DELTA TEST
MIDDLE EAST

TUBE INSPECTION METHODS

FSEC · RFT · MFT · IRIS | Air-Cooled Heat Exchangers (ACHE)

Technical Reference Leaflet
Rev. 1 | API 510 / API 661 / ASTM E2884

Overview

Air-cooled heat exchangers (ACHEs) use carbon steel or low-alloy steel tubes with external aluminium or steel fins. This geometry creates a unique inspection challenge: external methods requiring surface contact (MFT) are physically blocked by the fins, while internal methods must handle ferromagnetic material with variable permeability. This leaflet compares the three primary NDT methods — **FSEC**, **RFT** and **MFT** — and positions **IRIS** as the complementary verification tool for selected tubes.

Method Comparison

Parameter	FSEC	RFT	MFT	IRIS
Principle	DC Bias + AC eddy current Impedance analysis	Remote field Double wall transit	DC saturation Flux leakage (Hall)	Rotating UT mirror TOF wall measurement
Role	Primary screening 100% tube coverage	Alternative screening Limited applicability	Not applicable Fins block magnet contact	Verification / FFS Selected tubes only
Fin compatibility	No influence Fully internal sensor	Signal shift possible Al fins alter phase	Not possible Magnet contact blocked	No influence Fully internal sensor
Inspection speed	0.5 – 1.0 m/s ~30–60 s / 30 m tube	0.05 – 0.3 m/s ~3–10 min / 30 m tube	N/A	0.02 – 0.05 m/s ~10–25 min / 30 m tube
Wall thickness	Relative (% loss) Referenced to calibration std.	Relative (% loss) Phase vs. reference	N/A	Absolute (mm) ± 0.1 mm resolution
Ferromagnetic tube	Excellent DC bias eliminates μr noise	Good Low freq. overcomes μr	Requires saturation External contact needed	Excellent Material-independent TOF
Coupling / medium	Dry – no water required Air coupling, any condition	Dry – no water required	N/A	Water-filled tube required < 5 NTU turbidity
Optimum WT range	1.5 – 6 mm Ideal for typical ACHEs	2 – 8 mm Thin wall: sensitivity drop	3 – 12 mm Thin wall: unsuitable	Any wall thickness Frequency-independent
Key standards	ASTM E2884 API 510, API RP 585, API 661	ASTM E2096 API 510	ASTM E570	ASTM E2929 API 510, API 579 (FFS)

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Parameter	FSEC	RFT	MFT	IRIS
Air cooler suitability	**Recommended** First choice for CS/LA steel	**Restricted** Speed & fin signal issues	**Not suitable** Fin geometry incompatible	**Verification only** 5–15 % of tubes post-FSEC

Why FSEC Is the Preferred Method for ACHEs

1 Fin Geometry Is Not a Constraint

FSEC probes operate entirely inside the tube. Fins on the OD are invisible to the measurement process. Neither the DC bias coil nor the AC sensing coil has any interaction with external fin material, provided that fin-root corrosion on the OD is correctly represented in the calibration standard.

2 Ferromagnetic Material — Permeability Noise Eliminated

Carbon steel has a relative permeability μ_r of 100–1,000, depending on cold working, weld zones and thermal history. Conventional eddy current is swamped by permeability noise. FSEC applies a DC bias field sufficient to drive the tube into magnetic saturation (typically 0.5–2 T flux density). At saturation, the differential permeability $\mu_{diff} \approx 1$, so the superimposed AC field behaves as if the material were paramagnetic. Skin depth $\delta = \sqrt{2/\omega\mu\sigma}$ becomes stable and predictable, enabling reliable phase-based signal analysis.

3 Inspection Speed Enables Full Bundle Coverage

At 0.5–1.0 m/s, a typical 400-tube bundle (30 m tubes) can be screened in 6–8 hours including set-up. RFT at 0.05–0.3 m/s requires 50–130 hours for the same bundle — economically incompatible with a 48–72 h turnaround window. MFT is physically excluded by the fin geometry.

4 Optimum Wall Thickness Range

Typical ACHE tube wall thicknesses are 1.8–3.2 mm (API 661 / TEMA R). FSEC frequency is tuned to set skin depth $\delta \approx 1.2$–$1.5 \times$ nominal wall, achieving the best balance of full-wall penetration and phase resolution between ID and OD defects. RFT suffers reduced phase discrimination at thin walls due to the exponential double-transit attenuation $e^{(-2d/\delta)}$.

IRIS — Quantitative Verification for Selected Tubes

IRIS (Internal Rotary Inspection System) is not a screening method. It is a **metrological verification tool** used on a small subset of tubes (typically 5–15%) identified by FSEC screening. Its principal advantage over FSEC and RFT is that it measures wall thickness in **absolute millimetres**, independent of a reference calibration standard.

Physical Principle

A focused ultrasonic beam is deflected 90° by a rotating mirror (3–15 rev/s). The time-of-flight between the ID echo and the OD echo is converted to wall thickness using the known longitudinal wave velocity in steel (c ≈ 5920 m/s). The helicoidal scan produces a C-Scan image with 1–2 mm trace spacing, providing both axial and circumferential defect geometry.

$$\textit{Wall thickness} = \Delta t(ID \rightarrow OD) / 2 \times c\_steel$$

IRIS Selection Criteria

Selection criterion	Rationale
WT loss ≥ 20–25%	FSEC flag exceeds acceptance level per API 510; IRIS provides absolute value for RSF per API 579
Ambiguous phase signal	Overlapping ID/OD defects at same axial position cannot be resolved by FSEC phase alone; IRIS C-Scan separates spatially
Pitting cluster	Isolated deep pits require exact depth for pressure-retaining calculation
Weld / roll transition	FSEC calibration less reliable at dissimilar material zones; IRIS measures TOF material-independently
Pre-plugging confirmation	Irreversible action requires absolute WT datum; IRIS is the normative basis for plugging decisions

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Recommended Inspection Workflow

1	**FSEC 100% Screening** All tubes scanned at 0.5–1.0 m/s · Indicator list generated (amplitude + phase)
2	**Indicator Triage** Apply acceptance threshold (typically ≥ 20–25% WT loss) · Flag ambiguous phase signals
3	**IRIS Verification** Selected tubes filled and flushed · Rotating UT scan, C-Scan recorded
4	**FFS Assessment** Absolute WT from IRIS → API 579 RSF calculation · Plugging / repair / next-inspection decision

IRIS Operational Requirements

The mandatory water couplant is the main practical constraint for IRIS as a primary screening method:

- Tubes must be fully flushed and water-filled — turbidity < 5 NTU for adequate UT coupling
- Flushing, filling and subsequent draining / drying adds significant time — IRIS of all 400 tubes in the above example would require ~80–130 h of probe time alone
- Sludge or scale deposits can block the rotating mirror or attenuate the UT signal
- IRIS confirms the absolute WT datum required before an irreversible tube-plugging decision (API 510 § 6.5)

Normative References

ASTM E2884	Standard Guide for Eddy Current Examination of Tubing Using Partial Saturation
ASTM E2096	Standard Guide for In Situ Examination of Ferromagnetic Heat-Exchanger Tubes Using Remote Field Testing
ASTM E570	Standard Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products
ASTM E2929	Standard Practice for Guided Wave Testing of Above Ground Steel Pipework and IRIS of Heat Exchanger Tubing
API 510	Pressure Vessel Inspection Code — § 6.5 Heat Exchanger Tube Inspection
API 661	Air-Cooled Heat Exchangers for General Refinery Service
API RP 585	Pressure Equipment Integrity Management — Inspection Technique Selection
API 579-1 / ASME FFS-1	Fitness-For-Service — § 4 / 5 Remaining Strength Factor (RSF) Calculation

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Key Takeaways

- FSEC is the only method combining ferromagnetic capability, fin-geometry compatibility and practical inspection speed for ACHE bundles
- RFT is technically feasible but economically unviable for large bundles within typical turnaround windows
- MFT is excluded by fin geometry — external magnet contact on finned OD is not achievable
- IRIS provides the absolute wall-thickness datum required for API 579 FFS calculations and plugging decisions
- Best-practice workflow: FSEC 100% screening → IRIS verification of flagged tubes (5–15%) → API 579 RSF → maintenance decision