ASSET INTEGRITY · REFORMER TUBES

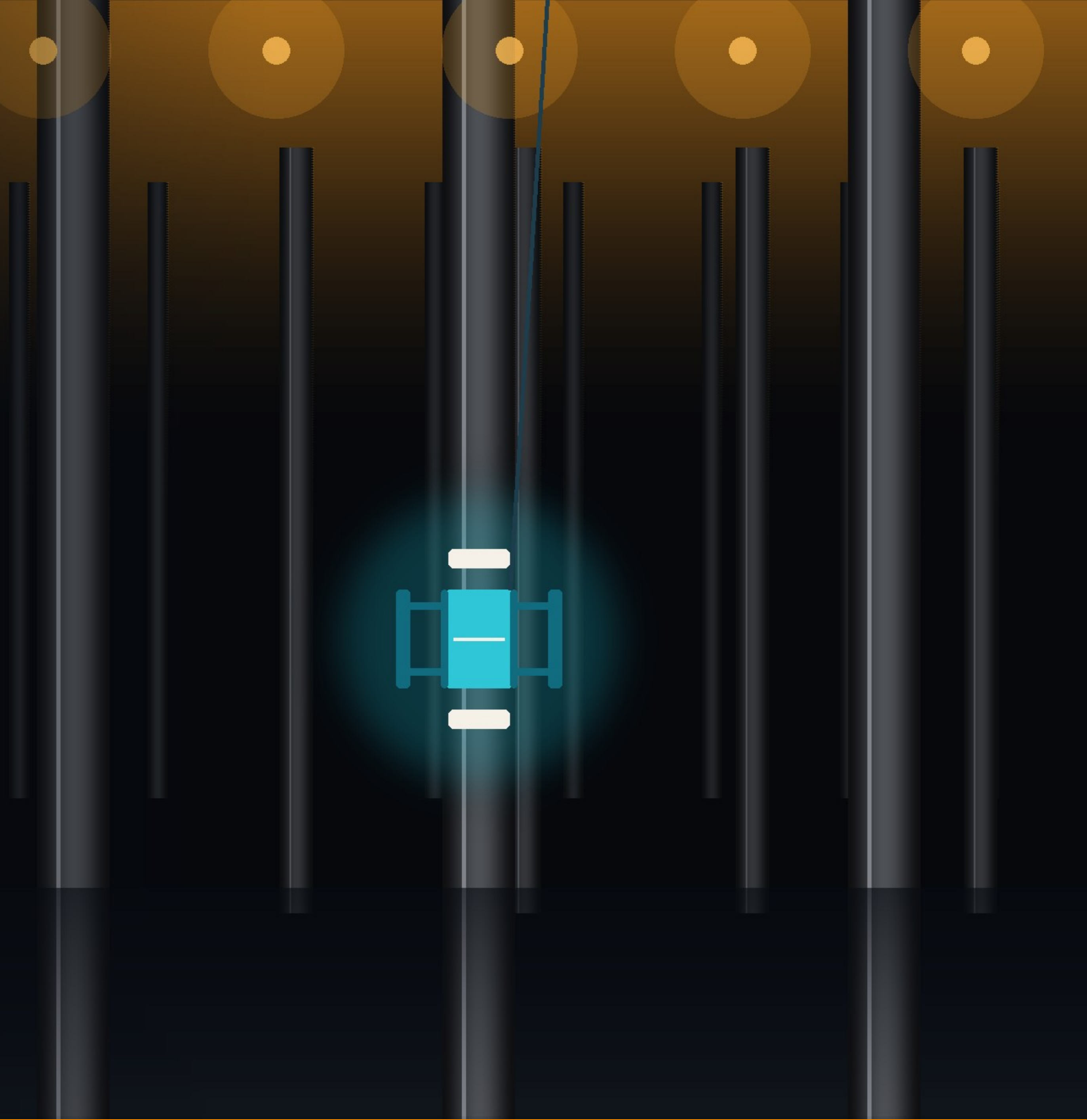
ARTiS

Automated Reformer Tube Inspection System

Condition assessment, Fitness-for-Service and Remaining Life Assessment to API 579-1 / ASME FFS-1, Level 3. One robotic crawler, four measurements, a retirement date for every tube.

100+ reformer assignments · 50,000+ tubes scanned · 7 countries

Transparency. Competence. Reliability.



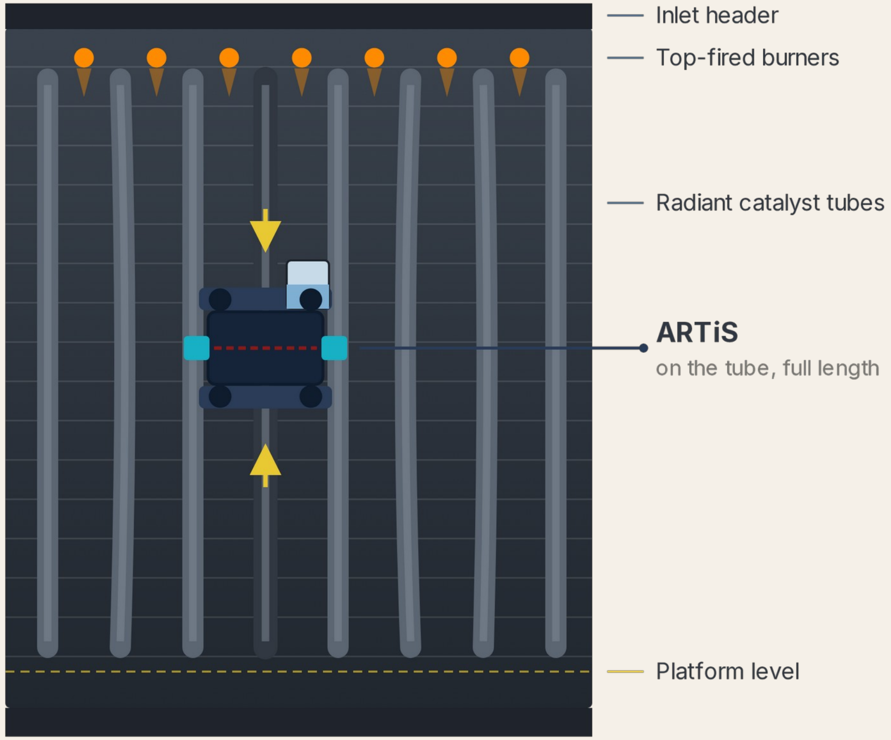
THE QUESTION THAT GOVERNS THE SHUTDOWN

An inspection that tells you a tube is damaged has answered the easy question. ARTiS answers the one that governs the shutdown: when does this tube come out?

Condition assessment, Fitness-for-Service and Remaining Life Assessment to API 579-1 / ASME FFS-1, Level 3. One robotic crawler, four measurements, a retirement date for every tube.

WHERE THE TUBES SIT, AND WHY ACCESS IS THE PROBLEM

- Primary reformer tubes crack hydrocarbons over a nickel catalyst above 800 °C under internal pressure. Creep is not a failure mode that waits: an overshoot of 10 to 20 °C in tube metal temperature roughly halves tube life.
- Damage appears first as diametral growth of 1 to 6 percent, then as creep voids at mid-wall, then aligned voids, mid-wall fissures and bowing. By the time a tube is visibly distressed the decision window has already closed.
- Tube lengths run to about 15 m. Manual scanning means scaffolding, and scaffolding is the first thing cut when a turnaround runs late. ARTiS clamps on at platform level and climbs the tube it inspects.



Radiant box, up to 15 m tube height

ASSET INTEGRITY · REFORMER TUBES

REFORMER TUBE LIFE IS NOT FORGIVING

100,000 h

Design life of a reformer tube, about 11.5 years

200,000 h

Achieved on the same tubes with operational control and periodic inspection, about 23 years

10-20 °C

Tube metal temperature overshoot that roughly halves tube life

0.8

Life fraction at which ARTiS sets the retirement date

Rising throughput shortens reaction time and pushes furnace temperature up. Reformer tube inspection is now one of the most focused activities in a turnaround.

Source: Haribhakti P. and Upadhyaya K., “Optimising Tube Life”, World Fertilizer, January/February 2019, pp. 53-56.

TUBE LIFE IS SET BY OPERATION, NOT METALLURGY

Reformer tubes are designed for 100,000 hours, about 11.5 years. Plants that operate within the envelope and inspect on a cycle have run the same tubes past 200,000 hours, about 23 years. The gap between those two numbers is operational control.

Every tube runs at the edge of its creep limit

At roughly 900 °C and 25 to 30 barg there is minimal margin for error. Minor process variation, nominal or local, raises skin temperature and cuts creep life.

Measured tube metal temperature is not reliable

Optical pyrometers work on emissivity. A new rough tube reads near 0.9; oxidation smooths the surface and emissivity falls towards 0.6. The reformer is then being run on a temperature that is wrong.

Catalyst condition moves the temperature

A catalyst changeover alone gives an 8 to 10 °C reduction. Friable catalyst chokes the gas path, raises skin temperature and shows up as inlet-to-outlet pressure difference.

Start-up and shutdown are where damage accumulates

Over-firing risk peaks during start-up and transients. Excessive cooldown rate induces thermal shock and uneven contraction, which is what bows a tube.

ARTiS does not ask what temperature the pyrometer read. It back-calculates the effective tube metal temperature that produced the damage actually present, then projects forward from that.

SIX MECHANISMS ONE TECHNIQUE CANNOT SEPARATE

Creep damage

Continuous exposure above the creep threshold. Voids initiate mid-wall, align, and link into fissures. Reflected as diameter growth.

Metallurgical degradation

Carbide coarsening and secondary carbide dissolution between 700 and 1000 °C. Creep rupture strength falls even where no crack exists.

Localised overheating and thermal shock

Burner misalignment, flame impingement, catalyst channelling, trip and restart transients. Abrupt, and not predictable from creep data alone.

External oxidation, or baldness

The protective chromia layer on 25Cr-35Ni spalls under thermal cycling. Effective wall is lost while OD appears to fall, masking true creep strain.

Bowing and wedging

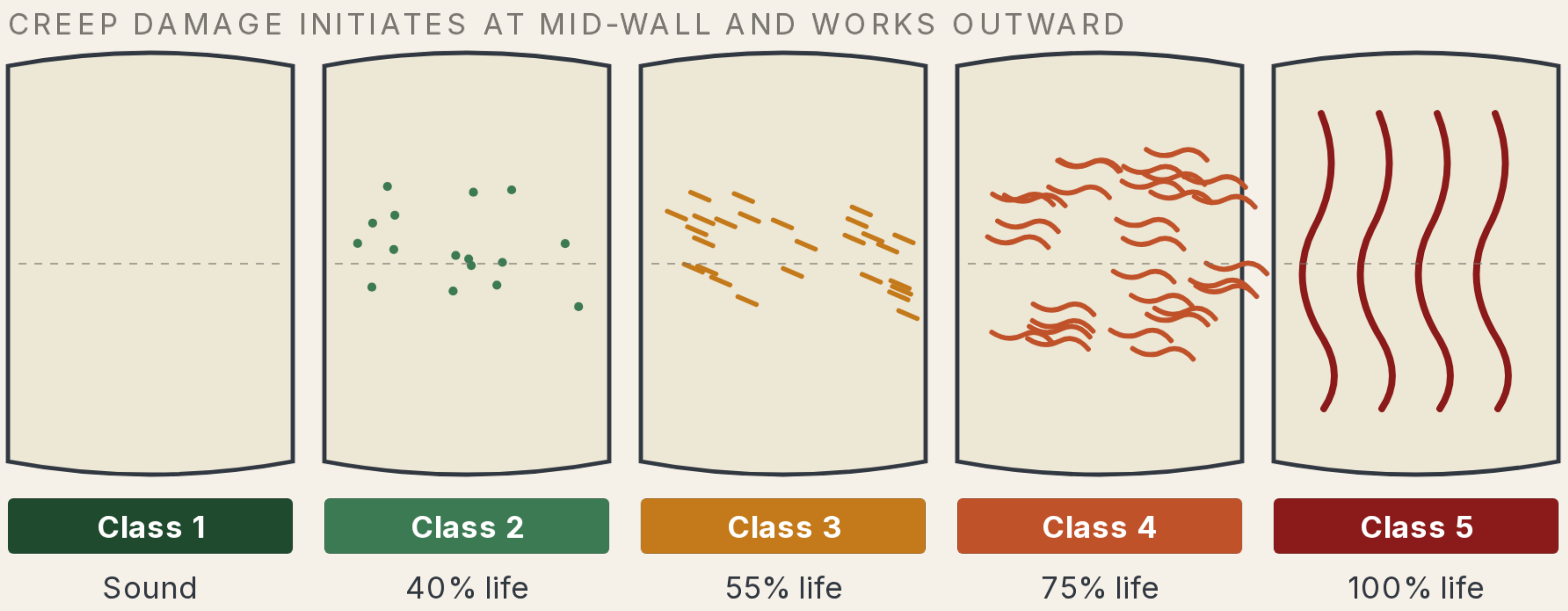
Thermal cycling, uneven firing, damaged supports. OISD accepts bowing to 1.5 x OD provided adjacent tubes are not wedged.

Catalyst deterioration

Nickel pellets attrit and channel the gas path, producing hot bands, tiger tailing and giraffe necking, and local temperature rise.

Damage mechanisms and their correlation with operation after Haribhakti and Upadhyaya, World Fertilizer, Jan/Feb 2019.

HOW CREEP DAMAGE ADVANCES THROUGH THE WALL

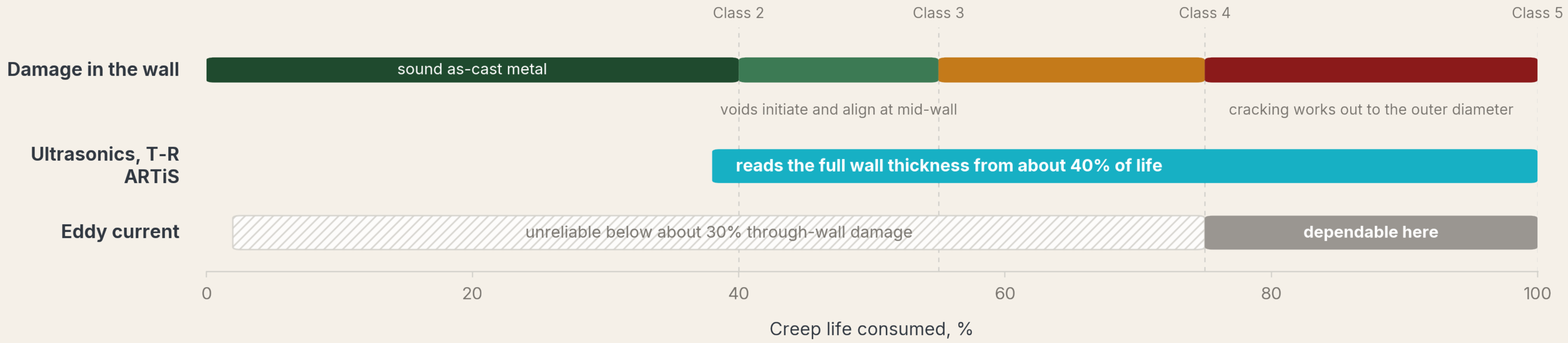


Damage initiates at mid-wall. By the time cracking reaches the outer wall, where a surface method could find it, roughly three quarters of tube life is already spent.

THE QUESTION WE ARE ASKED MOST OFTEN

WHY ULTRASONICS AND NOT EDDY CURRENT

WHEN EACH TECHNIQUE FIRST HAS SOMETHING TO REPORT



Class boundaries per the TCR reformer-tube severity classification. Eddy current limit reported in NACE Paper 07427.

Both techniques will find a tube that is about to fail. Only one of them finds it while there is still procurement lead time to replace it.

UT AGAINST ECT, CRITERION BY CRITERION

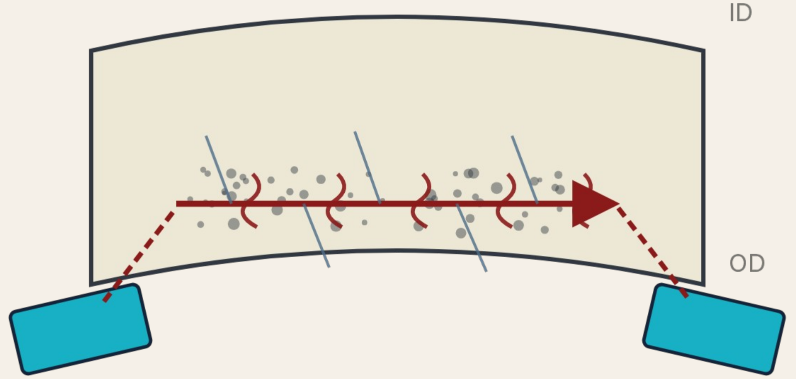
Criterion	Transmit-receive ultrasonics · ARTiS	Eddy current
Depth of interrogation	Penetrates the full wall of a thick centrifugally cast tube; the mid-wall is where creep starts.	Surface and near-surface. Penetration depth falls as conductivity and permeability change in service.
Response to creep damage	Attenuation in dB tracks carbide coarsening, void formation and fissure linkage. A graded reading, not a yes or no.	Responds to a discontinuity once it exists. No graded measure of microstructural degradation.
ID and OD cracking	Detects cracking from either surface, and mid-wall fissures, before either breaks out.	Struggles with deep internal cracking in aged tubes; reported unreliable below 30% through wall.
What disturbs the signal	Grain macrostructure and alloy family, both known and held in the reference base.	Conductivity shift with metallurgical change, permeability shift with Cr migration and oxide scale, probe lift-off on rough or welded surfaces.
Pairing with the RLA calculation	Same crawler pass also logs OD every 100 mm and quantified bowing; all three feed one remaining-life model.	No dimensional output. Creep strain and bowing must be collected separately.

Eddy current limitation below 30% through-wall damage reported in NACE Paper 07427.

TRANSMIT-RECEIVE ULTRASONICS: READING THE MID-WALL

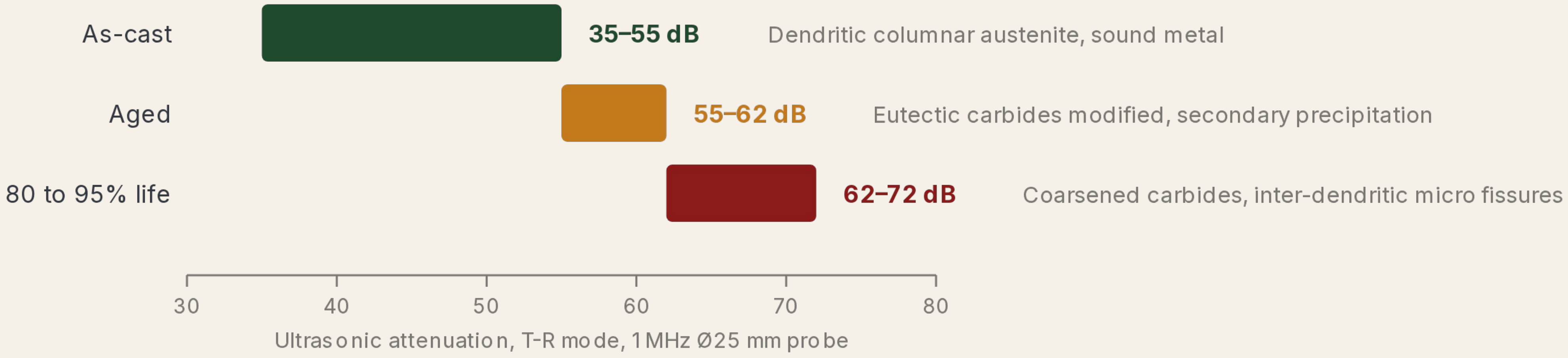
- Ultrasonic inspection runs in transmit-receive mode. Energy enters the wall at one probe, travels through mid-wall, and is received at the other. What arrives is what was sent minus what scattered.

- In as-cast metal the beam scatters at dendrite boundaries and primary carbides. With service exposure, secondary carbide precipitation adds to the scatter. With creep, voids add more; once voids align into mid-wall fissures, transmission is blocked and attenuation rises sharply.



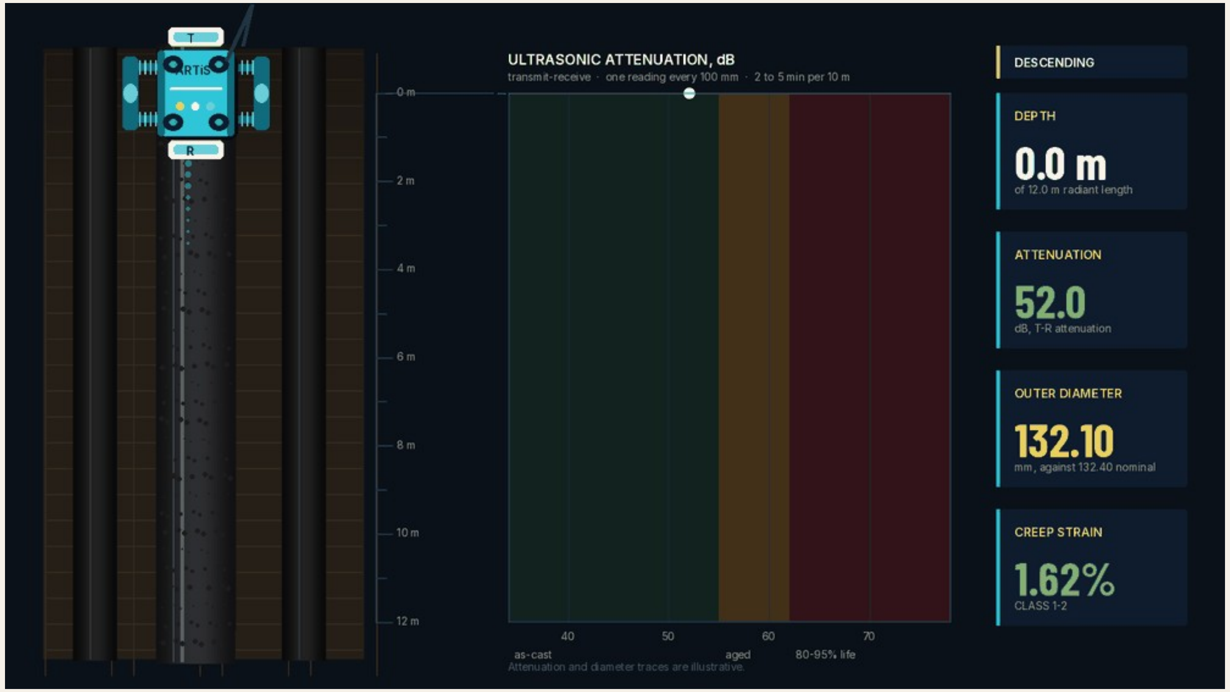
WHAT THE DECIBEL VALUE IS READ AGAINST

MICROSTRUCTURAL DEGRADATION READ AS ATTENUATION



The reference base is built from catalogued microstructure locations and a set of standard samples with known damage. It is what turns a decibel reading into a judgement.

THE CRAWLER ON THE TUBE



- Four metal gear motors, 200 W total, clamped by spring-locked arms
- Rubber padded shoes carry the transmit-receive probes, coupled with demineralised water
- Infrared sensors read outer diameter on the move; gyroscopic sensors record angle for bowing
- One reading every 100 mm over the full radiant length, descending and returning

Animated in slideshow mode. Attenuation and diameter traces are illustrative.

ONE MINUTE OF FIELD FOOTAGE

SEE IT RUNNING, ON A LIVE REFORMER TUBE

Play the clip: https://youtu.be/Gb_S5dd-th4

FOUR MEASUREMENTS, ONE PLATFORM, ONE PASS

Ultrasonic attenuation

Creep voids and mid-wall fissures, T-R mode

35 to 72 dB · 0.1 dB resolution

Outer diameter

Creep strain along the whole tube

every 100 mm · 0.5% of OD

ARTiS

Tube bowing

Gyro-measured, quantified not eyeballed

5 to 200 mm · digital output

Effective tube metal temperature

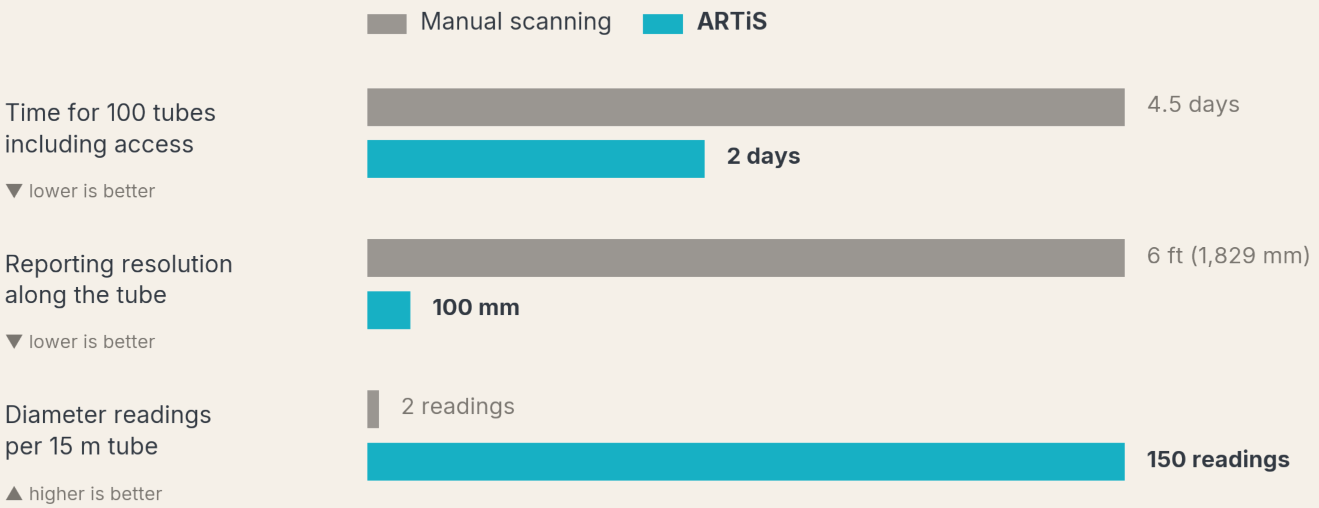
T-Eff back-calculated, then remaining life

API 579-1 / ASME FFS-1 Level 3

TECHNICAL SPECIFICATION

Tube OD range	105 to 190 mm	**Bowing sensing**	Gyro, 5 mm min
Scan speed	2 to 5 min / 10 m	**UT probe**	Ø25 mm, 1 MHz, T-R
Scan resolution	100 mm	**Range / resolution**	30 to 100 dB / 0.1 dB
Fixing time	3 min per tube	**Drive**	4 gear motors, 200 W
Climbing height	15,000 mm max	**Couplant**	500 ml DM water / 10 m
Diameter sensing	IR, 0.5% of OD	**Operating range**	10 to 40 °C, 20 to 80% RH

AGAINST MANUAL SCANNING



NOT QUANTITIES, SO NO BAR

Tube bowing	Apparent by eye, not recorded	**Gyro-measured, 5 to 200 mm, logged**
Access	Scaffolding required	**None: the crawler climbs the tube it inspects**

Both bars in a row share one scale and are true proportions of each other. Source: TCR ARTiS field records.

2 days

for 100 tubes

against 4 to 5 days manual, including access

100 mm

reporting resolution

against 6 ft segments manual

None

scaffolding required

the crawler climbs the tube it inspects

FROM RAW SCAN TO A DATE IN THE TURNAROUND PLAN

- **01 Scan** — OD, thickness, dB, bowing
- **02 Creep strain** — per tube, against nominal ID
- **03 T-Eff** — Larson-Miller back-calculation
- **04 Accumulated damage** — T-Eff against hoop stress
- **05 Retirement date** — the 0.8 life fraction

API 579-1 / ASME FFS-1 Level 1 passes below a damage fraction of 0.25. Where it does not, ARTiS carries the assessment to Level 3 rather than stopping at a pass or a fail.

DAMAGE CLASSIFICATION, AND THE ACTION IT CALLS FOR

Class	Condition	Life consumed	Action
1	As-cast, sound material	—	Continue in service
2	Creep voids at the inner wall	40%	Continue; re-assess next inspection
3	Aligned voids and cracking, inner to mid-wall	55%	Increase monitoring
4	Creep cracking, mid-wall to outer wall	75%	Plan replacement
5	Macro-cracking through 75% or more of wall	100%	Replace immediately

WHAT TCR DOES ON SITE, AND WHAT YOU RECEIVE

WHAT HAPPENS ON SITE

- Visual inspection by an experienced metallurgist: general appearance, bulging, baldness, sagging and bowing
- Outer diameter along the full tube by on-board infrared sensors, at 100 mm intervals
- Bowing by on-board gyroscopic sensors, quantified rather than estimated
- Ultrasonic attenuation in dB for creep fissure detection, by automated crawler
- In-situ metallography by surface replication to establish microstructural degradation
- Hardness measurement at each metallography location
- Manual ultrasonic wall thickness of every tube at platform level
- Manual outer diameter of every tube at platform level
- Magnetic permeability of every tube at platform level, for internal carburisation

WHAT IS DELIVERED

01 Level 3 assessment to API 579-1 / ASME FFS-1, Part 10

02 Accumulated creep damage per tube as at the date of inspection

03 Effective tube metal temperature (T-Eff) calculated for each tube

04 Theoretical accumulated damage projected to the next shutdown

05 The date at which accumulated creep damage exceeds the 0.8 life fraction

06 Remaining life, tube by tube, with a sensitivity case at a second temperature

WHERE ARTiS IS DEPLOYED

Refineries

Hydrogen units serving hydrotreating and hydrocracking; steam methane reformer catalyst tubes and outlet systems.

Petrochemical complexes

Steam and auto-thermal reformers upstream of syngas, olefins and derivative units.

Ammonia and fertiliser

Primary reformer catalyst tubes, the largest installed population and the most inspection-critical.

Methanol and merchant hydrogen

Reforming trains where furnace throughput is pushed above rated capacity.

Industrial gases

On-site and over-the-fence hydrogen generation with packaged reformers.

Tube materials assessed

HP modified micro-alloyed grades, G4852 Micro, KHR35CT, HP39W, IN519, HK40 and proprietary alloys such as Manaurite XM.

Deployed across India, the Gulf, Southeast Asia and East Asia. Attenuation behaviour differs between alloy families, so the reference base is read per material, not per reading.

ASSET INTEGRITY · REFORMER TUBES

THE RECORD BEHIND THE READING

53

years of materials testing, since 1973

100+

reformer tube assignments, 80+ of them using ARTiS

50,000+

reformer tubes scanned, cumulative

100,000+

in-situ replica microstructures in the reference base

9,000+

failure investigations across the group

7

countries of operation across India, GCC and Asia

PUBLISHED RECORD

Haribhakti P. and Upadhyaya K., "Optimising Tube Life", World Fertilizer, January/February 2019, pp. 53-56 · Accreditation: NABL TC-6739 (TCR Advanced) and NABL TC-6905 (TCR Engineering), ISO/IEC 17025:2017, accepted under the ILAC MRA

Talk to us

If your next turnaround is being planned, the time to talk is now: tube procurement lead time is the constraint, not the inspection.

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