Babcock Power®

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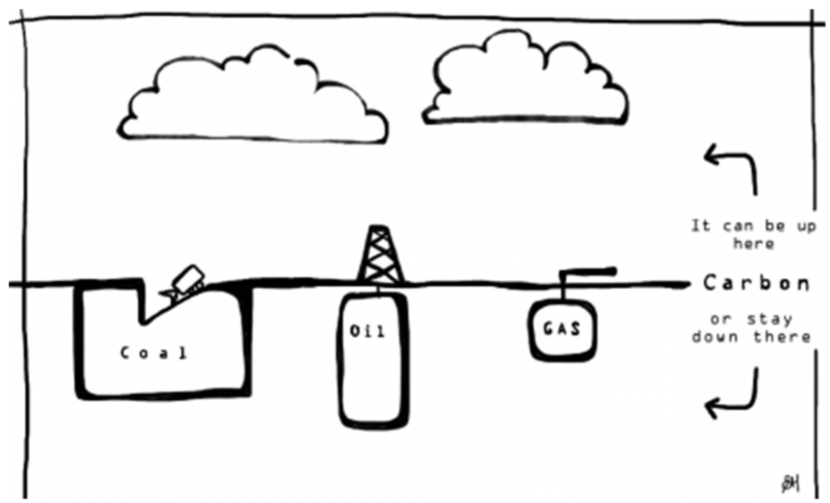
Boiler Tube Company of America | TEiC Construction Services | TEiC Heat Exchanger Services | Struthers Wells (a TEi line of products)

Moving Up The Dispatch Curve

Coal Power

What is coal competing against?

- Increased Coal Cost
  - $/Ton, Delivery & Additives
- Price of Gas
- Availability of Gas
- Nuclear Bias
- Perception
  - Dirty, Old Technology…



Coal Power

What is the benefits?

- Installed Capacity
- Available Fuel
- Fuel Storage – Reserve
- Cost – Lean & Mean
- Availability of Gas
- Nuclear Bias

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Dispatch Rate – $/MWh

How did you make money?

- Improve Efficiency/Heat Rate
  - Parasitic Power
- Improve Reliability
- Fuel Cost Optimization
- Personnel Optimization
- Regulations

Dispatch Rate – $/MWh

What has changed?

- Load Cycling
- Deregulation
- Startup Costs
- Startup Time
- Reliability Penalties

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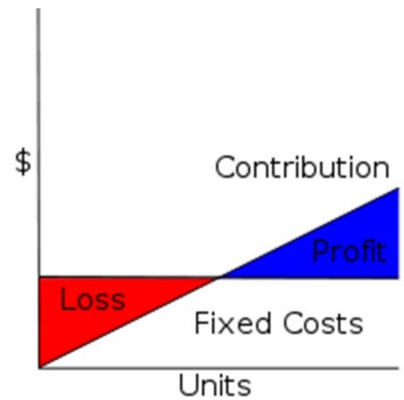
Day-Ahead vs. Real-Time

Is there a difference on the equipment?

Not Really, Both Have

- More Cycling
- More Off Periods
- Little Technical Decision Making
- Have Some Sort of Predictability



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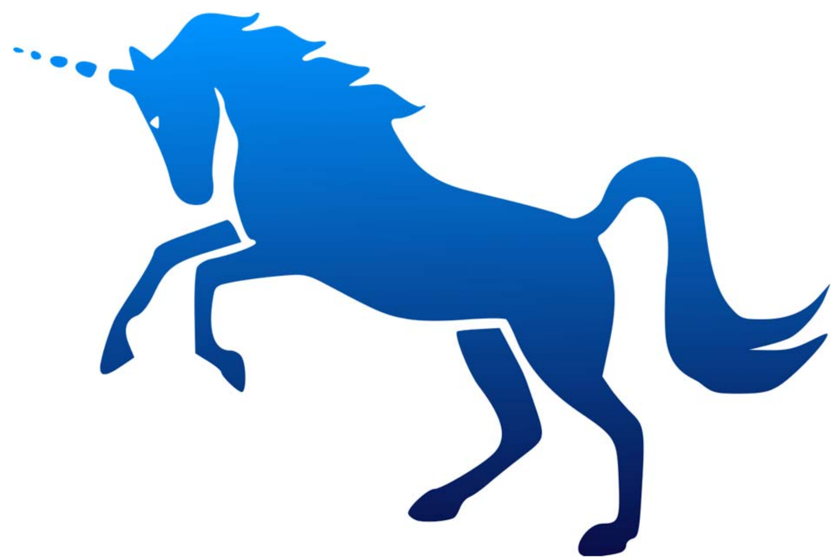
The Unicorn Unit

What would be the perfect unit in this market?

- Quick Start
- Cheap Startups
- High Capacity
- High Efficiency
- High Turndown
- Quick Load Changes
- Very Reliable
- Idle on Weekends & Holidays



Load Cycling

How Quick is Quick?

Type of original boiler design	%/min	MW/min for 500 MW as example
Typical drum unit, designed for constant pressure	4-5%/min	20-25 MW
Same boiler, subjected to sliding pressure*	1%/min	5 MW
Typical non-drum (supercritical) constant pressure	Varies per design; can be >5%	>25 MW
Typical Benson (non-drum) sliding pressure**	4-5%+/min	20-25 MW

* Note that turbine ramp rate limits are often 'opposite' those of the boiler, as related to constant vs. sliding pressure.
** Additional ramp capacity may be afforded by intermediate RH (and SH) sprays and other features.

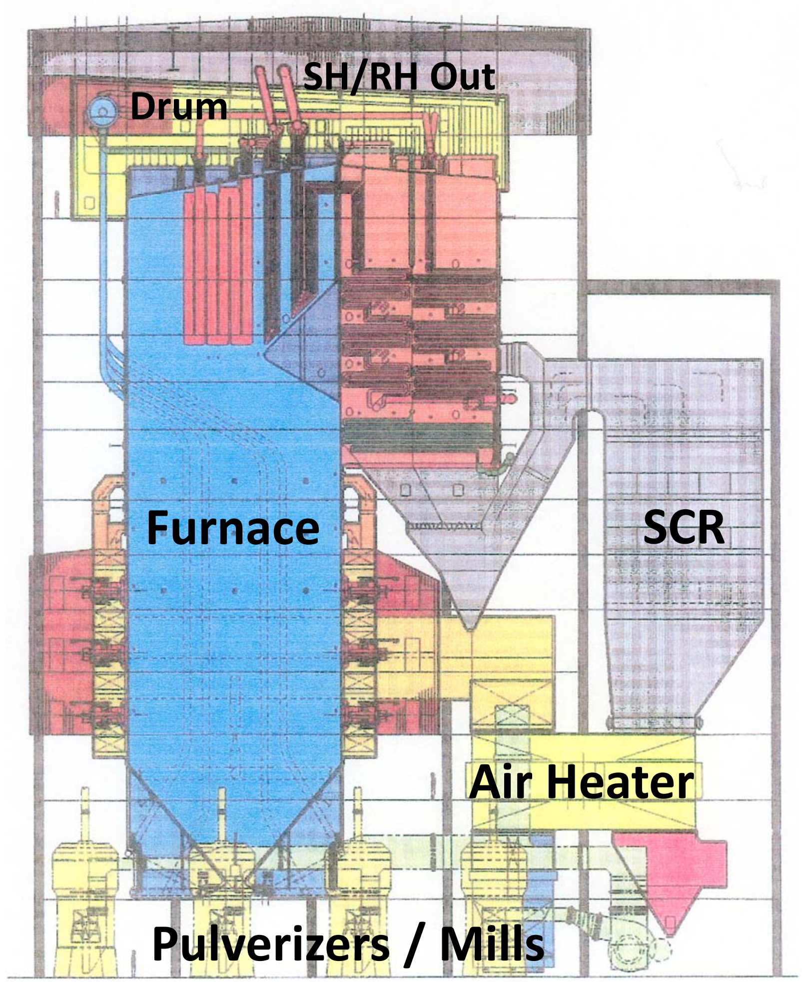
Load Cycling

Effect on Components?

Operational / controls:

- o Steam temperature swings / excursions; SH/RH imbalance
- o Drum level swells
- o Steaming economizer
- o Flow & temperature imbalances in SH/RH
- o Internal tube oxide exfoliation

- **Fatigue cracking of:**
  - o Furnace corner tubes
  - o Tube attachments (buckstays, windbox)
  - o Tube to header nozzles
  - o Tube to membrane fin
  - o Economizer inlet header
  - o SH/RH headers and piping
  - o **Header / drum ligament**
- **Drum / header bowing**
- **SH/RH tube leg flexibility failures**
- SH/RH dissimilar metal weld failures
- Startup related tube failures in furnace wall, SH, RH tubing



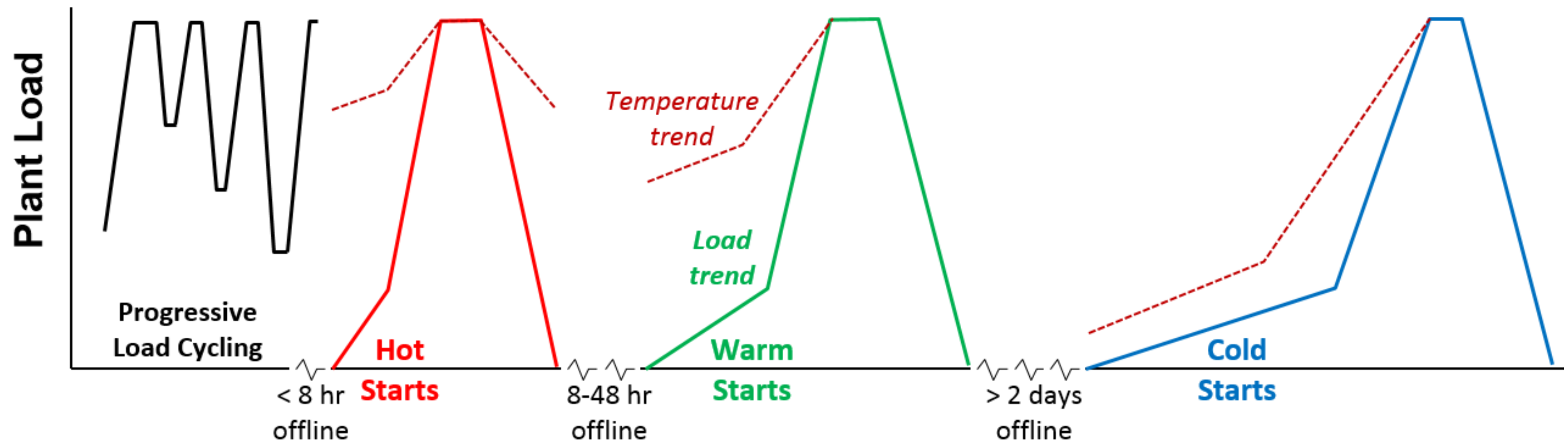
Load Cycling

Aspects of Coal Boiler Cycling!

- **Turndown or range**
  From high load to:
  - minimum load, or
  - offline (hot, warm, or cold)

- **Load ramp / shed rates**
  (rate of load change vs. time)

- **Load cycles**
  (number or frequency of changes)



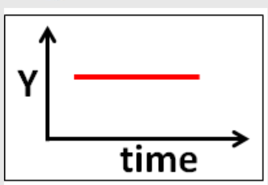
Load Cycling

Aspects of Coal Boiler Cycling! Pressure Parts?

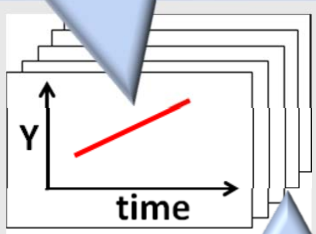
General plant cycling / operating parameters

Specific component operating parameters

Steady state loading / creep



Ramp rate and range (load, P, T, ... vs time)

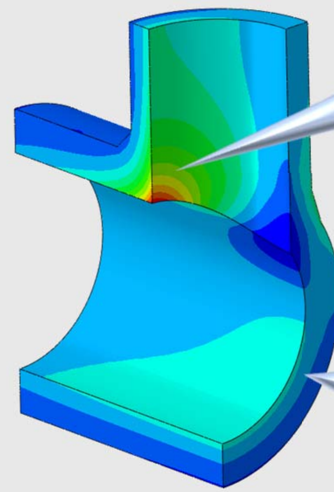


creep-fatigue analysis

"n"
Number of cycles

+

Component design



Geometry & restraints

Material properties

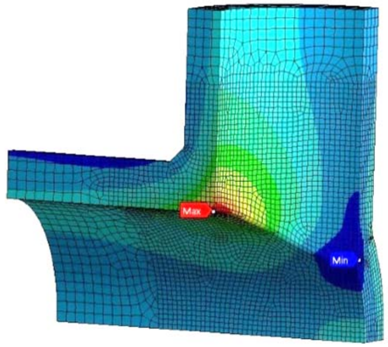
Combination of these factors is used to assess the cumulative fatigue damage and expected service life

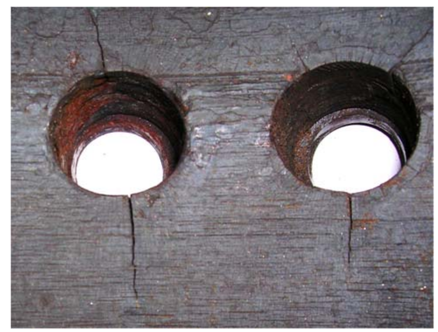
Load Cycling

Mechanical Issues?

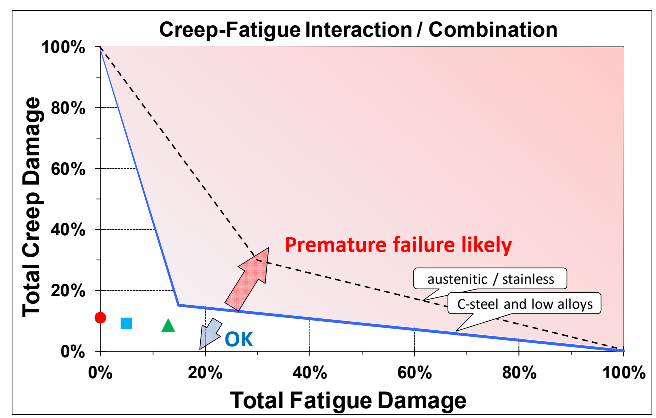
- Cycling → large pressure & thermal stresses.
    - Thick walled components
- Steam temp changes take time to conduct through metal thickness. Temp profile → Thermal stresses.
- Can reduce the life of components through fatigue.
- Damage can be accentuated due to creep-fatigue interaction for high temp components.
- Rate of damage accumulation depends on existing conditions and the types and frequency of the cycling.

Finite element model – Stress contour plot





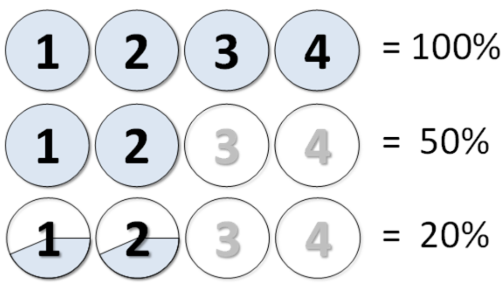
Ligament cracking on inside of superheater header



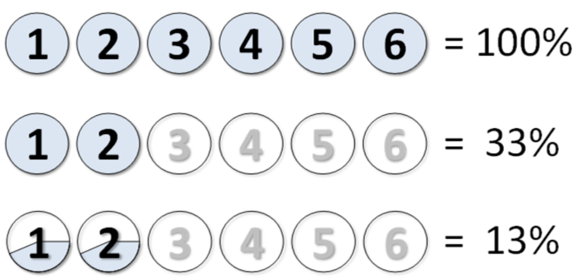
Low Load Operation

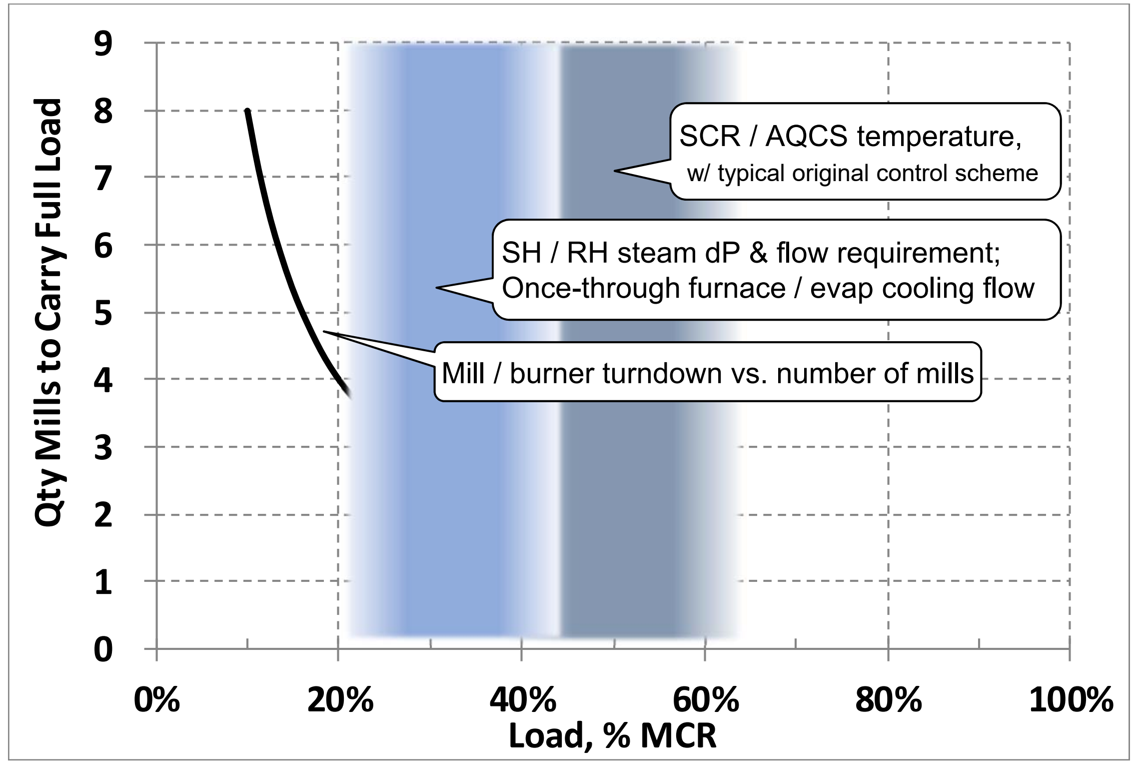
AQCS vs. Turndown?

Mill / Pulverizer Turndown:



2 mills @ 40%





- Natural gas (or other non-solid fuel) firing removes the mill turndown limitation.
- Gas burner turndown typically 10% or better. Also not subject to lags in ramp rate due to mill starts.
- Spreading of heat input in furnace (to multiple burner levels) is still a consideration.

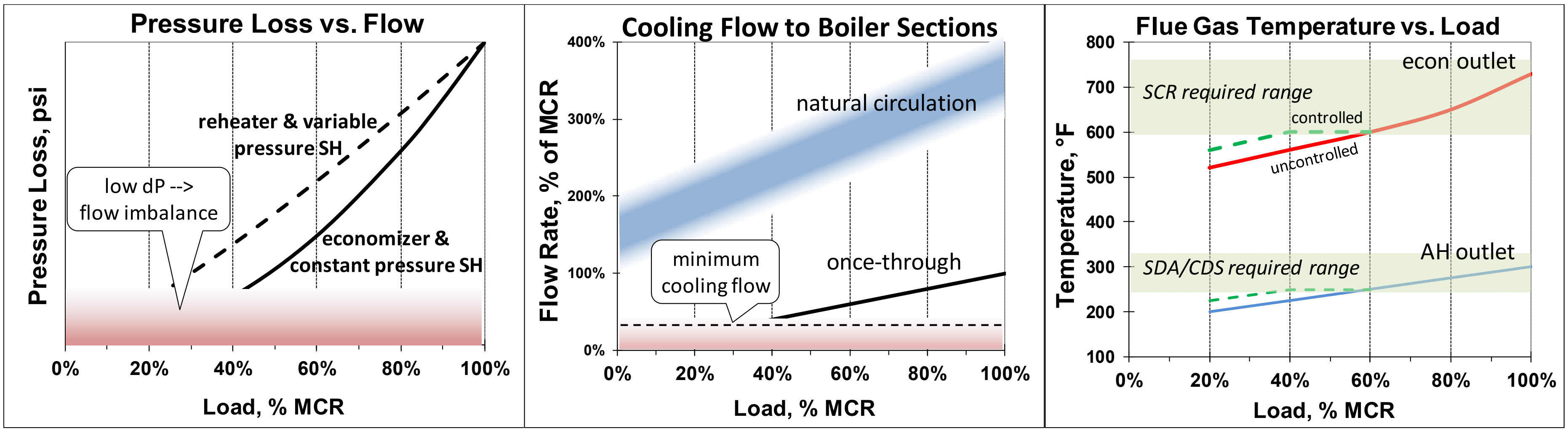
Low Load Operation

AQCS vs. Turndown?

Low flow in econ, SH, and once-thru evaporators can lead to flow imbalance and high metal temps:

Once-through evaporator (furnace) requires min flow:

SCR requires minimum flue gas temperature to avoid ABS fouling: (SDA also requires range)

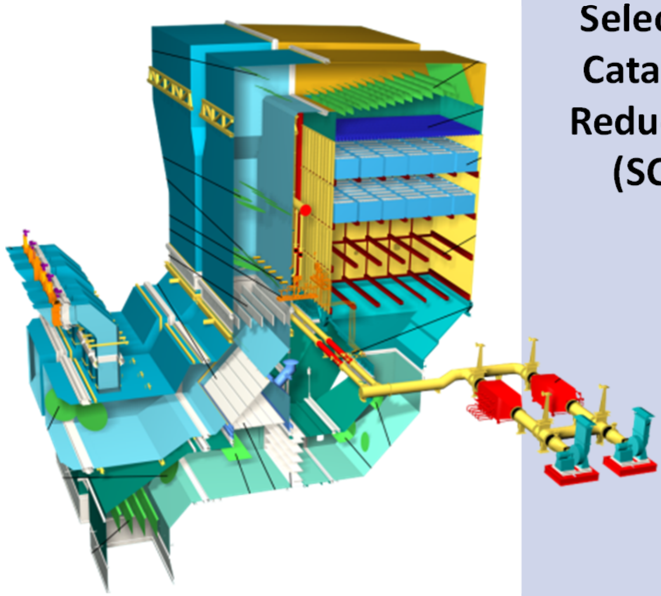


<u>SCR temperature control may include:</u>

- Economizer flue gas bypass
- Economizer water bypass
- Pegging FW heaters
- Direct heating

Equipment Considerations

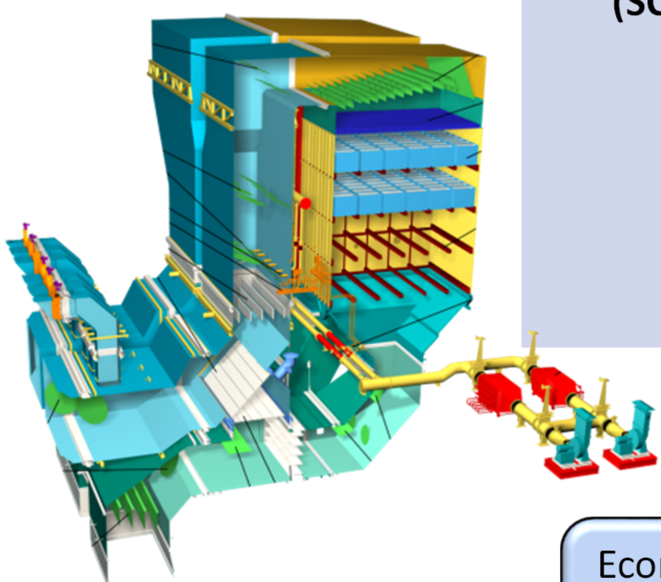
NO_x Control?



System	Considerations
Selective Catalytic Reduction (SCR)	• Gas temperature control range: • At lower loads / temperatures, ammonium bisulfate (ABS) may form and foul / plug catalyst pores (and foul air heater baskets). • At time of retrofit, min load for SCR temp control was often 40-50% load and modest control was designed. • May need to extend SCR gas temp control capabilities. • Other ways to reduce ABS potential: • Improve flue gas mixing. • Change catalyst formulation (limited effect). • Consider sorbent injection to reduce available SO_3. • Fire natural gas (no sulfur) at low loads. • Consider time-averaging NOx emissions if permit allows.

Equipment Considerations

NO_x Control?



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Methods to increase flue gas temp to SCR:

- Economizer flue gas bypass
- Economizer water bypass
- FW heater steam pegging
- Direct heating

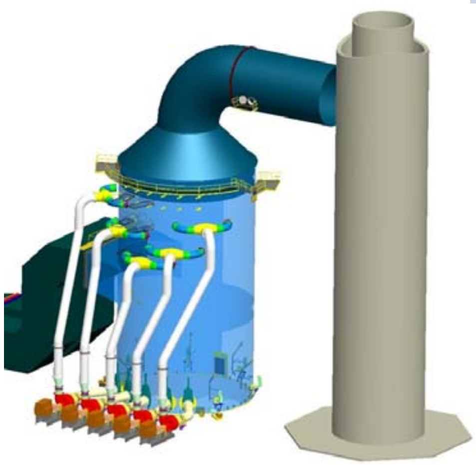
Equipment Considerations

SO_2 Control?

System	Considerations
DRY Scrubbers: **Circulating Dry Scrubber (CDS)** **Spray Dryer Absorber (SDA)**	• For water spray, typically need flue gas 100 F° (56 C°) above saturation. • Raise temp at low loads by increased AH air bypass, direct heating (subject to other limits). • AH flue gas bypass often not a good option due to ACET / corrosion concerns. **CDS:** • Recycles solids (ash and lime). • Has advantage of independent control of water and lime feed. • As temperature drops, may make trade-off of reducing water spray and reduced SO_2 removal. No need for additional dry sorbent injection system. **SDA:** • SDA requires wet lime feed, and thereby imposes a minimum flue gas temp. • For SDA, operation below temp limit will prohibit lime feed and all SO_2 reduction. • To get modest SO_2 removal at very low loads, consider a dry sorbent injection (possibly upstream of SCR).

Equipment Considerations

SO_2 Control?



System	Considerations

Wet Scrubber
 	
WFGD
Wet Flue Gas Desulfurization
	• Low flue gas temp generally not an issue.
	• Typically not amenable to frequent cold startups due to:
	  • need to purge systems to avoid slurry solidification.
	  • production of low-purity gypsum at each startup.
	  • potential impact of startup fuel oil residues on linings.
	  • lengthy warm-up time.
	• Keep slurry system operating for shorter shutdowns.
	• Low load control may be difficult if reagent flow is at fixed rate. Batching process.
	• Address potential water imbalance.
	• Optimize performance and power consumption at low loads (turn pumps off, etc...).

Seasoned Coal Plant

What can you do?

- Quick Start
  - Some companies are offering quicker start capabilities
  - Predictive warmups
    - Auxiliary boilers
    - Turbine seals
  - Optimize Offline Practices
- Cheap Startups
  - Igniter fuel (dual)
- High Capacity
  - Capacity Increases
  - Minimal De-rates
  - Prioritized Upgrades
- High Efficiency
  - Condenser
  - Feedwater Heaters
  - Air Heaters
  - Sootblowers

Seasoned Coal Plant

What can you do?

- High Turndown
  - Single feed pump operation
  - Less mills in service
  - Steam temperatures
  - Avoid circulation issues
  - SCR temperature issues
  - Cold end air heater temperatures
  - Low load optimization
- Quick Load Changes
  - Optimize mill startup/shutdown sequences
  - Firing master
- Very Reliable
  - Tune boiler & controls
  - Minimize forced outages
- Idle on Weekends & Holidays

Seasoned Coal Plant

What can we do?

Problem / limitation	Solutions
Drum level swings	• Larger drum (new unit design) • Advanced / anticipatory controls • Add drains / vents
Steam temperature control	• Advanced / anticipatory controls • Multi/late-stage sprays (incl. RH) • Larger capacity sprays
Steam & metal temperature ramping / fatigue	• Minimize wall thickness with materials upgrades • Design for flexibility • Appropriate header/drum design • If possible, ramp boiler under constant pressure, then ease pressure
Steaming economizer	• Add instrumentation / alarms • Recirculation • Utilize gas bypass if equipped for SCR • Heat exchanger, spray, and/or temporary FWH out of service • Design for steaming / venting

Seasoned Coal Plant

What can we do?

Problem / limitation	Solutions
Heat input limitations	• Advanced / anticipatory controls (including for pulverizers) • Extensive thermocouples / instrumentation / alarms to reduce need for margins in operations...
Improper or non-ideal startup / shutdown procedures	• Review procedures; identify key bottlenecks • Evaluate possible improvements – to either speed the process or to reduce damaging conditions • Add instrumentation / alarms to facilitate procedures and guide through transients • Consider improvements to retain heat / bottle up unit (Off-line recirculation) • Consider nitrogen purge/blanketing during shutdowns (boiler, condensate storage tank, etc...). Enhance drainability / add drains in strategic locations. • Consider steam turbine bypass system... incl. condenser modifications • Improve pulverizer start/stop procedures, maintenance
Excessive shutdowns (due to min load greater than dispatch requirement)	• Review and make modifications to reduce the unit's low load limit; stay online overnight rather than shutdown • Extend SCR gas temp control capabilities. Natural gas firing and sorbent injection can allow lower temp & load

Seasoned Coal Plant

What can we do?

Problem / limitation	Solutions
Dynamic ramping issues	• If sliding pressure for reasons other than dynamic ramp rate, and boiler transients are problematic, consider load ramping under constant pressure, and then slowly ease into a lower / matched pressure with the turbine.
Miscellaneous	• Motor issues: VFD or soft-start of large motors such as fans, etc... • Make operational or design changes to eliminate acid gas dew point issues at low loads. • Ensure makeup water / treatment is sufficient for increased requirements of more frequent startups. • Review & improve location, operation, and capacity of drains.

Seasoned Coal Plant

Summary of Cycling Operation?

- Plants originally designed for baseload operation will require targeted equipment and operational modifications to allow more extensive cycling.
- Unit-specific study is required to:
  - Define past and future operations.
  - Determine the capabilities and limits of existing equipment.
  - Prioritize further efforts.
- OEMs can work with plant staff to develop solutions for each unique plant.
- For any increased ramping or cycling, consider adding thermocouples / alarms at key locations.

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