MASTERAIR

By
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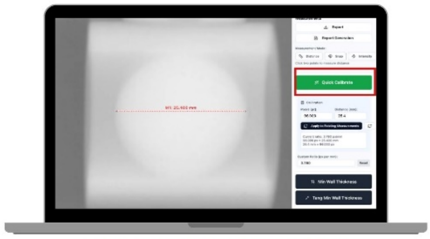
# Your RT films know more than your ruler can tell you

## How digital measurement standardization addresses the hidden cost of operator variability in radiographic wall thickness profiling?

### About MasterAIM™

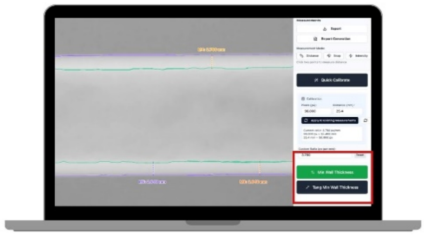
MasterAIM is a digital measurement platform developed by MasterAIR Technologies Pte Ltd, Singapore, for the analysis of digitized conventional radiographic films. For more information, visit masterair.ai/ai-automation/masteraim

*This application note is based on findings from a study pending submission for a peer-reviewed journal publication. Full statistical methodology and results will be available in the accompanying publication.*



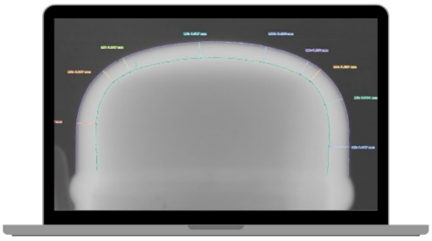
**QUICK CALIBRATION**

INSTANTLY CONVERT PIXEL DATA TO REAL-WORLD UNITS WITH A KNOWN REFERANCE FOR CONSISTENT MEASUREMENTS.



**WALL LOSS DETECTION**

AUTOMATE ACCURATE WALL THICKNESS MEASUREMENTS, WHETHER ON STRAIGHT OR CURVED PIPE SEGMENTS.



**REPEATABILITY & CONSISTENCY**

ENSURES CONSISTENT RESULTS FOR REPEATED MEASUREMENTS WITH A FIRST CLASS RELIABILITY SCORE (ICC) OF 0.851.

**CLOUD-BASED SECURE WORKFLOW**

INTERPRET INSPECTION DATA SECURELY IN THE CLOUD FOR CONSISTENT AND TRACEABLE WORKFLOWS.

### The Measurement That Matters Most

In every petrochemical refinery, power plant, and offshore platform, a single number drives some of the most consequential engineering decisions: the remaining wall thickness of a pipe. That number determines whether a line stays in service, gets scheduled for repair, or triggers an emergency shutdown. It underpins fitness-for-service assessments, informs risk-based inspection strategies, and ultimately protects both people and assets.

For decades, the industry has relied on skilled radiographic interpreters to extract that number from conventional film. The process is well-established: expose the pipe, develop the film, place it on a light box, measure with a ruler and calipers, correct for magnification, and report the result. It works. It has kept plants running safely for generations. But here is a question that is rarely asked out loud: if you gave the same film to three qualified interpreters, would they give you the same answer?

### Three Operators, One Film, Different Answers

A recent independent study set out to answer exactly that question.

Three qualified radiographic interpretation operators were given 28 carbon steel pipe segments, yielding 84 distinct measurement locations, and asked to measure wall thickness three times each, using both traditional manual tools and a digital measurement platform (MasterAIM). That is 756 individual measurements per method, designed to quantify not just whether the measurements are accurate, but whether they are *consistent*. The study applied Gage Repeatability and Reproducibility (Gage R&R) analysis, a formal statistical framework widely used in manufacturing quality control but rarely applied in NDT, to decompose measurement variability into its component sources. The results revealed a clear picture. When the same operator measured the same location repeatedly, both methods performed well. **Repeatability was comparable: approximately 8-9% of total variation for both digital and traditional methods.** The individual operator's hand is steady. The expert's precision is real.
The divergence appeared when *different* operators measured the same location. **Reproducibility, which is the variation between operators, accounted for 19.31% of total variation in the traditional method, compared with 6.07% in the digital method.** That is a threefold difference. In practical terms, it means that the answer you get depends, in part, on who reads the film.

### Why Skilled Operators Disagree

This is not a question of competence. The operators in this study were qualified, experienced professionals. The variability arises from a fundamental limitation of manual radiographic interpretation: ambiguous visual features are interpreted differently by different people. Two steps in the measurement workflow are particularly susceptible. The first is calibration, establishing the pixel-to-millimeter (or on-film-to-real-world) conversion ratio using a reference object, typically a 25.4 mm steel sphere. In the traditional method, the operator measures the projected sphere diameter with a ruler.

Critically, this variability is not simply an equipment offset that could be corrected by standardizing the display. When the study removed each operator's systematic baseline difference, the operator-specific interaction, which is the pattern of which images each operator found difficult, remained substantial at 37.63% of total variation. Operators do not just disagree by a constant amount; they disagree differently on different images.

The second susceptible step is wall edge identification.

Determining where the inner and outer wall boundaries lie within the blurred transition zone of the radiographic image. This is an inherently subjective judgement call. One operator's "midpoint" is another operator's "slightly inside." The cumulative effect of these two interpretive steps, calibration and edge identification, produces the reproducibility gap observed in the study.

Post-study feedback from one of the operators confirmed these findings. The operator identified three categories of variability in their own traditional calibration measurements: outright measurement mistakes, ambiguous sphere geometry where the measured value depended on which reference points were selected, and unexplained trial-to-trial drift. On the ambiguous geometry, the operator noted:

"Both values are valid based on the selected edges."

This single statement captures the core of the problem. When two equally valid interpretations of the same feature produce different numbers, the measurement system has introduced uncertainty that no amount of operator training can fully eliminate.

### What This Means for the Inspection Vendor

For inspection companies, measurement variability is a reputational and operational risk. If two operators from the same company produce materially different wall thickness reports on the same pipe, the client has reason to question the reliability of the service. Disputes arise, re-inspections are requested, and confidence erodes.

The study quantified this using the Intraclass Correlation Coefficient (ICC), a single metric that captures overall measurement system reliability on a scale from 0 to 1. The digital method achieved an ICC of 0.85, compared with 0.72 for the traditional method. In practical terms, 85% of the variation in digital measurements reflects true differences between pipes, while only 72% does so for traditional methods. The remaining variation is measurement noise. Noise that the inspection vendor's client is paying for but receiving no value from.

A digital measurement platform addresses this directly. Standardizing how calibration is performed and how wall boundaries are identified, it reduces the operator-dependent component of the measurement. The result is that different operators within the same company produce more consistent reports, building client confidence and reducing the cost of rework and dispute resolution.

### What This Means for the Asset Owner

For the plant operator or asset owner, measurement variability translates directly into decision-making uncertainty. The remaining wall thickness is compared against a minimum required thickness, and the difference constitutes the available safety margin. Any measurement uncertainty consumed by the measurement system reduces the effective margin available for engineering judgement. Consider a practical example. A pipe has a true remaining wall thickness of 3.0 mm and the minimum required thickness is 2.0 mm, leaving a safety margin of 1.0 mm. If the measurement system has a precision of 0.5 mm, then measurement uncertainty alone accounts for 50% of the available safety margin. The asset owner is making a run-or-replace decision with only half of the margin they think they have. Reducing the measurement system's variability from 0.5 mm to 0.25 mm effectively doubles the usable safety margin without changing the physical condition of the pipe.

The consequences of this uncertainty flow in both directions. An optimistic measurement may delay necessary maintenance, increasing the risk of in-service failure. A conservative measurement may trigger premature replacement of serviceable pipe, incurring unnecessary capital expenditure and operational downtime. In either case, the asset owner is paying a price for measurement noise that a more reliable system could reduce.

### How Digital Standardization Addresses Both

The MasterAIM digital measurement platform applies software-based measurement tools to digitized conventional radiographic films. Rather than replacing the film acquisition workflow, it replaces the interpretation layer, the calibration and wall edge identification steps, where the majority of operator-dependent variability originates. The study demonstrated that this approach preserves the repeatability of skilled manual interpretation (both methods at ~8-9%) while reducing reproducibility variation by a factor of three (6.07% vs. 19.31%).

Beyond the statistics, a digital measurement environment provides something that manual interpretation fundamentally cannot: a complete, auditable record of how every measurement was made. When a measurement is performed, the digitized image, the calibration parameters, the edge detection results, and the final wall thickness value are all captured and stored together. If a measurement is ever questioned, by a client, a regulator, or a future inspector revisiting the same pipe years later, the entire measurement process can be reconstructed and reviewed.

With traditional manual measurement, the only record is the number written on a report. If that number is disputed, there is no way to determine how the operator arrived at it, where they placed the ruler, how they identified the wall edges, or which part of the calibration sphere they measured. The measurement is a black box. A digital system turns that black box into a transparent, reviewable, and defensible process.

A digital measurement platform also transforms the relationship between the inspection vendor and the asset owner. Traditionally, the asset owner receives a report containing final wall thickness values with no visibility into how those numbers were derived. If the asset owner questions a result or commissions a second opinion, the re-inspection starts from scratch, with a different operator, potentially a different interpretation, and no basis for reconciling the two. When both parties operate on a shared digital platform, the measurement becomes a conversation rather than a handoff. The vendor can present not just the result but the digitized image, the calibration parameters, and the edge detection overlay alongside it. The asset owner or their independent reviewer can open the same file, verify the measurement methodology, and if necessary, re-measure the same image using the same tools. Discrepancies become traceable to specific interpretive decisions rather than opaque disagreements between competing numbers. This shared visibility reduces the adversarial dynamic that often accompanies measurement disputes and creates a collaborative framework for decision-making.

There is a further, often overlooked advantage to this approach. High-quality conventional radiographic film captures spatial detail at a resolution that can exceed that of many digital detector arrays. When these films are digitized at high resolution, the resulting digital image contains information that was always present in the film but was inaccessible to manual interpretation. Subtle density gradients, fine edge profiles, and sub-millimeter features that a ruler on a light box simply cannot resolve. Digital measurement tools can access and analyze this latent information, extracting more from existing films than was previously possible. For the inspection vendor, this means the ability to demonstrate the basis of every reported value, protecting against disputes and supporting quality management systems. For the asset owner, it means confidence that the numbers driving their integrity decisions are traceable, reproducible, and grounded in a standardized methodology rather than individual operator judgement.

### Looking Ahead

*The findings of this study represent a first step in the formal validation of digital measurement tools for conventional radiographic films. While digital radiography continues to gain adoption, conventional film remains a mainstay in most inspection workflows and the existing archive of historical films represents a vast, largely untapped resource. Adopting a digitized interpretation workflow allows operators to extract greater value from these existing assets while integrating conventional data into modern digital pipelines, bridging the gap between legacy practice and the digital future of asset integrity management.*