Addendum to RFT Condition Assessment Reports
Technology & Analysis Background

PICA – Pipeline Inspection & Condition Analysis Corporation
(A Subsidiary of Russell NDT Holdings Ltd.)

Supplementary Information for RFT Reports:

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Abbreviations & Terminology

Abbreviations

AGM	Above-Ground Monitor
B&S:	Bell and Spigot connection
CC	Coupled or Clamped connection
CI	Cast Iron
DI	Ductile Iron
DS	Downstream
F	Feature
FM	Force Main
ILI	In-Line Inspection
NWT	Nominal Wall Thickness
P&P	Plan & Profile drawings
PARW	Pipe Average Remaining Wall (also Tavg)
PRC	Probable Repair Coupling
RFT	Remote Field Testing
RW	Remaining Wall
STL	Steel
Tavg	Average Wall Thickness (also PARW)
Tcircmin	Minimum Circumferential Wall Thickness
Tcircmax	Maximum Circumferential Wall Thickness
Tmin	Minimum Wall Thickness
TH	Through Hole (ie: 0% Remaining Wall)
UF	Unknown or Unidentifiable Feature
US	Upstream
WL	Wall Loss

Glossary

Circumferential Wall Thickness: Metal loss that is uniform in depth around the pipe's circumference at a given axial location. The "maximum" circumferential wall thickness (Tcircmax) indicates the thickest circumferential wall thickness for a single pipe while the "minimum" circumferential wall thickness (Tcircmin) indicates the thinnest. Figure 1 illustrates all wall thickness terms.

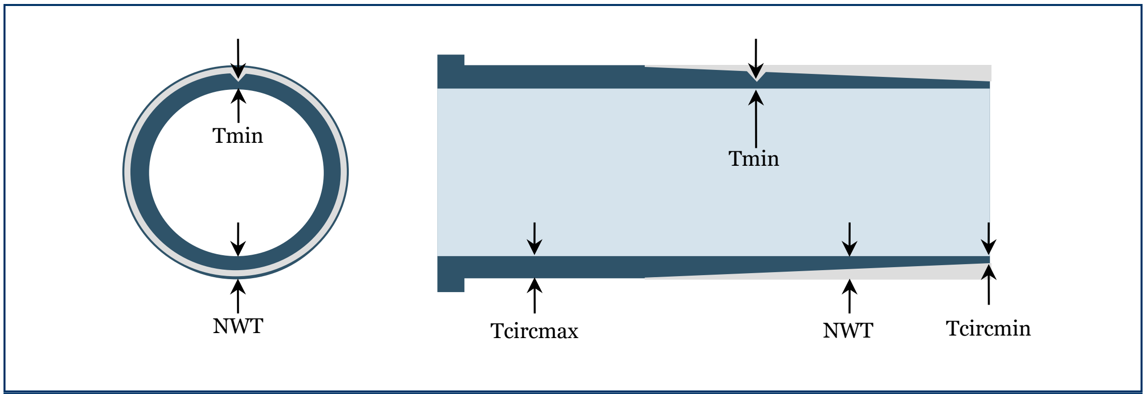


Figure 1. Wall loss terminology

Nominal Wall Thickness (NWT): The thickness of the pipe wall where there is assumed to be no corrosion or circumferential wall loss (ie: 100% RW). Normally, a manufacturer will designate a NWT or NWT range (in mm or inches) for a specific pipe material, diameter and class.

One-Sided Wall Loss: Metal loss that occurs predominantly on one side of the pipe – also referred to as "pitting" or "eccentric wall loss".

Pipe Average Wall Thickness (Tavg, PARW): The wall thickness that would occur by recasting the existing metal on the pipe barrel so that it is uniform across the axial length. The average pipe wall can vary up to ±15% due to manufacturing. Variations outside the normal 15% spread can be an indicator of a different nominal wall thickness or pipe type, or a point towards a problem like aggregate pitting or general wall loss.

Pitting: Localized corrosion of a metal surface that is confined to a point or small area. Up to three deepest pitting regions in each pipe are provided in this report as Tmin1, Tmin2 and Tmin3.

Remote Field Testing (RFT): A non-destructive examination method that induces an electromagnetic field that is then detected outside the direct coupling zone (ie: in the "remote" zone) after it has passed completely through the object being examined. RFT is also called "remote field eddy current" (RFEC).

Condition Categories

In some reports, pitting is expressed as Shallow, Medium, Deep or Advanced. For example, if a pitting region has 35% remaining wall, the pitting would be classified as “Deep” pitting.

Shallow	Wall thickness at thinnest point ≥ 65% of NWT
Medium	Wall thickness at thinnest point 40%-64% of NWT
Deep	Wall thickness at thinnest point 20%-39% of NWT
Advanced	Wall thickness at thinnest point < 20% of NWT

The condition of the thinnest point on each pipe (as defined above) in conjunction with the number of corrosion indications is used to determine the overall condition of the pipeline into poor, fair or good. Loosely defined:

Poor	The majority of inspected pipes have corrosion deeper than 50% of NWT
Fair	The majority of inspected pipes have corrosion between 25% - 50% of NWT
Good	The majority of inspected pipes have corrosion less than 25% of NWT

If you would prefer to use a different condition coding system for this report, please inform your PICA representative.

Remote Field Operation

SeeSnake Tool Description

PICA Corp's SeeSnake line of tools employs Remote Field Technology (RFT) for measuring pipe wall thickness. RFT technology works by detecting changes in an AC electromagnetic field generated by the tool by interacting with the metal in the pipe, becoming stronger in areas of metal loss. These electromagnetic field interactions are measured by on board detectors. All data is processed using analog-to-digital (A/D) converters and digital processors and then stored on the tool itself. This data is then downloaded to PICA offices and analysed using dedicated in house software to calculate wall thickness of the line.

The SeeSnake tools' articulated mechanical design gives it flexibility to negotiate 90-degree short radius elbows. The hard diameter of the tool is significantly smaller than the inner diameter (ID) of the pipe to allow for protrusions, lining and scale. Centralizers maintain a uniform annulus between the tool and the pipe. The connection with the street-level operator is made through a wireline, which runs over an odometer sheave to provide an accurate distance reading of the tool's progress through the pipeline. The tool detects wall thinning caused by corrosion or erosion, as well as line features such as joint couplings, branches and elbows. The maximum range is defined by the length of the wireline for tethered runs.

Figure 2a: PICA's SeeSnake tool used for smaller diameter inspections.

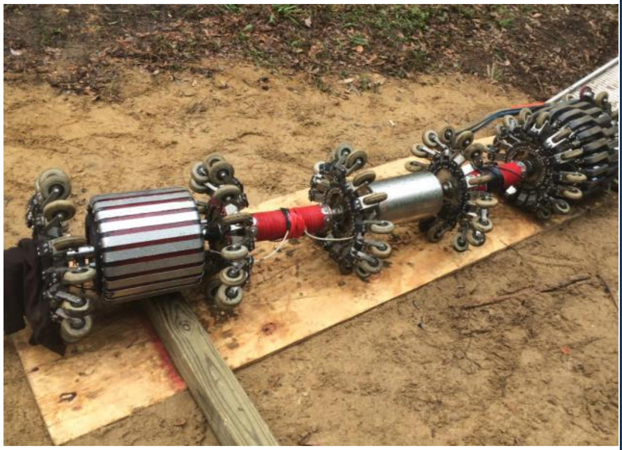
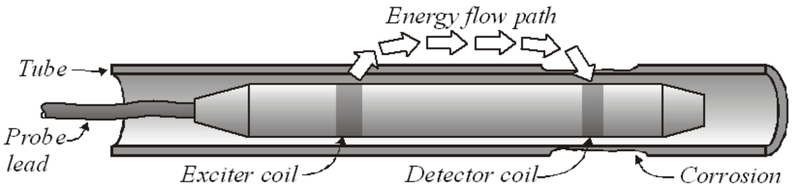


Figure 2b: PICA's Chimera tool used for larger diameter inspections.

Background Information

In the basic RFT probe shown below, there is one exciter coil and one detector coil. Both coils are wound co-axially with respect to the examined pipe and are separated by a distance greater than two times the pipe diameter. The actual separation depends on the application, but will always be a minimum of two pipe diameters. It is this separation that gives RFT its name: the detector measures the electromagnetic field remote from the exciter. Although the fields have become very small at this distance from the exciter, they contain information on the full thickness of the pipe wall.



The detector electronics include high-gain instrumentation amplifiers and steep noise filters. These are necessary in order to retrieve the remote field signals. The detector electronics output the remote field signal to an on-board storage device. The data is recalled for display, analysis and reporting purposes after the examination process is completed.

Remote Field Technology (RFT)

RFT Tools work by measuring the “time of flight” (phase shift) and the signal strength (amplitude) of a signal emitted by an exciter coil and detected by an array of receivers. The receivers are positioned circumferentially so that they essentially are sensitive to the many clock locations of the pipe circumference.

For each cycle of the exciter frequency, a clock is started and the arrival time of the signal at the detector is used to re-set the clock. The time interval is a measurement of the time of flight, and indirectly, the wall thickness of the pipe.

There are many important considerations affecting in-line RFT inspection results. These can be subdivided into four categories:

- The physical quantities measured by the ILI tool. Most ILI tools indirectly measure the wall thickness and infer the wall thickness though a calibration. Ultrasonic (UT) tools measure the “time-of-flight” of sound, while Magnetic Flux Leakage (MFL) tools measure the magnetic field. RFT tools measure both the time-of-flight and the signal strength of a varying electromagnetic field.
- The design of the tool. Pipe inspection tool design is a compromise between countless design criteria. Lift-off and resolution are important considerations, but so are bend negotiation ability, battery life, pipe size range, centralization, wall thickness range, suspension, etc.
- The delivery procedure. Most tools have an optimal inspection speed and provide the best results when the speed is consistent. Going faster or slower means less than optimal results. This is an especially important consideration when tools are run in gaseous media.
- Noise and other interference sources. These can be caused by both internal sources and external sources. A major problem for many tools is the cleanliness of the pipe. A dirty pipe can cause artifacts in the data that may mask flaws.

Physical Parameters Measured by RFT Tools

RFT technology measures three quantities:

- Wall thickness of ferromagnetic pipes
- Magnetic permeability
- Electrical conductivity

These three factors are measured simultaneously and convey different, important information. For steel pipes, the electrical conductivity remains fairly constant over the length of a pipe segment, meaning that any RFT signal changes along the length of a pipe are mainly due to wall thickness and permeability changes.

Magnetic permeability is not usually a factor of interest. However, in lines that are subjected to soil load stresses, the permeability variations can be significant. For lines known to be under external stresses (for example due to geological ground movement) the permeability variations measured by an RFT tool can be very valuable. Permeability variations produce signals that generally lie just outside the RFT wall loss reference curve that analysts use to differentiate between wall loss and permeability; while wall loss signals lie inside the reference curve.

In the data from cast and ductile iron water lines, we generally notice significant changes in wall thickness along the length of a pipe segment. This appears to be fairly typical, even for brand new pipes that come straight from the foundry. The variation is believed to be the result of the manufacturing process. To capture the spread in wall thickness, we generally report both the minimum and maximum wall thickness per pipe (measured circumferentially without local defects).

Besides wall thickness variations, we occasionally note magnetic permeability variations in the data. These are generally from two sources:

- Roller marks. These present themselves as a band of noise across all channels on the tool. The marks can be sizeable and can mask small volume wall loss defects.
- Permeability changes caused by stresses induced during installation of the line. These typically are localized indications within a couple of feet of a bell and spigot joint. They are believed to mark the points where the pipes were held when the joints were assembled.

Tool Propulsion and Delivery

A common problem encountered during tethered runs in air-filled pipe is tool surging. The surges consist of the tool being stationary one moment and surging forward the next. Speed surges are most severe when the length of the tether on the pulling winch is at its maximum, or the tether is wrapping around multiple bends. The surges are often completely missed by the field operator as the winch reels in at a constant velocity and no surging is visible from above ground. Contributors to surging are tool friction, wireline friction and wireline stretch and weight.

Interference and Noise Sources

There are three different sources of interference on the RFT data:

1. Interference from electrical sources on board the tool

There are two types of interferences caused by the tool itself: electrical noise and the exciter response to defect signals.

Electrical noise from onboard the tool will be consistently present in the data and will therefore result in a constant noise amplitude. This type of noise can be filtered out easily during the post processing stage.

When the exciter coil on an RFT tool passes an area with significant wall thickness change, the “exciter response” to this wall thickness change (like a Bell and Spigot joint, an Elbow, or Valve) will be visible in the data. If the exciter response is large, it can mask the tool response to smaller defects.

2. Noise from electrical sources outside the tool

The noise from these types of sources will increase with proximity. The closer the tool to the source, the higher the noise level will become. The noise will fade out as the tool moves away from the noise source. This type of noise can be hard to remove during post-processing and may mask flaws in the pipe. Cathodic Protection systems can induce electrical noise on the data from the pipeline and electrical cables that run parallel to the line or cross it can induce noise as well.

3. Vibration induced noise

Mechanical vibration can create false indications or cause the tool to miss flaws. This is called “travel noise”. For example when the tool moves through a larger cross, the tool is subjected to a significant diameter change that causes the tool modules to tilt and temporarily lose concentricity with the pipe. This tilting action will create signal artifacts on the data.

Presenting RFT Data: Stripchart Display & Phase-Amplitude Diagrams

A stripchart displays the detector data as a function of time or the axial distance along the length of the pipeline. Phase and log-amplitude are the preferred quantities for the stripchart display because they are both linear indicators of overall wall thickness. The general convention for stripcharts is that deflections to the left represent metal loss and deflections to the right wall thickening (Figure 3).

A phase-amplitude diagram (Figure 4) is a two-dimensional representation of the detector output voltage with the angle representing phase with respect to a reference signal and the radius representing amplitude (ASNT E 2096). Axial distance information is not available on phase-amplitude diagrams yet they are used for sizing flaws. By combining phase-amplitude diagrams with stripcharts, the distance information can be included.

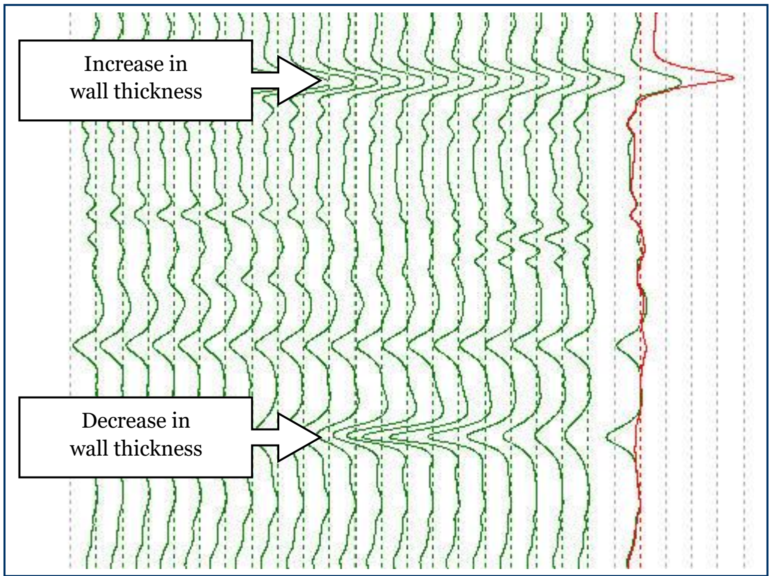


Figure 3: RFT stripchart display.

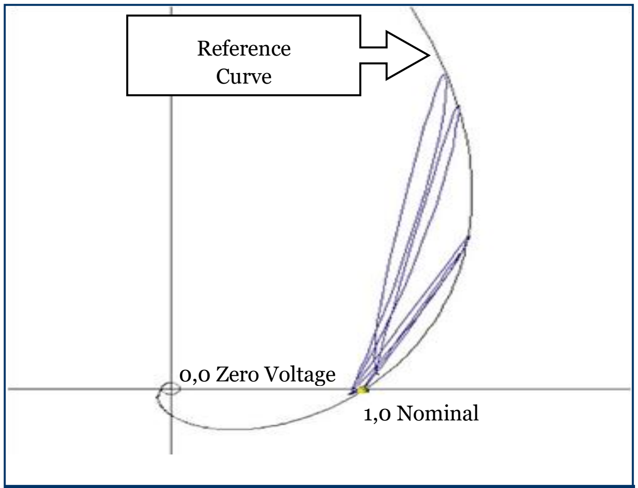


Figure 4: RFT phase-amplitude diagram.

Phase-amplitude diagrams are also known as “voltage plane displays”. On the voltage plane display, the nominal signal is placed at (1,0). Besides the detector information, the voltage plane has a number of static components: the origin, the x- and y-axes and the exponential skin depth reference curve. The curve starts at (0,0) (ie: zero voltage at origin) and follows a spiral that traces the path (locus) of the phasors as the overall wall thickness decreases. Full circumferential flaws fall directly on this curve. The figure on the left illustrates examples of fully circumferential defect indications.

Calibration

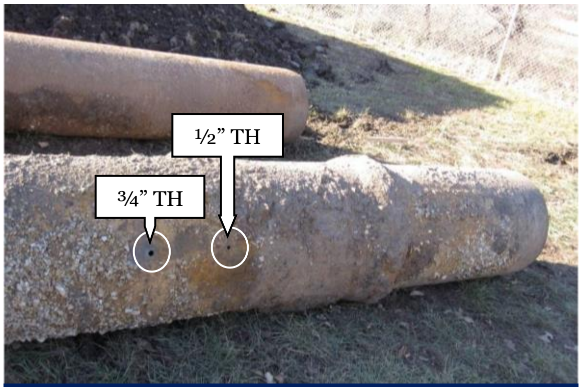


Figure 5: Typical calibration pipe.

For the best possible RFT accuracy, a calibration is performed using a short section of pipe with the same nominal pipe properties (wall thickness and grade) as the pipe being inspected. Under ideal conditions, a full pipe section with a half pipe on each end (to create two full connections and eliminate any "end effect") in good condition are provided by the Client. PICA will create artificial defects of varying depth and diameter in this pipe and run the RFT tool through it several times at various frequencies. The signal produced during this process is then compared to the signal produced during the field surveys to better quantify remaining wall calculations.

In the absence of such a calibration pipe or to confirm the accuracy of the calibration (especially in the case where the test sample is not representative of the majority of the pipes in the inspected line), calibration test results are supplemented by mathematical calibrations. Simply, the analyst will build a histogram of the thickest RFT phase reading per inspected pipe section and create a calibration from this histogram. This assumes that the thickest phase readings are unaffected by possible corrosion. Using this method, defect sizing accuracy is expected to be ±20% for short (local) wall loss and ±10% for long (general) wall loss for pitting above the limit of detection and sufficiently removed from major features (such as Girth Weld connections).