

TESORO ANACORTES REFINERY INCIDENT

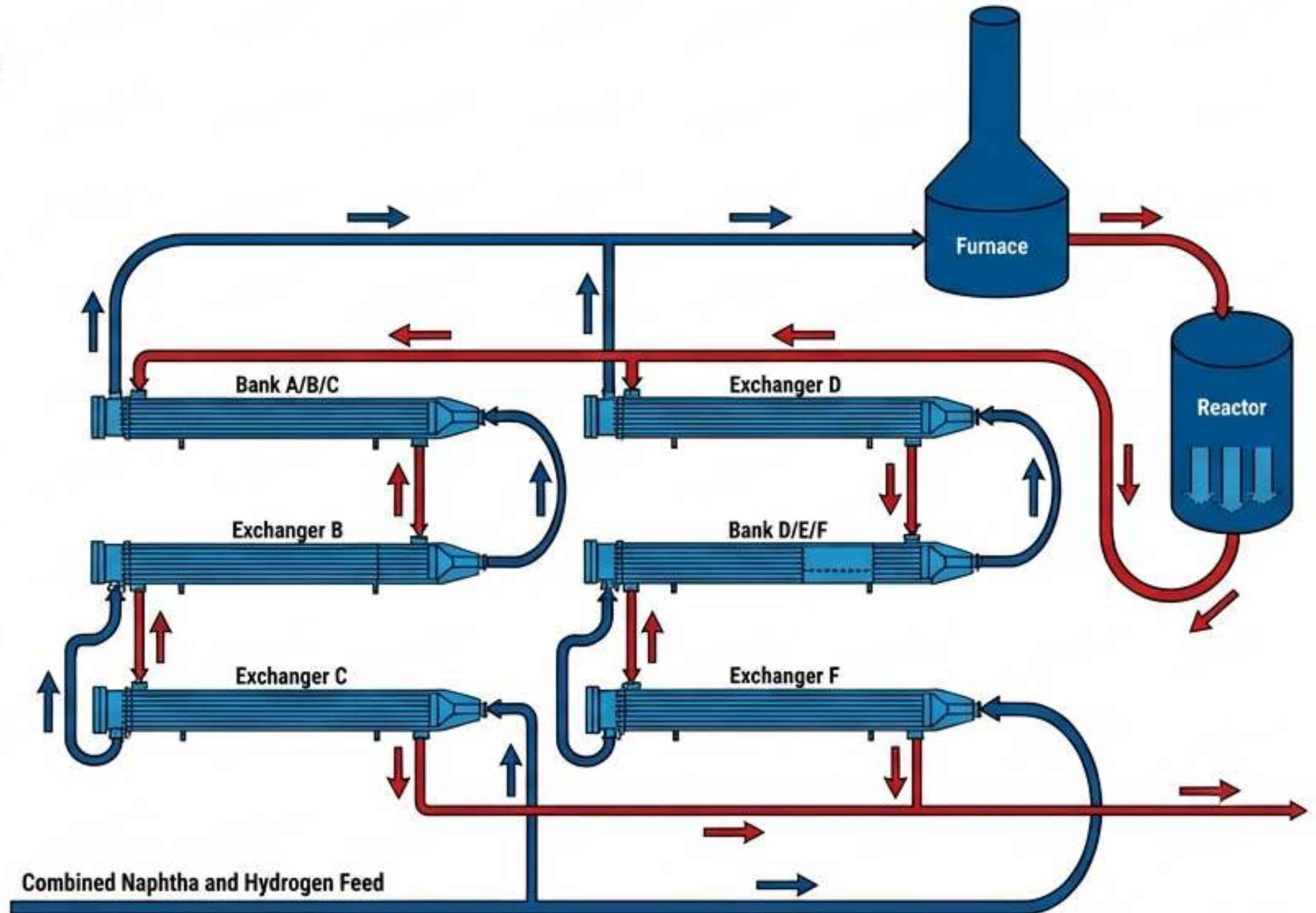
A system-level examination of equipment failure, operating context, and escalation



Investigation Analysis based on CSB Report (2014)

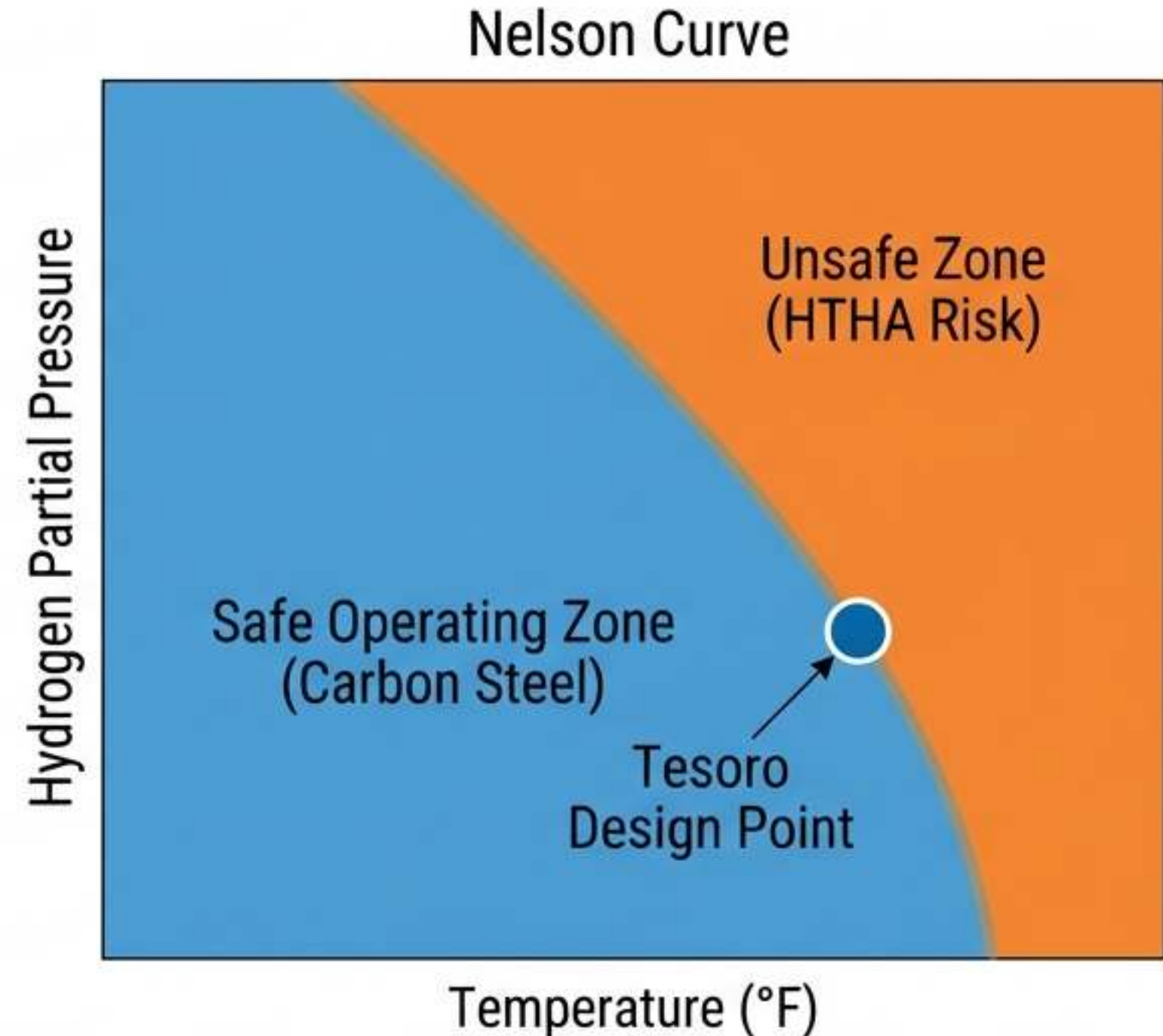
System Overview: Naphtha Hydrotreater (NHT)

- **Unit Function:** Removes impurities (sulfur/nitrogen) from naphtha to prepare for catalytic reforming.
- **Critical Equipment:** Two parallel banks of shell-and-tube heat exchangers (Banks A/B/C and D/E/F).
- **Operational Role:** Critical energy recovery system designed to reduce furnace load.
- **Service History:** Commissioned in 1971; approx. 39 years of service at time of incident.



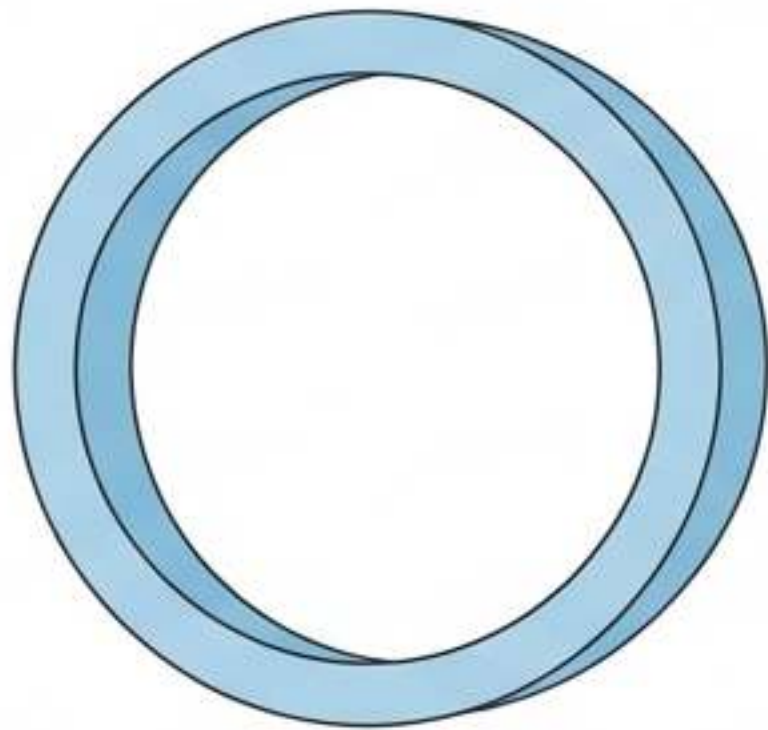
Intended System Function & Boundaries

- Primary Function: Transfer heat while maintaining a high-pressure boundary (approx. 600+ psig).
- Operating Envelope: High temperature (500°F - 650°F) in a hydrogen-rich environment.
- Material Selection Basis: Carbon Steel (SA-515-70) selected based on API 941 "Nelson Curves".
- Reliability Requirement: Zero loss of containment due to auto-ignition potential.



Operating Context & The Reality of Aging

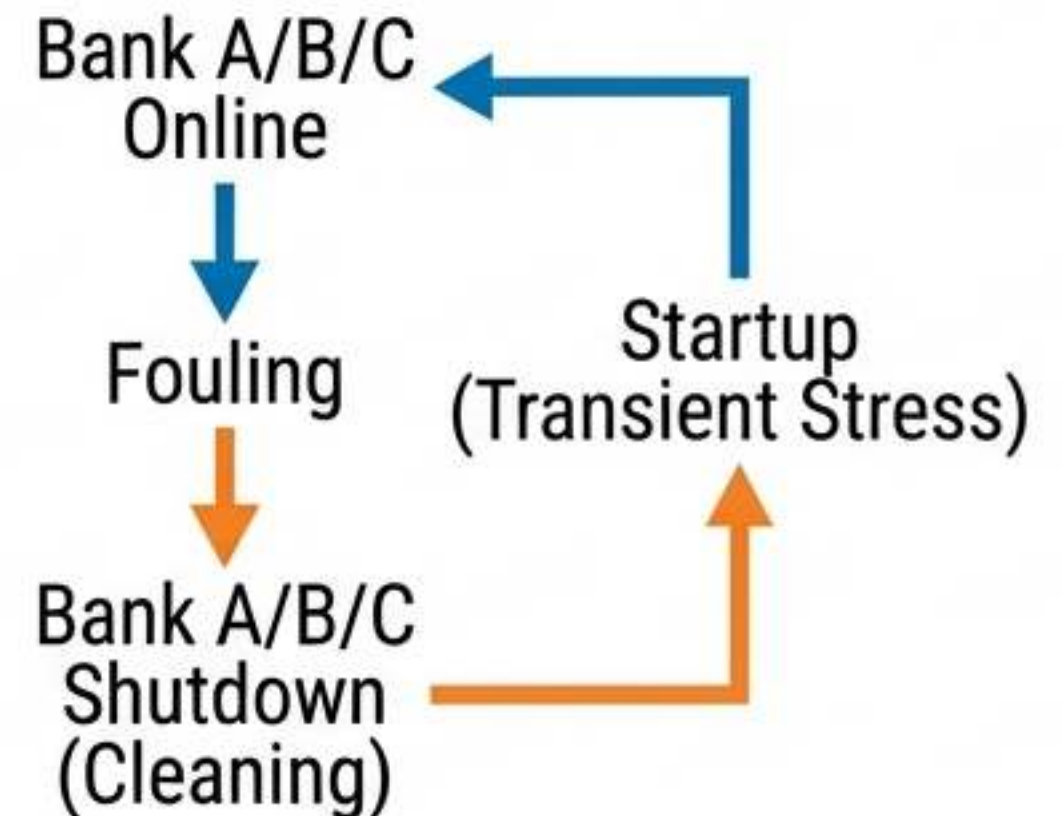
- **Fouling Conditions:** Internal deposits inhibited heat transfer, requiring higher temperatures to maintain efficiency.
- **The “Clean-and-Switch” Routine:** Periodic cleaning required one bank (e.g., A/B/C) to be taken offline while D/E/F remained online.
- **Stressed State:** Startup was a non-routine, transient operation involving thermal cycling.



Design State: Clean Tube

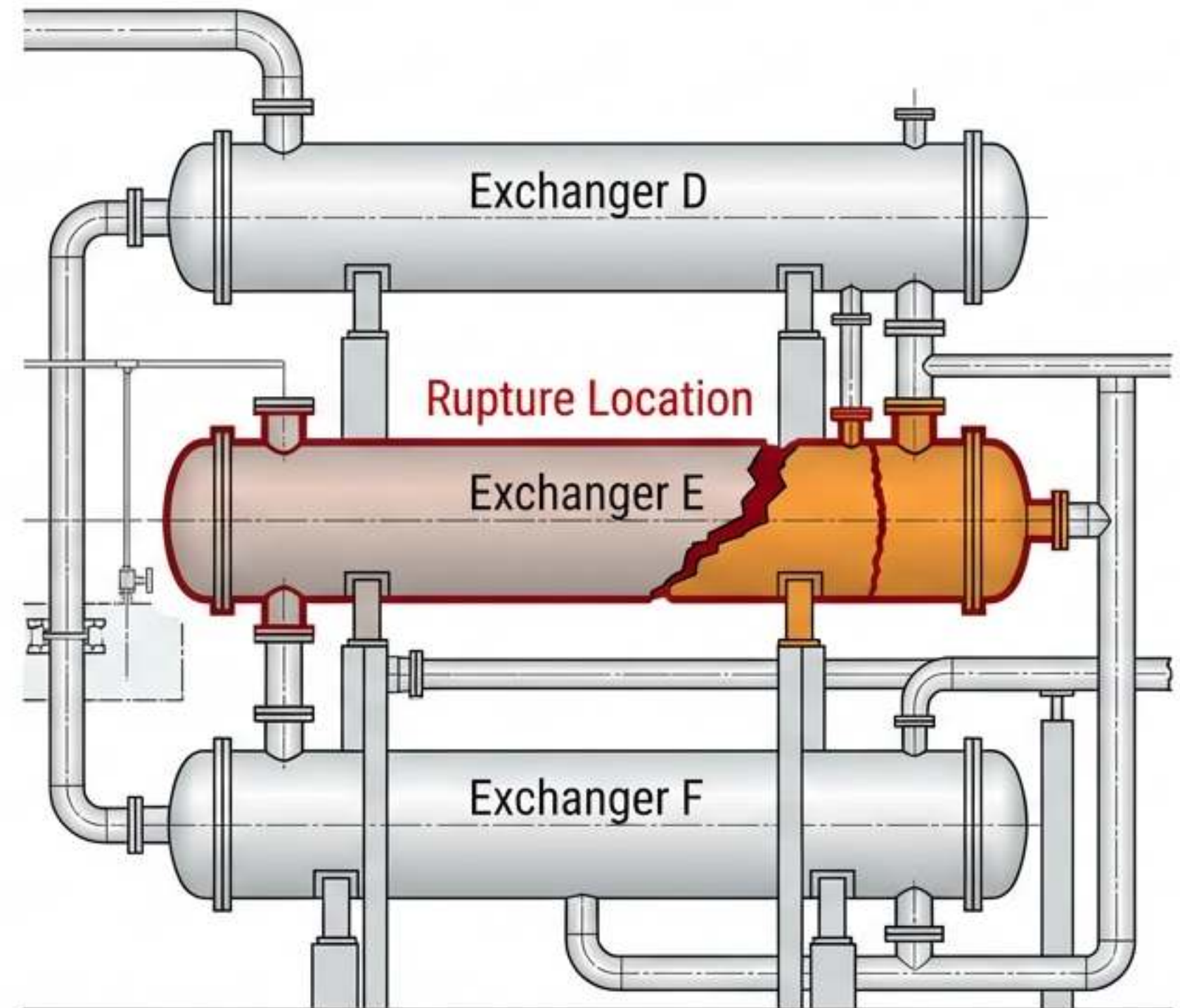


Operating State: Fouled Tube



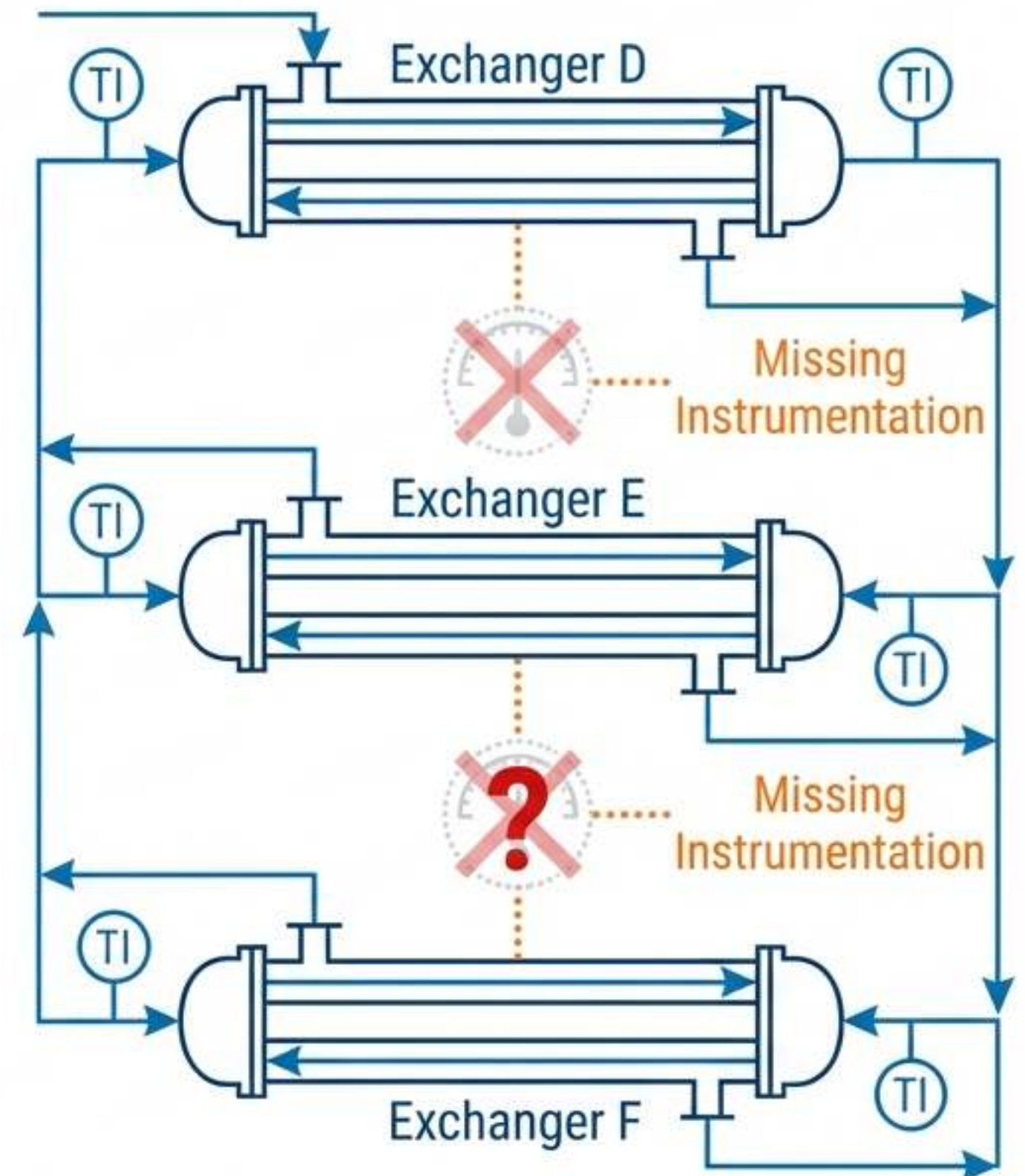
Functional Failure: Loss of Containment

- **The Event:** Catastrophic rupture of the Exchanger E shell during startup.
- **Failure Mode:** Shell separation at weld seams (circumferential and longitudinal). Rupture occurred below relief valve settings.
- **Consequence:** Sudden, high-energy release of hydrogen/naphtha causing auto-ignition and massive fireball.
- **Classification:** Total loss of primary containment function.



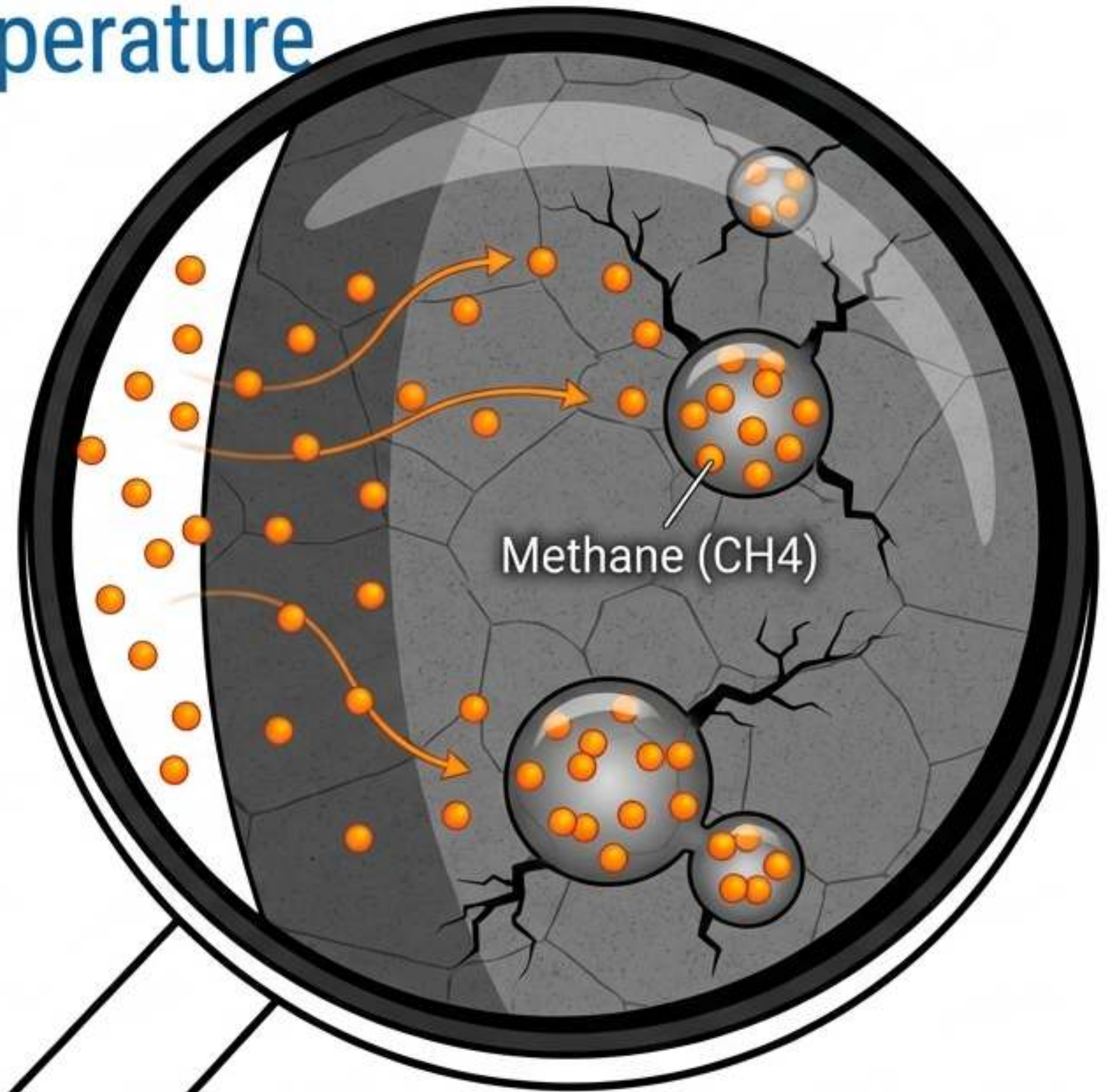
Warning Signs & Detectability Challenges

- **Normalized Deviation:** Frequent flange leaks during startup were managed with steam lances, not stop-work authority.
- **Instrumentation Gaps:** No temperature sensors existed *between* the exchangers. Operators could not see actual shell-side temperatures.
- **Inspection Limitations:** Standard inspections did not target High Temperature Hydrogen Attack (HTHA), which is microscopic.



Failure Mechanism: High Temperature Hydrogen Attack (HTHA)

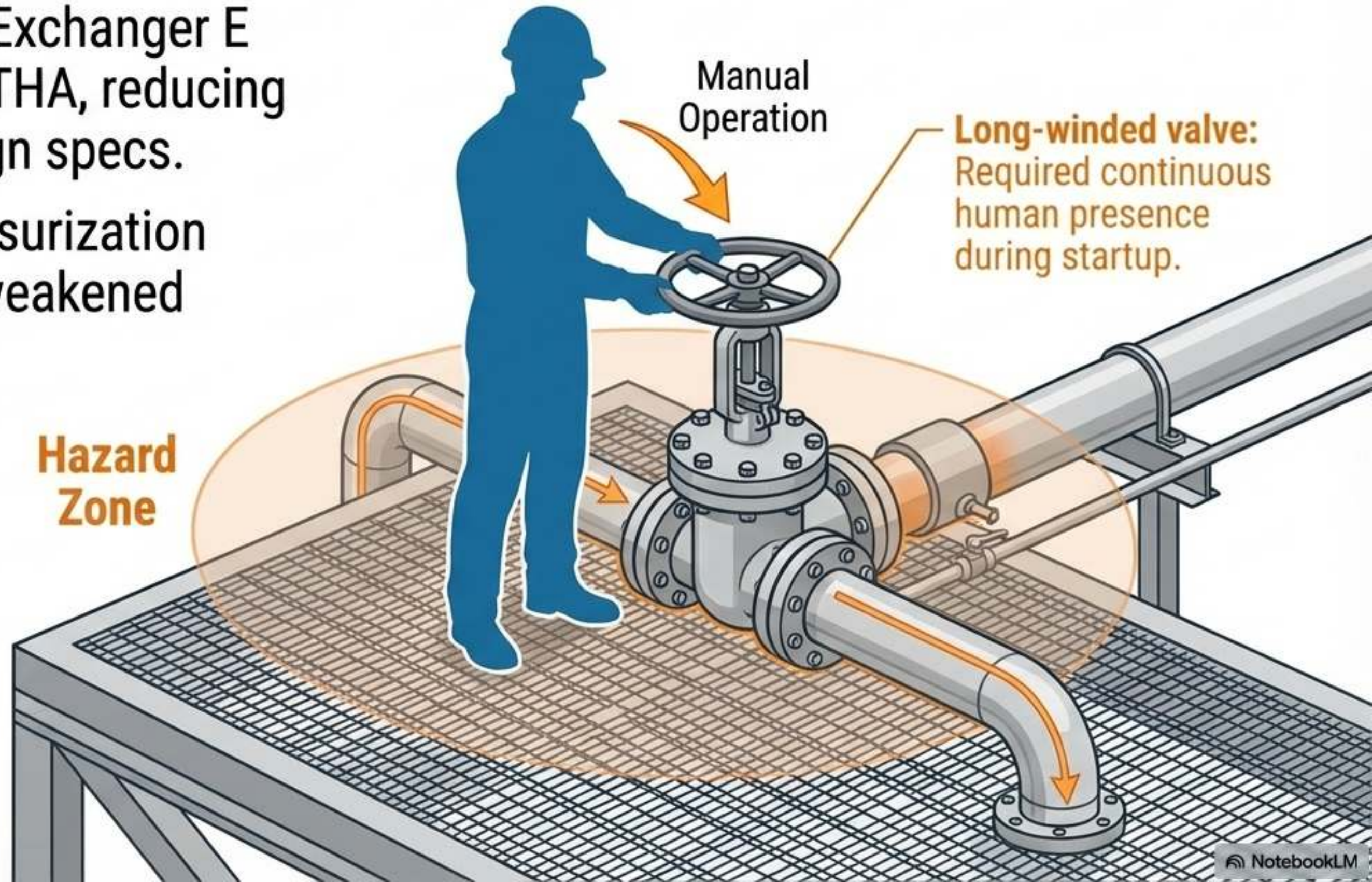
- **The Mechanism:** Atomic hydrogen diffuses into steel, reacts with carbides to form **methane** gas bubbles.
- **Material Vulnerability:** Carbon Steel components, specifically in non-heat-treated Heat Affected Zones (HAZ) near welds.
- **The Anomaly:** Failure occurred at conditions *below* the carbon steel Nelson Curve.



Why the Failure Escalated

Degraded Material: Exchanger E was embrittled by HTHA, reducing strength below design specs.

Startup Stress: Pressurization applied load to the weakened vessel.



Consequences

Human Impact

- Seven fatalities (Operations personnel).
- Loss of highly experienced staff.

Asset Impact

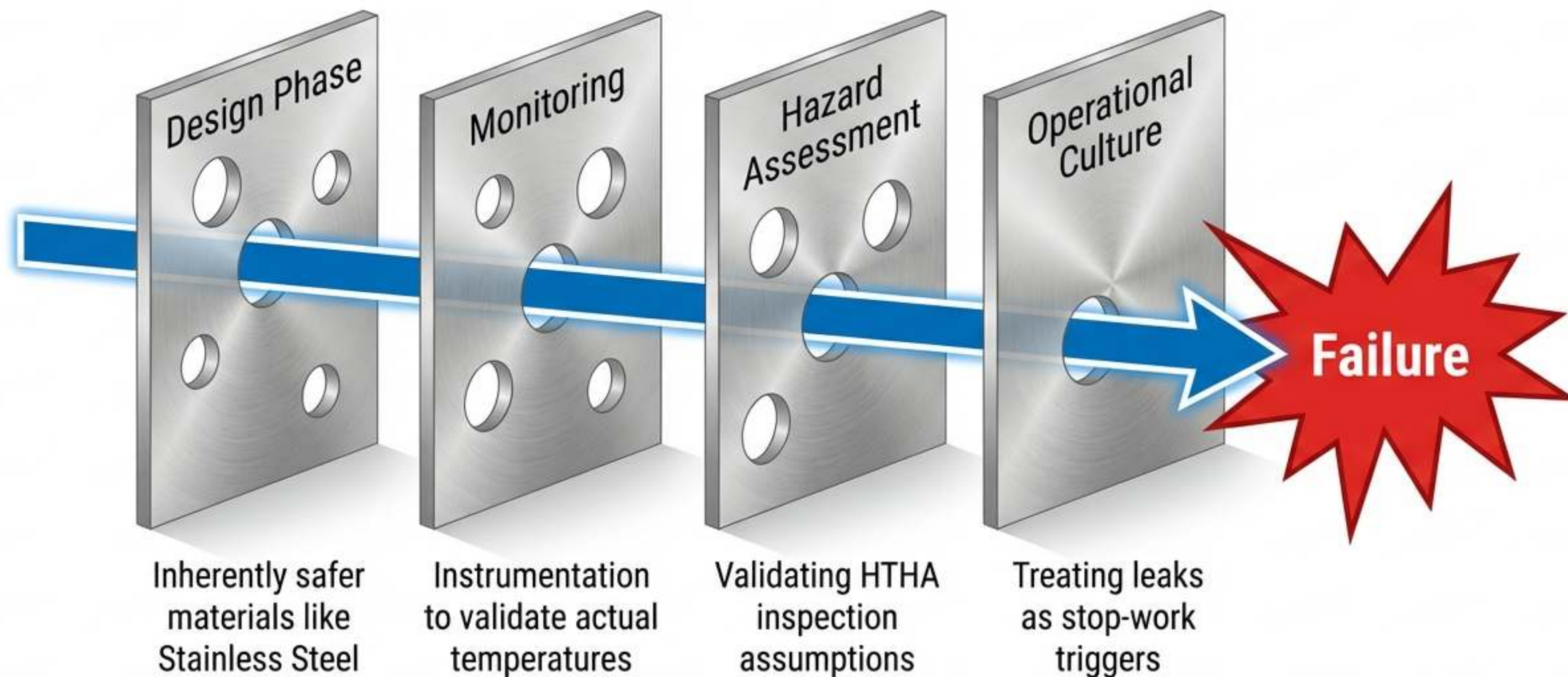
- Total loss of NHT heat exchanger banks.
- Refinery unit shutdown for approx. 7 months.

Industry Impact

- Forced re-evaluation of API 941 Nelson Curves.
- Key Finding: Carbon steel Nelson curve is inaccurate and cannot be relied on to prevent HTHA.

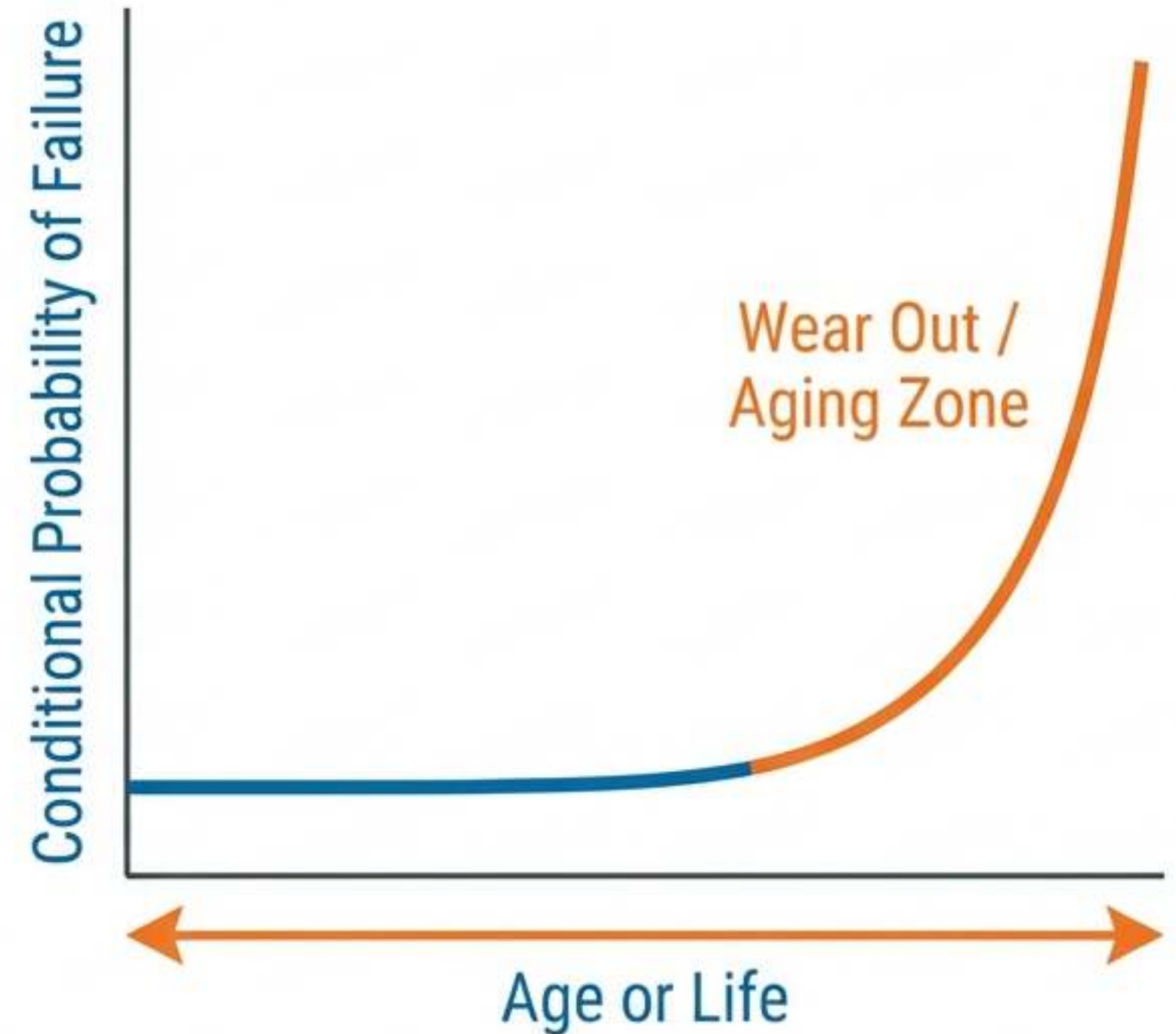


Where Earlier Intervention Was Possible



Transferable Insight for Asset Management

- **The "Design Data" Trap:** Managing aging assets based on original design data is dangerous.
- **Silent Degradation:** Mechanisms like HTHA give no visible warning until rupture.
- **Standards are Lagging:** Compliance with code does not guarantee immunity from physics.
- **Normalization of Deviance:** Routine leaks collapse risk perception.



Closing Reflection

How confident are we that our understanding of asset condition reflects reality rather than assumption?

Which of our systems are operating safely—and which are merely operating quietly?

Based on the Tesoro Anacortes Refinery Investigation Report (2014)