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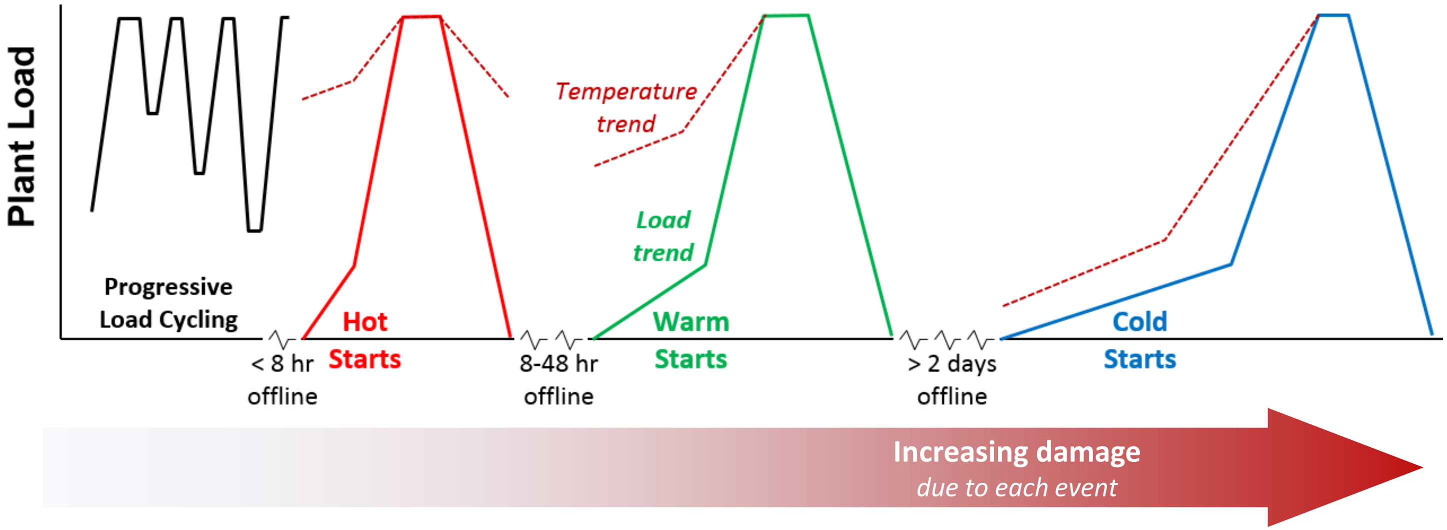
Flue Gas Temperature Control for SCRs and Scrubbers

RMEL Plant Management, Engineering and Operations Conference
August 7, 2019

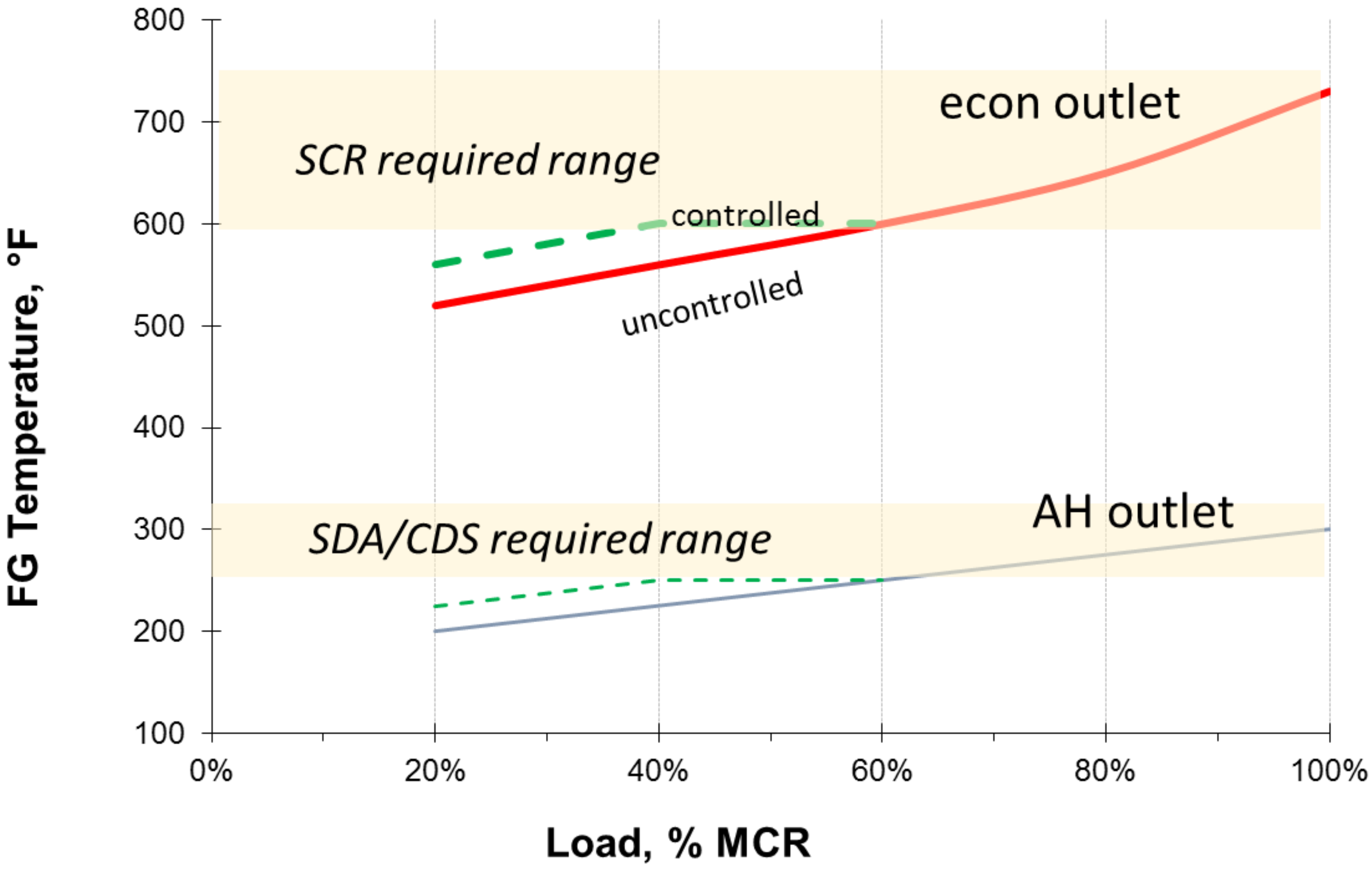
Low Load Operation of AQCS Equipment

Motivation:

As penetration of intermittent renewable generation increases, traditional assets are increasingly required to reduce their minimum dispatchable load in order to avoid startup costs and asset damage during periods where they are not economically competitive.



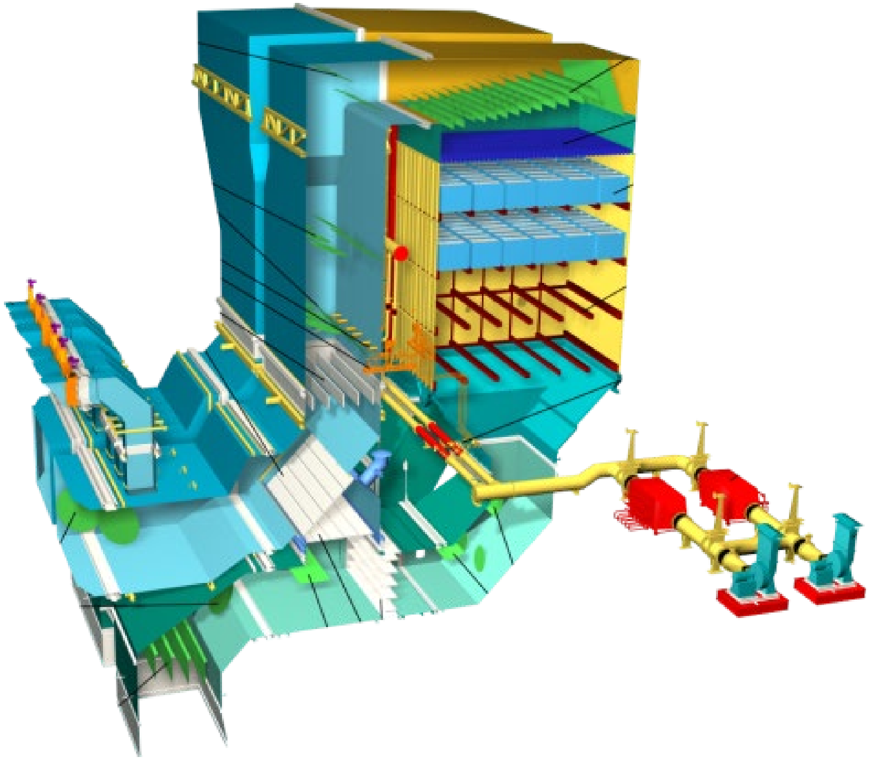
Required Temperature Control Ranges for AQCS Equipment



Selective Catalytic Reduction (SCR)

Flue Gas Temperature Control

Selective Catalytic Reduction



Considerations

- 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.

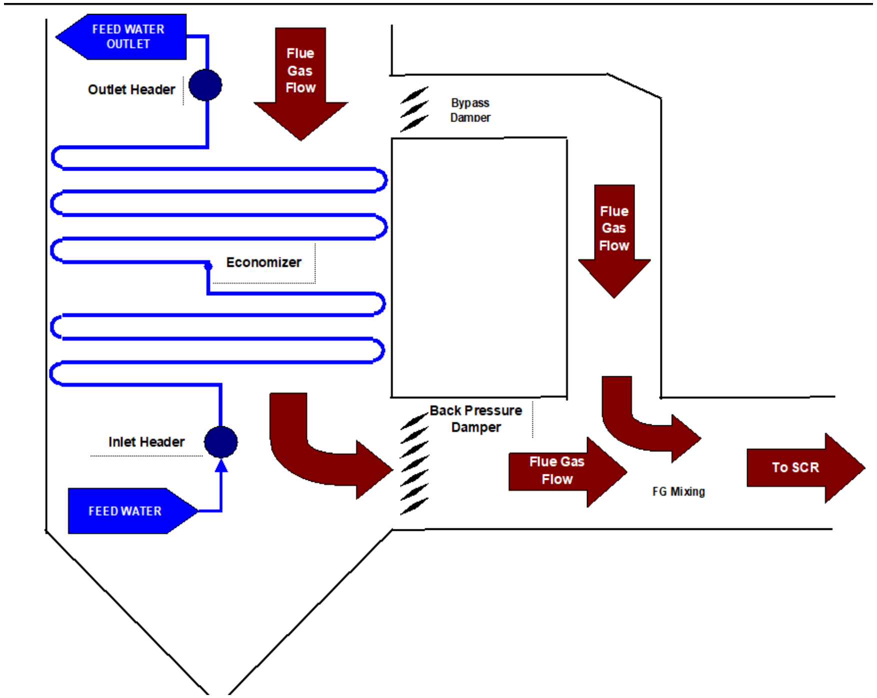
Available Control Systems/Techniques

1. Economizer Flue Gas Bypass (most common)
2. Economizer Water-Side Bypass
3. FW Temperature Control
4. Split Economizer (most efficient)
5. Remove Economizer Surface
6. Direct Heating

Economizer Flue Gas Bypass

Advantages

- No effect on boiler efficiency at higher loads
- Simple design that is reliable and easy to control
- Quick flue gas temperature response
- Minimal operational risks
- Minimal pressure part modifications



Disadvantages

- Reduction in boiler efficiency with increasing exit gas temperature
- Requires addition of ducts, dampers, expansion joints, controls and structural steel supports
- Requires flue gas mixing prior to SCR inlet

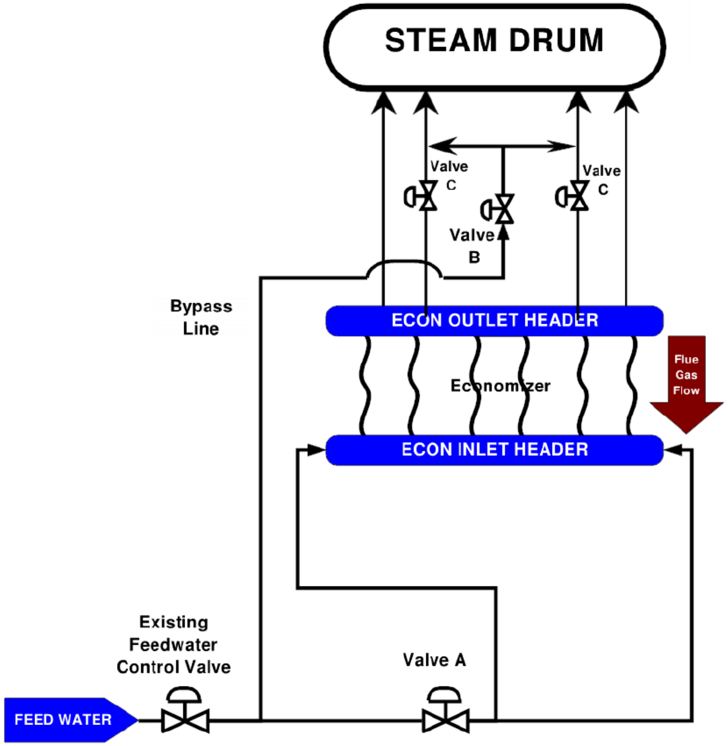
Economizer Water-Side Bypass

Advantages

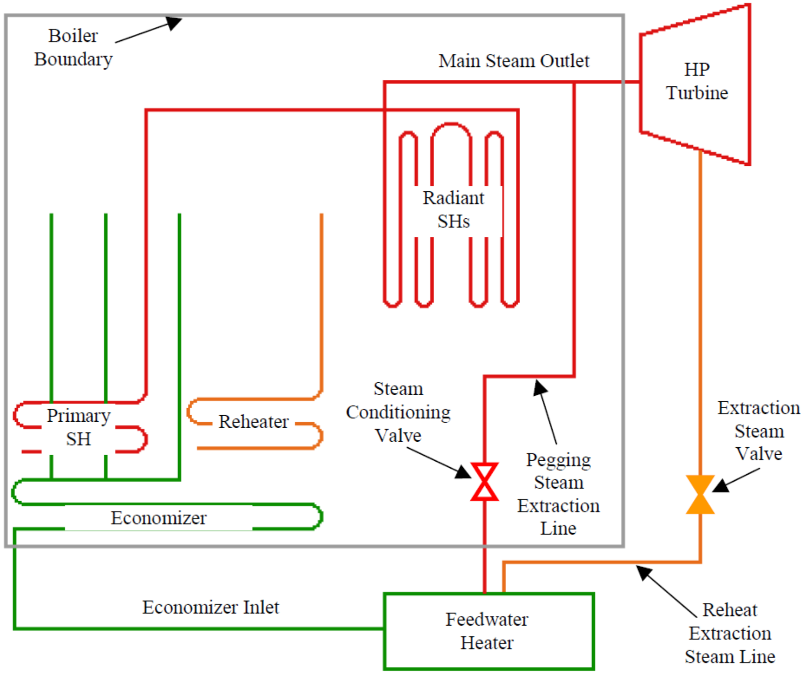
- No effects on boiler efficiency at high loads.
- Possible to maintain minimum flue gas temperature at lower loads
- Minimal space requirements (no ductwork as in flue gas bypass)
- Does not require flue gas dampers

Disadvantages

- Reduction in boiler efficiency with increasing exit gas temperature
- Pressure part modifications required
- Additional piping, valves, controls and steel supports required
- Possibility of steaming in the economizer



FW Temperature Control (FW Htr Pegging)



Advantages

- No effect on boiler efficiency at high loads
- No additional ductwork required
- May be possible to control flue gas temperature with existing equipment

Disadvantages

- Requires additional steam extraction to feedwater heater.
- Possible pressure part modifications required
- Adversely impacts plant heat rate when raising feedwater temperature
- Steaming in the economizer possible
- Additional controls required.

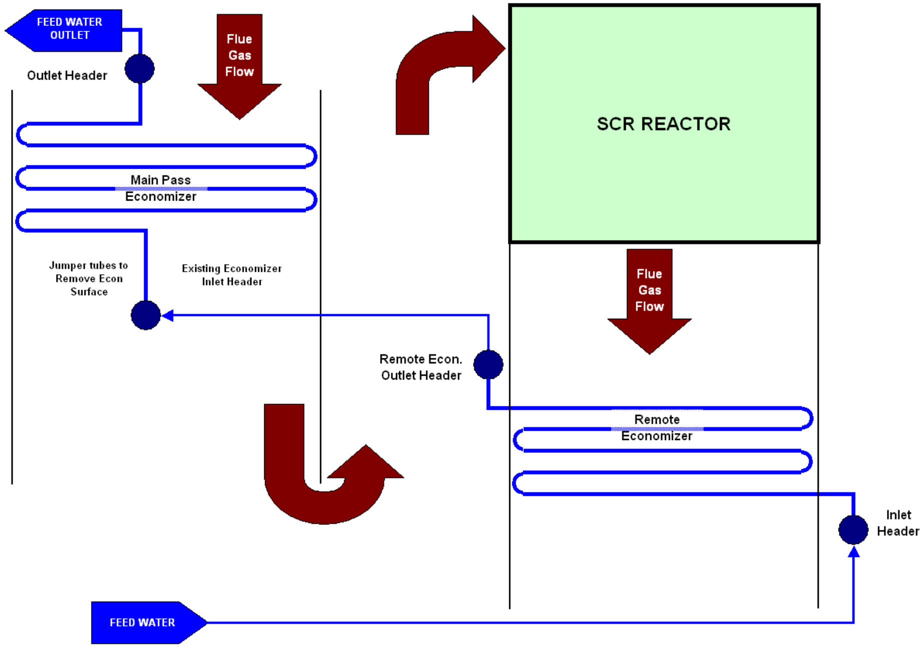
Split Economizer

Advantages

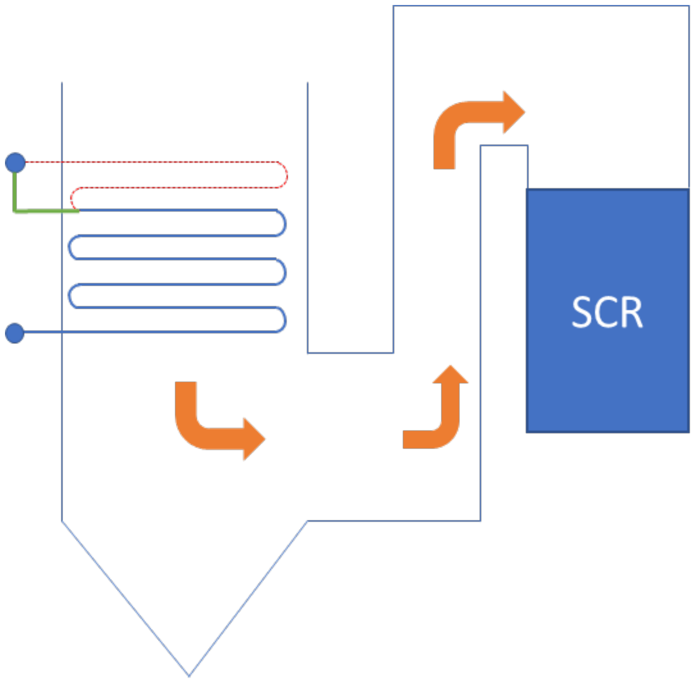
- Meets or exceeds existing boiler efficiency at all loads
- No additional controls
- No flue gas temperature adjustment
- Ability to optimize existing economizer surface for desired operating range

Disadvantages

- Pressure part modifications (new remote economizer and associated piping)
- Structural support steel required and space considerations for added remote economizer.



Remove Economizer Surface



Advantages

- Minimal initial cost
- No additional controls
- No flue gas temperature adjustment

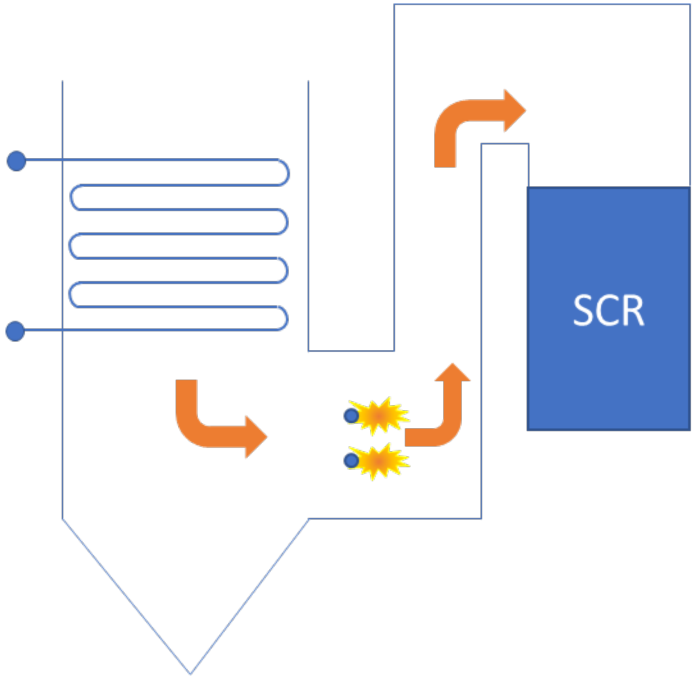
Disadvantages

- Increase in flue gas exit temperature, even at full load
- Loss of boiler efficiency across load range
- Requires pressure part modifications

Direct Heating (Duct Burner)

Advantages

- No effect on boiler efficiency at high loads
- Minimal boiler modifications required



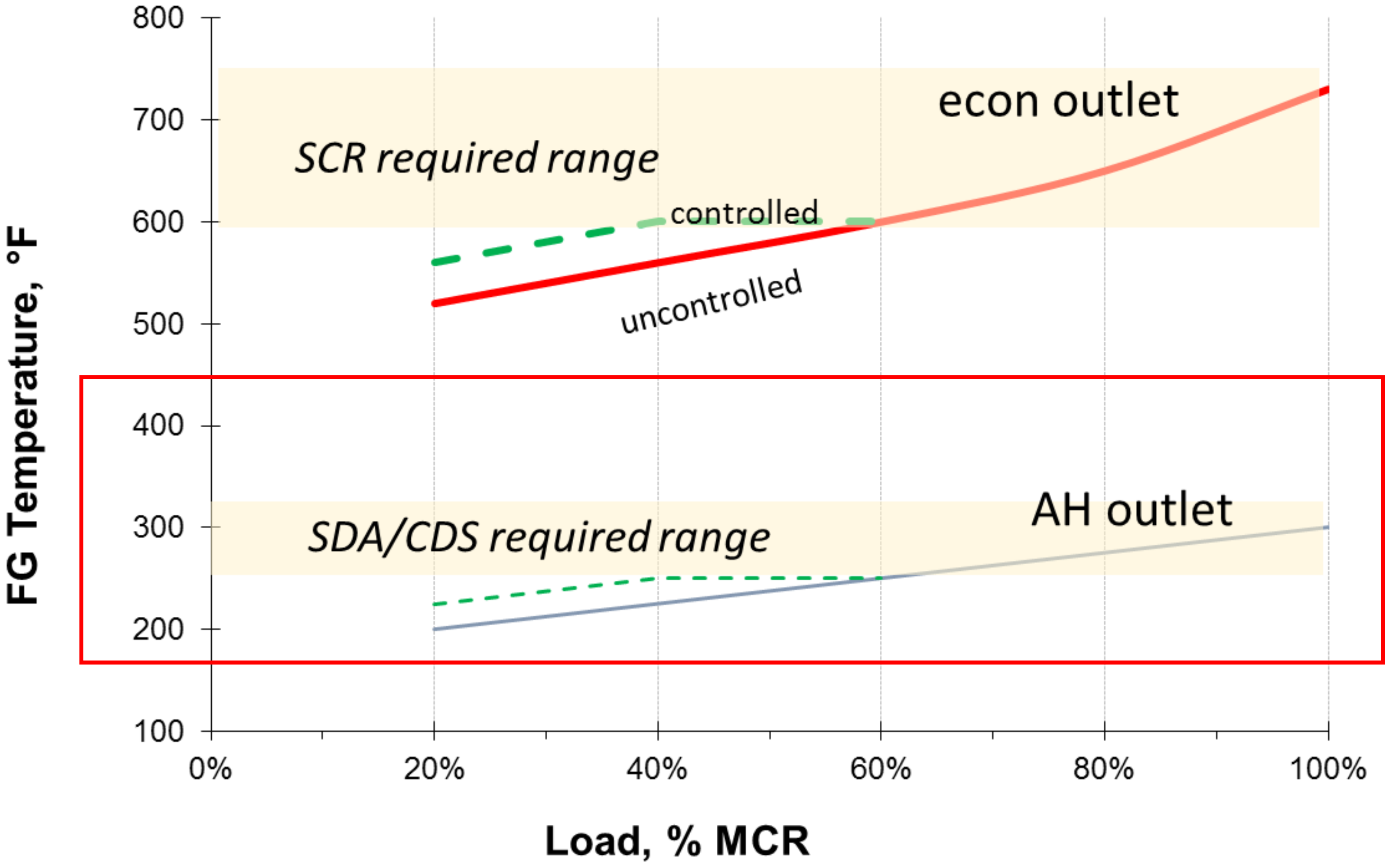
Disadvantages

- Adversely impacts unit heat rate when duct burner in operation
- Additional fuel consumption
- Additional controls required
- Addition of gas flow control and regulation skids required
- Increased maintenance (valves, burners, piping)
- Additional structural steel

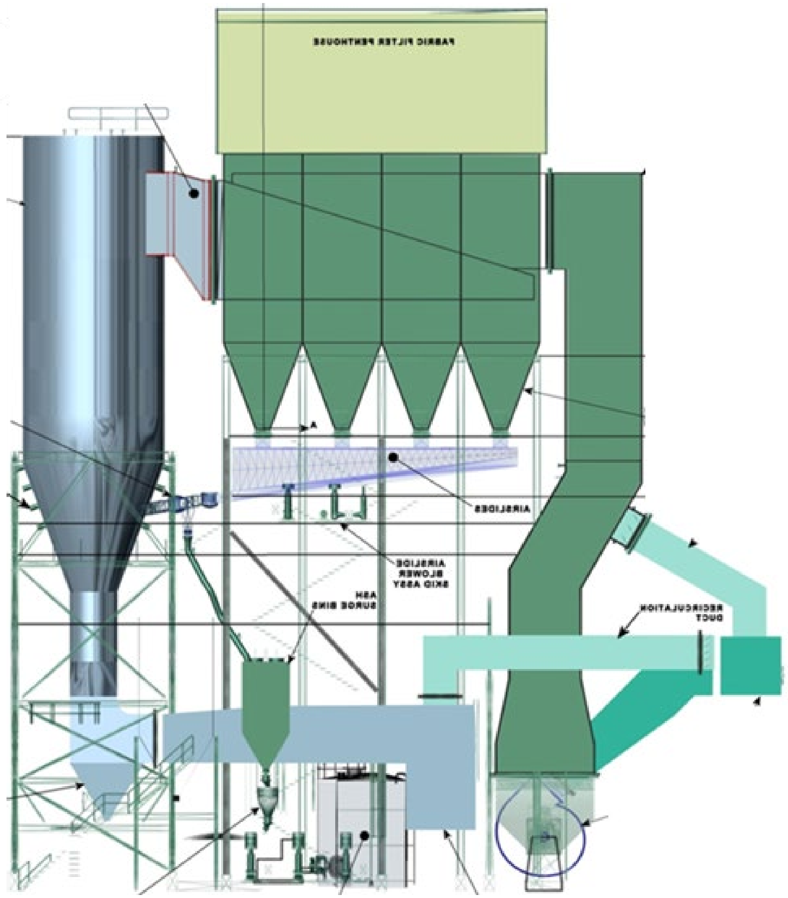
Desulfurization Systems

Dry and Wet Scrubbing

Flue Gas Temperature Control Requirements Revisited



Dry Scrubber Systems



Considerations

- 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.

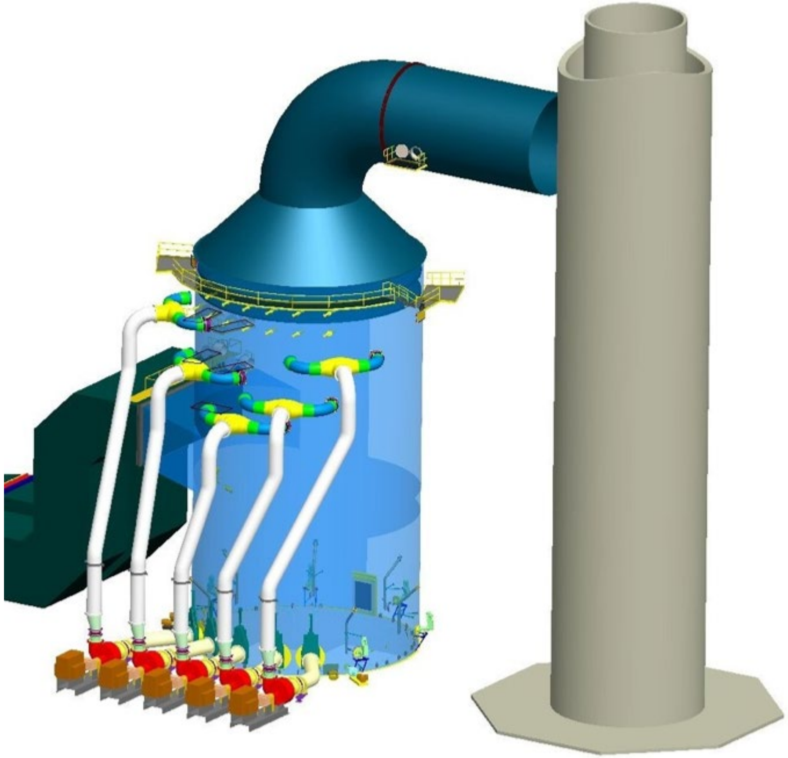
Circulating Dry Scrubber (CDS):

- 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.

Spray Dryer Absorber (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).

Wet Scrubber Systems (WFGD)



Considerations

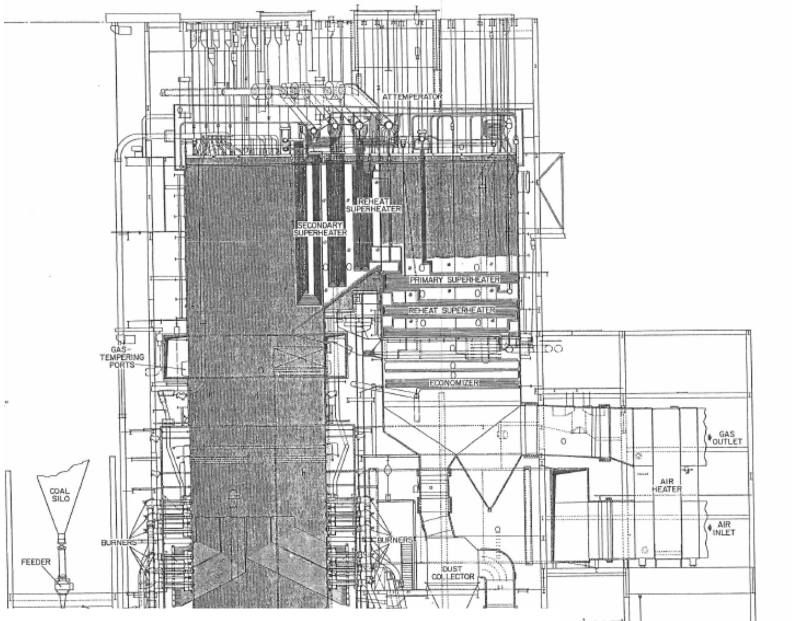
- Low flue gas temp generally not an issue.
- Typically not amenable to frequent cold startups due to:
    - need to purge systems to avoid slurry solidification;
    - production of low-purity gypsum at each startup;
    - potential impact of startup fuel oil residues on linings;
    - lengthy warm-up 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...).

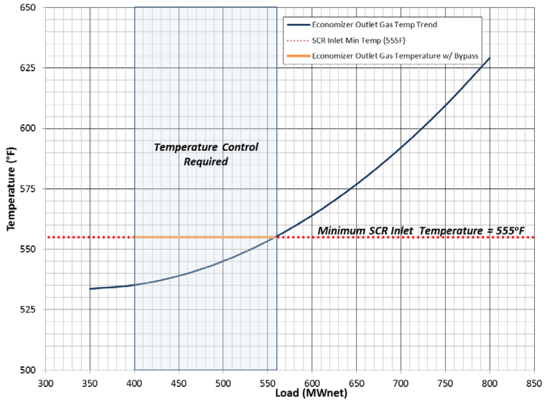
Example Projects

Flue Gas Temperature Control for AQCS Equipment

Example #1 – Waterside Bypass

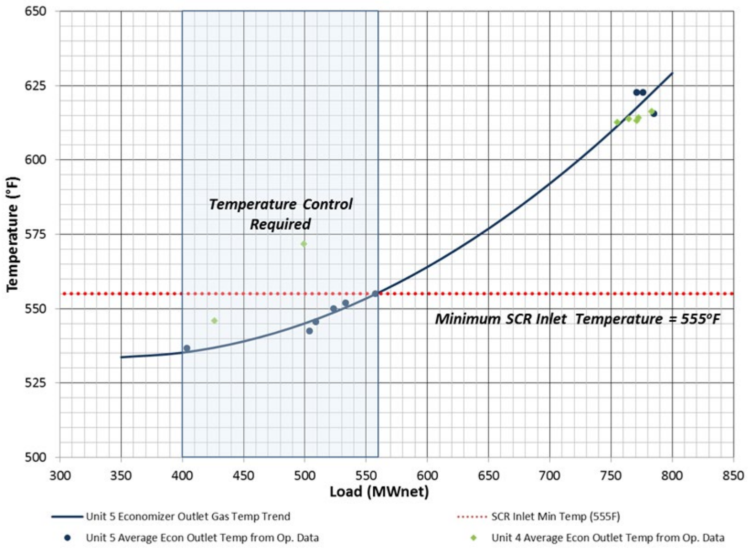
- **Supercritical B&W UP Boilers**
  - 770 MWn at full load
  - 5,446 KPPH main steam
  - 1,005 / 1,005 °F SH/RH Temps
  - Operating Pressure 3,750 psig
  - FW inlet temp. of 500 °F
- **SCR Addition Requirements**
  - Min. FG temp. of 555°F w/ online.
  - Max. boiler operating envelope
  - Turndown (with no water bypass): 550 MWn min. at 555 °F SCR inlet
  - Guaranteed turndown (with water bypass): 440 MWn
  - Targeted minimum operating load of 400 MWn (with water bypass)



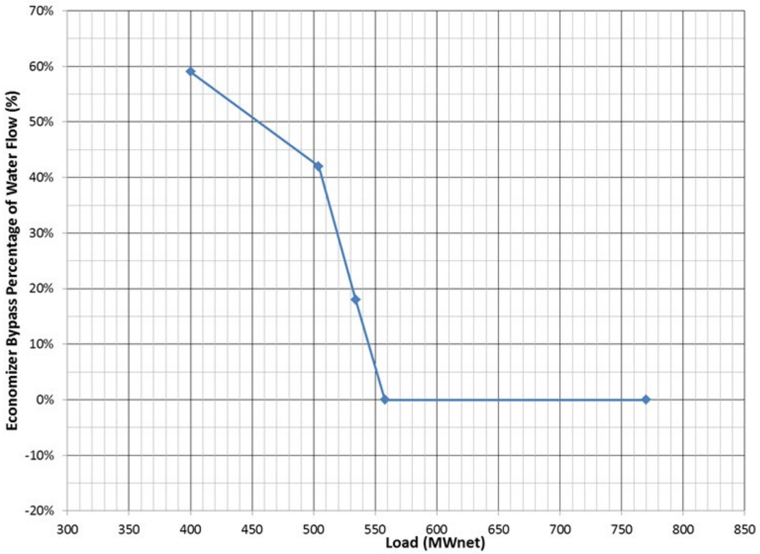


Example #1 (cont.) – Waterside Bypass

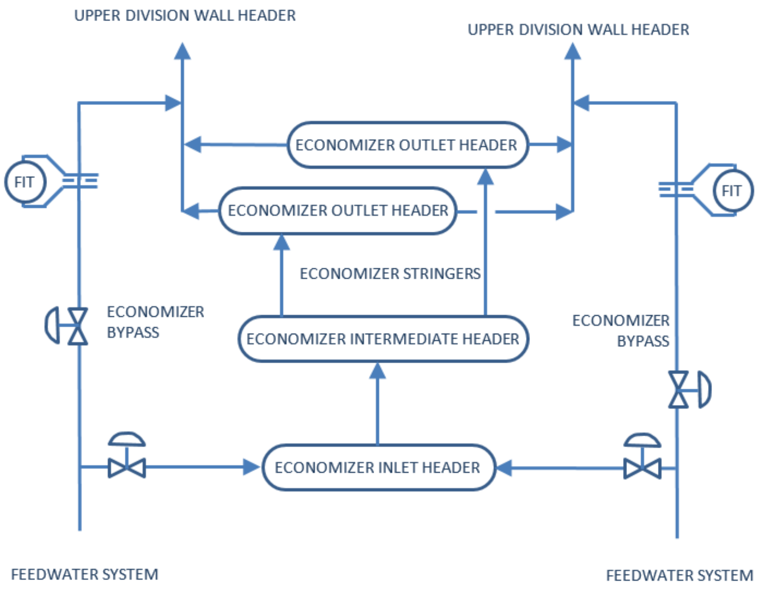
SCR Inlet Temperature (w/o bypass)



Required bypass flow



Example #1 (cont.) – Waterside Bypass



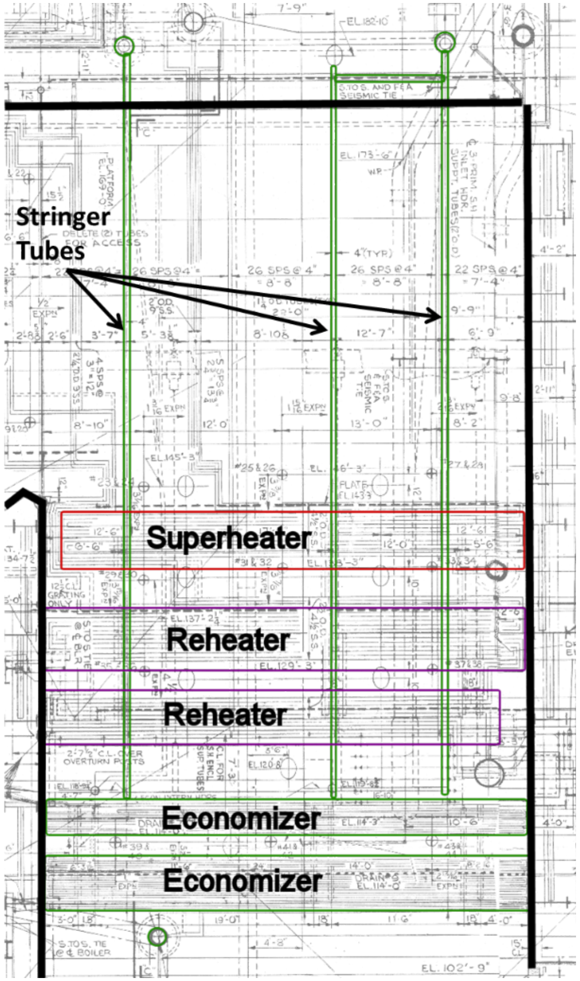
Economizer Bypass System Overview

- When the economizer exit flue gas temperature drops to 555°F:
  - Bypass routes fraction of FW around the economizer
  - Reduces heat transferred from FG to the FW by ↓ log mean temperature difference (LMTD) between FG and FW
  - When bypass valves are 100% open and add. bypass flow is req’d, back pressure control valves begin to close

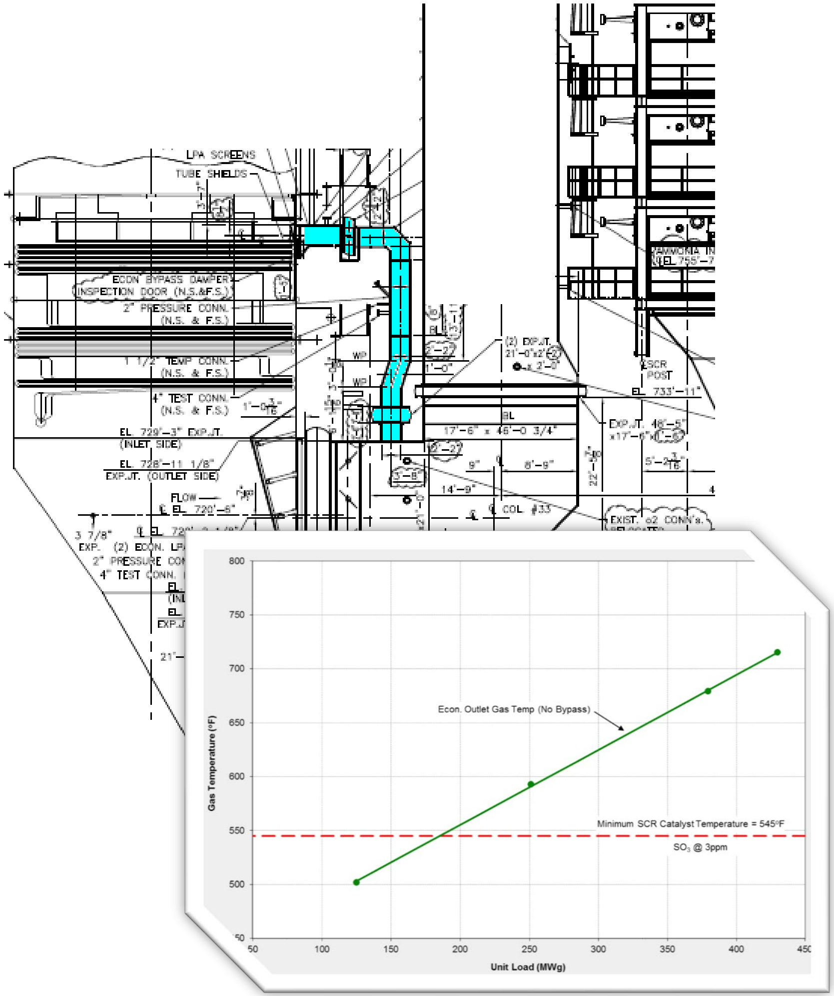
Example #1 (cont.) – Waterside Bypass

Waterside Bypass Flow Limitations

- Econ. outlet stringer tubes support conv. pass heating surfaces
- Waterside bypass design must consider combined “hoop” stresses from 4,200 psi fluid pressure + “longitudinal” support stresses from the LTRH, LTSH & economizer on stringer tubes.
- Stringer tubes will have adequate strength if fluid temp. leaving stringer tubes ≤ 650°F
- 34 tube metal T/Cs attached to econ. out terminal stringer tubes located in penthouse.
- These temps used to limit the bypass flow to maintain stringer tube water out temp ≤ 650°F



Example #2 – Flue Gas Bypass System

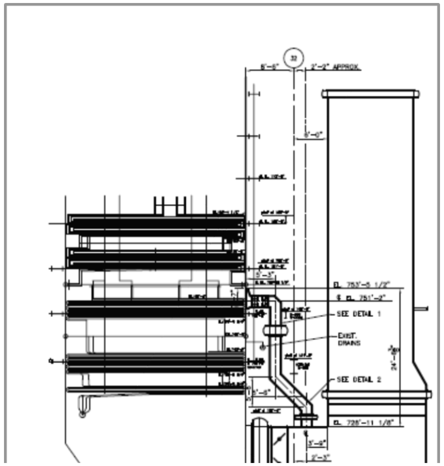


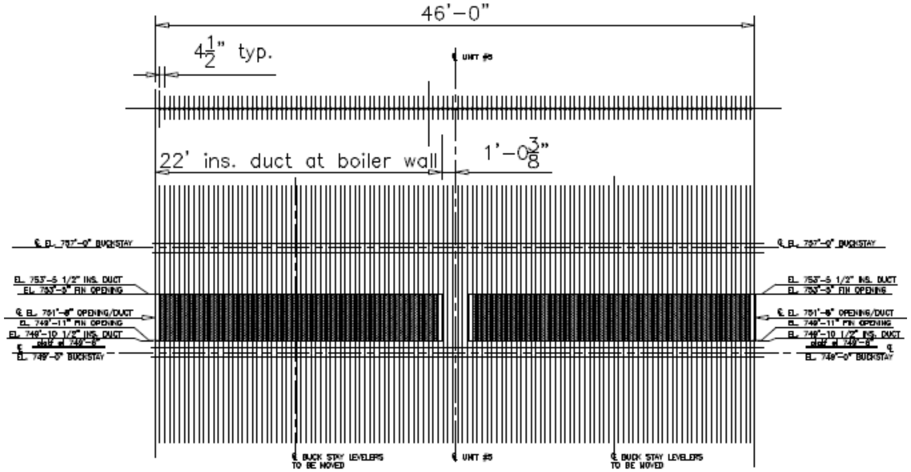
- **B&W sub-critical boiler**
  - 430 MWg at URGE Condition
  - 2,800 KPPH main steam
  - 1,005 / 1,005 °F SH/RH Temps
  - Operating Pressure 2,620 psig
  - FW inlet temp. of 480 °F
- **SCR Addition Requirements**
  - Min. FG temp. of 545°F w/ SCR online.
  - Turndown (with no FG bypass): 185 MWg (43%) at 545 °F SCR inlet
  - Targeted minimum operating load of 125 MWg (with FG bypass)

Example #2 (cont.) – FG Bypass

Design Features

- No pressure part modifications necessary
  - Only fins removed at duct inlet
  - Saved outage time and fabrication time
- Max. FG velocity through bypass opening of 60 ft/s
- Tube shields for econ. tubes at bypass inlet to control erosion
- LPA screens provided at bypass duct inlet





Questions?

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