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PREPARING BASELOAD UNITS FOR FLEXIBLE OPERATION

Large-Scale Grid Integration of Renewable Energy in India

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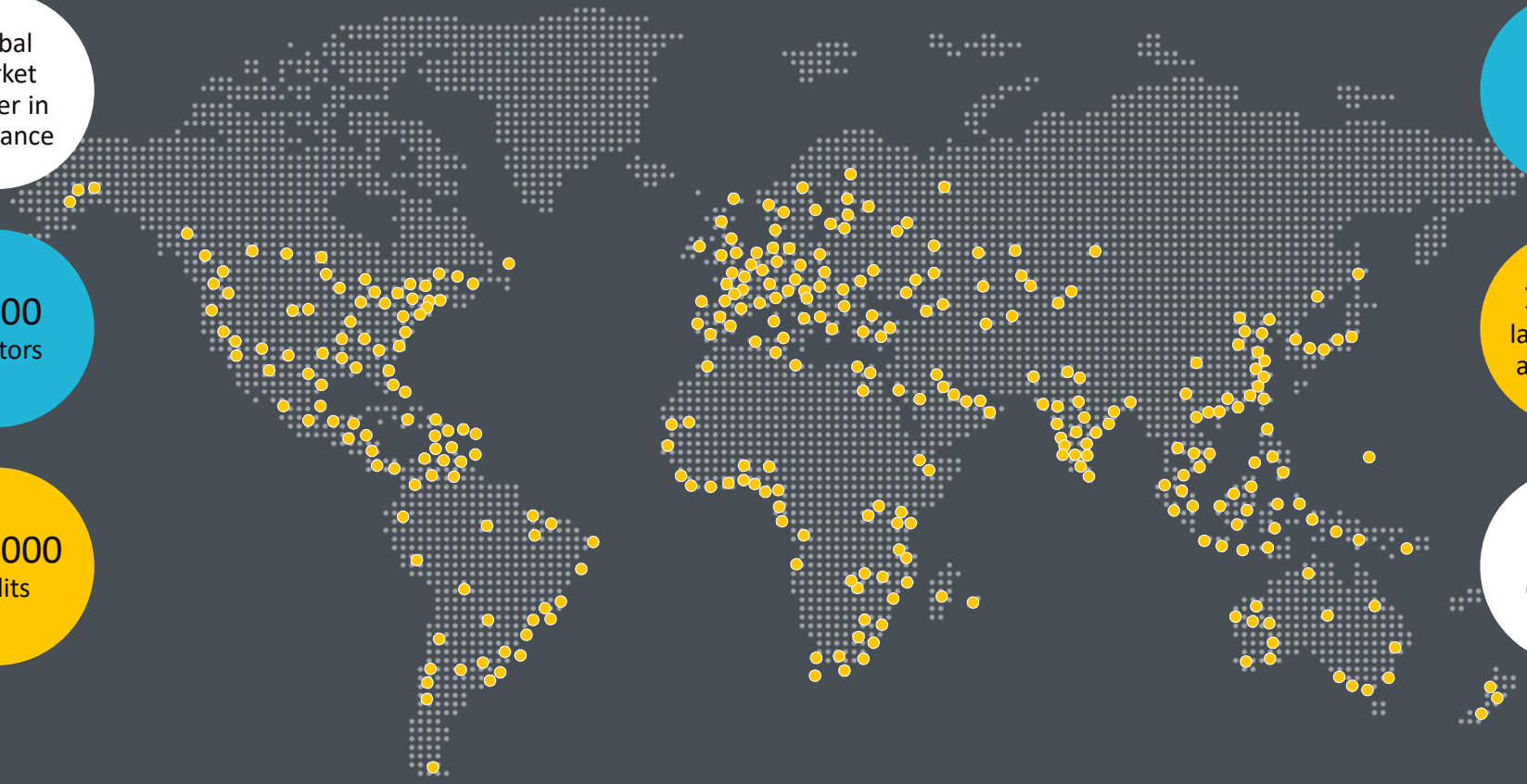
OUR GLOBAL NETWORK AND CAPABILITIES

Global ATIC Business with over **42,000 Employees**

Global Market Leader in Assurance

3,000 auditors

100,000 audits

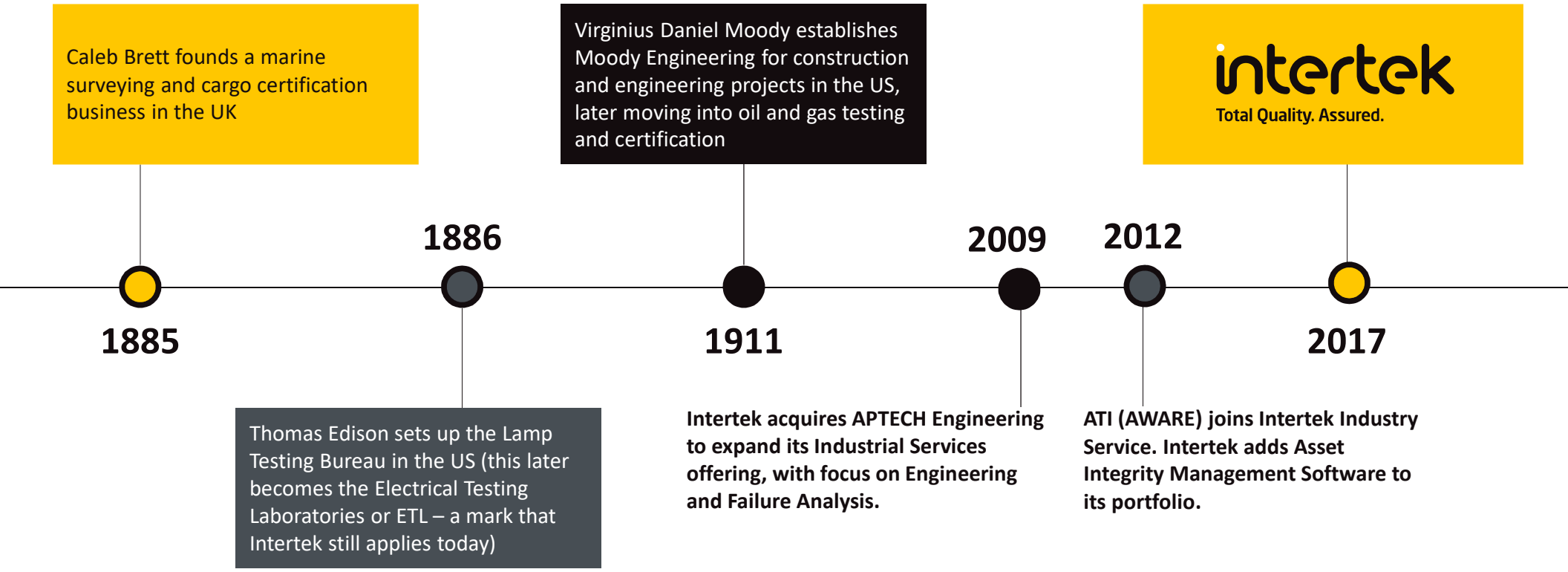


Global Market Leader in TIC

1,000+ laboratories and offices

100+ countries

OUR HERITAGE



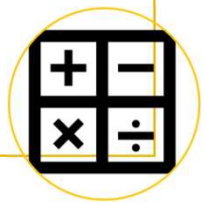
POWER PLANT FLEXIBILITY THEMES

- Startup time
- Minimum Load (Turndown)
- Emissions Compliance
- Ramp Rates

What's Important?

- Safety
- Equipment Life
- Reliability
- Costs
- Revenue

Impact

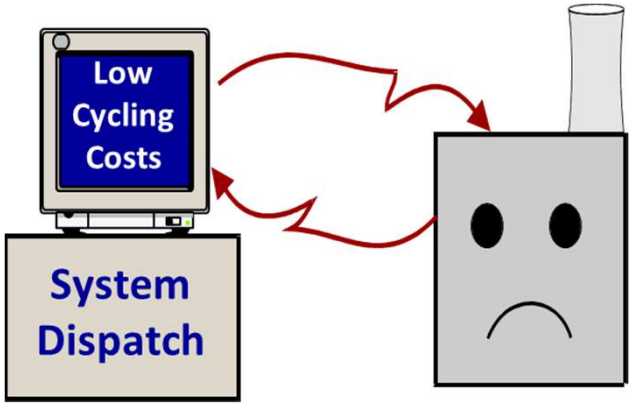


- Operational adjustment
- Capital Improvements
- Assess which flexibility attributes are the most valuable

Mitigation

PROBLEM STATEMENT

- Why do we need to incentivize power plant flexibility?
  - A major root cause of increase in Capital and Operations & Maintenance (O&M) cost for many fossil units is unit cycling.
  - Utilities have been forced to cycle aging fossil units that were originally designed for base load operation.
  - Market signals are resulting in lower revenue.
- What can and should we do once we understand the impacts and costs?

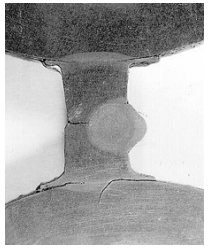


Generation Units Originally Designed for Baseload Operations Running in Cycling Modes

SO WHAT?

Accelerated Boiler Failures

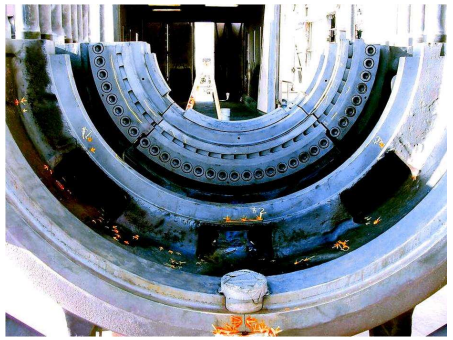
- Startup-Related Tube Failures in Waterwall, Superheater, and Reheater Tubing
- Burner Refractory Failure Leading to Flame Impingement and Short-Term Tube Overheating



- Boiler Seals Degradation
- Tube Rubbing
- Boiler Hot Spots
- Drum Humping/Bowing
- Downcomer to Furnace Sub cooling
- Expansion Joint Failures
- Superheater/Reheater Tube Leg Flexibility Failures
- Superheater/Reheater Dissimilar Metal Weld Failures

Turbine Failures

- Seals/Packing Wear/Destruction
- Blade Attachment Fatigue
- Silica and Copper Deposits
- Shell/Case Cracking
- Wilson Line Movement
- Bearing Damage

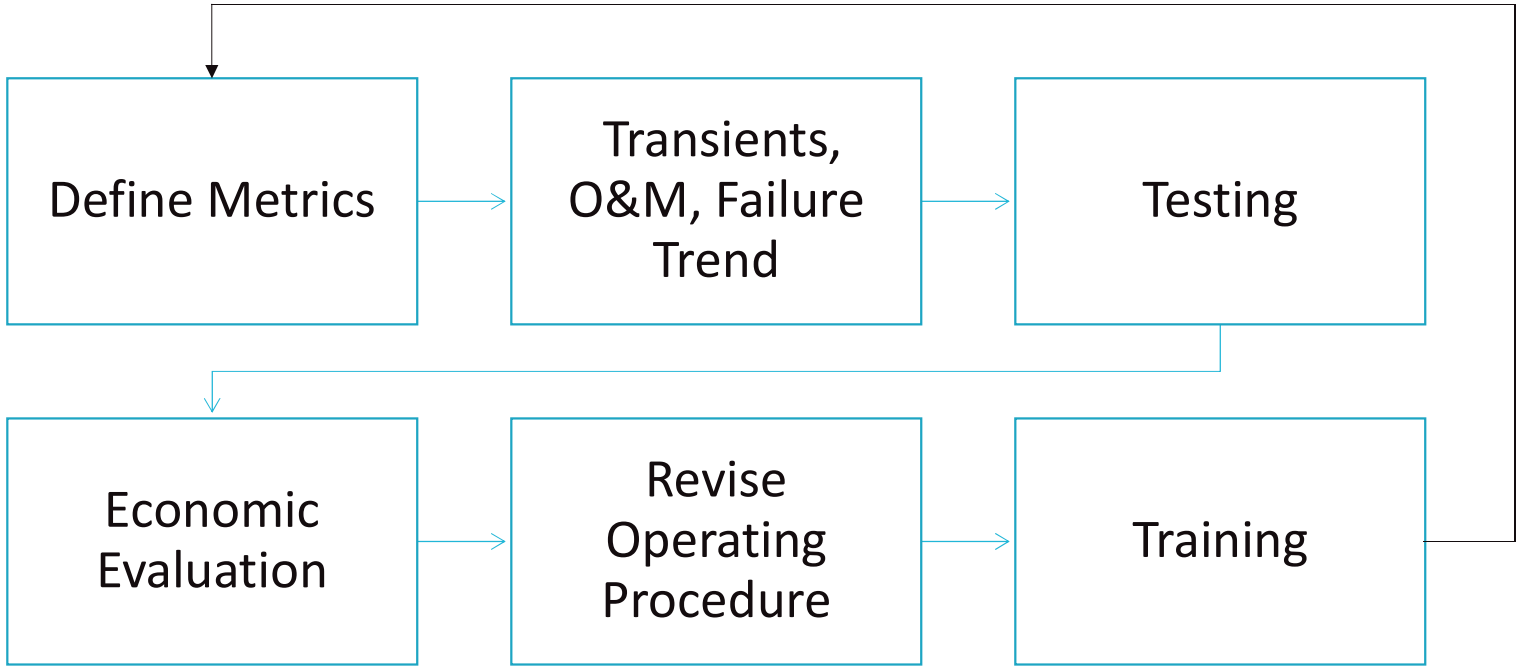


- Water Induction to Turbine
- Increased Thermal Fatigue Due to Steam Temperature Mismatch
- Steam Chest Fatigue Cracking
- Steam Chest Distortion
- Bolting Fatigue Distortion/Cracking
- Blade, Nozzle Block, Solid Particle Erosion
- Rotor Stress Increase
- Rotor Defects (Flaws) Growth

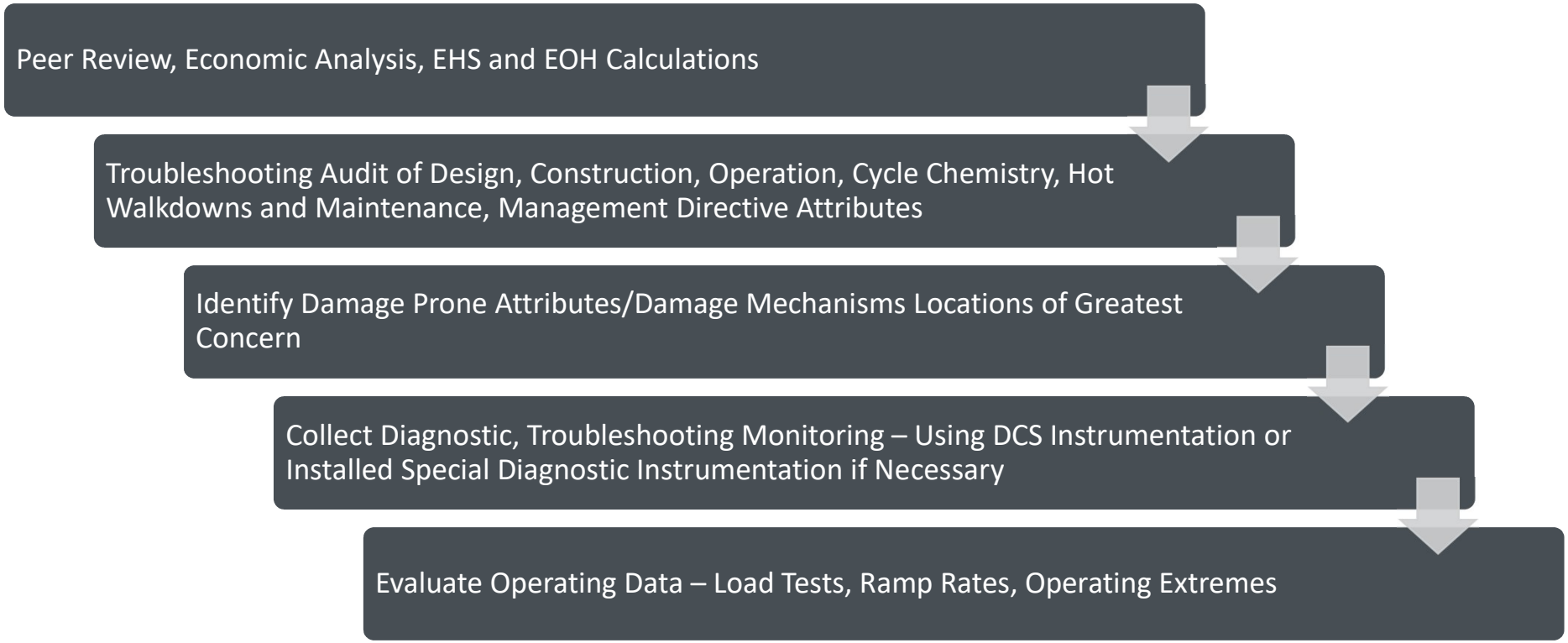
OUR VIEWPOINT

- Almost any unit can be cycled.
  - This can be done with minimal capital investment.
- However, we have to account for:
  - Long term penalty of **increased wear & tear damage** and reduced reliability.
  - Short term penalty of **higher heat rate, increased O&M, training requirements, and equipment efficiency**.
- Component Damage can be determined
  - Understand amount of damage present
  - Rate of accumulation
  - Total damage before failure
- Cycling a power plant is more difficult operating mode than baseload operation.

STRATEGY


Define Metrics
Transients, O&M, Failure Trend
Testing
Economic Evaluation
Revise Operating Procedure
Training

FLEXIBLE OPERATION ROADMAP – PRE OUTAGE



Source: Effect of Flexible Operation on Boiler Components: Theory and Practice, Volume 1: Fundamentals [Product ID:3002001180]

FLEXIBLE OPERATION ROADMAP – MAINTENANCE

PLANNED

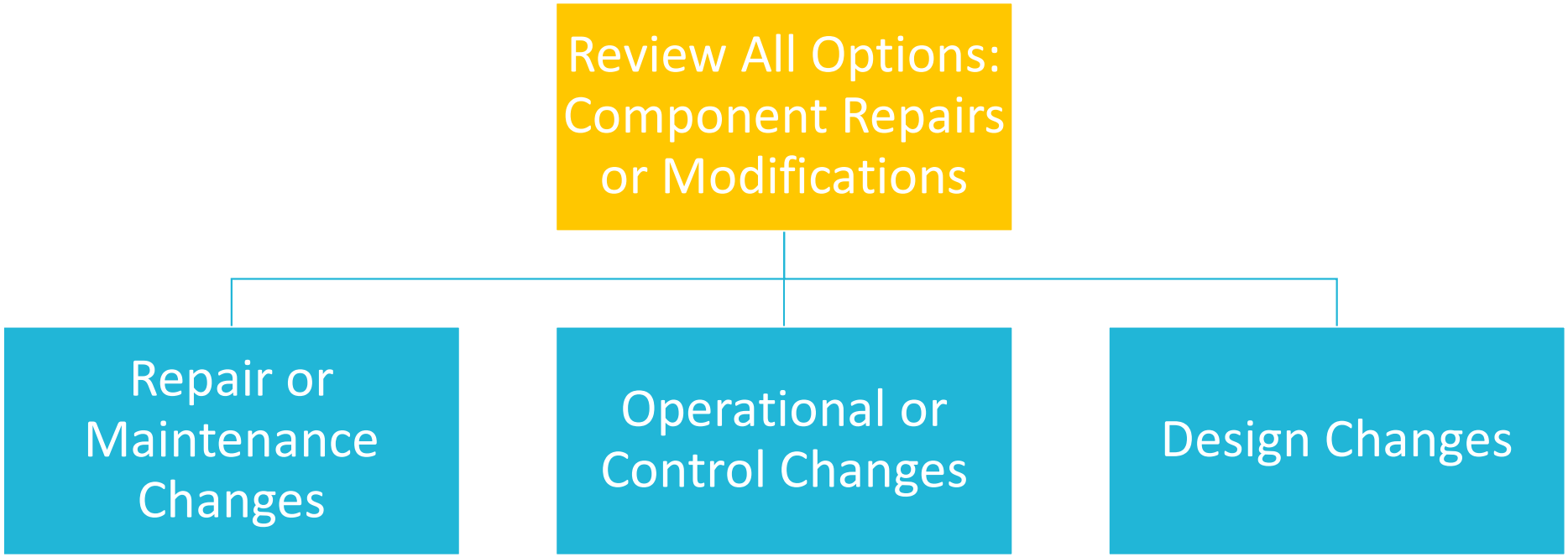
Component Condition Assessment – NDE, Maintenance

UN-PLANNED

Characterize the Location, Size and Mechanism of Damage

Source: Effect of Flexible Operation on Boiler Components: Theory and Practice, Volume 1: Fundamentals [Product ID:3002001180]

FLEXIBLE OPERATION ROADMAP – MITIGATION



Source: Effect of Flexible Operation on Boiler Components: Theory and Practice, Volume 1: Fundamentals [Product ID:3002001180]

1

DEFINE METRICS

Pressing base-load units into cyclic operation?

Cycle chemistry	Thermally induced cyclic stress	Extent of fatigue damage
Nature & frequency of the transients	Thermal gradient of the components	Material properties

Strain softening significantly changes a materials strength	Damage is difficult to identify

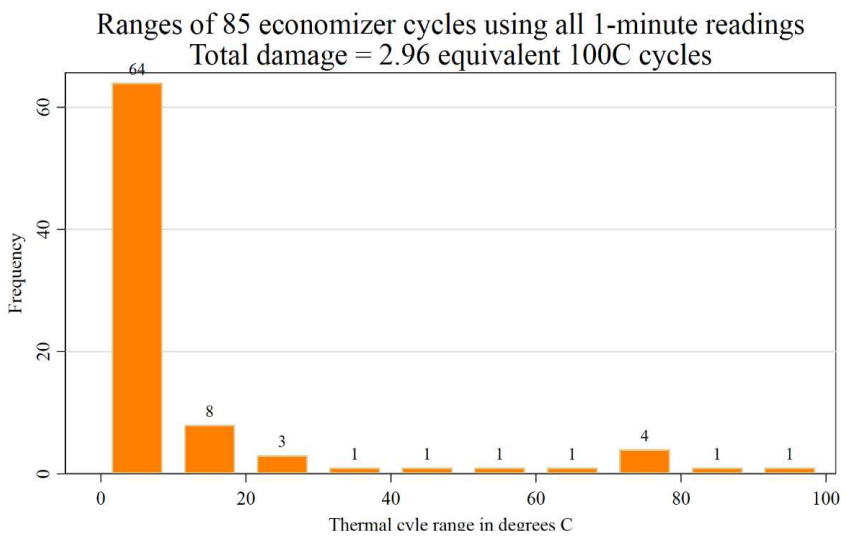
2

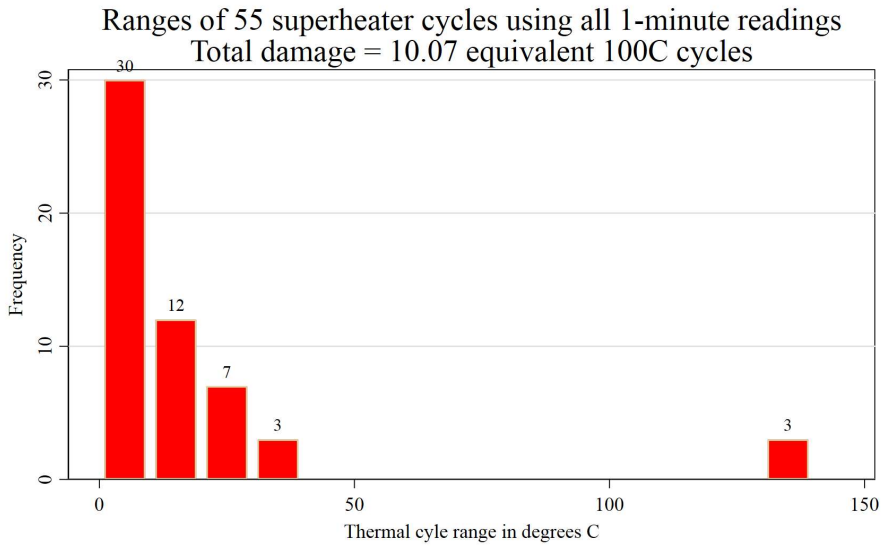
FACTORS AFFECTING POWER PLANT

Maintenance-related activities	Equipment design and manufacturer	Vintage of technology	Turbine design and pressure and MW capacity
Fuel type, quality and deviation from design fuel specifications	Environmental equipment (including retrofits)	Time between planned outages (boiler overhauls)	Timing of turbine/generator overhauls,
Plant configuration, size, economies of scale and scope	Controls and instrumentation	Retrofit of equipment, especially, for greater flexibility in moving among duty cycles, and	Modes of cycling operation over time

2

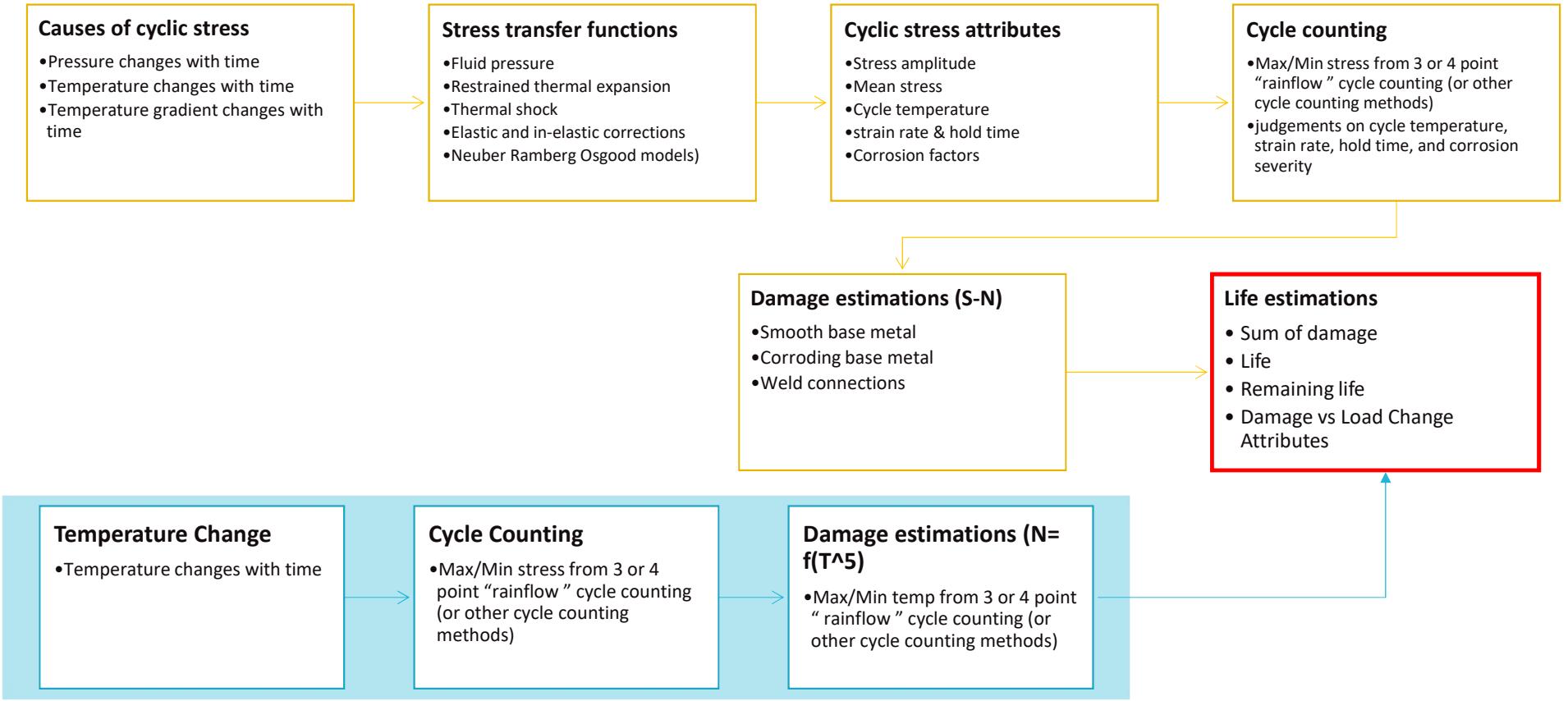
TRANSIENT ANALYSIS – OBSERVED FATIGUE CYCLES





2

ELEVATED TEMPERATURE FATIGUE OF BOILER PRESSURE PARTS



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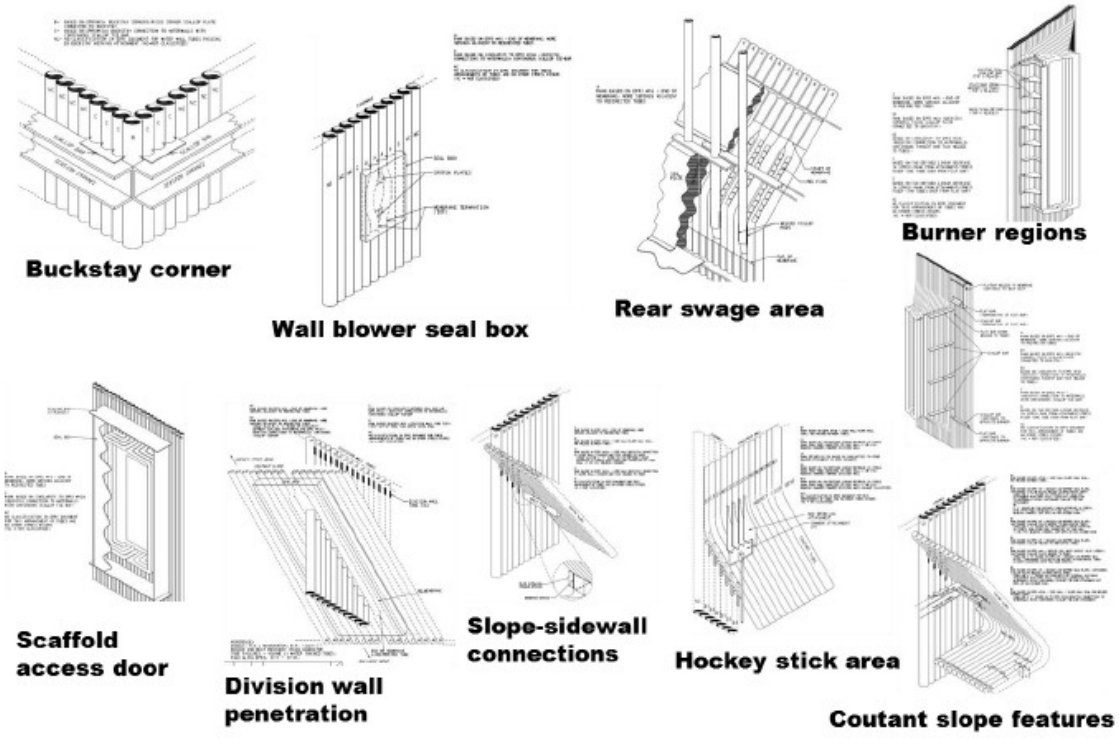
DESIGN DETAILS THAT ARE PRONE TO CORROSION FATIGUE DAMAGE

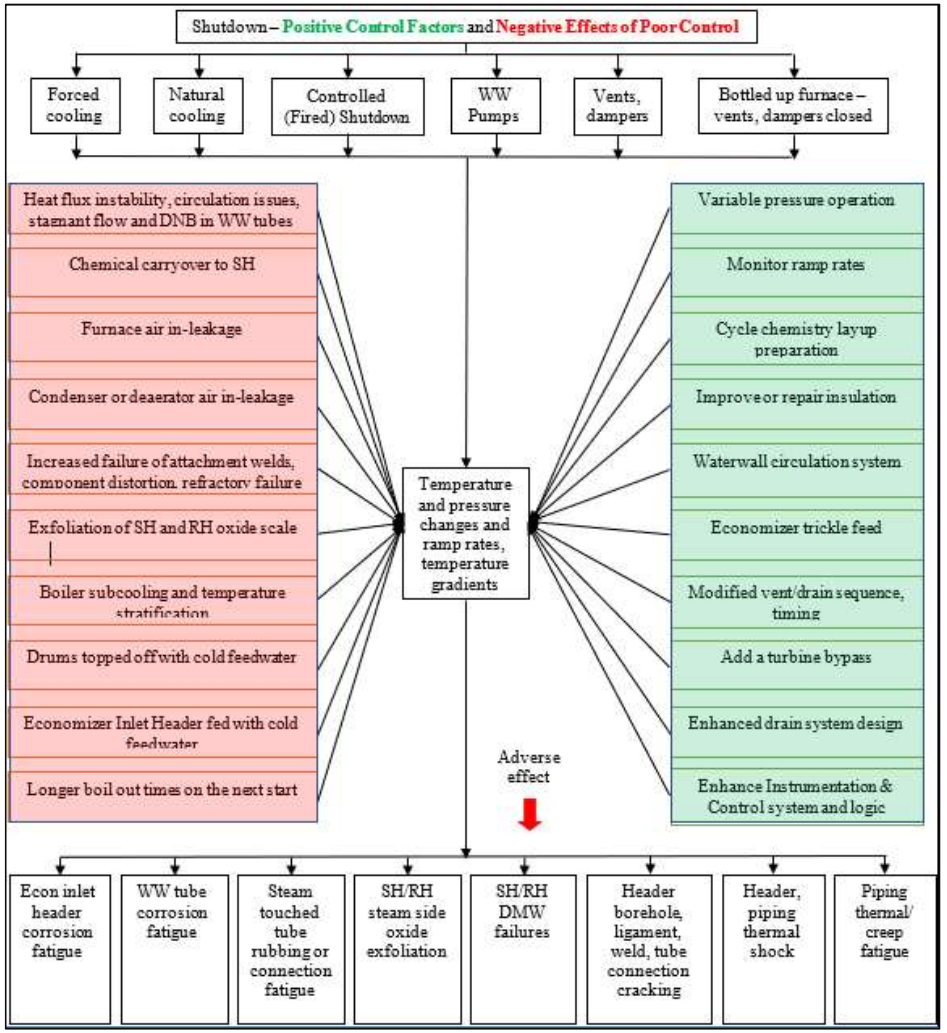


Source: Paterson et al. EPRI Life Assessment Conference 2012

2

SHUTDOWN OPERATION

Correlate flexible operation with component damage.



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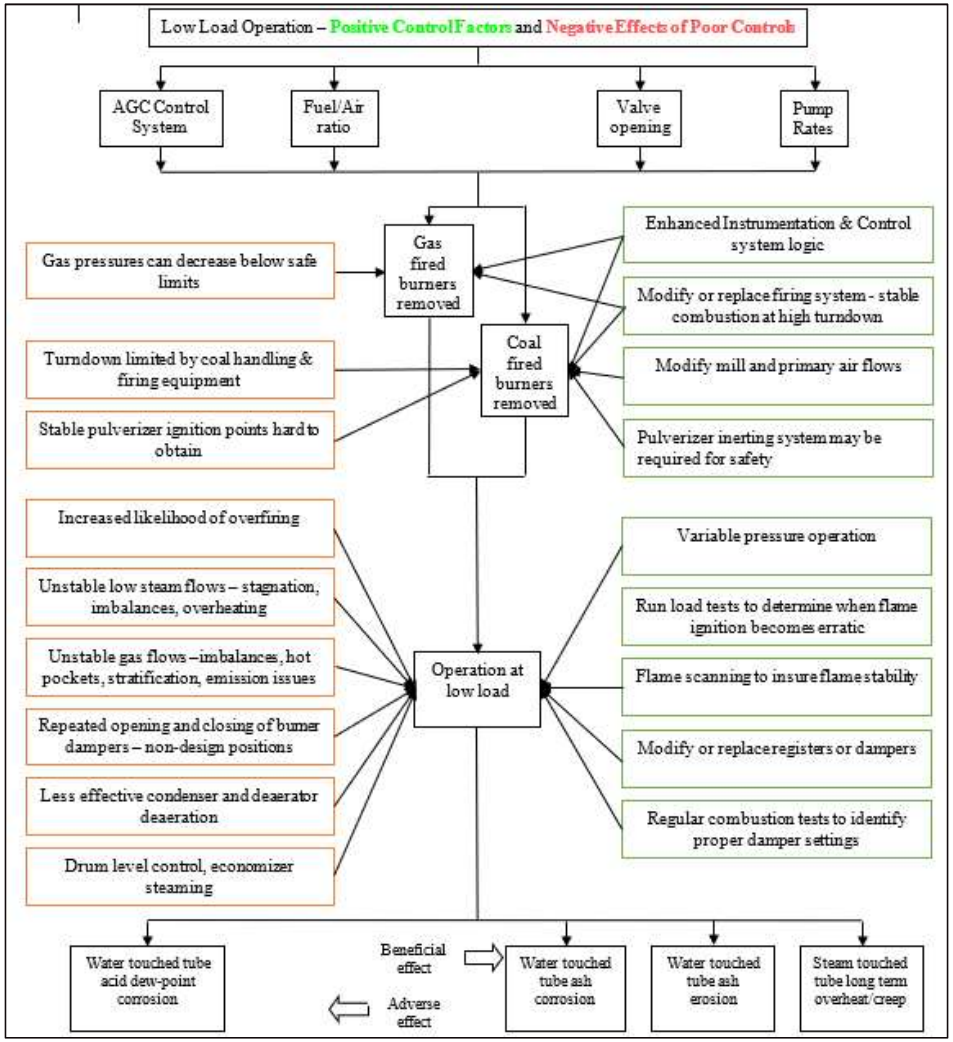
2

LOW LOAD OPERATION

Correlate flexible operation with component damage.



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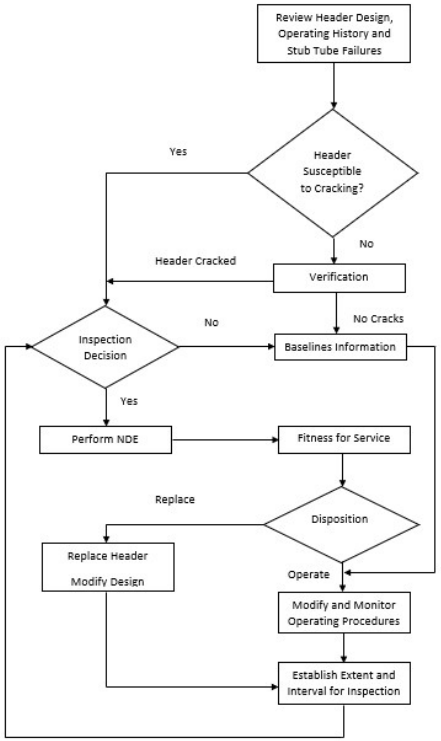
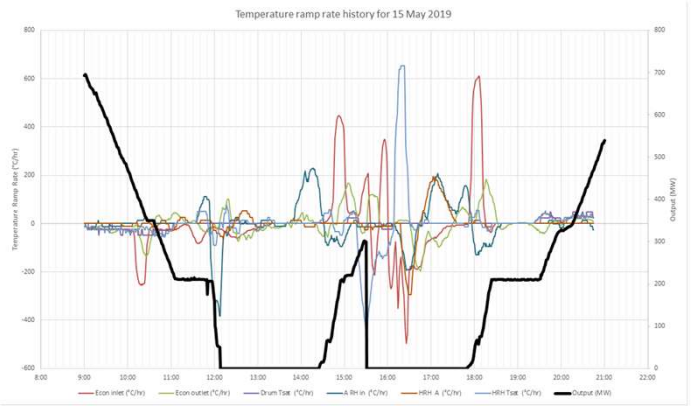
3

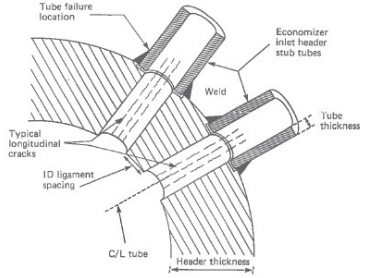
GET SPECIFIC



Example: **Economizer Inlet Header Cracking**

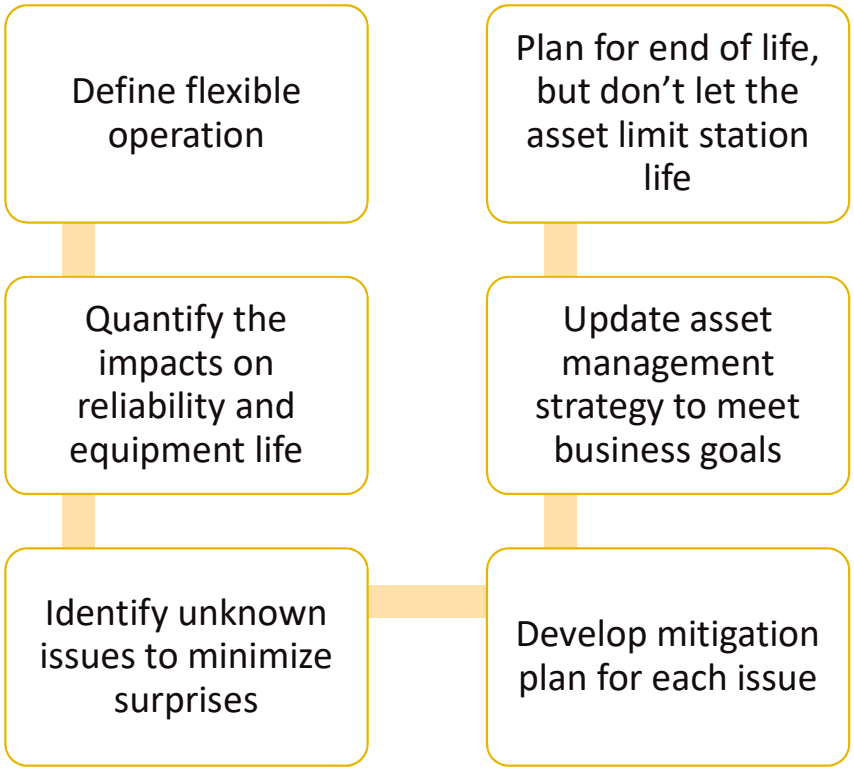
- Review Header Design
  - Review Design
  - Operating History
  - Investigate Stub Tube Leaks
  - Establish Susceptibility to Cracking
- Fitness for Service
  - Review NDE Results
    - No Defects or Defects in Borehole → Monitor for damaging transients
    - Cracks between the ID circumferential ligament → Decide run/repair/replace





Source: EPRI: Guidelines for the Prevention of Economizer Inlet Header Cracking in Fossil Boilers, EPRI GS 5949s

ASSET MANAGEMENT STRATEGY



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