Flexible Operations in a Changing World

Session 8A

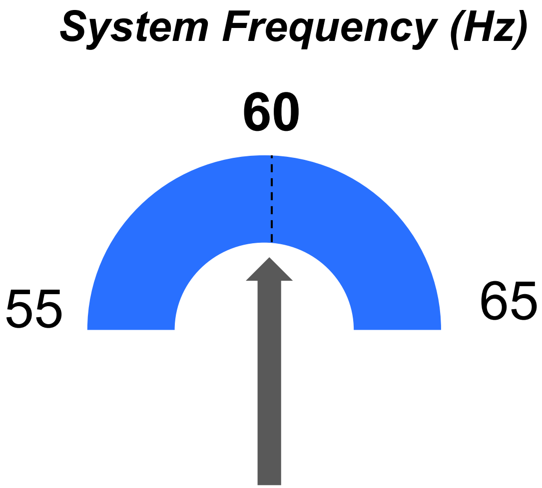
Coal Power Plants

Stephen Storm
September 4-6, 2019
International Conference
New Delhi, India

Grid Stability Demands Dispatchable Generation

Non-Dispatchable Power Generation

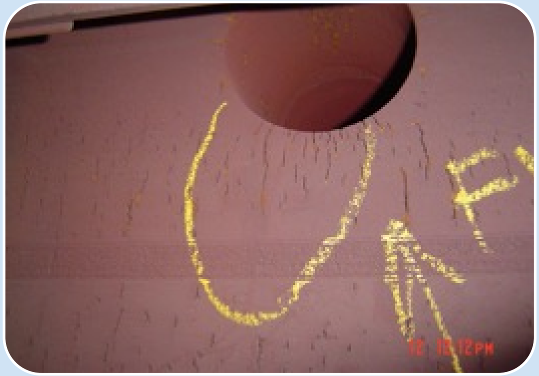
Dispatchable Power Generation

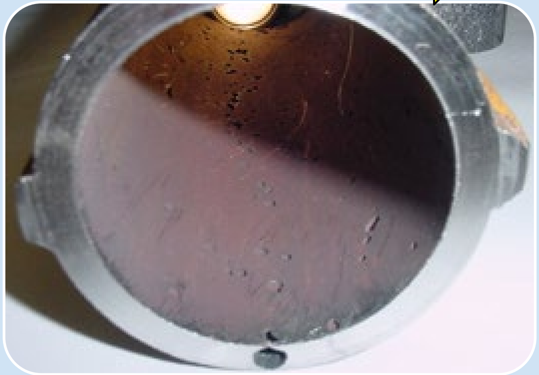


For stable operation of the grid, supply and demand must be in perfect balance at all times

Flexible Operations: Impact on Boiler Reliability

Creep, Fatigue, Corrosion & Erosion Impacts for Flexible Operation





Minimum or Reduced Load Operations

- Circulation Issues and overheat (DNB)
- SH and RH Overheat
- High Spray Flow rates & Attemperator Damage
- Economizer Steaming
- Flow Accelerated Corrosion

Two Shifting

- Increased thermal fatigue damage
- Operator error or injuries
- Increased wear on valves motors
- Longer operation time with chemistry out of specification

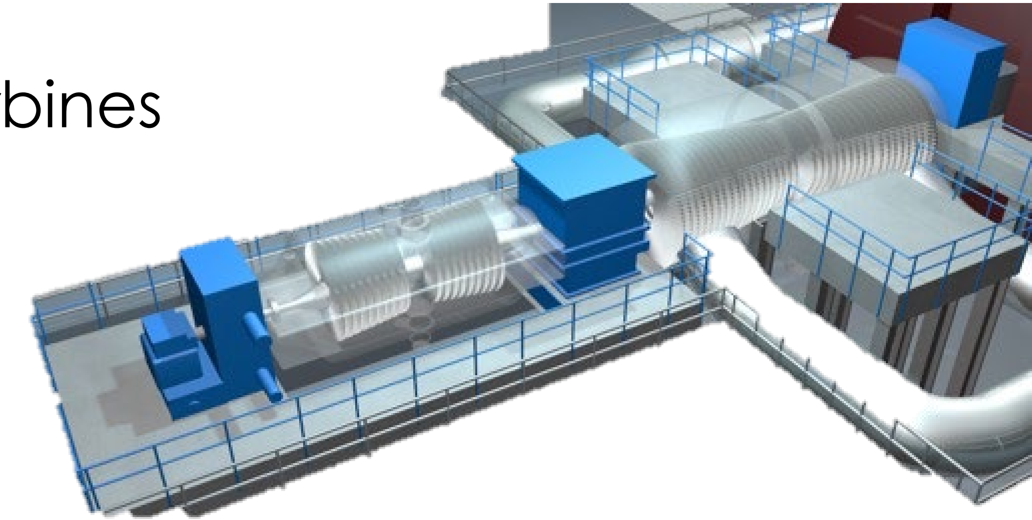
Weekend Shutdown

- Operator Error
- Same as two shifting with increase in
- Corrosion fatigue
- Pitting corrosion
- Potential for increase in oxide exfoliation
- Overheating of tubing if is startups are rushed

Extended Shutdown

- Same as two shifting with increase in Corrosion fatigue
- Pitting corrosion
- Potential for increase in oxide exfoliation
- Overheating of tubing if is startups are rushed

Flexible Operations: Impact on Steam Turbines



Challenges:

- Increased operator training to improve temperature matching and reduce over-temperature operation
- Increased wear on valve components
- Casing humping due to base-to-cover temperature differentials
- Rotor differential expansion limitations
- Water induction risk increases with more unit starts
- Increased in SPE rate on valves and blading due to increased starts
- Increased risk of blade flutter with low exhaust volumetric flow rates
- Upstream movement of phase transition zone; SCC risk increases; higher exhaust wetness; solubility changes
- Steam seal pressure control issue
- Excessive use of hood sprays as exhaust temperature increases results in LSB erosion, especially with flow recirculation
- Control valves throttling at very low loads; increase heat rates; wear on plug/seat
- BFP turbine steam supply issues
- Impact of reduced minimum loads on shaft rotor dynamics (bearing unloading under partial-arc)
- Trade-off between low load and ramping rate
- Increased air in-leakage

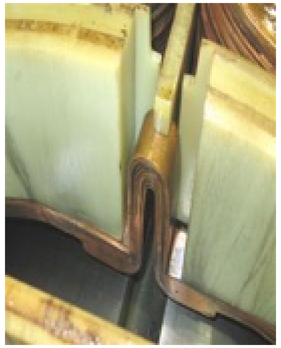
Flexible Operations: Impact on Main Generators

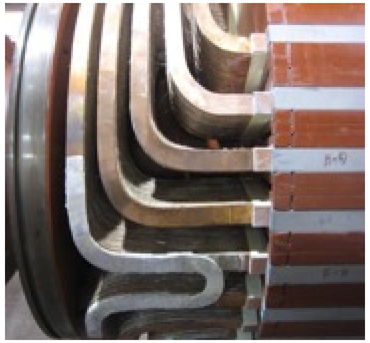
Cycling Main Generators

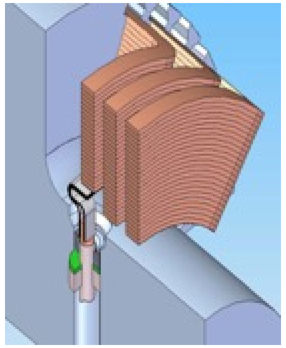
- Determination of generator maintenance intervals under cycling duty
- Generator winding insulation system
  - Copper dusting – differential expansion
  - rotor coil ratcheting
- Core tightness changes due to thermal cycles
- End winding blocking and tie failure
- Fatigue in bore, tooth-tops, rings
- Wedge fretting

Main Generators Extended Shutdown

- Safe operation of generator hydrogen system
- Generator stator cooling water system protection
- Generator protection against moisture-related damage
- Collector ring pitting of generator and exciter field







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Outage Intervals for Generators in Flexible Operation

Major Challenges: 0 – 30% MCR

Flexibility Challenges: *Boiler, Turbine, BOP, Environmental*	Cycling On/Off	Turn Down	Fast Ramping	Load Cycling
Equipment Turndown				
Burners/Combustion Stability				
Boiler Circulation				
Pressure Part Damage				
Fans/Motor Reliability				
Ramp Rate				
Steam Temperature Control				
Air Heater Issues				
Environmental Control Systems				
Turbine Thermal Stresses				
Condenser Issues				
Water/Steam Cycle Chemistry				
FW Pumps & Motors				

Understand where training & awareness is needed

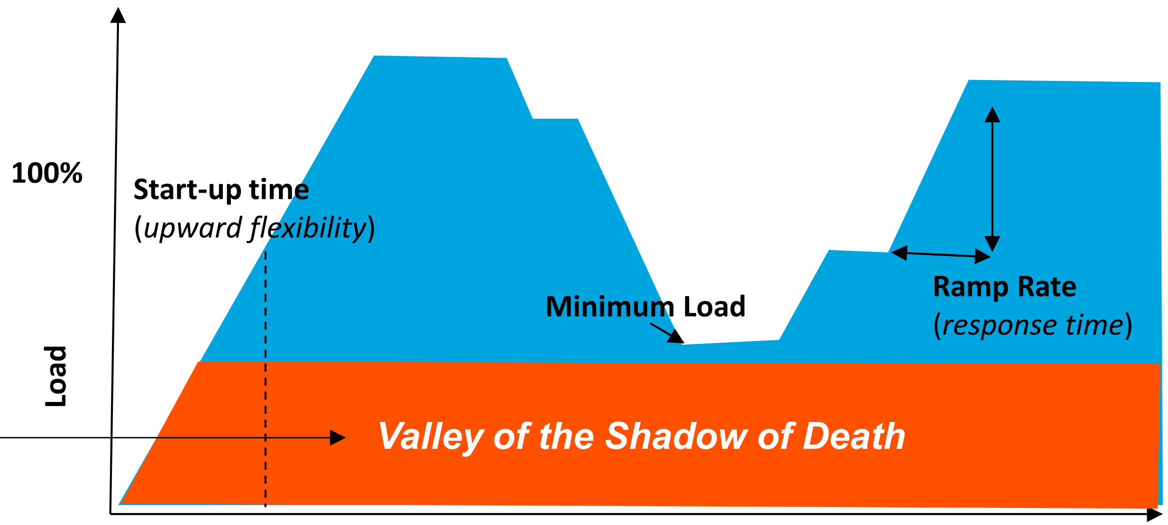
Understand what O&M best practices are needed

Flexible Operations

Identify areas needing systematic program management

Identify needs for defense strategy

Managing FLEXIBLE OPERATIONS



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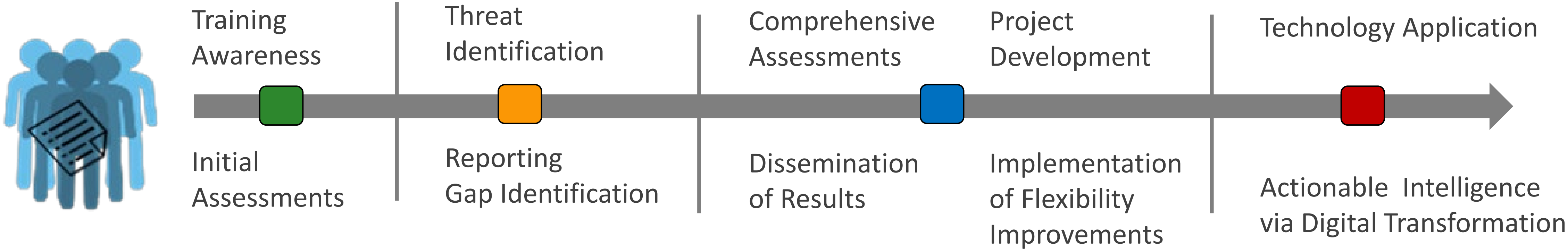
Vision – *The Flexible Future*

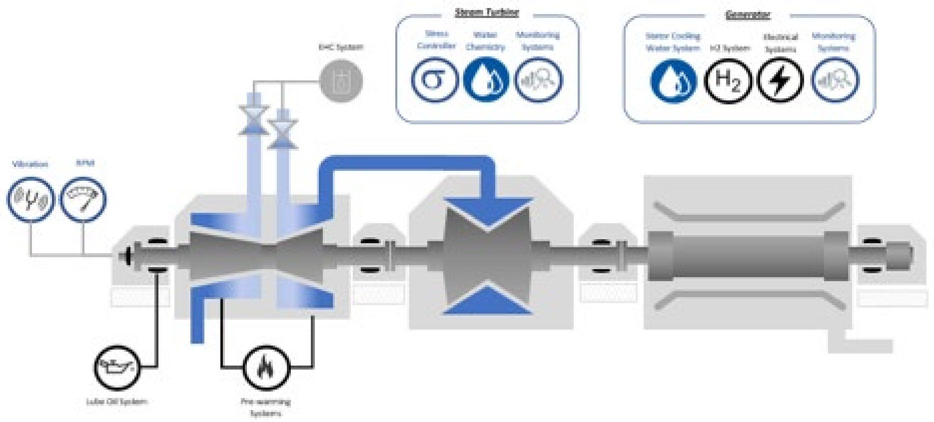
Adapting to change demands enhanced plant defense strategies that utilize systematic processes. Flexibility is complex and strategic countermeasures to protect assets undergoing the new operating regimes.



Managing fleet flexibility requires the inclusion of both quantitative and qualitative actions that drive awareness, apply best practices, encourages benchmarking and most importantly, integrates modifications and defense strategies to protect assets:

Operational Flexibility: Impacts People and Processes

Varying Operating Modes → Procedures → Operations, Monitoring & Diagnostics → Operations & Maintenance Activities → Layup Requirements



FLEXIBLE OPERATIONS

People | **Process** | **Technology**

Process Optimization

Mission Profile

Digital Transformation & Optimization

Aware → ***Managed*** → ***Proactive*** → ***Predictive***

Expanding the Flex Ops Tool Box - *People, Process, Technology*

Welcome Stephen

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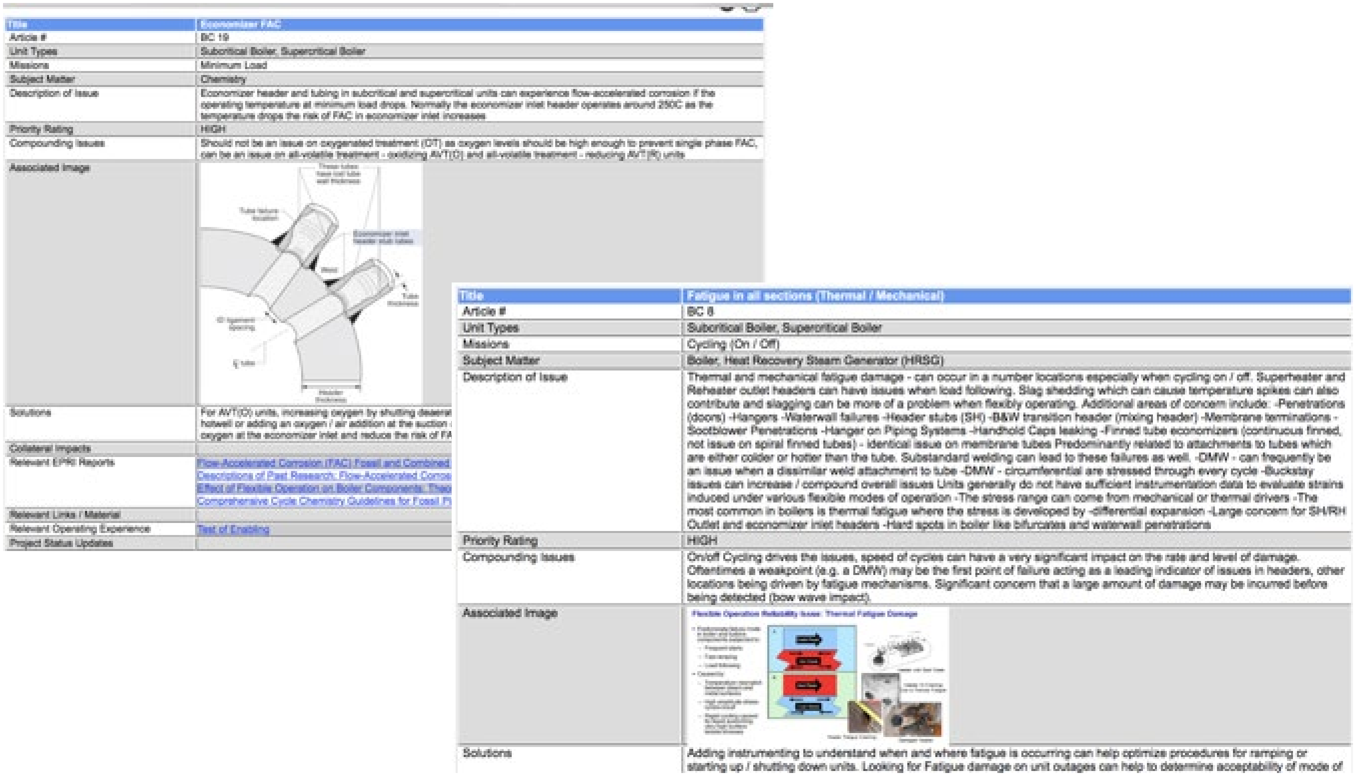
Flexible Operation Tools

Click one of the buttons below to access the appropriate site.

Flexible Operation Database (FlexOps)

Minimum Load Reduction Web Tool (MinLoad)

Resource Database for Flexible Operation (RDFlex)



Title	Economizer FAC
Article #	BC 19
Unit Types	Subcritical Boiler, Supercritical Boiler
Missions	Minimum Load
Subject Matter	Chemistry
Description of Issue	Economizer header and tubing in subcritical and supercritical units can experience flow-accelerated corrosion if the operating temperature at minimum load drops. Normally the economizer inlet header operates around 250C as the temperature drops the risk of FAC in economizer inlet increases
Priority Rating	HIGH
Compounding Issues	Should not be an issue on oxygenated treatment (OT) as oxygen levels should be high enough to prevent single phase FAC, can be an issue on all-volatile treatment - oxidizing AVT(O) and all-volatile treatment - reducing AVT(R) units
Associated Image	
Solutions	For AVT(O) units, increasing oxygen by shutting deaera… hotwell or adding an oxygen / air addition at the suction … oxygen at the economizer inlet and reduce the risk of FA…
Collateral Impacts	
Relevant EPRI Reports	Flow-Accelerated Corrosion (FAC) Fossil and Combined … Descriptions of Past Research: Flow-Accelerated Corros… Effect of Flexible Operation on Boiler Components: Theo… Comprehensive Cycle Chemistry Guidelines for Fossil Pl…
Relevant Links / Material	
Relevant Operating Experience	Test of Enabling
Project Status Updates	

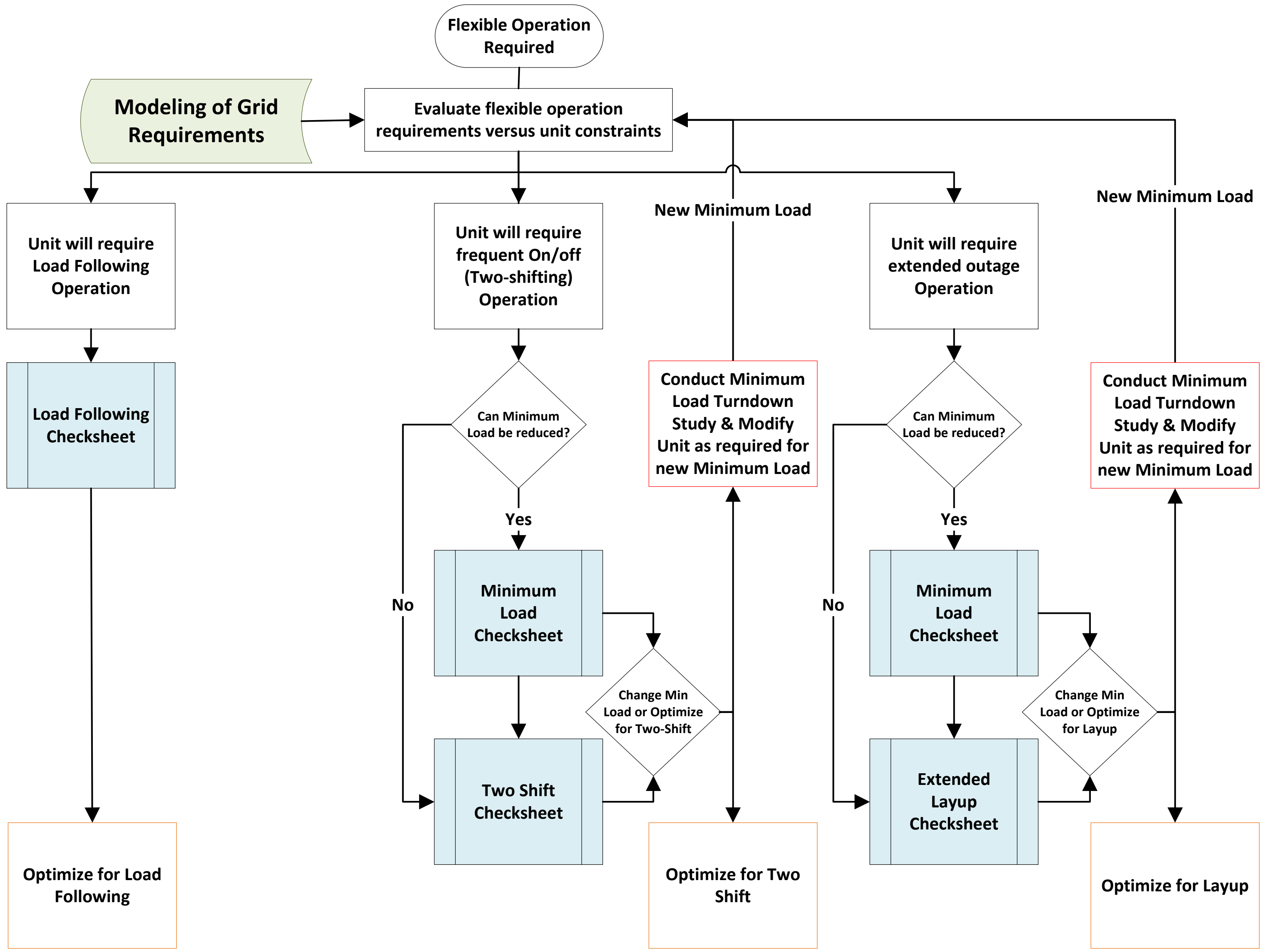
Title	Fatigue in all sections (Thermal / Mechanical)
Article #	BC 8
Unit Types	Subcritical Boiler, Supercritical Boiler
Missions	Cycling (On / Off)
Subject Matter	Boiler, Heat Recovery Steam Generator (HRSG)
Description of Issue	Thermal and mechanical fatigue damage - can occur in a number locations especially when cycling on / off. Superheater and Reheater outlet headers can have issues when load following. Slag shedding which can cause temperature spikes can also contribute and slagging can be more of a problem when flexibly operating. Additional areas of concern include: -Penetrations (doors) -Hangers -Waterwall failures -Header stubs (SH) -B&W transition header (mixing header) -Membrane terminations -Sootblower Penetrations -Hanger on Piping Systems -Handhold Caps leaking -Finned tube economizers (continuous finned, not issue on spiral finned tubes) - identical issue on membrane tubes Predominantly related to attachments to tubes which are either colder or hotter than the tube. Substandard welding can lead to these failures as well. -DMW - can frequently be an issue when a dissimilar weld attachment to tube -DMW - circumferential are stressed through every cycle -Buckstay issues can increase / compound overall issues Units generally do not have sufficient instrumentation data to evaluate strains induced under various flexible modes of operation -The stress range can come from mechanical or thermal drivers -The most common in boilers is thermal fatigue where the stress is developed by -differential expansion -Large concern for SH/RH Outlet and economizer inlet headers -Hard spots in boiler like bifurcates and waterwall penetrations
Priority Rating	HIGH
Compounding Issues	On/off Cycling drives the issues, speed of cycles can have a very significant impact on the rate and level of damage. Oftentimes a weakpoint (e.g. a DMW) may be the first point of failure acting as a leading indicator of issues in headers, other locations being driven by fatigue mechanisms. Significant concern that a large amount of damage may be incurred before being detected (bow wave impact).
Associated Image	Flexible Operation Reliability Issue: Thermal Fatigue Damage
Solutions	Adding instrumenting to understand when and where fatigue is occurring can help optimize procedures for ramping or starting up / shutting down units. Looking for Fatigue damage on unit outages can help to determine acceptability of mode of

20/20 and Beyond - *Visions for the Future*

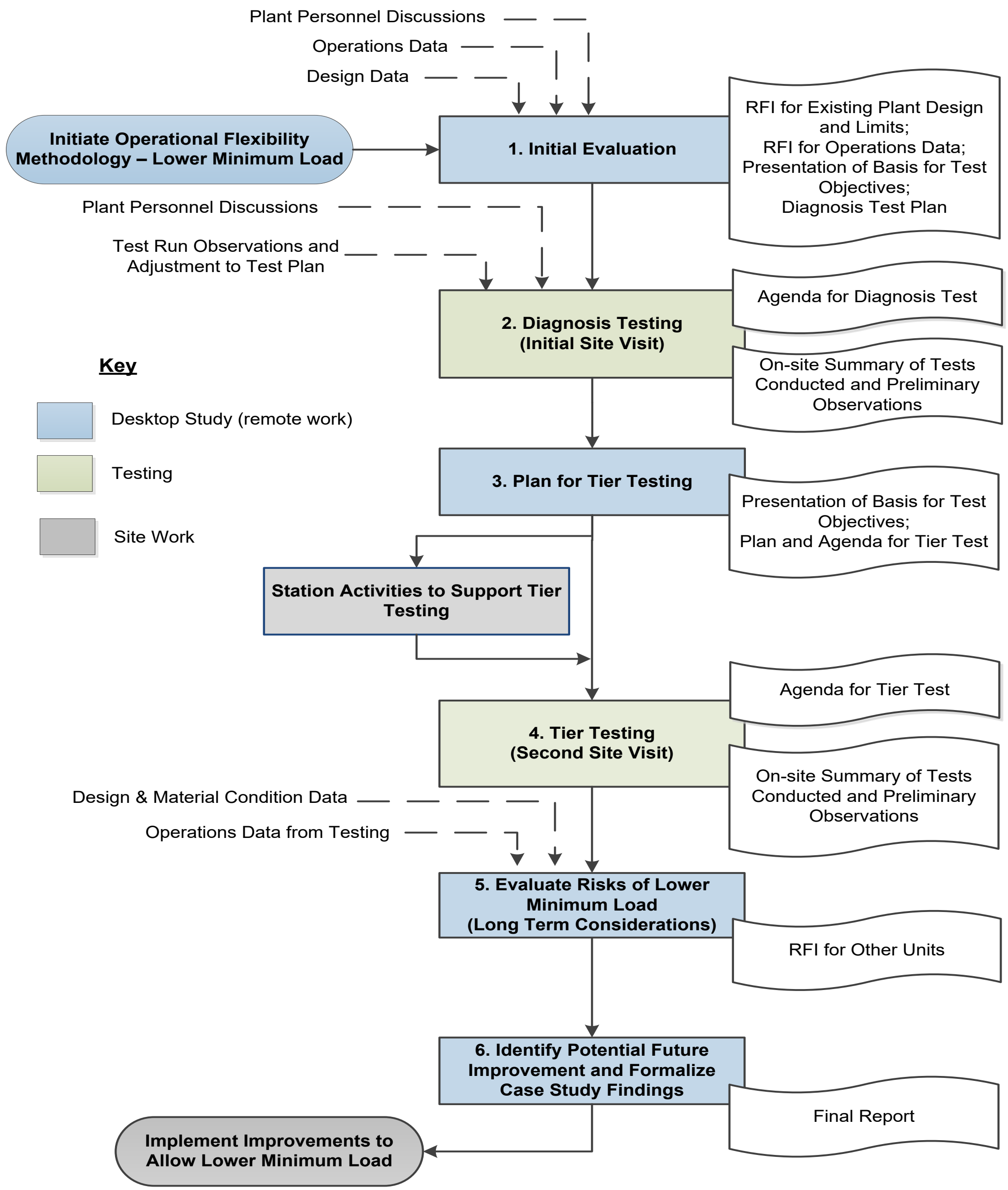
- Flexibility Training
  - Workshops
  - Webcasts
  - 60 Second Flex Minute(s)
- Assessment Template (s)
- Flexibility Assessment Benchmarking Guide
- Flexibility Management with Monitoring & Diagnostic Tools
- Dynamic Optimization and Control of Flexible Operations

Flexible Operations

1) Training workshops / Awareness
2) Operational Readiness Guideline
3) Systematic Assessments / Studies
4) Minimum Load Tool
5) Modeling of Grid Requirements
6) Mission Profile Working Group Database
7) Ramp Rate Guidelines
8) Controls Optimization
9) **Benchmarking**
10) **Ongoing Flexibility Assessments**
11) **Digital Dashboards**
12) **Optimization**



Reducing Minimum Load (Turndown)



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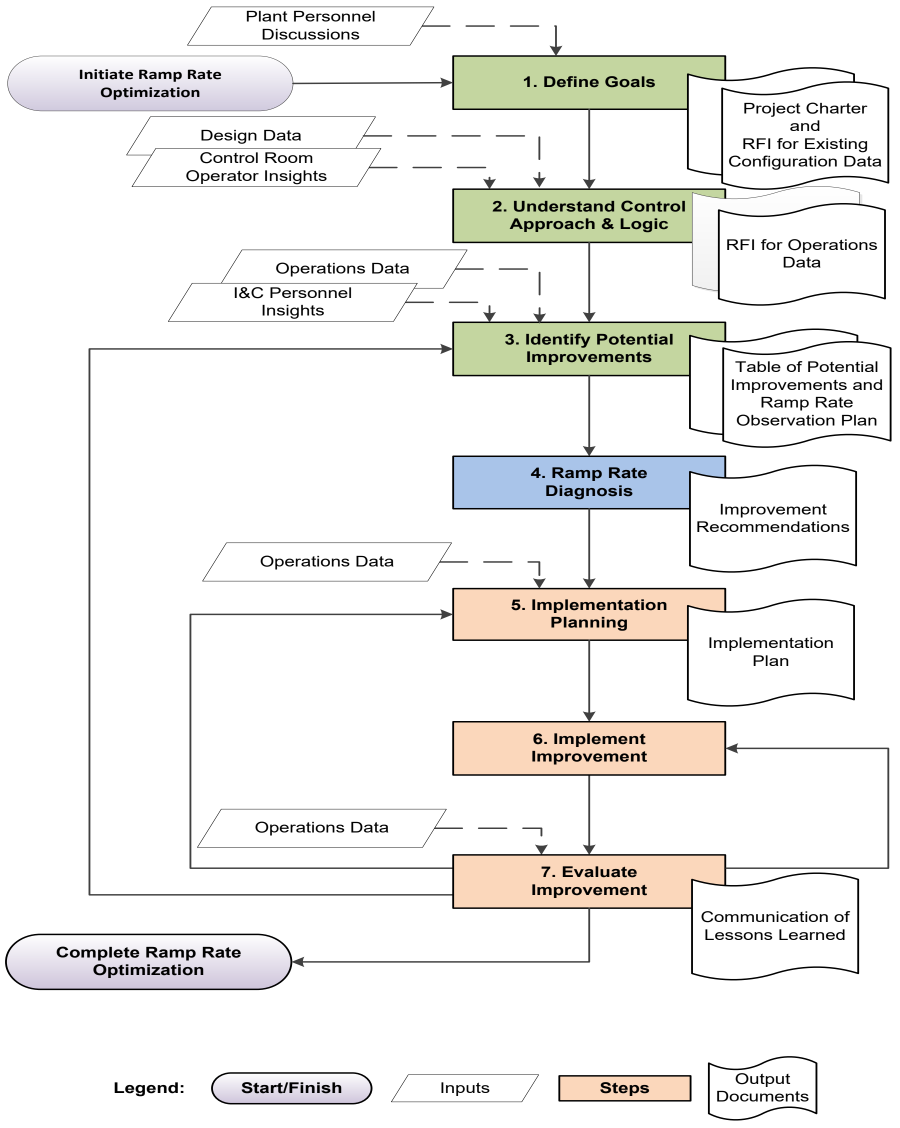
Systematic Approach to Reducing Minimum Load

Common Turn-down Challenges:

- Fuel Loading / Heat Input Management
- Controlling steam temperatures.
- Flame Stability
- Feedwater control
- Environmental Controls
- Excessive cooling of steam turbine due to control valve throttling
- Feedwater heater cascade drain function
- FD and ID fan vibrations
- Damage to back end of LP turbine

Fast Load Ramping



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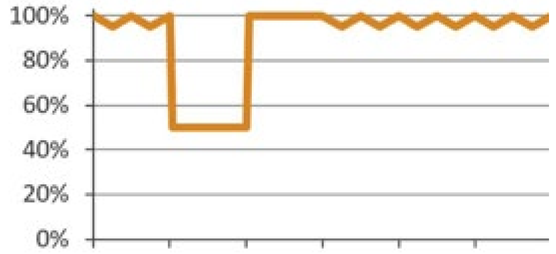
Unit Ramp Rate Optimization Guidelines: Methodology and Technical Approach

Limitations

- Temperature control
- Pressure Control
- Level Control
- Instability due to imbalances in mass flows from various plant systems and energy flows between the boiler and turbine.

Solution

- Control loop tubing
- Improved coordination of boiler and turbine masters



Steam Plant Controls: Not Designed for Turndown

- Many units were designed and tuned to operate best at full load, or close to it.
  - When sliding pressure, the boiler pressure response to changes in firing rate becomes more sluggish.
  - Operating with the upper level burners in service, reduces heat input to the water walls, thereby dulling pressure response to changes in firing rate.

- All of these factors combined often create a situation where the boiler controls respond very poorly when in automatic, as the existing level of proportional response is insufficient to prevent large lazy swings in boiler pressure.
- Steam temperature and drum level controls are also often likely to be poorly tuned for extreme low load operation.

Process-Control Strategies for

Low- Load Operation

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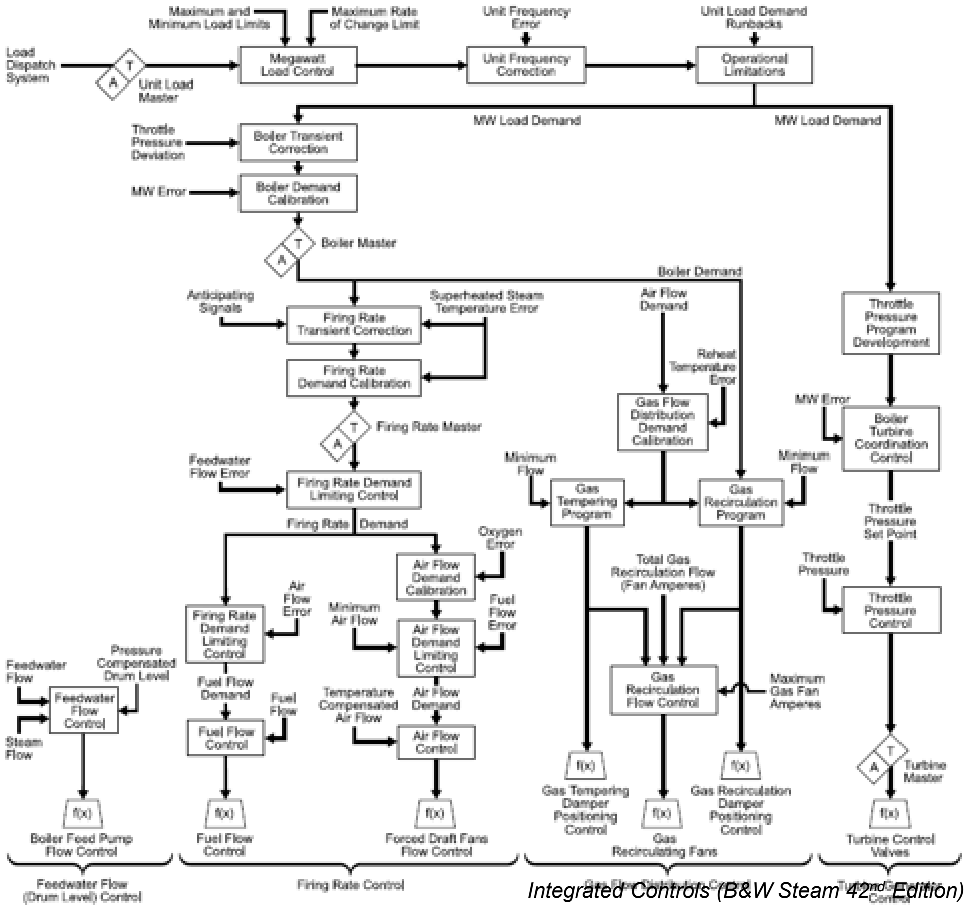


Integrated Controls (B&W Steam 42nd Edition)

Managing Precursors to Boiler Damage

Boiler Component Damage Influencers

Material

Shape, dimension, properties, flaws, surface scales, oxides and deposits

Flue Gas

•Temperature, Velocity

•Heat Transfer, Fuels, O_2, Boiler Cleaning System Process, etc.

Fluid Side Environment

Temperature, Pressure, Flow, Quality, Chemistry, Scale

Air Side Environment

Atmospheric conditions, temperature, chemistry, insulation characteristics and condition

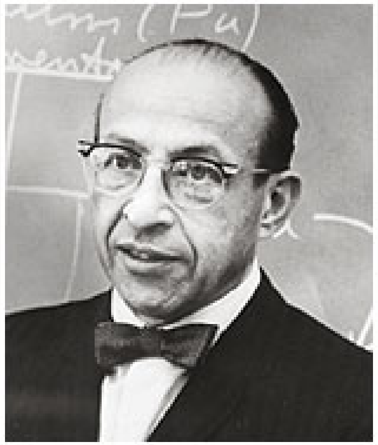
Effect of Flexible Operation on Boiler Components

Volume 1: Fundamentals, **3002001180**

Volume 2: Water-Touched Components **3002005871**

Volume 3: Steam-Touched Components **3002010385**

Managing Fossil Generation as a Tool for Grid Flexibility and Stability



"You can't wipe out society and make a whole new society. You have to deal with the society that exists. But you have to figure out how you're going to change it to something that's better."

Chauncey Starr, EPRI Founder

Qualitative Operational Assessment

	Issue	Area of Concern	Best Practices	B	P	I
1.1	Clear and concise communications by operations personnel at shift turnover.	Communications during shift turnover are a critical part of facility operations and should provide oncoming operators with an accurate picture of facility status. Flexible operations will create new areas of focus for operators.	Shift turnovers should be guided by a checklist and should include a thorough review of appropriate documents describing the important aspects of facility status. They should be complemented by a discussion among oncoming and off going operators.			
1.2	Baseload operations often do not provide enough hands-on experience with startups, shutdowns, and transient operations. Flexible operations often require this to be done regularly, quickly, and efficiently.	As personnel experience more transient operations, shutdowns, and startups, the opportunities for personnel injury, equipment damage, and higher operating costs are greater. Startups and shutdowns might not occur in a way that gives all personnel the same opportunity to gain experience. Personnel need to understand the functional requirements of flexible operations, the commercial aspects of plant running costs and efficiency, and the long-term effects on the life expectancy of the plant.	Provide training on basic principles, plant design, system/cycle fundamentals, safety, and environmental requirements. As opportunities to experience these modes of operation present themselves, consider bringing in additional personnel to gain experience. Use a simulator if one is available. Use tabletop drills.			
1.3	Reducing startup times.	Utilities prefer the fastest safe and efficient startup times. Each plant will have its own characteristics and constraints. The main constraint will be matching steam and turbine metal temperatures.	Sliding pressure offers advantages over throttle control (constant pressure) during startup by establishing a flow to the turbine earlier. It also retains higher temperatures on shutdown. Plants need to perform operational trials to determine the best operating practices and incorporate them into the plant's operating procedures. Automate as much as possible, develop startup procedures, track times taken for each step during each startup, and update procedures with best practices.			

Benchmark B	Probability P	Implication I
Red (1) Yellow (2) Green (3)	1 = Very low 2 = Low 3 = Moderate 4 = High 5 = Very high	1 = Minimal 2 = Moderate 3 = Significant 4 = Severe 5 = Critical

Item	Issue	Area of Concern	Recommendation	Benchmark		
1	---	---	---	✓		

Item	Probability	Impact	Risk Rating		
1	4	4	✓		

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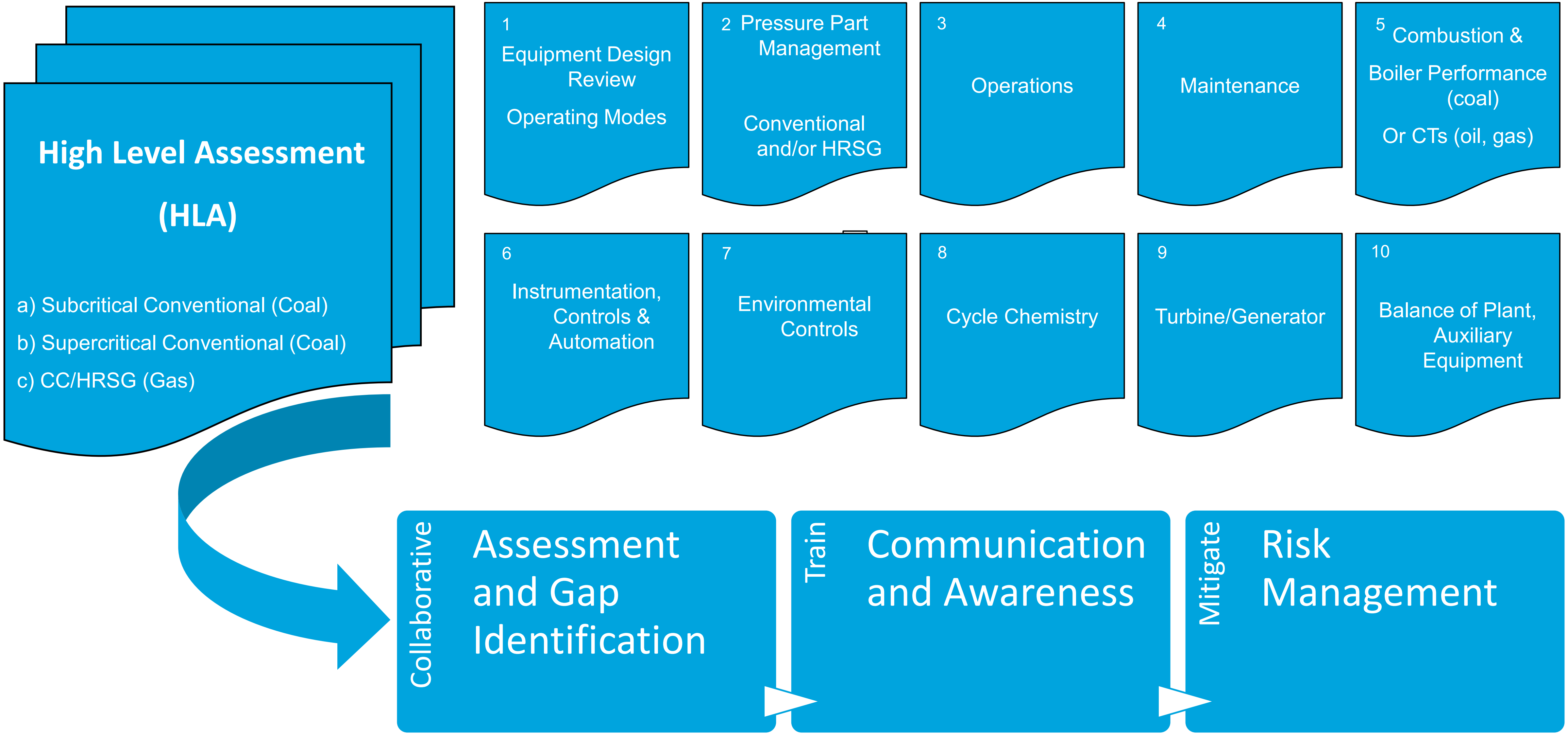
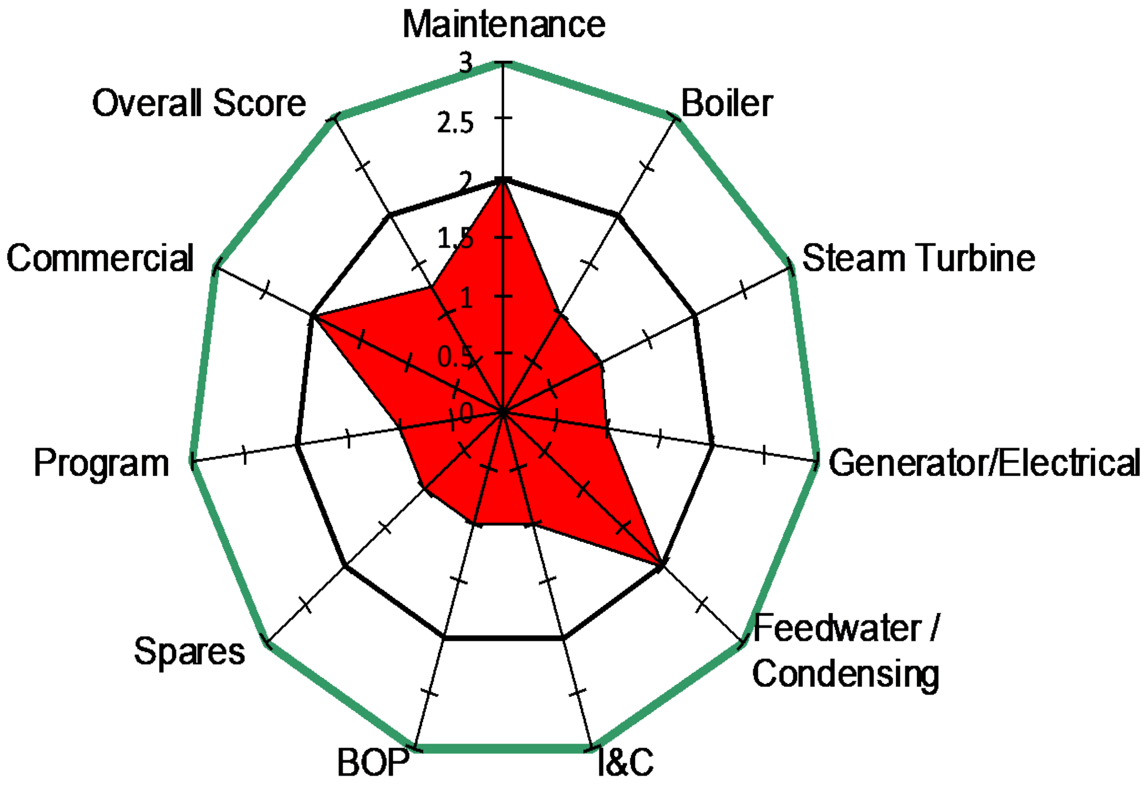
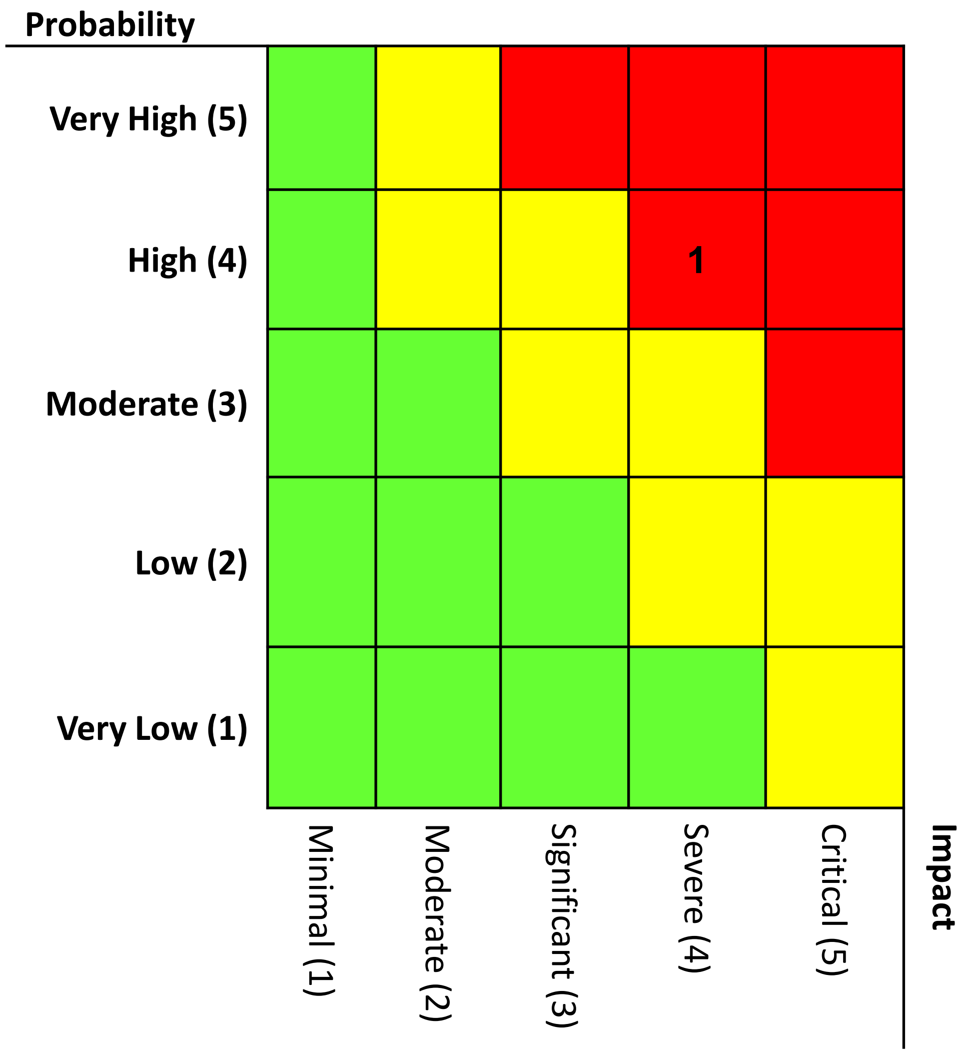
Quantitative Benchmarking Assessment



Asset Management: Prioritizing w/ *Impact vs. Probability*





Offsetting Implications through Programmatic Actions

Cycling Impact
- Thermal Fatigue
- Layup Corrosion
- Balance of Plant
- Corrosion Fatigue
- Creep Fatigue

Economics Impact
- Fuels Management
- Heat Rate
- Operator Skills
- Environmental Controls
- Layup O&M

Managing O&M, Capital $ and Assessments

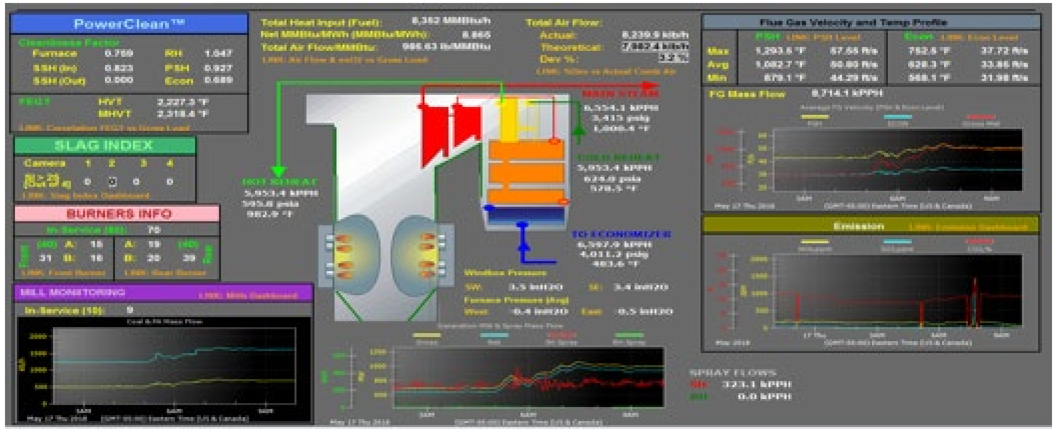
Flexible Operations Cost Management

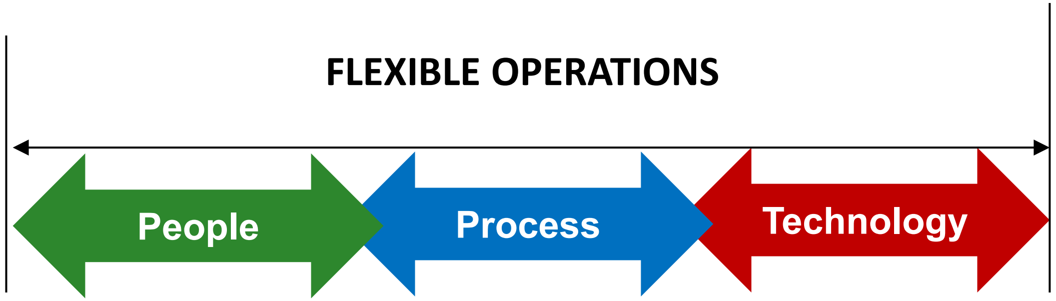
Both Inspection and Operational data is needed to assess actual impact of cost and life assessment.

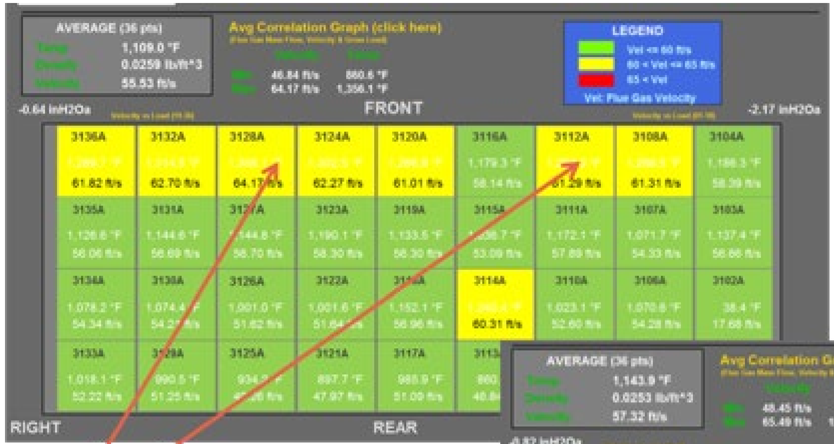
Reliability Offset
- Asset Management
- Controls and Sensors
- Damage Tracking; Improved Layups
- Process Optimization
- Heat Retention

Economics Offset
- Training and Awareness
- Assessments
- Diagnostic Reporting
- Alarm Management
- People Resource Management

Assessment via Monitoring & Diagnostics



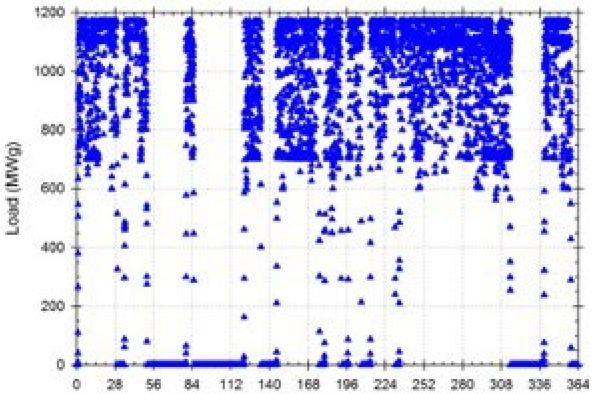




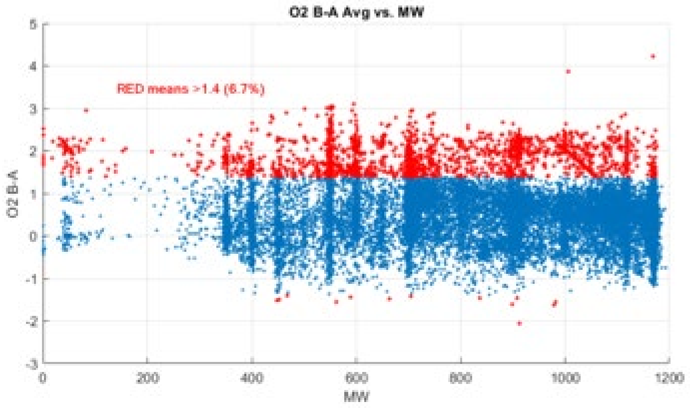
High Velocity Zones in Yellow & Red; Keeping in mind that this is not corrected for flow mal-distribution.

Optimization of Flexibility *- People, Process, Technology*

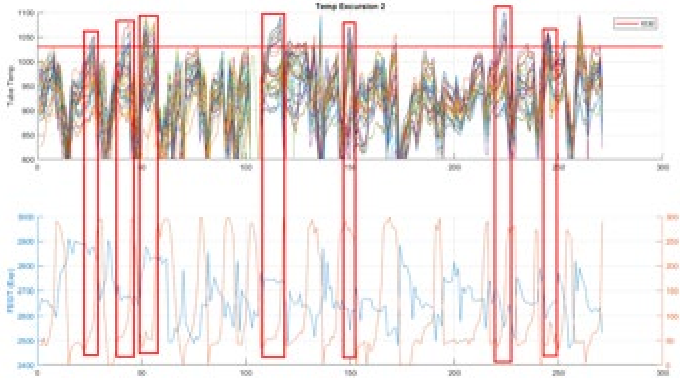
Annual Load Profile



Combustion Optimization



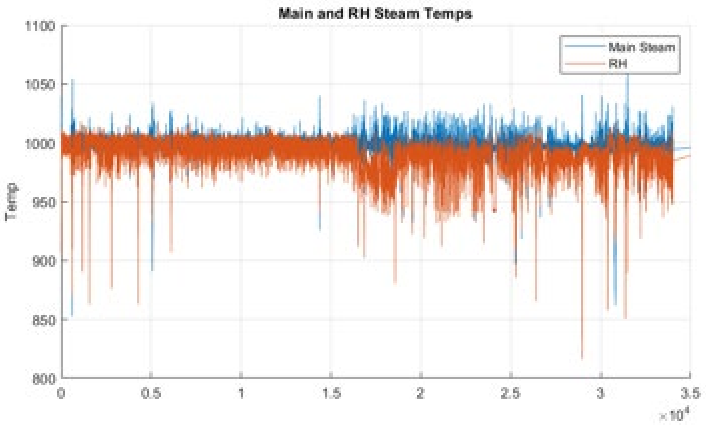
Start-up Protection



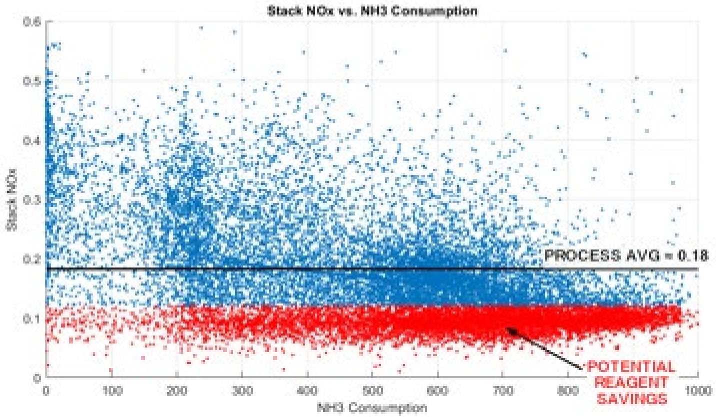
P-71 Pilot Project on a 1,200MW Unit

- Initial data analysis and model development (PEOPLE)
- Characterize roadmap and KPIs (PROCESS)
- Improve controls with application of an open architecture optimizer to help manage big data applications to help improve a systems flexibility, functionality, interoperability, potential use and useful life (TECHOLOGY).

Steam Temperature Control



SCR Optimization



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Together…Shaping the Future of Electricity