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Asset Protection
Solutions®

Detecting Corrosion in Online Insulated and Bare Piping Using Automated Radiographic Testing Technology

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We Need Reliable Integrity Information

- ▶ Visual inspection can't identify corrosion or moisture
- ▶ Traditional inspection methods are too slow or costly
- ▶ Spot checking is insufficient
- ▶ Lines are unpiggable



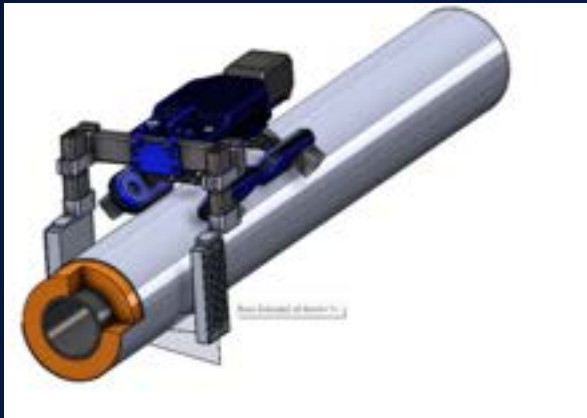


We could...

- ▶ Prevent costly failure
- ▶ Defer repair activity to align with budgeting
- ▶ Prioritize stripping based on severity/region
- ▶ Generate a holistic condition of the asset

ART Crawlers are remotely operated platforms designed to deploy radiation sources with digital imagers to generate radiographic mapping of insulated and non-insulated piping for the rapid detection and qualitative assessment of CUI, moisture and internal corrosion.

CUI Mini single-view



CUI multi-view



CUI 360



Internal Corrosion

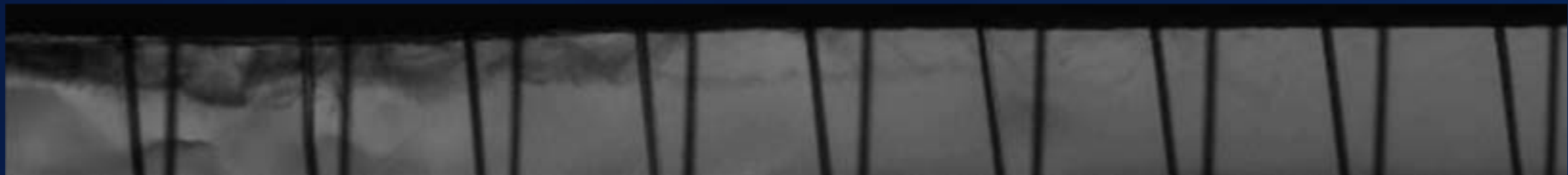
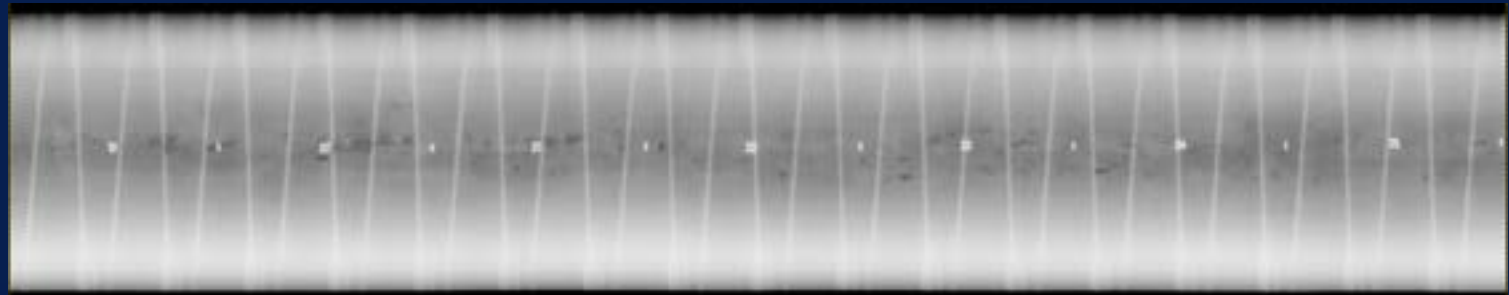


**CUI & Moisture
Detection**

**Internal
Detection**

ART systems rapidly scan piping producing radiographic mapping capable of displaying, locating and categorizing the following:

- ▶ Corrosion Under Insulation (CUI)
- ▶ Moisture ingress and saturation level
- ▶ Insulation damage or voids
- ▶ Geometry under insulation
- ▶ Internal corrosion

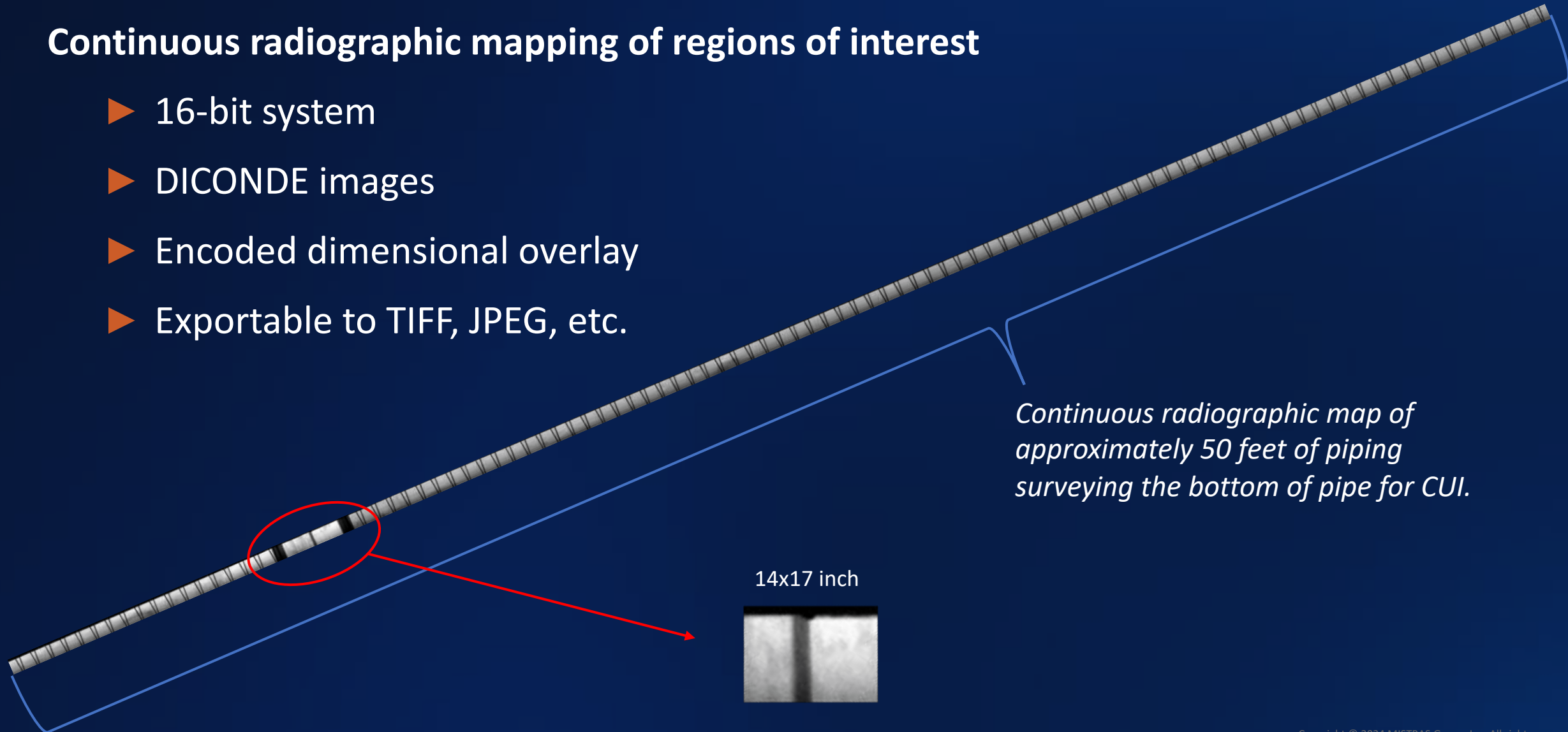


Wireless	Up to 1km line of sight
Power	20-56VDC Lithium-Ion battery
Deployment	Single or multi point deploy & retrieve, Rope Access
Detector	Photon detecting line scanner with Time Delay Summation
Radiation	Collimated X-ray: 50kV up to 225kV
Controls	Remote laptop; Semi-autonomous self balancing
Piping range	CUI 2 to 60-inch OD Internal 2 to 24-inch OD



Continuous radiographic mapping of regions of interest

- ▶ 16-bit system
- ▶ DICONDE images
- ▶ Encoded dimensional overlay
- ▶ Exportable to TIFF, JPEG, etc.



ART systems are capable of detecting moisture as it settles or gets trapped in the insulation.

Moisture in contact with the pipe wall is a good indicator that CUI is likely present or will be present in the near future.

ART Systems can identify, locate, and estimate the height and density of the moisture trapped in insulation.

10.1.1 Moisture Classification – Wetness of Insulation

Moisture shall be classified in accordance with the four classes defined below (or redefined by client; contract specific), as Dry, Light, Medium, or Heavy Moisture:

a. Dry

The area examined is free of indications of moisture in the insulation.



b. Light H₂O

The area examined has damp insulation present, usually at the bottom of the insulation, and ≤ half the distance between the cladding OD and pipe OD surface.



c. Medium H₂O

Moisture is present in the insulation and extends from the insulation cladding OD to over half-way between the cladding and the pipe OD, but not in contact with the pipe OD.



d. Heavy H₂O

Moisture is saturated in the insulation and is in contact with the pipe OD surface.



ART systems are capable of detecting CUI as it produces oxidized material resulting in the reduction of the pipe wall.

This oxidation or corrosion by-product “blooms” away from the pipe wall into the insulation. The more corrosion, the greater the bloom in most cases.

ART programs work with clients to evaluate the correlation between CUI oxidation growth and estimated wall loss.

10.1.2 CUI Classification – Severity of Corrosion

CUI shall be classified in accordance with the four classes defined below (or redefined by client; contract specific), as Light, Medium, Heavy, or Inconclusive:

a. Class 3 – Light CUI

Light corrosion is the starting presence of corrosion byproducts (exfoliation), presented as a thin scale build-up on the OD of the pipe surface, of an approximate thickness of $\leq 0.125"$. This is approximately similar to the height of the external reinforcement (cap) of most girth welds (rule of thumb; dependent on pipe schedule and/or allowable by governing code).



b. Class 2 – Medium CUI

Medium corrosion is a significant buildup of corrosion byproducts (exfoliation) of an approximate thickness greater than $0.125"$, up to the nominal wall thickness of the pipe being examined.



c. Class 1 – Heavy CUI

Heavy Corrosion is a significant buildup of corrosion byproducts (exfoliation) of an approximate thickness that exceeds the nominal wall thickness of the pipe being examined, or of Medium CUI that has a substantial network length (longer in length than the diameter of the pipe being inspected), and/or presenting itself as significant exfoliation (corrosion propagated along intergranular paths parallel to the material surface) sheets connected to or flaking off of the pipe OD into the insulation.



d. Inconclusive

Heavy moisture or ice saturation of insulation with a density that obstructs the ability to detect CUI.



Single Azimuth CUI Detection



Multi-Azimuth CUI Detection

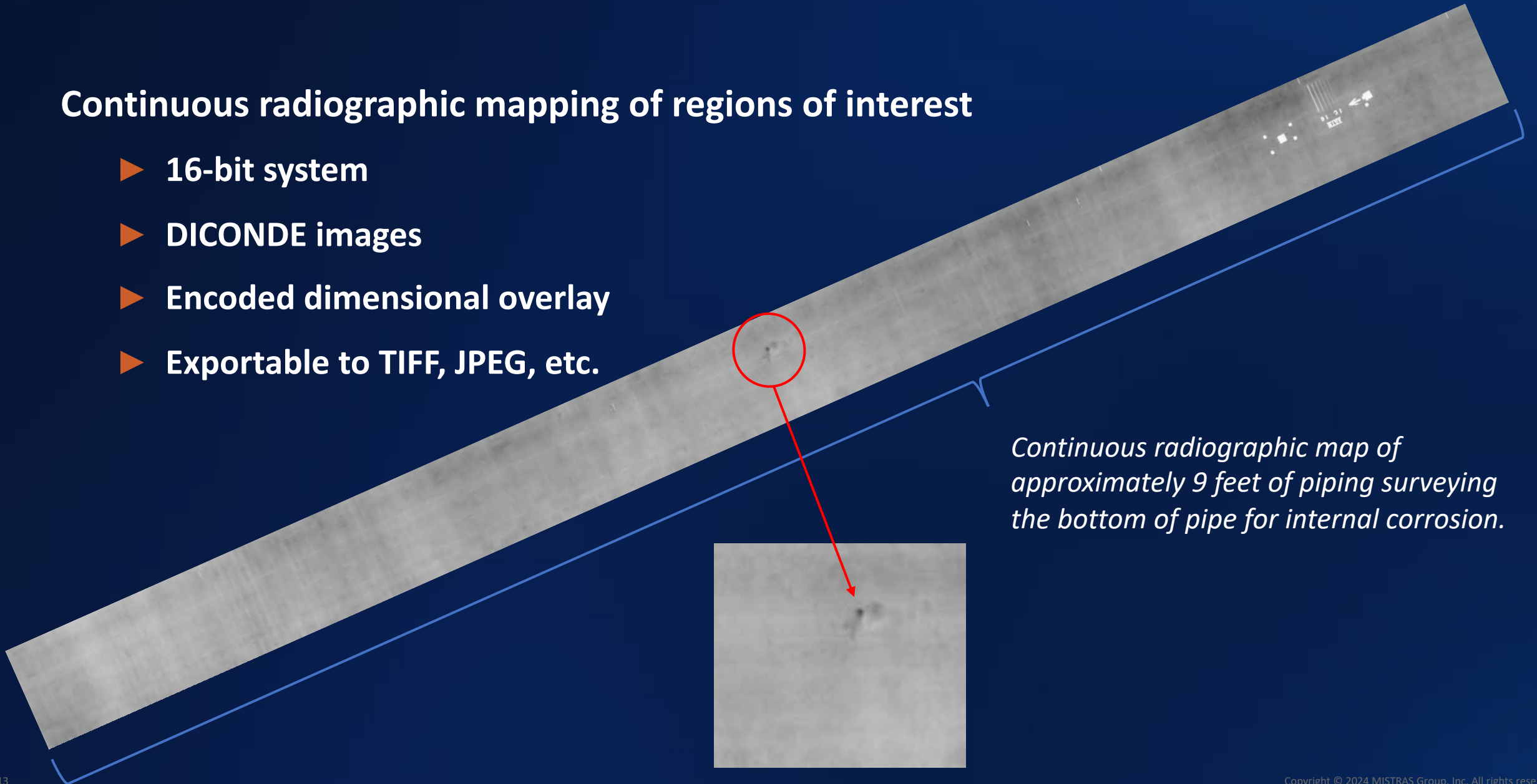


CUI Mini Crawler single view



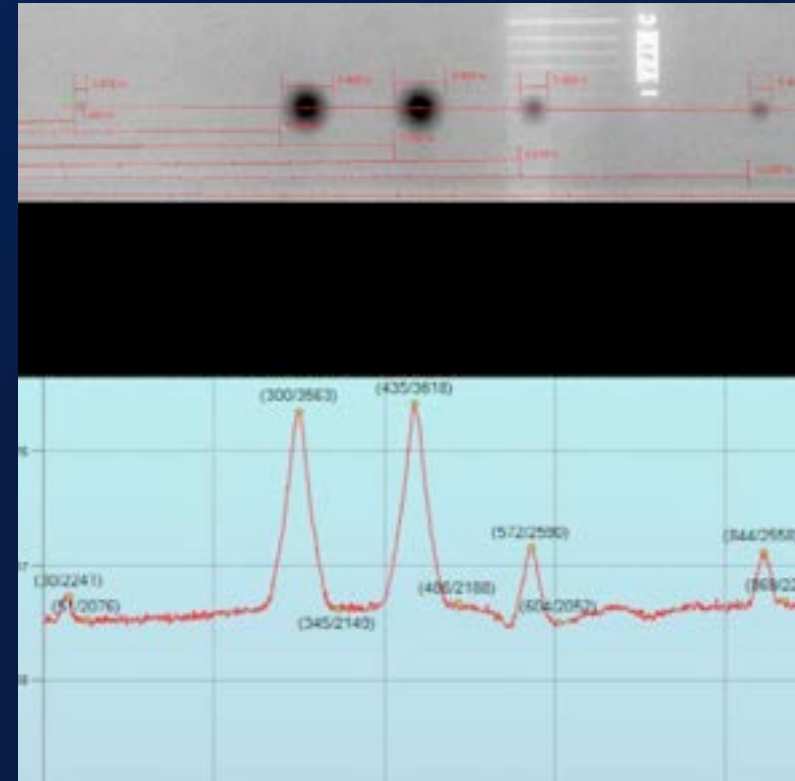
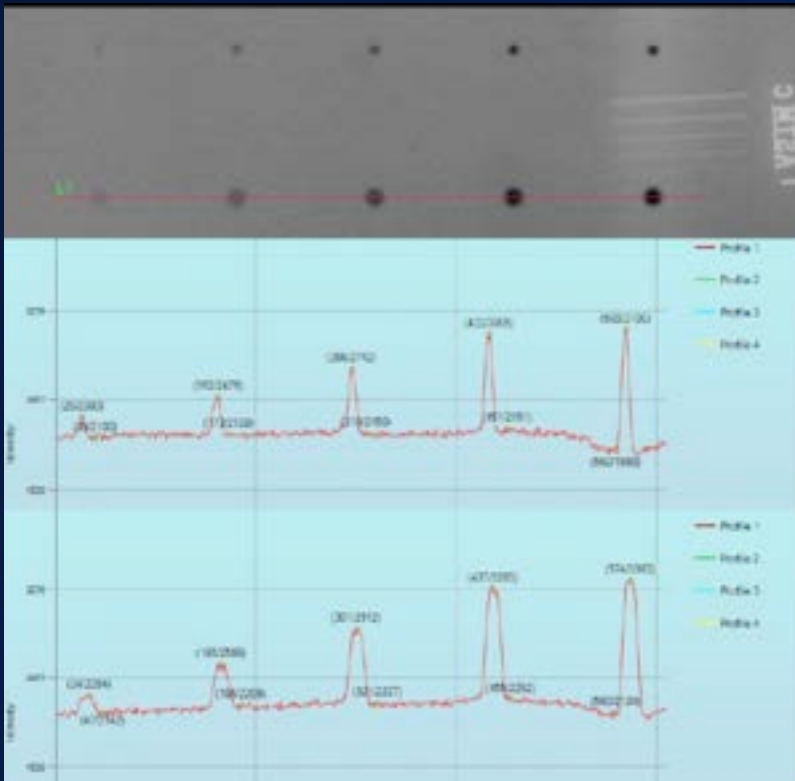
Continuous radiographic mapping of regions of interest

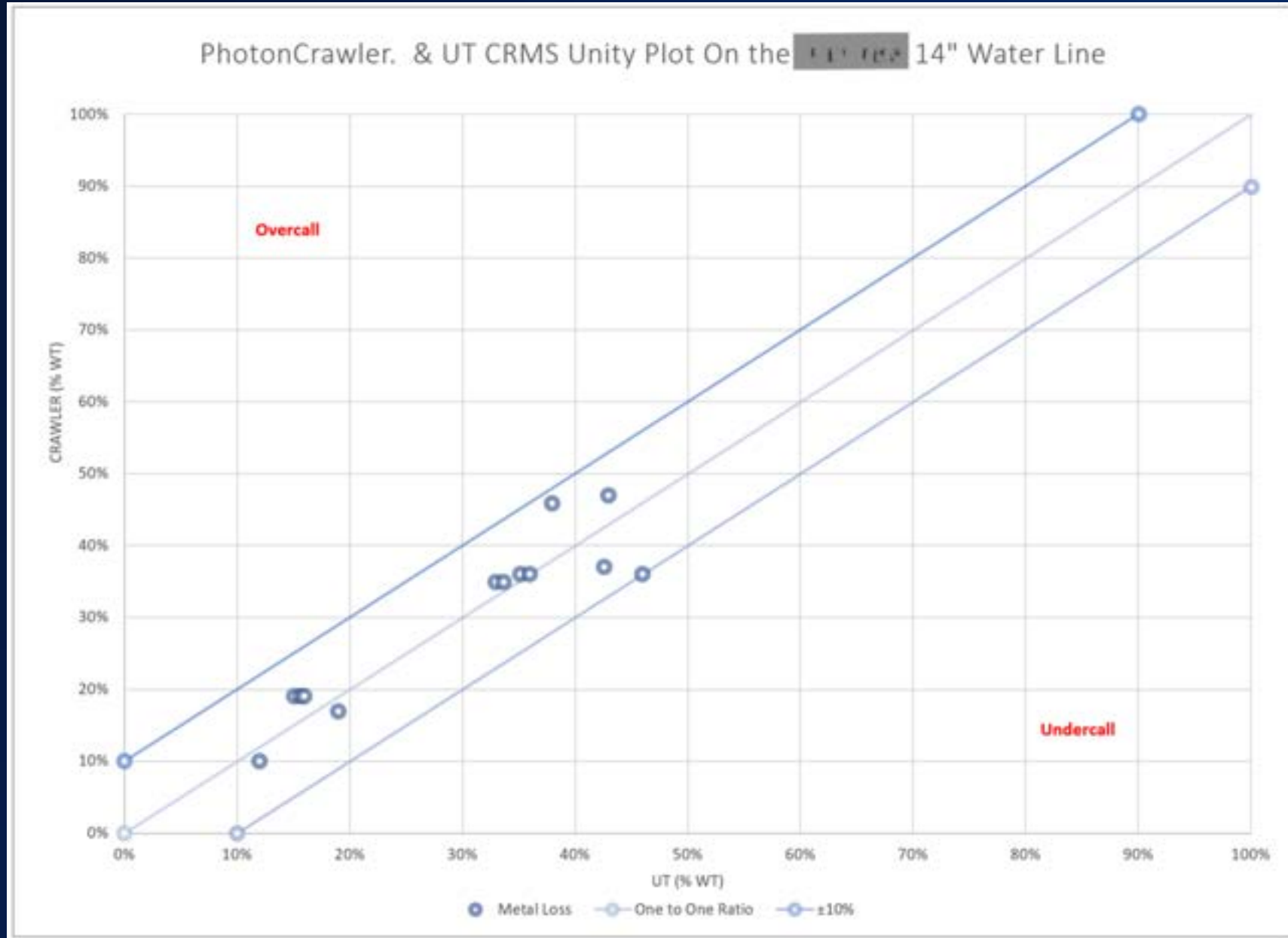
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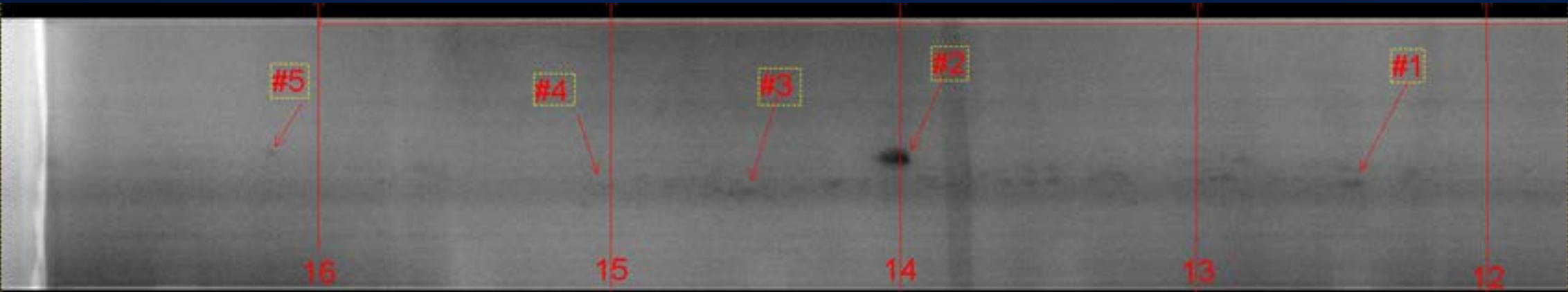
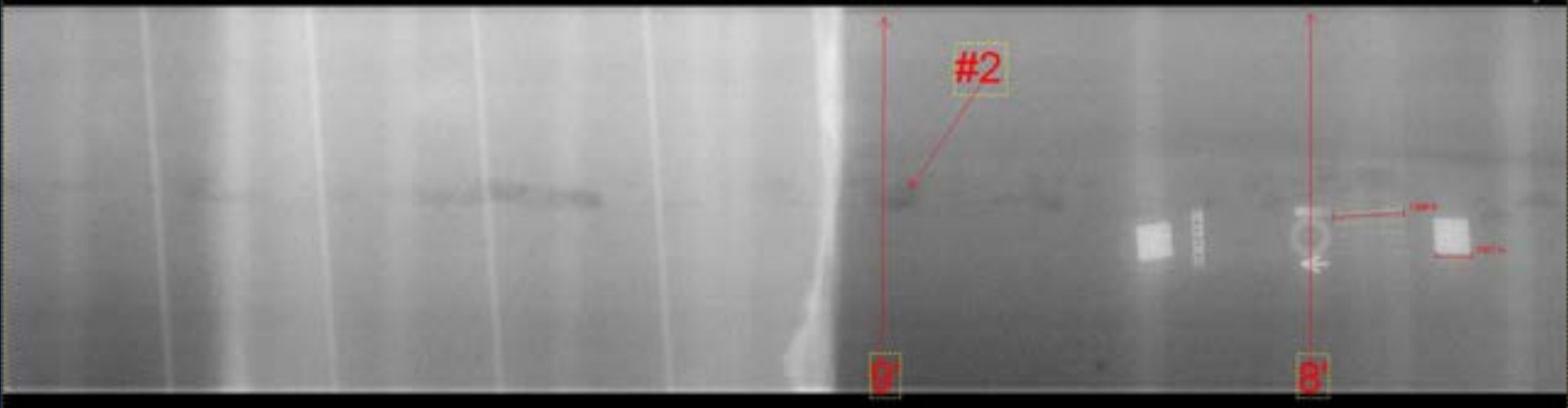


Continuous radiographic map of approximately 9 feet of piping surveying the bottom of pipe for internal corrosion.

The internal corrosion detection system was validated on a series of test spools with wall thicknesses of 6mm to 22mm and reference holes of diameters 3mm and 6mm at depths of 10% to 50% wall thickness. Spool specimens were tested empty, and water filled.







Internal Survey at Pipe Bottom





A recent application of the ART internal corrosion crawler required the crawler to crawl on a 2-inch insulated line directly overhead a 6-inch insulated line while scanning the 6-inch insulated line for internal corrosion.

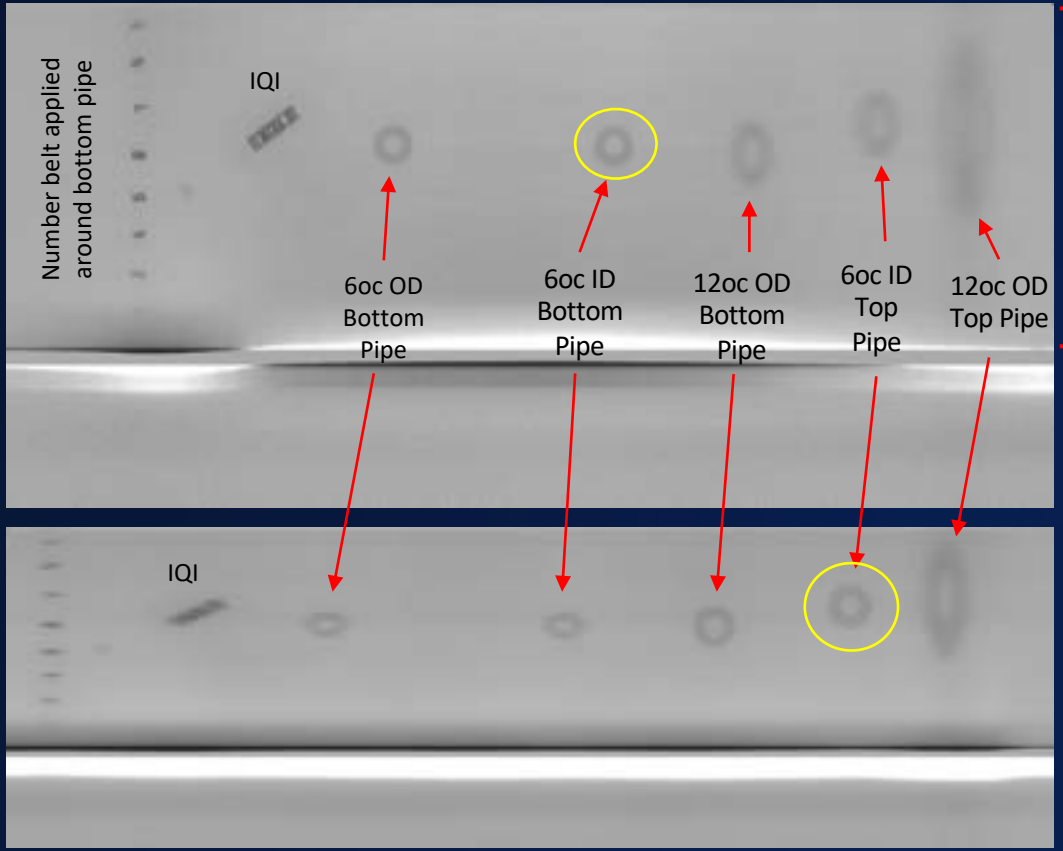




Customer had 3- and 4-line bundles that required full insulation strip to inspect



FOCAL SPOT POSITION CONTROL APPLIED TO BUNDLED LINES



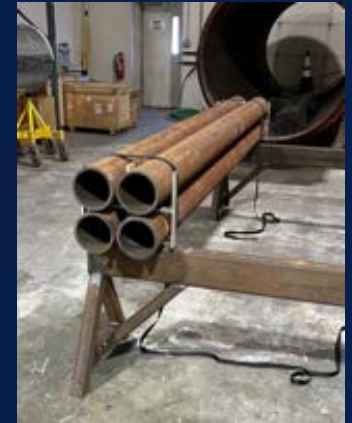
FSC @ 85%
Targeting 6oc
of bottom
pipe

FSC @ 50%
Targeting 6oc
of top pipe

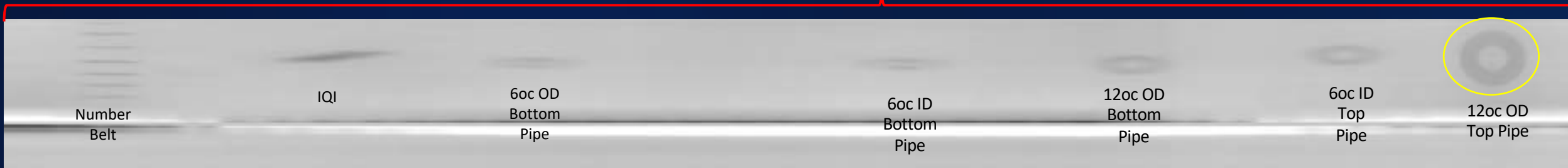
Focal spot positioning was applied to a 4-line bundle to determine if the technique could distinguish between the 6oc region of both pipes as they are stacked one over the other. In addition, the technique was also able to distinguish 12oc indications on the top pipe.

As the focal plane is adjusted all other indications outside of the focused plane will lose sharpness as seen in these images.

The demonstration bundle was uninsulated, empty 6in pipe schedule 80. The addition of insulation or contents will not change the ability to focus the imaging at specific planes.



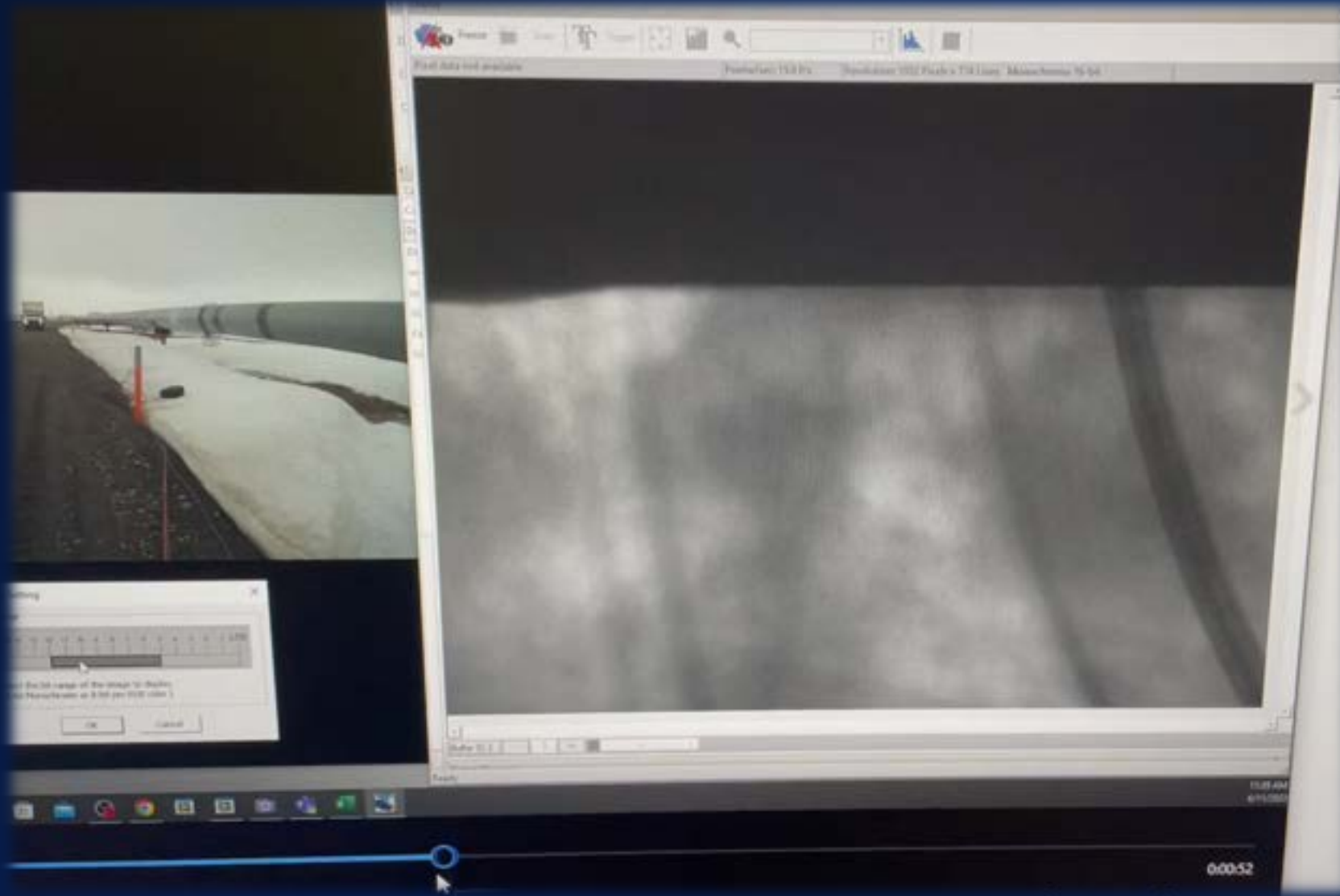
FSC @ 15% Targeting 12oc of top pipe



ART 360-degree CUI scanners capture a true 100% coverage of the outside diameter of a pipe detecting CUI and moisture.



*Time-delay video of 360-degree scanner



ART 360-degree CUI scanner displaying real time digital radiography.

Current ART Technology is limited by the following:

▶ Accessibility

- Crawlers require sufficient space around the pipe to be inspected ranging from 2-in to 14-in

▶ Piping Orientation

- Current ART crawlers do not travel vertically
- Only large diameter long radius elbows can be crawled

▶ Pipe Supports

- Pipe supports may restrict the crawler's movement and require manual adjustment

▶ X-ray Physics

- For online internal corrosion detection the largest diameter successfully inspected to date is 24-in diameter, .875-in wall thickness, filled with water

THE PROJECT(S)

There are hundreds of miles of above-ground insulated piping on the north slope of Alaska, much of which is not piggable. Due to harsh conditions and extreme weather changes these pipelines are extremely susceptible to CUI.

THE SOLUTION

An automated radiographic crawler designed to operate under the harshest conditions targeting CUI and moisture saturated insulation while scanning up to 2,500 feet per shift.

THE EXECUTION

The multi-azimuth CUI crawler in Alaska was specifically designed for the North Slope's oil assets. These crawlers operate yearly in rain, snow, ice, fog and extreme sub-zero temperatures. ART crawlers produce digital radiographic maps of each line segment in a fraction of the time it would take to manually inspect these lines.



THE RESULTS

Established:	2018
Inspected:	>1MM feet
Diameters:	2–60-inch OD



THE PROJECT(S)

A piping facility susceptible to CUI with insulated pipe ranging from 2-inch to 36-inch diameter located at ground-level and overhead. Manual RTR (C-arm) inspection techniques were too slow and lacked consistency and archive-ability.

THE SOLUTION

An automated radiographic crawler capable of deployment across varying diameter lines producing DICOM compliant digital radiographs.

THE EXECUTION

The CUI-mini crawler utilized rope access techniques to accessible horizontal spans. The CUI-mini crawler quickly generated radiographic maps of CUI indications and moisture saturated locations within the insulation. Due to the advanced photon counting imager and low energy X-ray generator impact to the facility and nearby crews was minimal. The CUI-mini crawler successfully reduced man-hours at risk simultaneously providing higher quality data for the customer.



THE RESULTS

Production: 700ft/shift
Inspected: 11,500 feet
Time Savings: 3 weeks
(vs manual)



THE PROJECT(S)

A 60-inch diameter, un-piggable, above ground, insulated, gas line susceptible to CUI in need of comprehensive inspection. Previous owners had never been able to obtain true 360-degree inspection coverage. Line failure would result in complete shut down of the oil field.

THE SOLUTION

An automated radiographic crawler capable of 360-degree coverage remotely controlled from the ground.

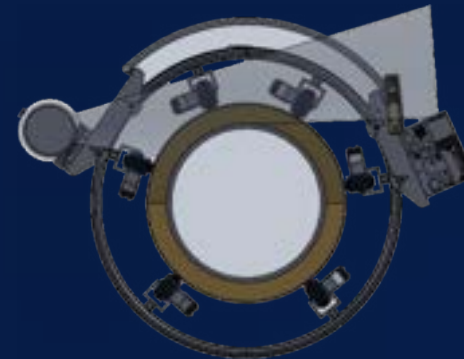
THE EXECUTION

The 360 crawler was designed for the inspection of the 60-inch diameter pipeline. The system included a proprietary 24-inch wide-area real-time CMOS X-ray imager paired with a 225kV X-ray tube controlled remotely from the operator's vehicle. The crawler traveled both circumferentially and axially along the pipe achieving 100% coverage of accessible areas.



THE RESULTS

Duration:	16 months
Line Length:	>12 miles
Inspected:	>1MM sq. ft.
CUI Findings:	1,001



THE PROJECT(S)

A central gathering facility susceptible to CUI with big-bore pipe ranging from 36-inch to 60-inch diameter located up to 65 feet overhead. Manual inspection techniques proved to be too risky, slow and lacked the ability to ensure 100% coverage of outside diameter surfaces.

THE SOLUTION

An automated radiographic crawler capable of 360-degree coverage remotely controlled from the ground.

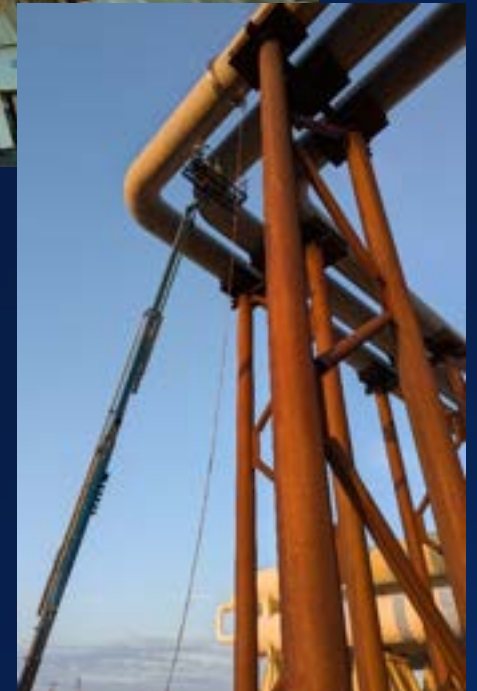
THE EXECUTION

The 360 crawler was deployed safely from manlifts to accessible horizontal spans. Once the deployment crew was safely on the ground the operator activated the crawler interpreting real-time digital radiographic images of the pipe OD detecting CUI and moisture saturation. The crawler traveled both circumferentially and axially along the pipe ensuring 100% coverage of accessible areas.



THE RESULTS

Duration:	53 days
Inspected:	2,616 feet
CUI findings:	19 locations
Moisture findings:	71 locations
Incidents:	0



THE PROJECT(S)

Multiple insulated and un-insulated lines ranging from 4-inch to 22-inch diameter susceptible to internal corrosion. Total inspection campaign of 2,722 feet of piping.

THE SOLUTION

An automated radiographic crawler capable of detecting internal corrosion without insulation removal or requiring line shutdown rapidly producing semi-quantitative (percentage) of wall loss measurements.

THE EXECUTION

The internal corrosion crawler was deployed across all diameter lines. The crawler was capable of rapidly screening all lines for indications of internal corrosion at the 6oc region and provided the customer with an actionable plan for further investigation and mitigation.

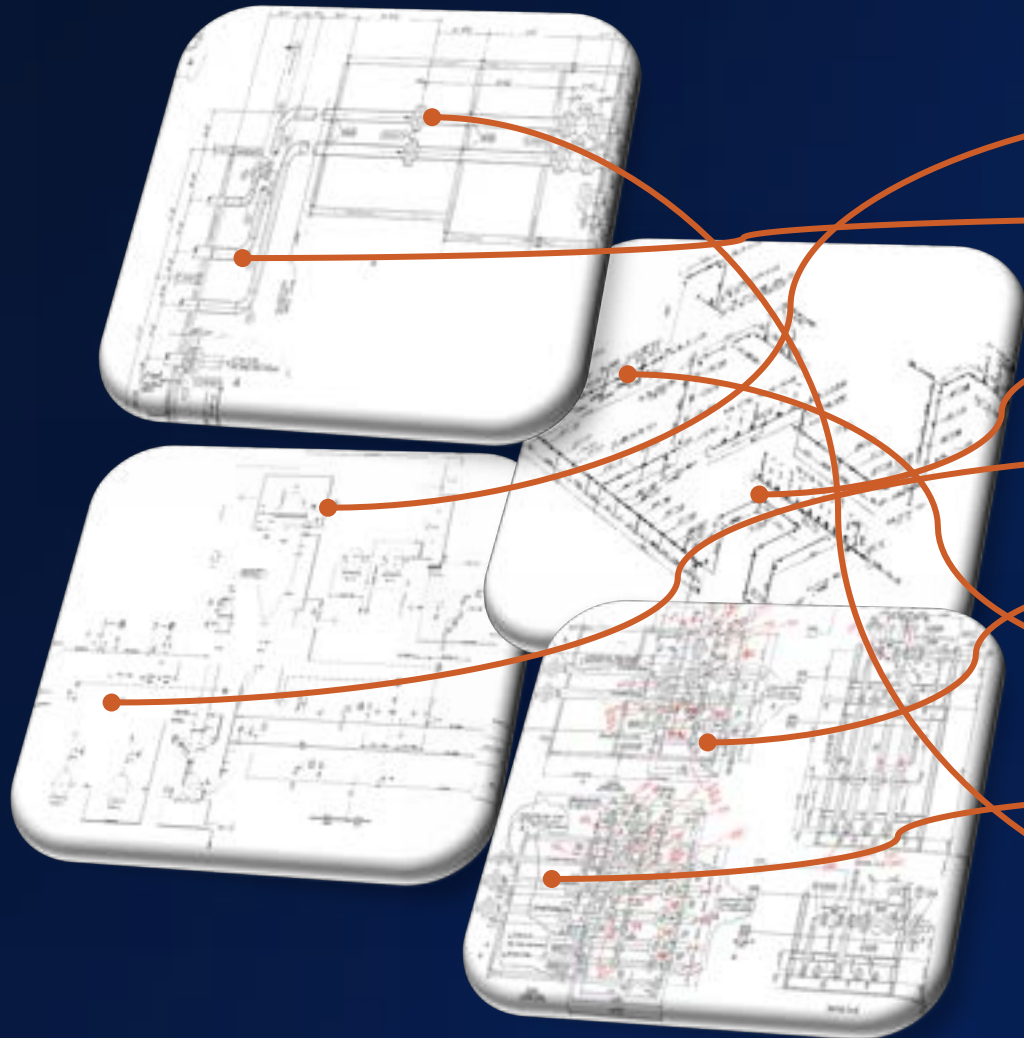


THE RESULTS

Corrosion findings: 338 locations
Maximum finding: 70% wall loss
Efficiency: 3x faster



Assets at risk



ART SCREENING

- 1. Clean
- 2. Moisture
- 3. Corrosion
- 4. Moisture
- 5. Clean
- 6. Corrosion
- 7. Clean
- 8. Moisture

ART GRADING

- 3. L Corrosion
- 6. H Corrosion
- 4. H Moisture
- 8. M Moisture
- 2. L Moisture

STRIP LIST

- 6. H Corrosion
- 3. L Corrosion

Low risk,
schedule
maintenance

Moderate to high
risk, requires
immediate action





QUESTIONS?

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