and 18”
Isotope	Gadolinium 153 (1Ci)
Inspection Time	20m to 150m a day

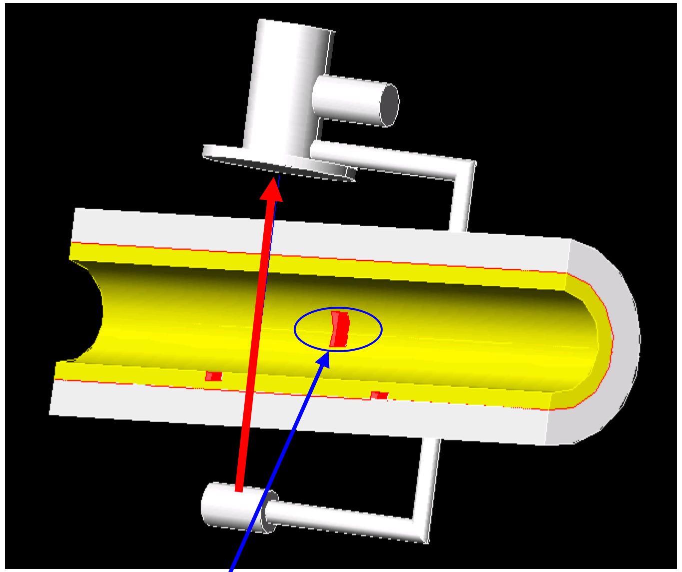
Pipe Profiler

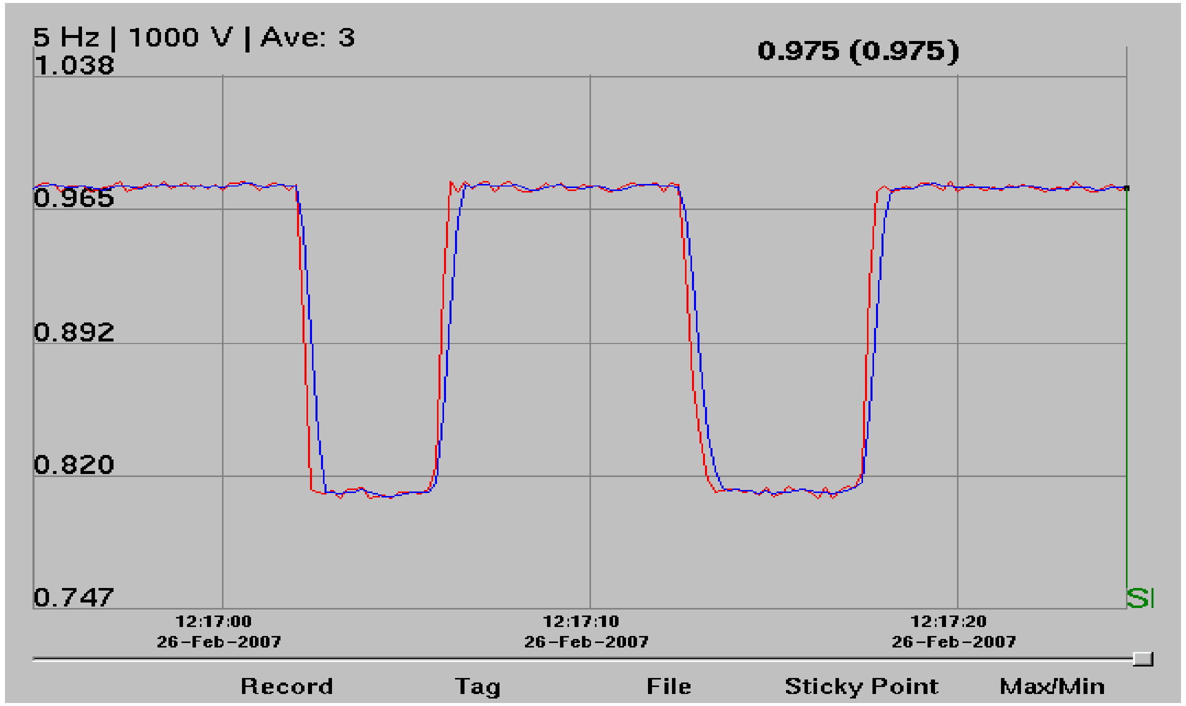


This is what an **Axial Scan** would look like of this section of pipe.

PARTO AZMOON AZAR





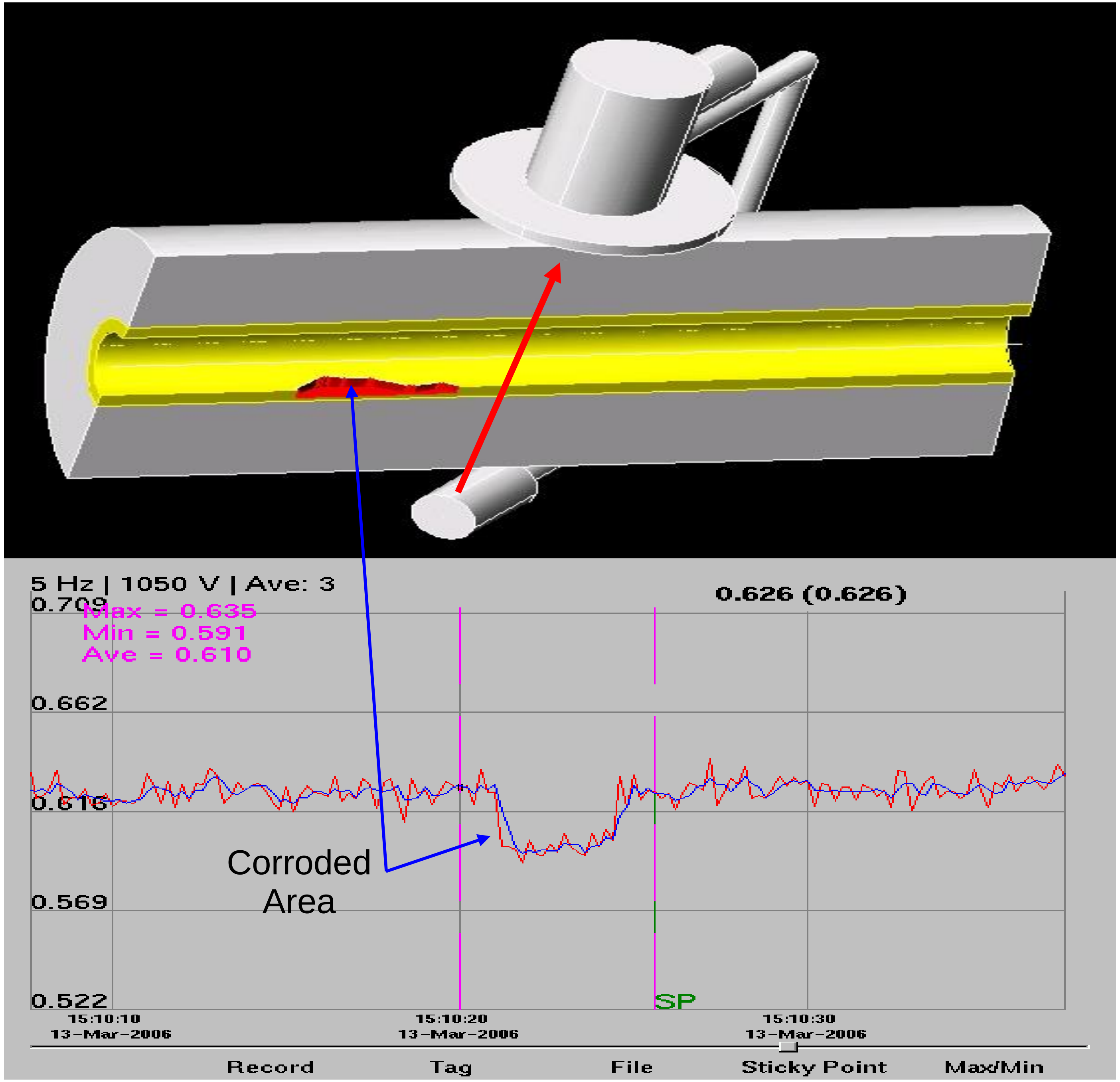


These are the same indications located on the side of the pipe. Only the indications on the bottom (or top) of the pipe would be detected with a vertical radiation beam.

The Profiler will only detect anomalies that are in-line with the radiation beam

Axial Scan
of insulated
piping with
internal corrosion

Real-time Profiler results of axial scan



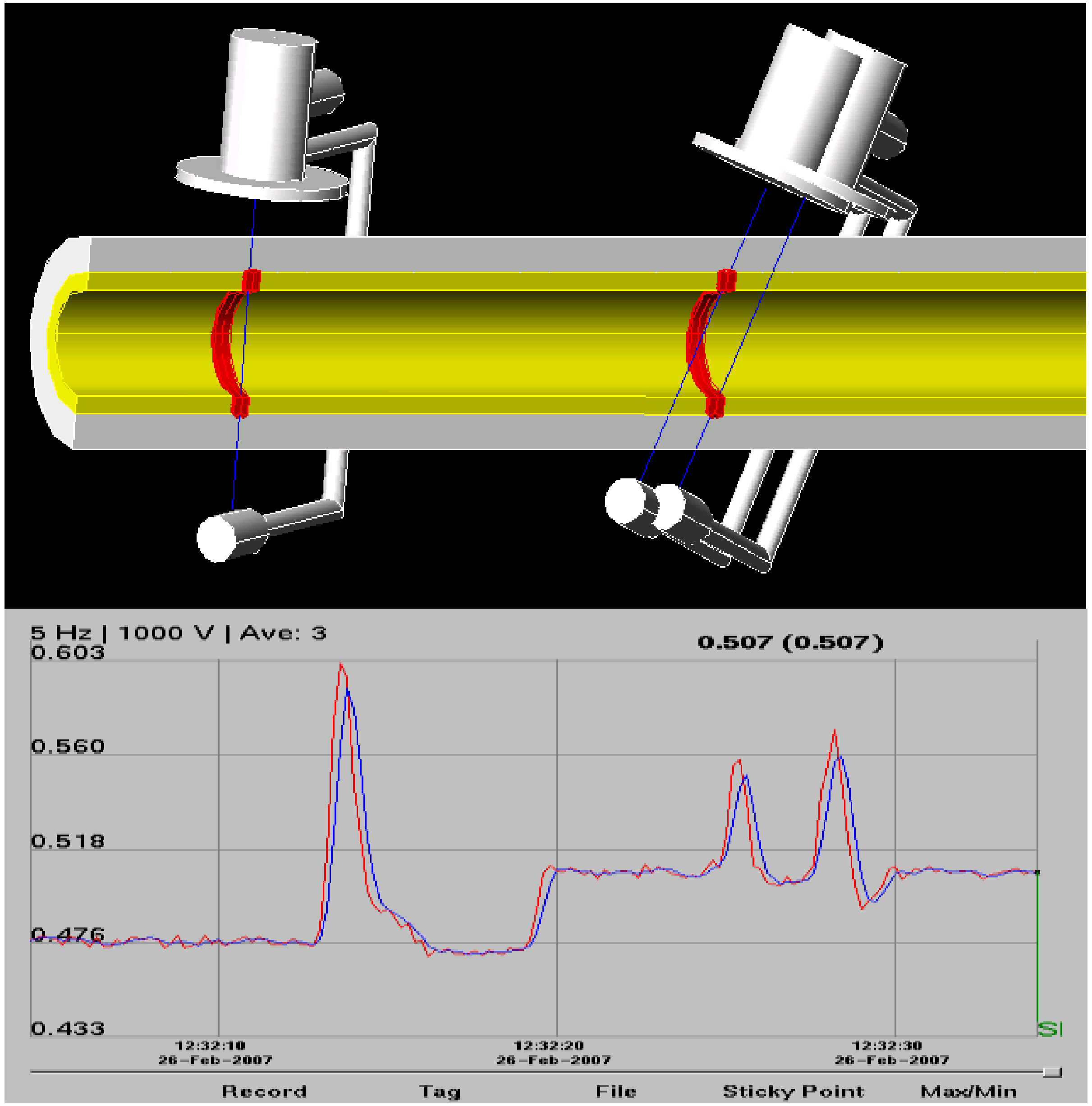
Left:

Profiler oriented perpendicularly over weld. Response is single, high-amplitude peak.

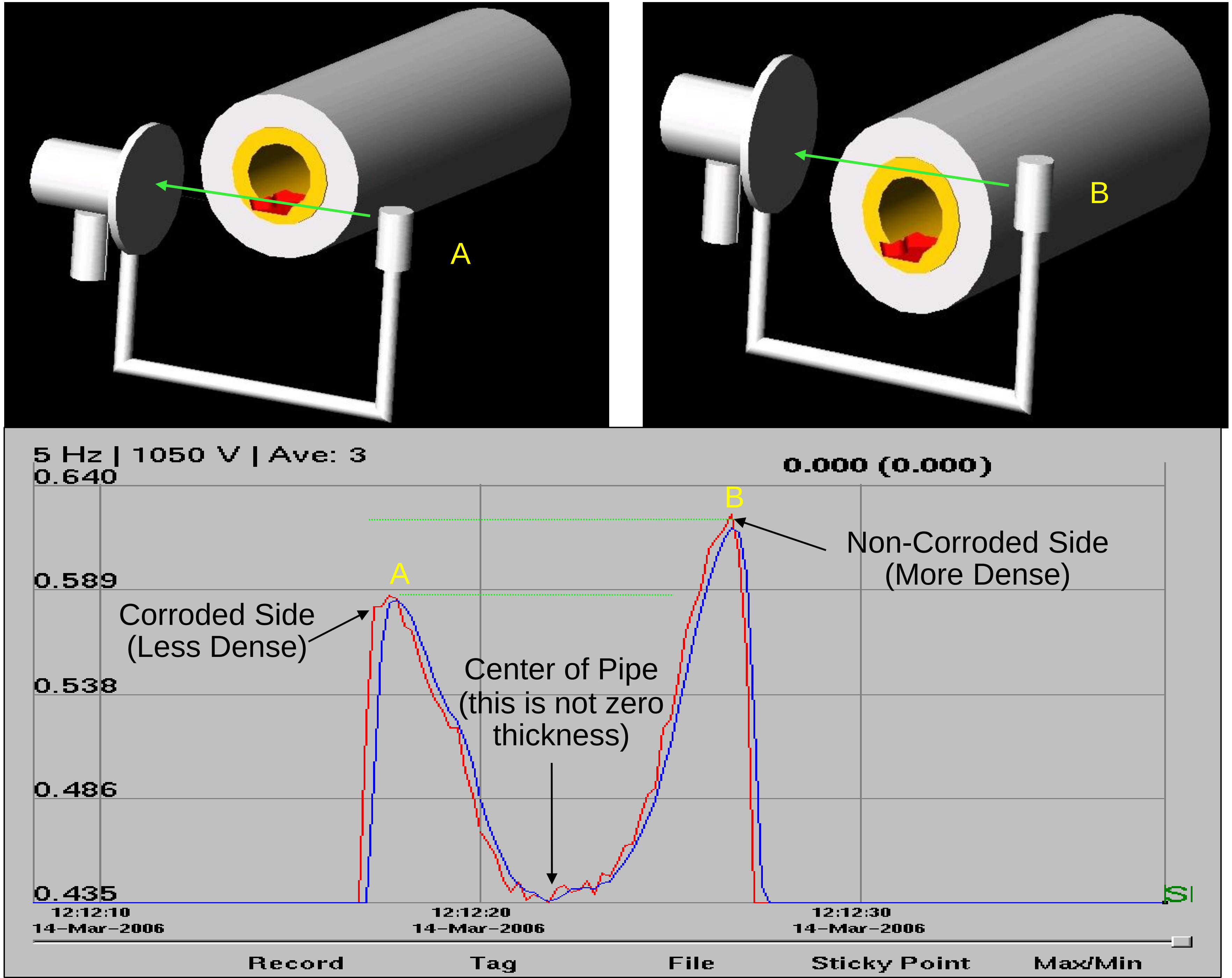
Right:

Profiler oriented at an angle while scanning over weld. Result-baseline thickness increases and two lower amplitude peaks result:

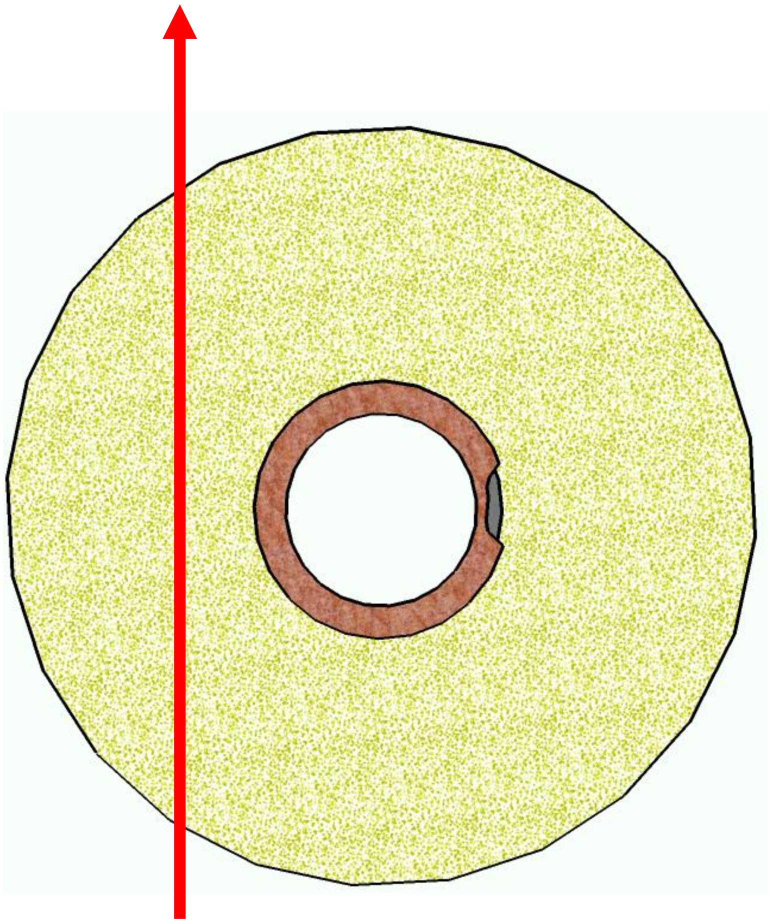
one when the detector crosses the top of the weld and one when the source crosses the bottom of the weld.

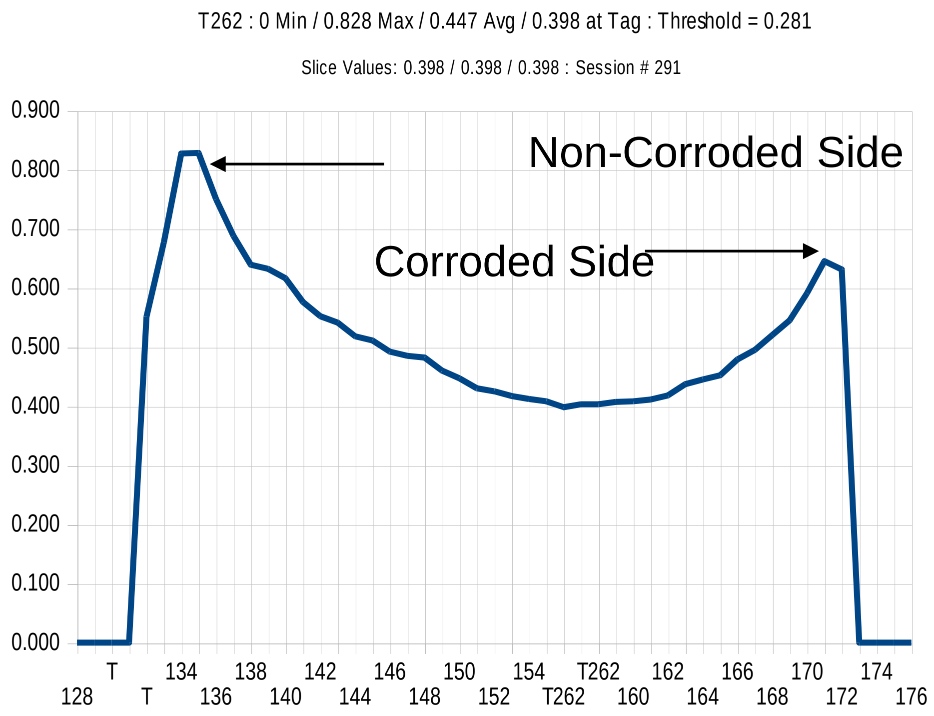


PARTO AZMOON AZAR

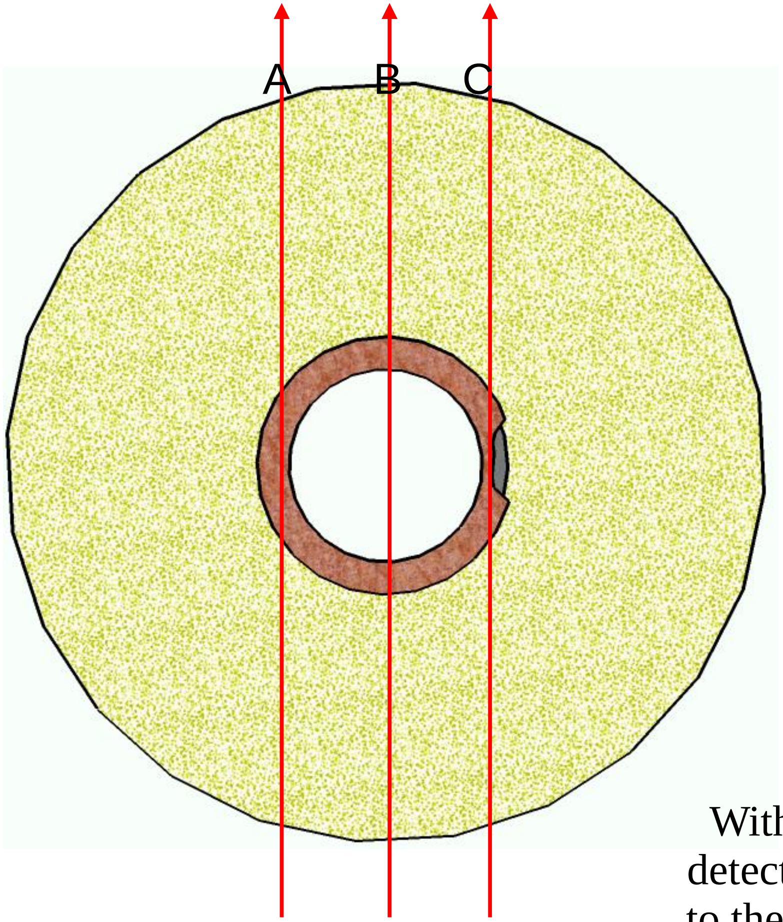


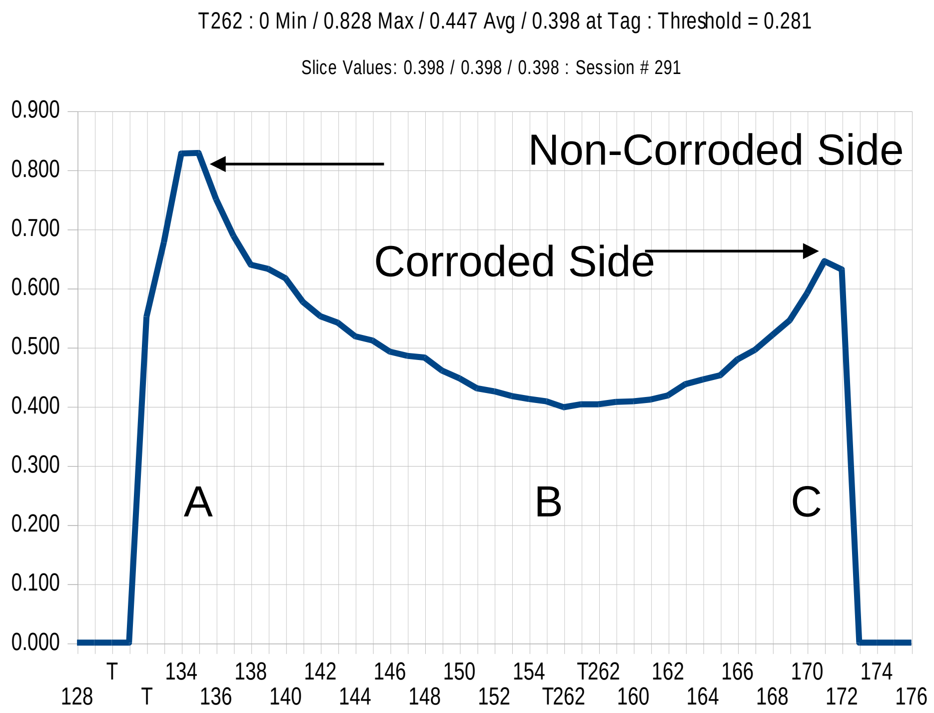
Corrosion on Side of Pipe



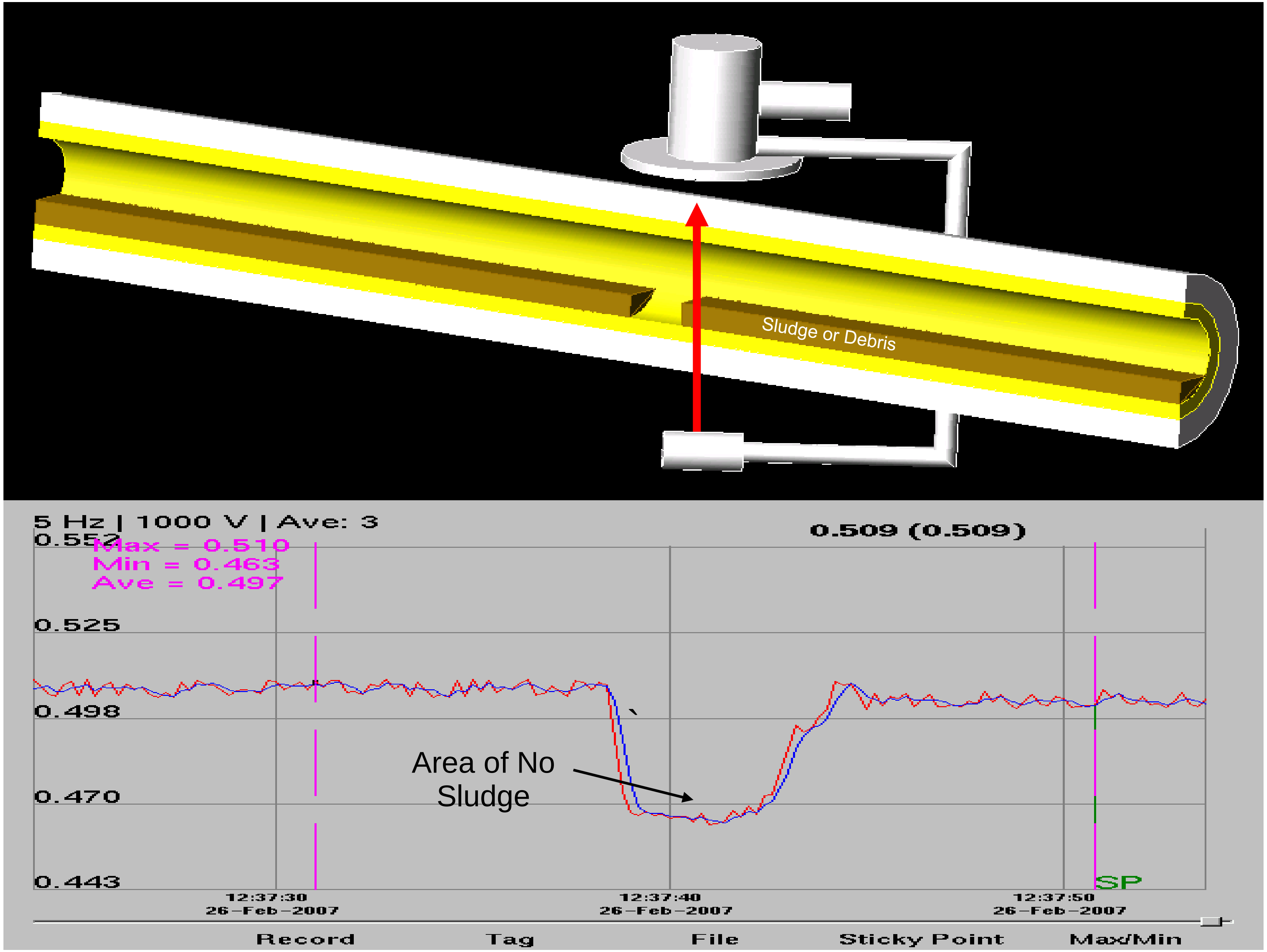


Corrosion on Side of Pipe

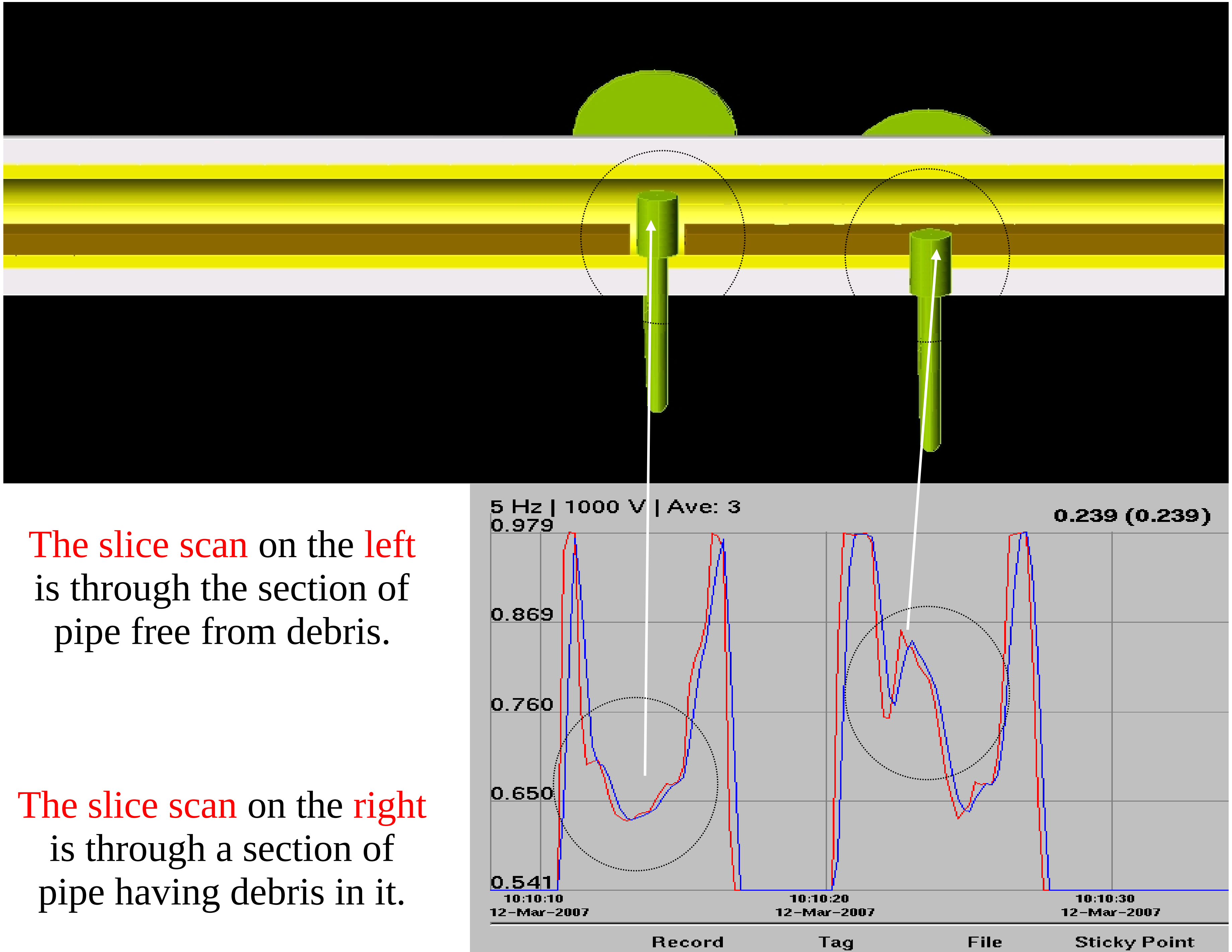




With a Slice Scan, corrosion on the side of the pipe can be detected even though the radiation beam is not perpendicular to the axis of the pipe. If detected, a second slice scan should be performed at a right angle to the first slice scan.

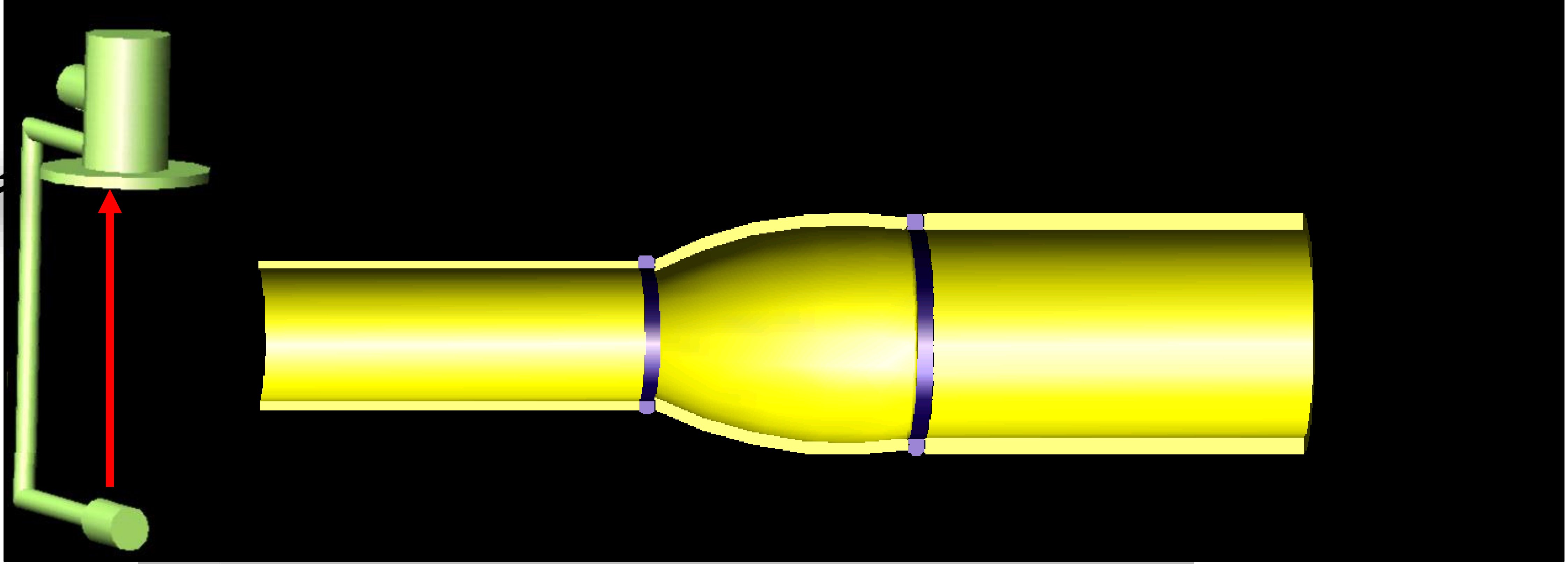


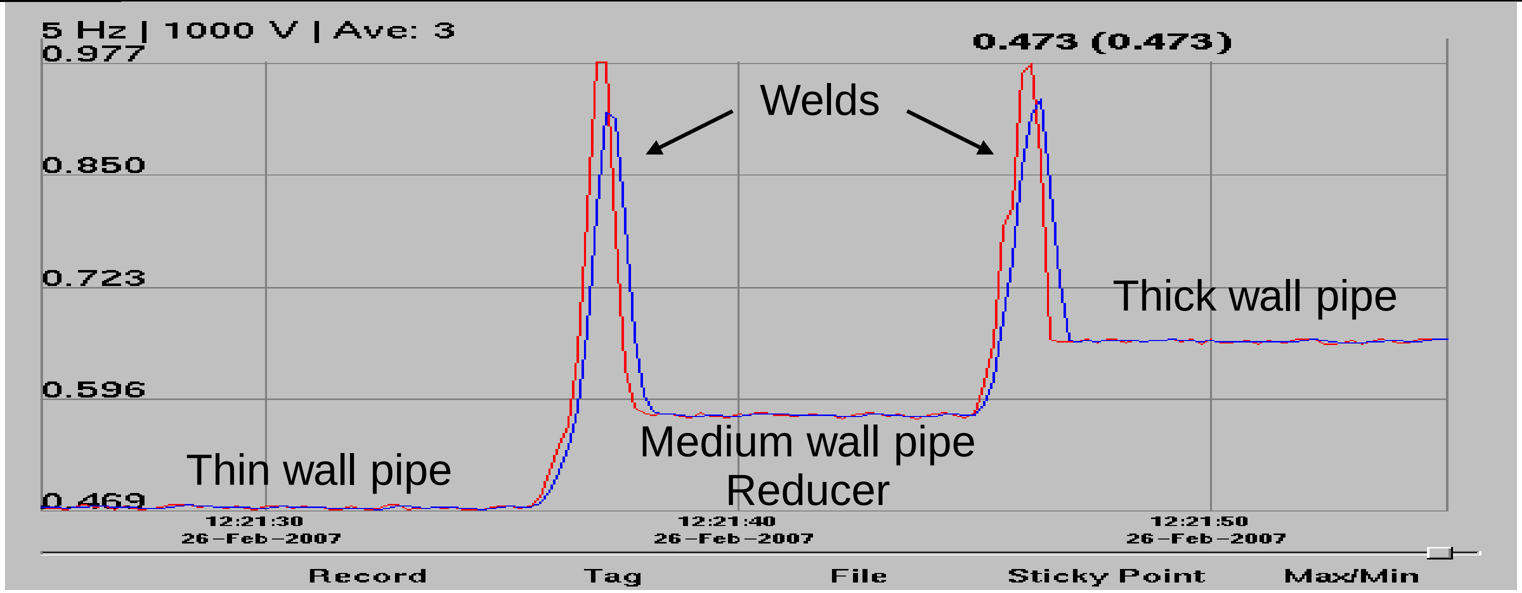
Sludge or Debris
5 Hz | 1000 V | Ave: 3
0.509 (0.509)
0.552
Max = 0.510
Min = 0.463
Ave = 0.497
0.525
0.498
0.470
0.443
Area of No Sludge
SP
12:37:30
26-Feb-2007
12:37:40
26-Feb-2007
12:37:50
26-Feb-2007
Record
Tag
File
Sticky Point
Max/Min

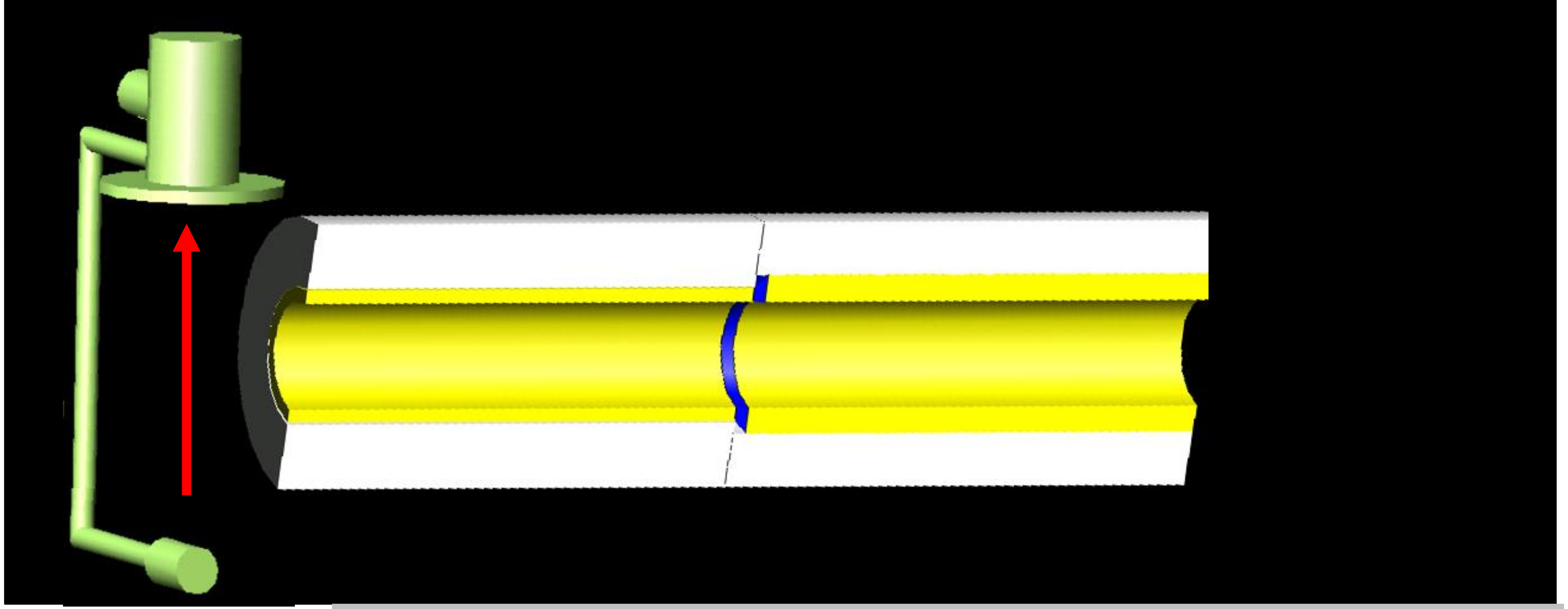


The slice scan on the left is through the section of pipe free from debris.

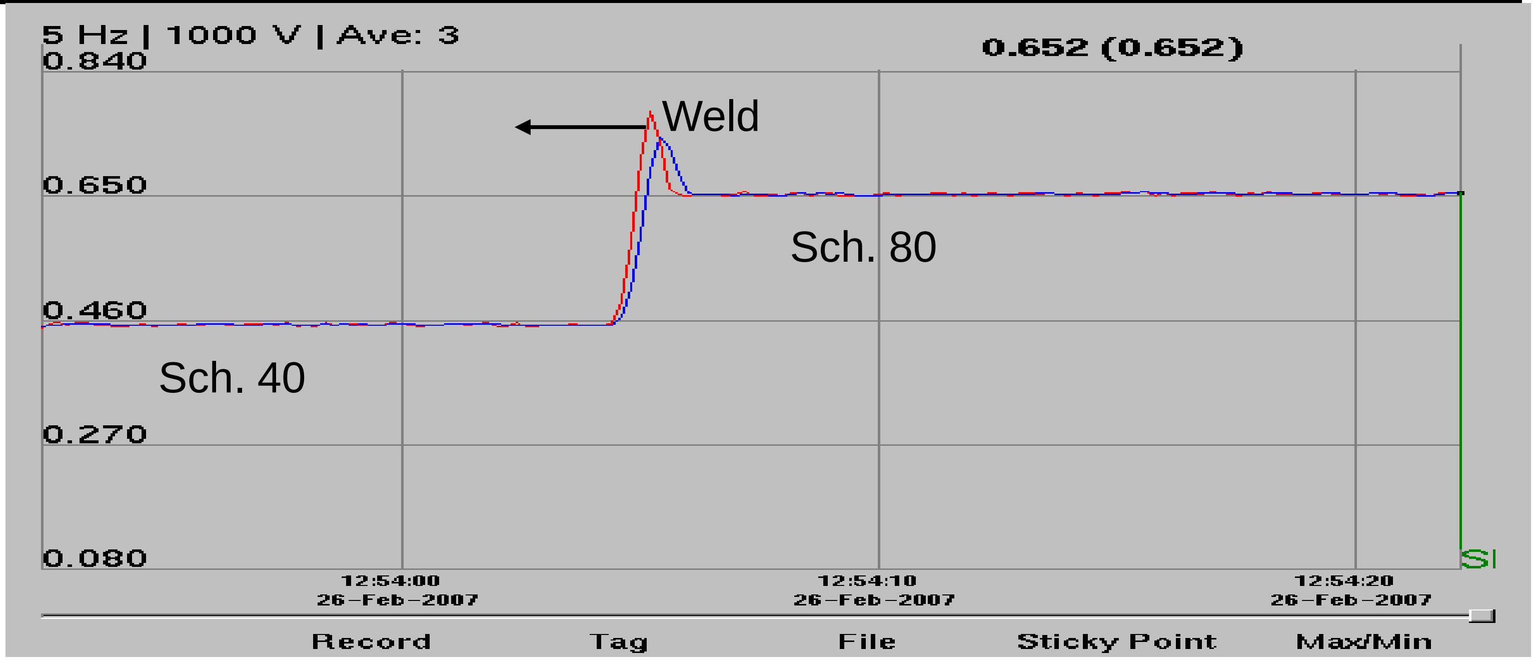
The slice scan on the right is through a section of pipe having debris in it.

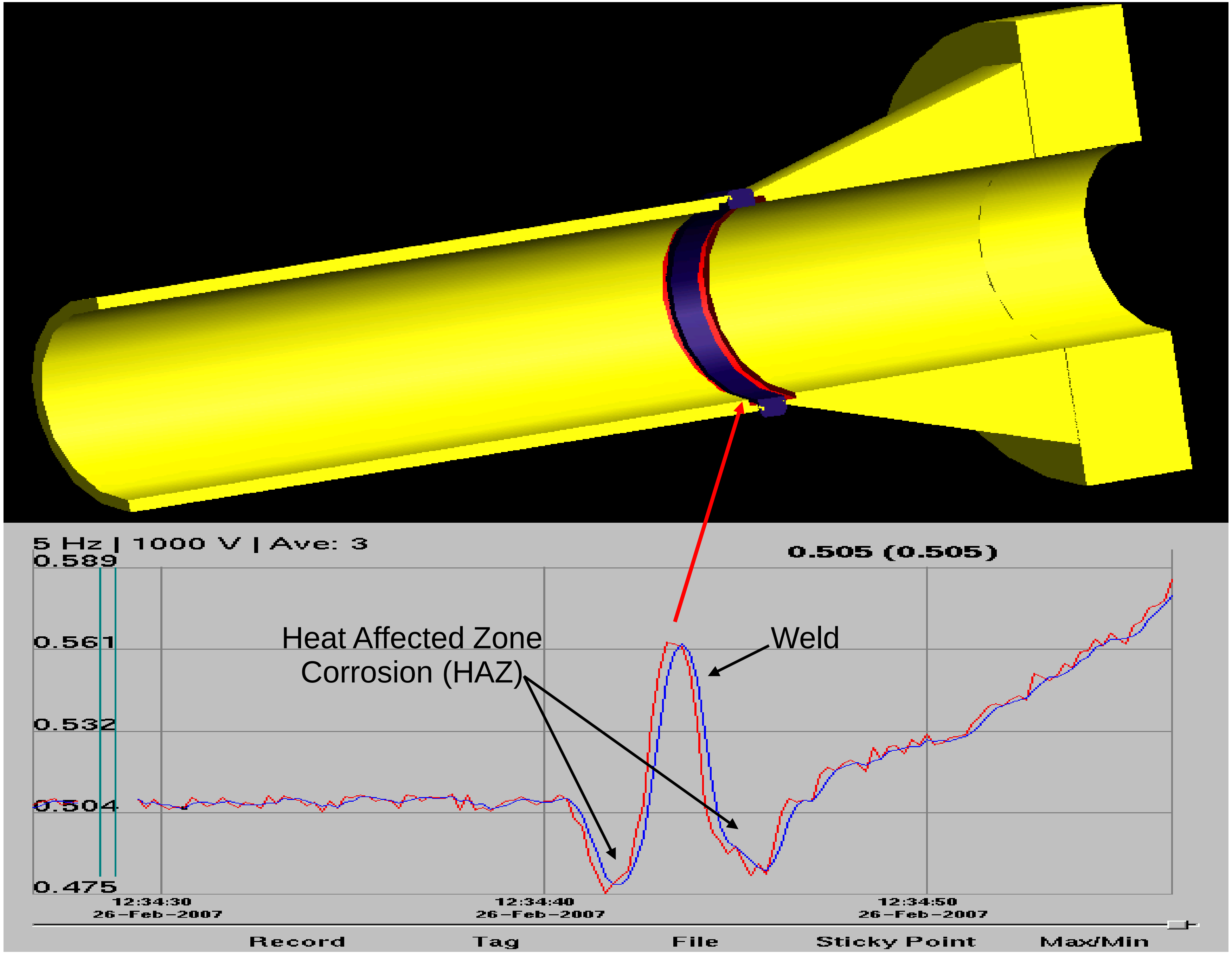


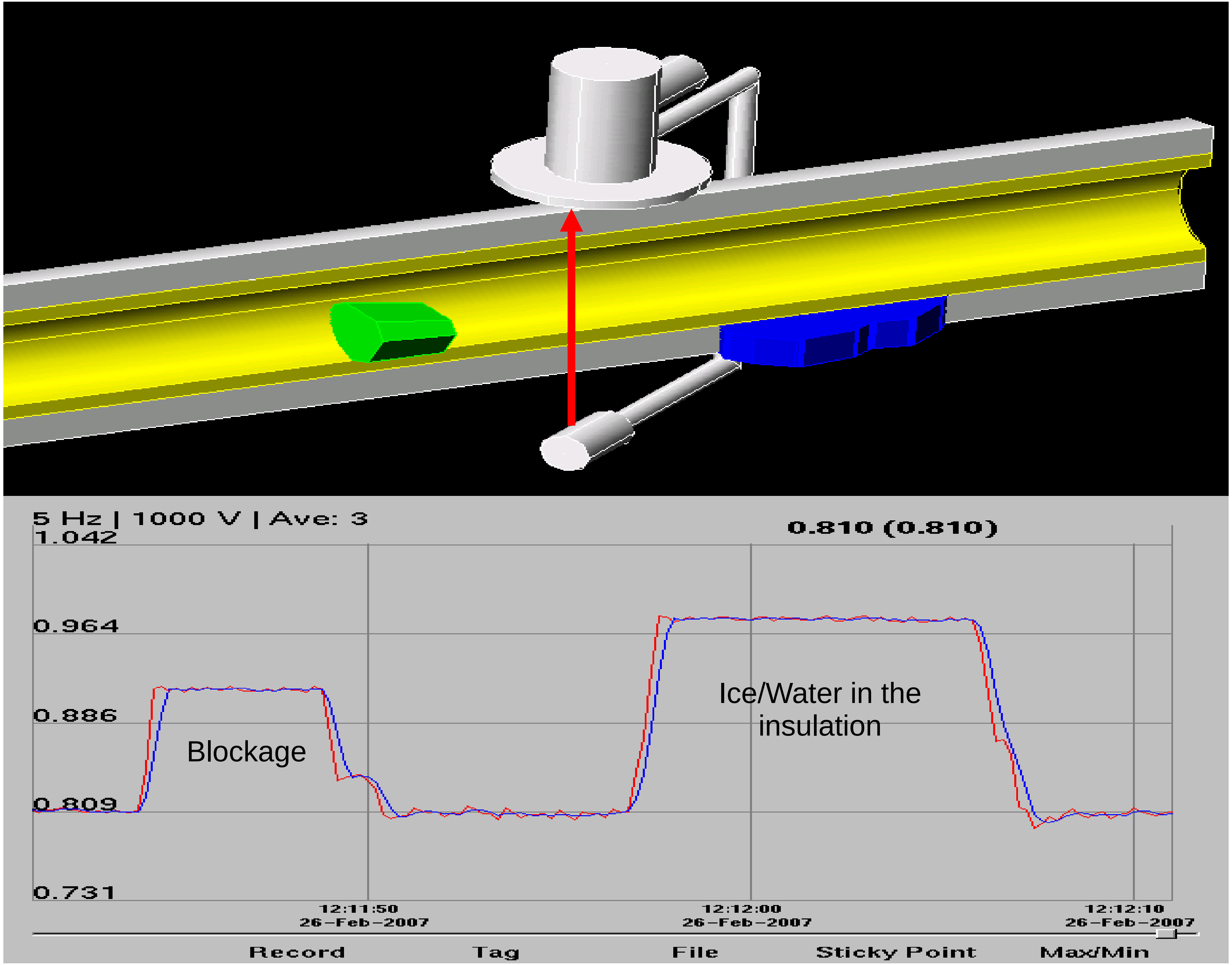

5 Hz | 1000 V | Ave: 3
0.977
0.850
0.723
0.596
0.469
0.473 (0.473)
Welds
Thick wall pipe
Medium wall pipe
Reducer
Thin wall pipe
12:21:30
26-Feb-2007
12:21:40
26-Feb-2007
12:21:50
26-Feb-2007
Record
Tag
File
Sticky Point
Max/Min



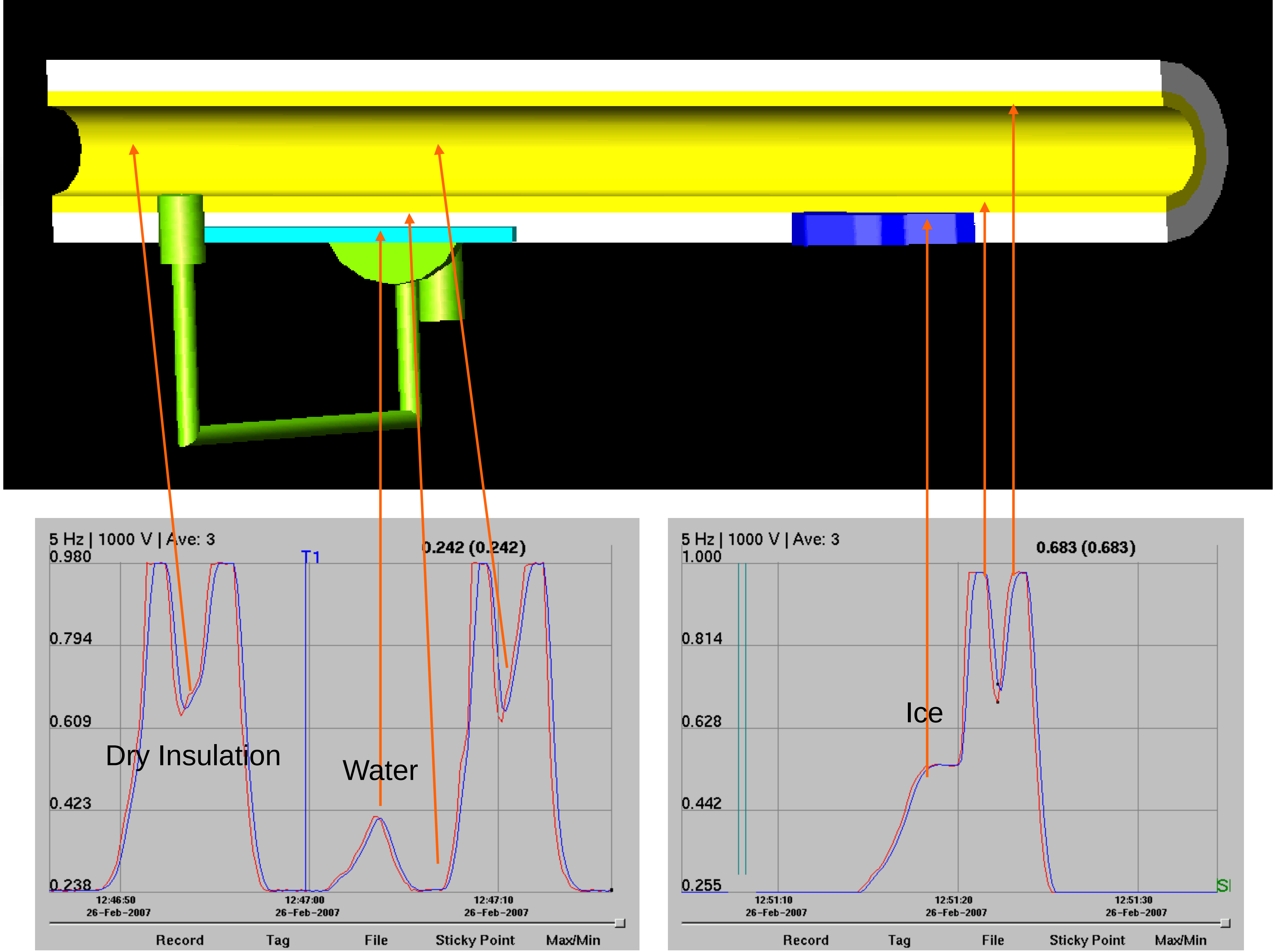
Detecting Pipe Schedule Changes




5 Hz | 1000 V | Ave: 3
0.505 (0.505)
0.589
0.561
0.532
0.504
0.475
Heat Affected Zone
Corrosion (HAZ)
Weld
12:34:30
26-Feb-2007
12:34:40
26-Feb-2007
12:34:50
26-Feb-2007
Record
Tag
File
Sticky Point
Max/Min

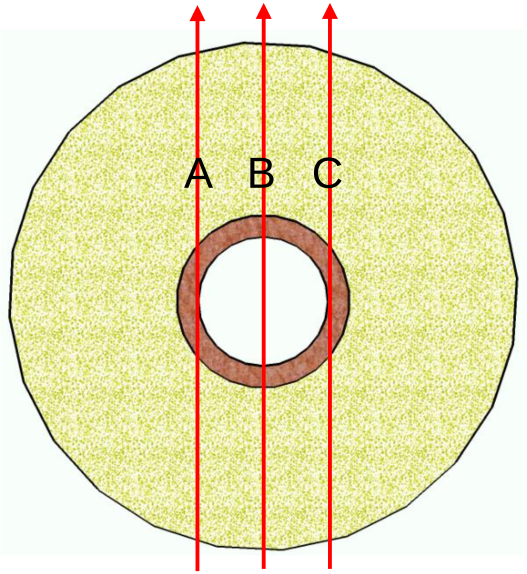

5 Hz | 1000 V | Ave: 3
1.042
0.810 (0.810)
0.964
0.886
0.809
0.731
Blockage
Ice/Water in the insulation
12:11:50
26-Feb-2007
12:12:00
26-Feb-2007
12:12:10
26-Feb-2007
Record
Tag
File
Sticky Point
Max/Min

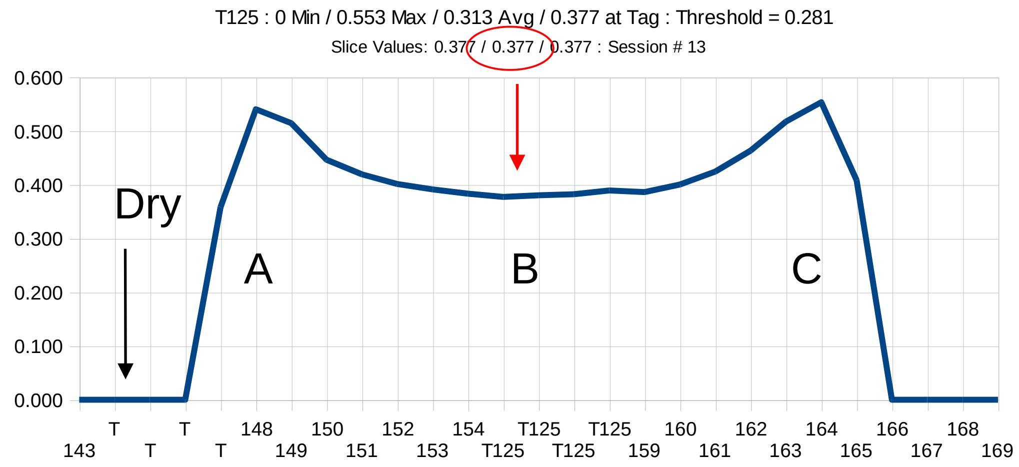
PARTO AZMOON AZAR

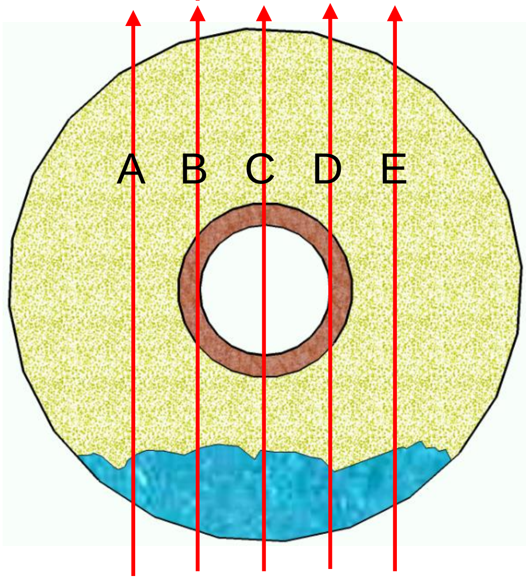


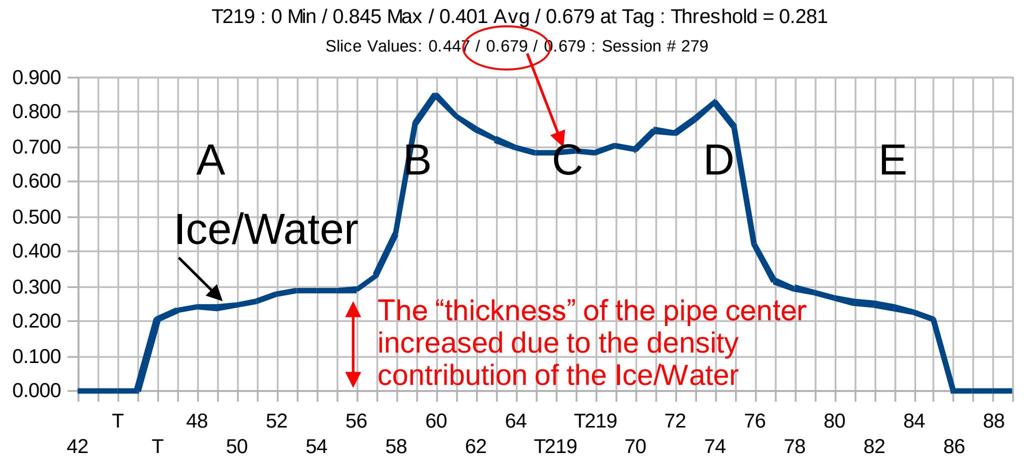
Dry vs. Wet Insulation

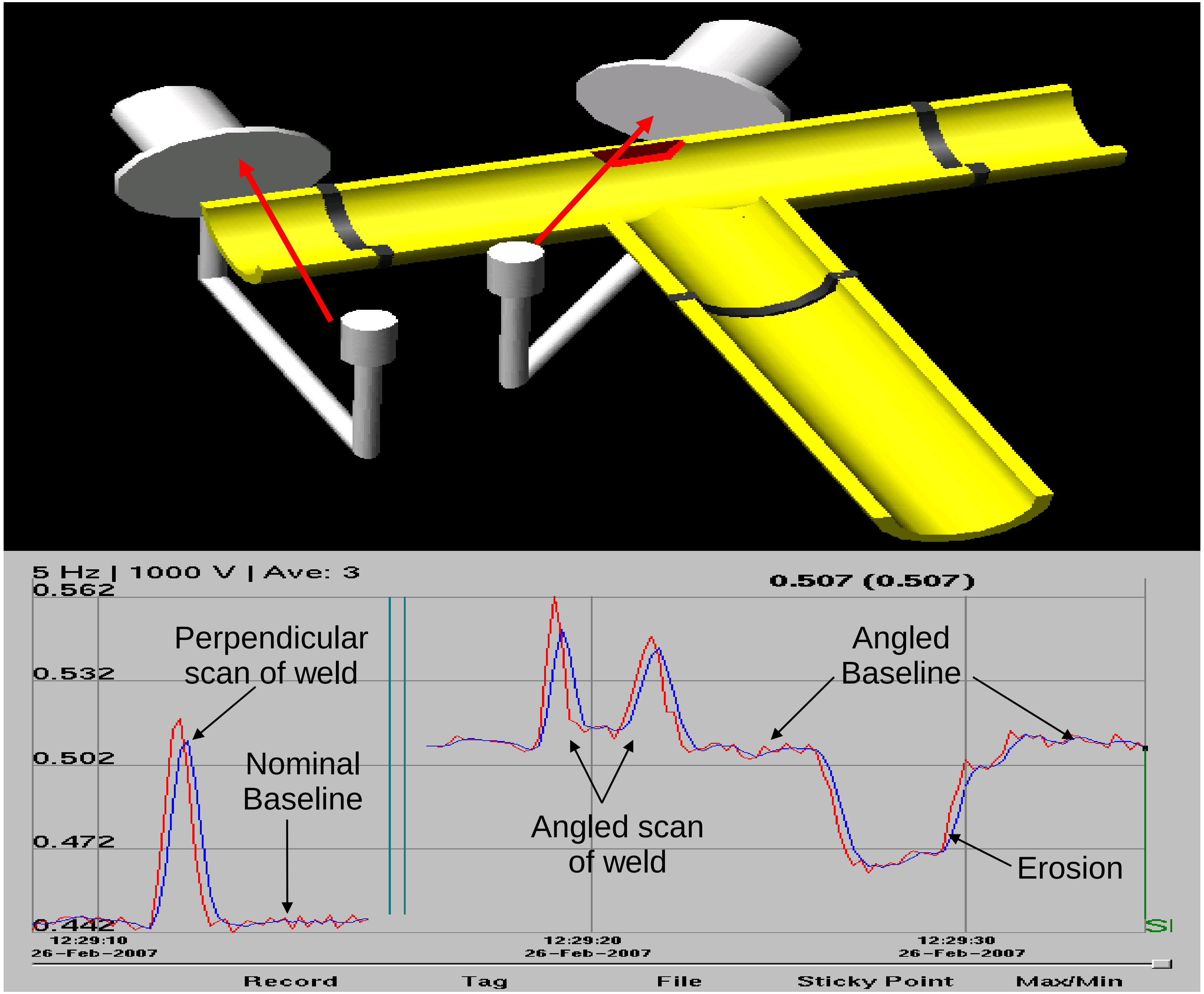
PARTO AZMOON AZAR



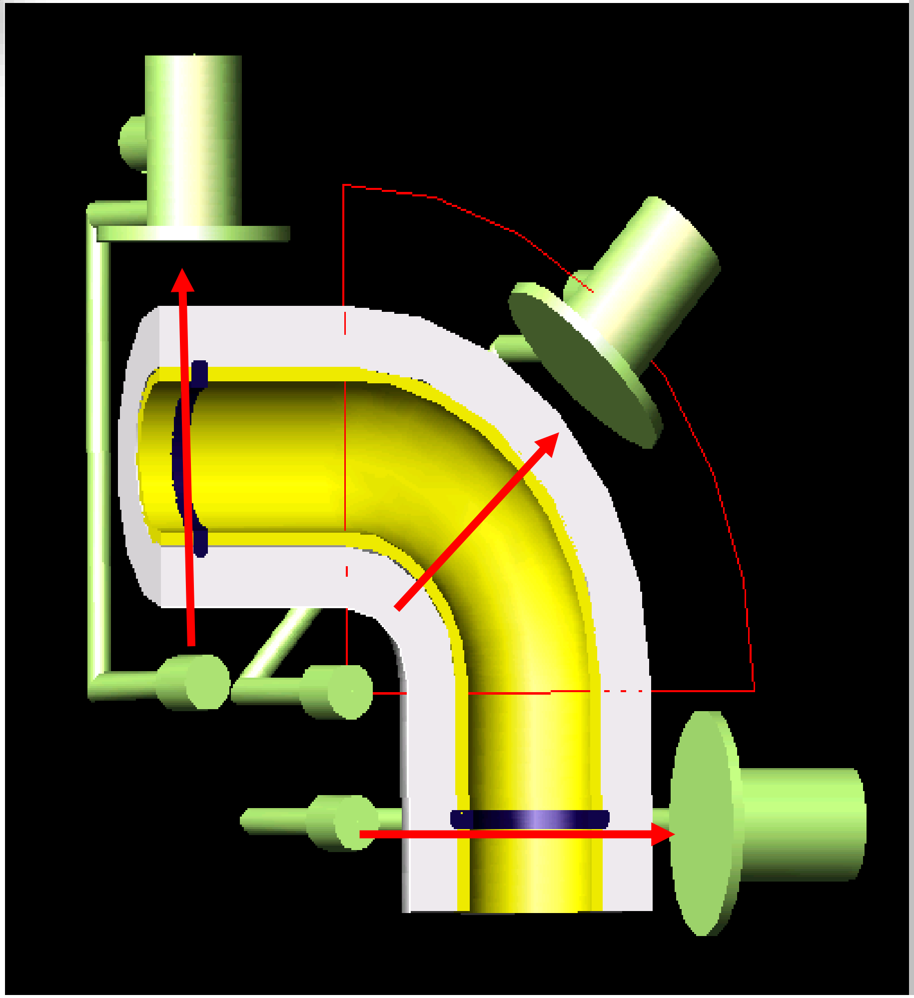


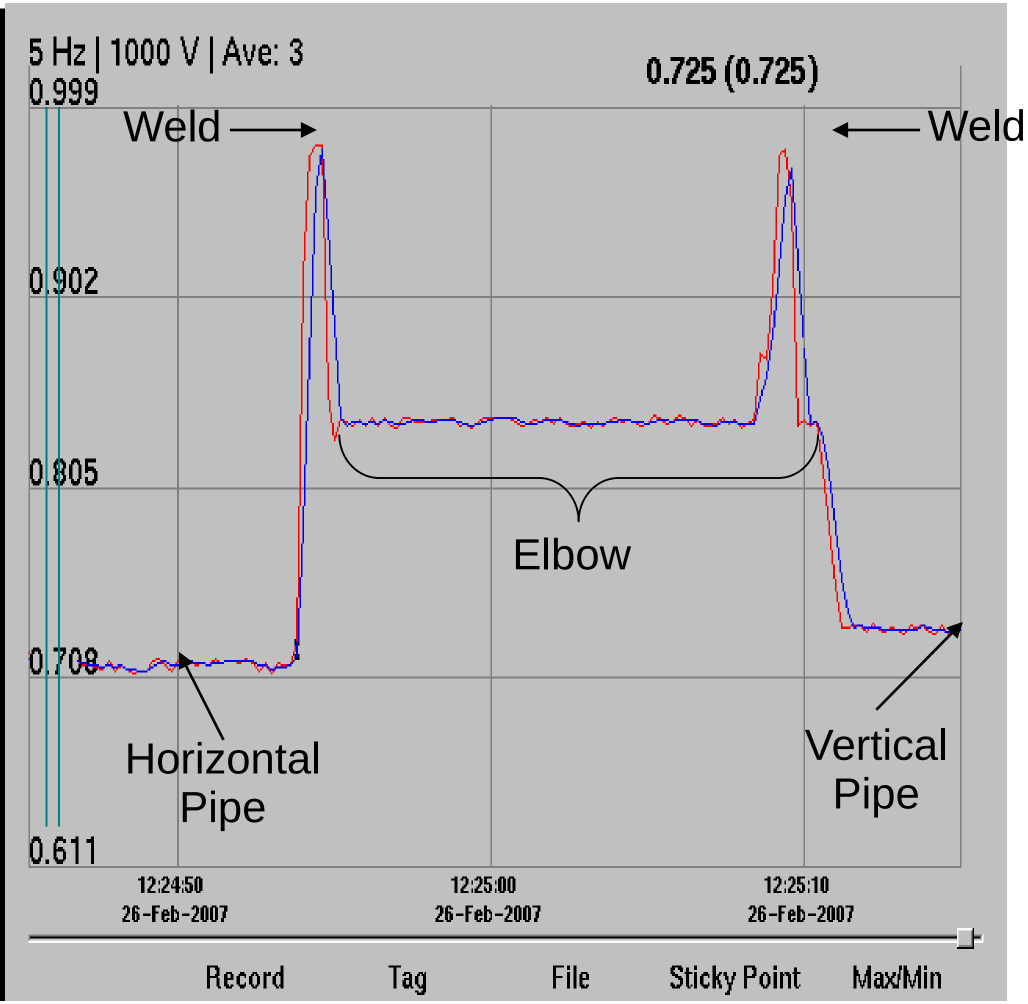




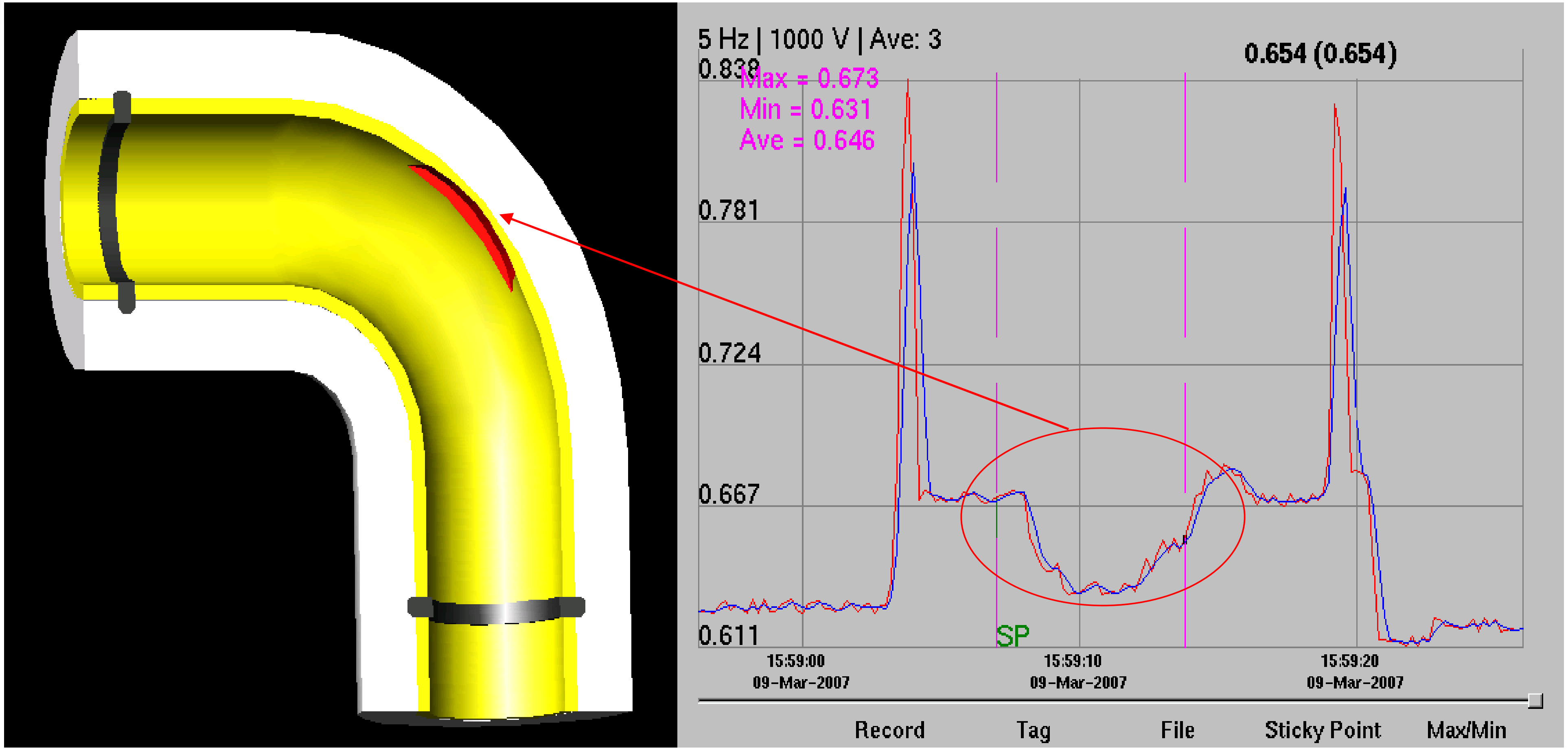

5 Hz | 1000 V | Ave: 3
0.507 (0.507)
0.562
0.532
0.502
0.472
0.442
Perpendicular scan of weld
Nominal Baseline
Angled scan of weld
Angled Baseline
Erosion
12:29:10 26-Feb-2007
12:29:20 26-Feb-2007
12:29:30 26-Feb-2007
Record
Tag
File
Sticky Point
Max/Min

PARTO AZMOON AZAR

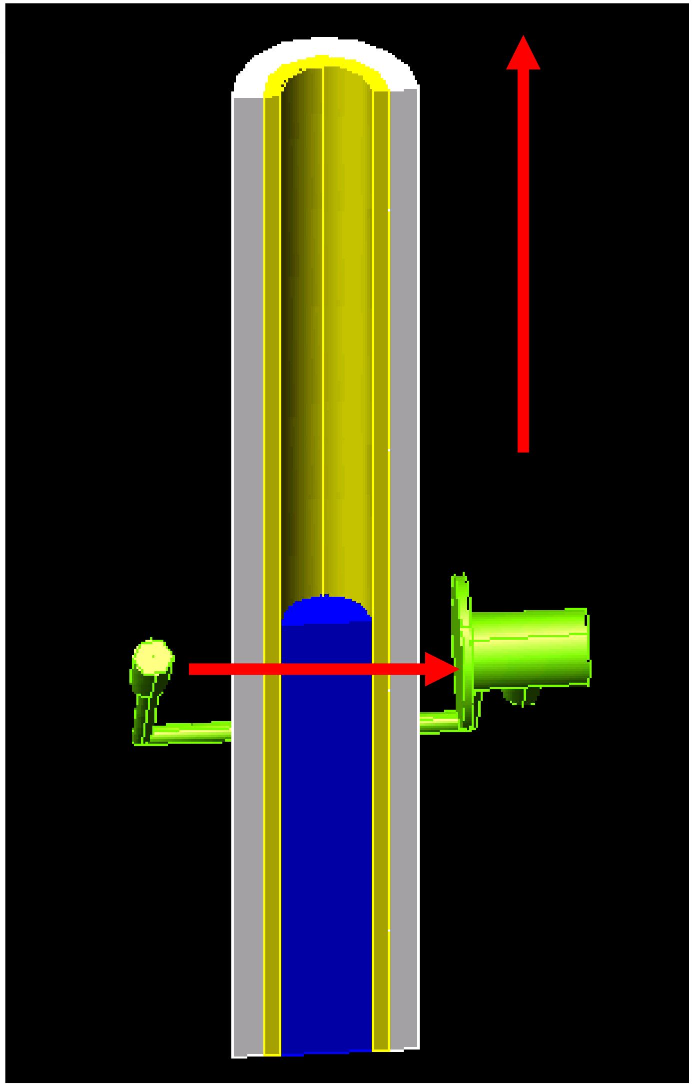


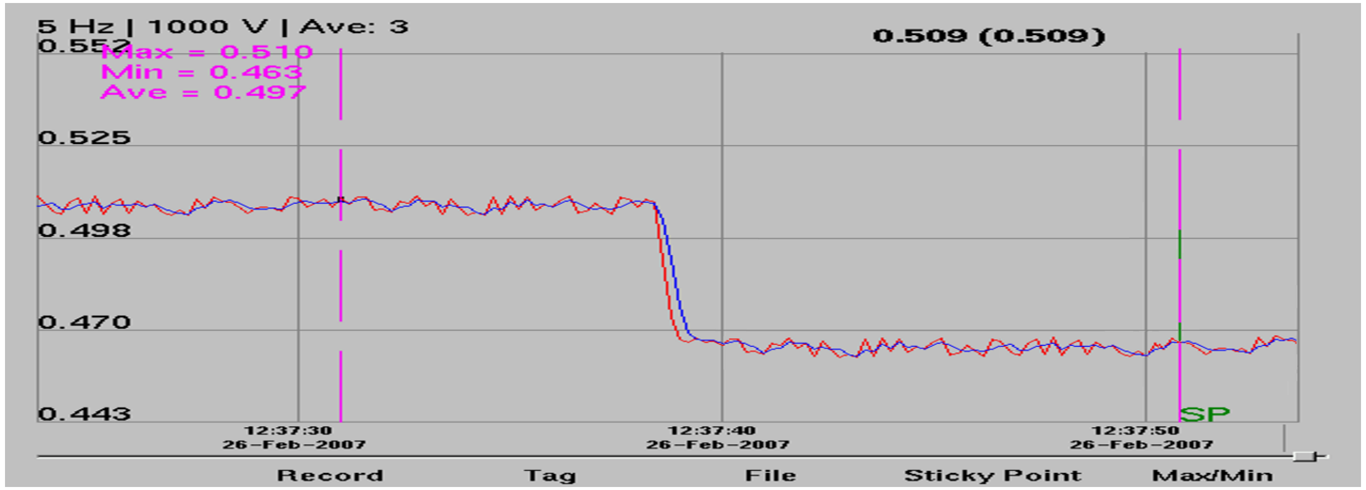


Typical Erosion Detection



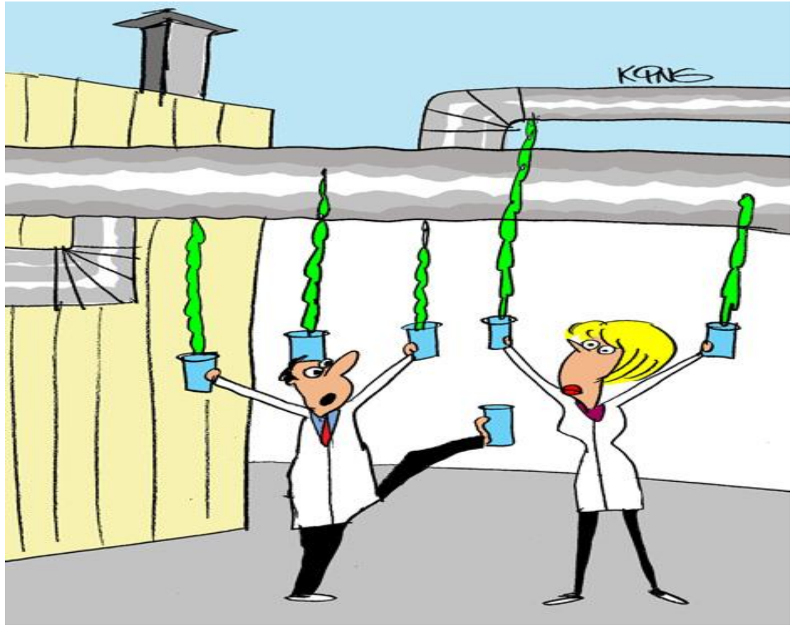
Typical Level Gauging





Summary:

- Have a Plan for CUI Inspections If you Fail to Plan you Plan to Fail,
- Choose Inspection Methods Accordingly,
- Be proactive, don’t wait for a CUI failure to spark your inspections,



IT MAY BE TOO LATE!!

References:

1. API-RP583 (2014), "Corrosion Under Insulation and Fireproofing" American Petroleum Institute (API) Recommended Practice 583 First Edition, May 2014,

2. "ASNT Nondestructive Testing Handbook" Third Edition: Volume 4, Radiographic Testing (RT), Third Edition,

3. "Radiographic Evaluation of Corrosion and Deposits in Pipelines: Results of an IAEA Co-ordinated Research Program" ECNDT 2006 ,Uwe ZSCHERPEL, Uwe EWERT, BAM, Berlin, Germany Silvia INFANZON, AENDUR, Montevideo, Uruguay Nasser RASTKHAN, Atomic Energy Organization of Iran, Teheran P. R. VAIDYA, Bhabha Atomic Research Centre, Mumbai, India Isaac EINAV, IAEA, Vienna, Austria Sinasi EKINCI, Turkish Atomic Energy Authority, Istanbul, Turkey,

4. BS-EN 16407-1 (2014), Non-destructive testing, Radiographic inspection of corrosion and deposits in pipes by X and gamma rays, Part (1): Tangential Radiographic Inspection,

5. BS-EN 16407-2 (2014), Non-destructive testing, Radiographic inspection of corrosion and deposits in pipes by X and gamma rays, Part (2): Double Wall Radiographic Inspection,

Thank you very much for your attention!!