

REINHOLD ENVIRONMENTAL®



2022 Reinhold/PCUG Round Table Presentation

Hosted by Duke Energy in the Charlotte Sheraton/Le Meridien
Hotel, Charlotte, NC on June 27-28, 2022

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AdvX[®]-FLX

X-Ratio Management for Operational Flexibility



Reinhold Conference – June 27, 2022

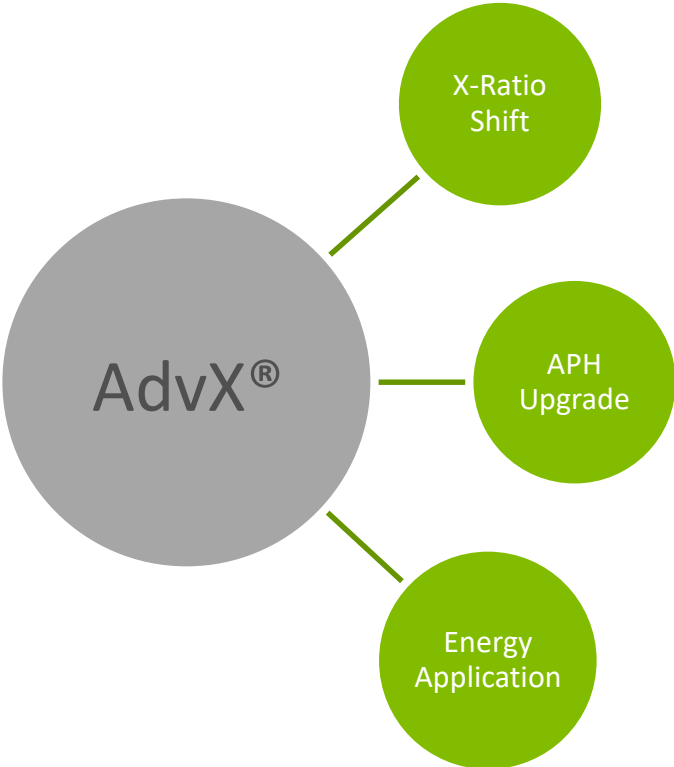
Roadmap

1. *Introduction*
2. *Operational Constraints*
3. *AdvX[®]-FLX*
4. *Case Studies*
5. *Heat Rate*
6. *Q&A*

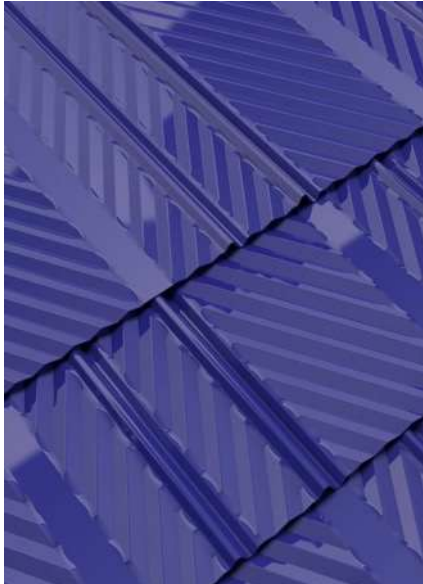
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WHAT IS AdvX[®]?



DN8[™]



TF4[™]

AdvX[®] PRODUCTS

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AdvX[®]-ZLD

Zero Liquid Discharge

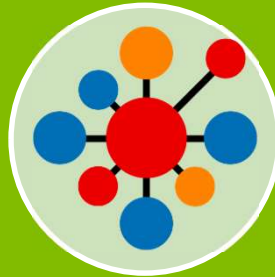
ELG compliance with no impact to plant heat rate



AdvX[®]-HRI

Heat Rate Improvements

Enhanced heat recovery and utilization to 5% HRI



AdvX[®]-FLX

Flexibility

Improved operational flexibility and low load operation



AdvX[®]-ENV

Environmental

Reduce airborne emissions of SO₃, NO_x, PM_{2.5}, and Hg



AdvX[®]-SGR

Stack Gas Reheat

The most efficient way to a clean and dry stack

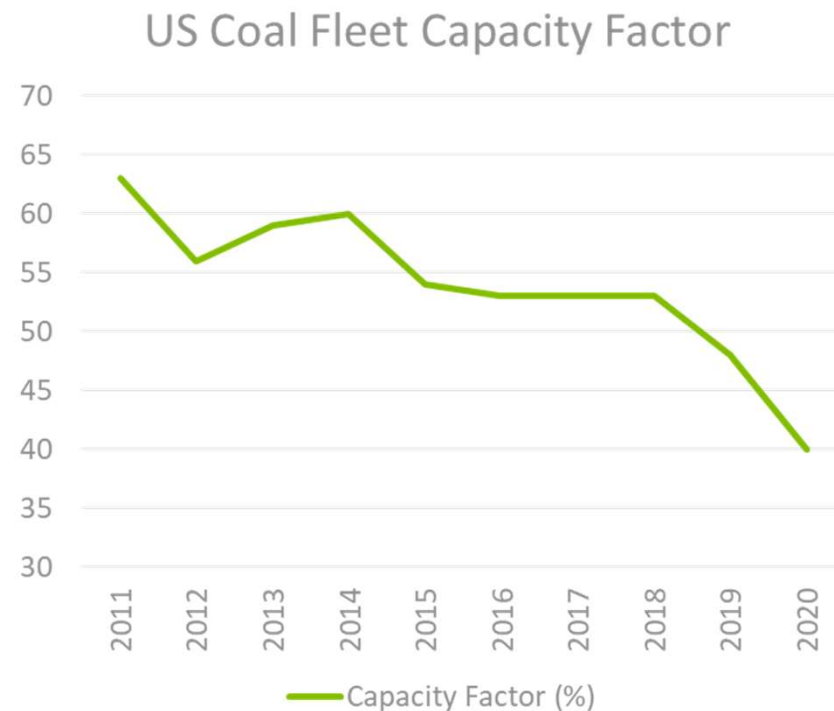


WE DON'T OPERATE LIKE WE USED TO

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- **US Coal Utilities are running at lower loads and capacity factors more often.**
- **Many systems were not designed with low capacity factors in mind.**
- **Cycling and low load operation can introduce operational constraints for APH, mills, SDA, CDS, FGD, etc.**
- **Operational flexibility is becoming more important to deal with changing operations, regulations, fuel availability, etc.**



OPERATIONAL CONSTRAINTS

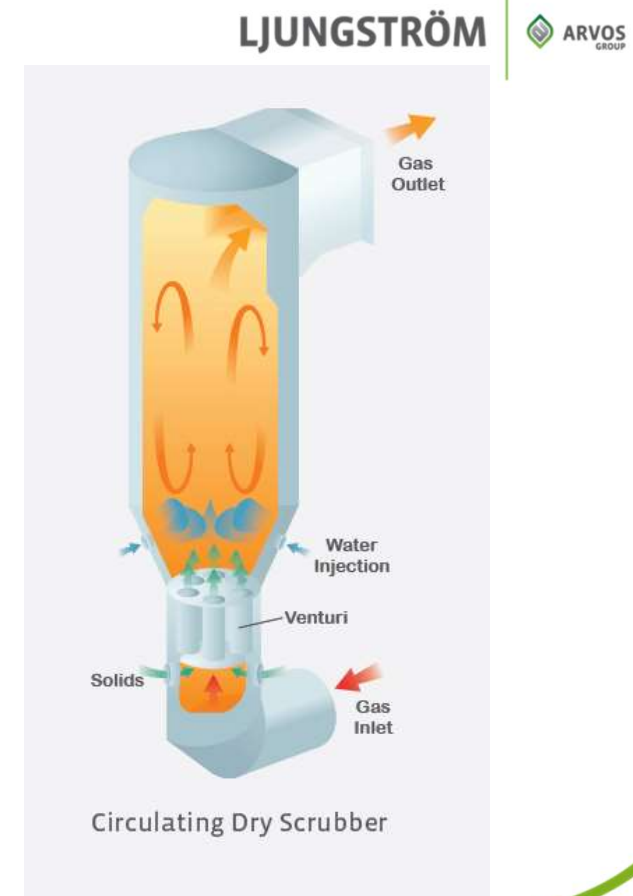
Scrubber (SDA/CDS/FGDw)

1. SO₂ removal
2. Wastewater evaporation capacity
3. Minimum load/temperature/flow

Unit

1. Coal moisture / mill temperature
2. Average cold-end temperatures (ACET)
3. Acid gas dewpoint

As a power plant decreases load, the flue gas flow and temp both decrease – impacting all the above.



AdvX[®] HEAT RECOVERY SOLUTIONS

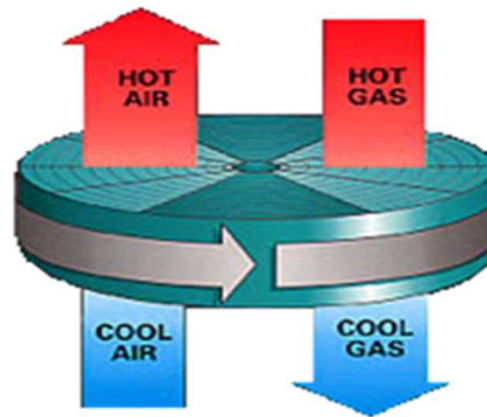
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AdvX[®]-FLX is a patented, simple, low-cost **SYSTEM** that employs x-ratio management and APH upgrades to mitigate operational constraints.

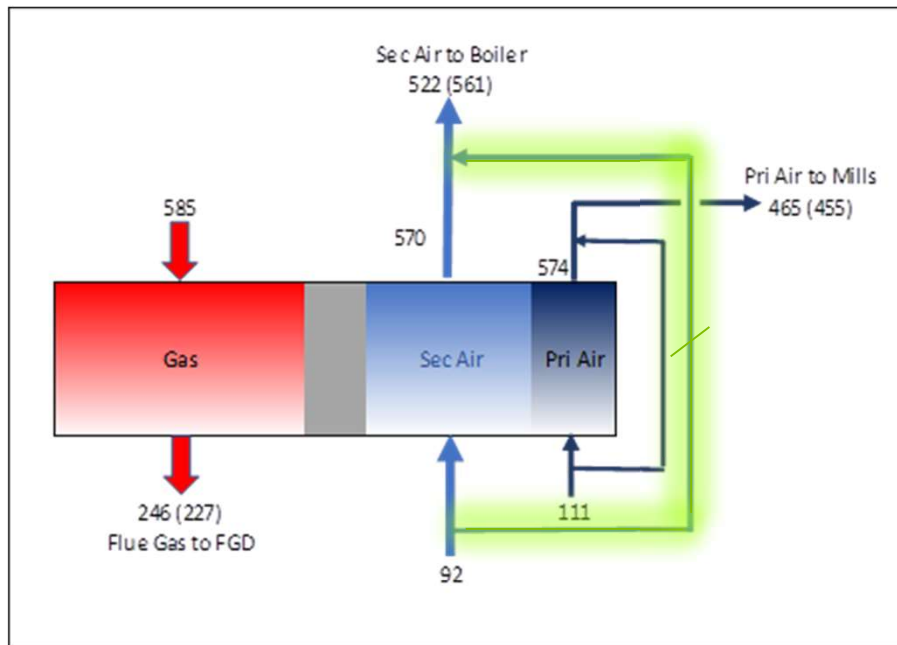
What is X-Ratio?

$$\frac{\text{Air Flow} \times C_{p_{\text{air}}}}{\text{Gas Flow} \times C_{p_{\text{gas}}}}$$



AdvX[®]-FLX utilizes bypass air for Operational **Flexibility**.

AdvX[®]-FLX EXAMPLE (TRI-SECTOR)



Temperatures shown (before) and after modification

AdvX[®] FLX

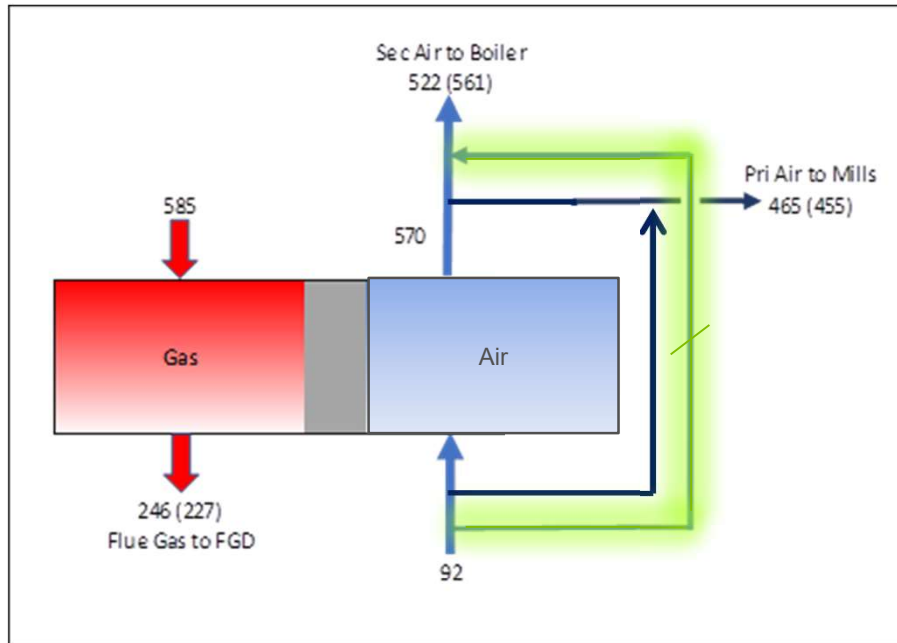
Typical Scope of Work

- Secondary air bypass duct
- Control damper
- APH upgrade

Performance

- ✓ Temp increase in Flue Gas Outlet
- ✓ Temp increase in Primary Air
- ✓ ACET increase
- ✓ Acid dewpoint approach increase
- ✓ Negligible change in dP
- ✓ HRI at low load offset at high load.

AdvX[®]-FLX EXAMPLE (BI-SECTOR)



Temperatures shown (before) and after modification

AdvX[®] FLX

Typical Scope of Work

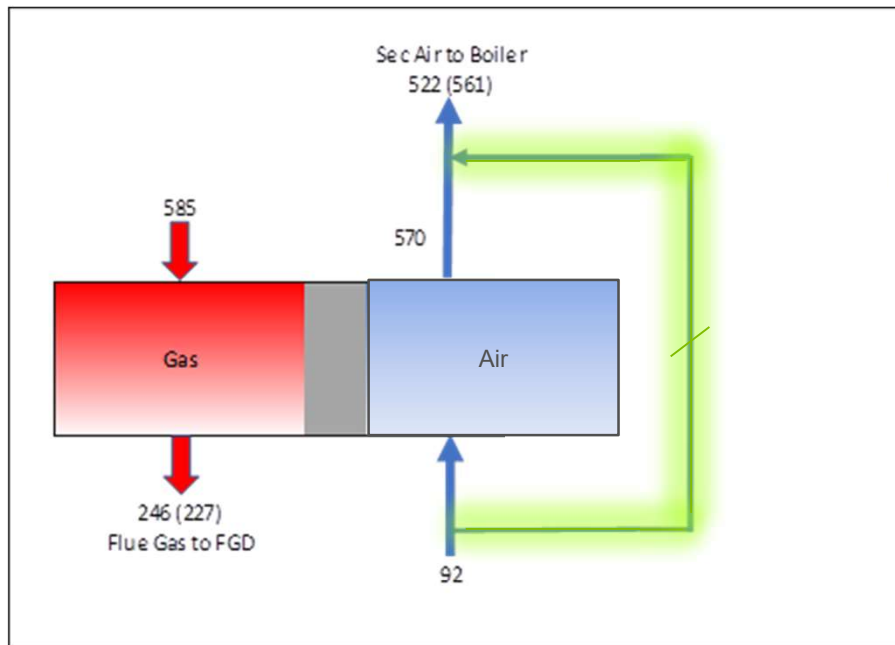
- Air bypass duct
- Control damper
- APH upgrade

Performance

- ✓ Temp increase in Flue Gas Outlet
- ✓ Temp increase in Primary Air
- ✓ ACET increase
- ✓ Acid dewpoint approach increase
- ✓ Negligible change in dP
- ✓ HRI at low load offset at high load.

AdvX[®]-FLX EXAMPLE (SEPARATE PRI/SEC APH)

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Temperatures shown (before) and after modification

AdvX[®] FLX

Typical Scope of Work

- Secondary air bypass duct
- Control damper
- APH upgrade

Performance

- ✓ Temp increase in Flue Gas Outlet
- ✓ ~~Temp increase in Primary Air~~
- ✓ ACET increase
- ✓ Acid dewpoint approach increase
- ✓ Negligible change in dP
- ✓ HRI at low load offset at high load.

SCRUBBER OPERATIONAL CONSTRAINTS, 1

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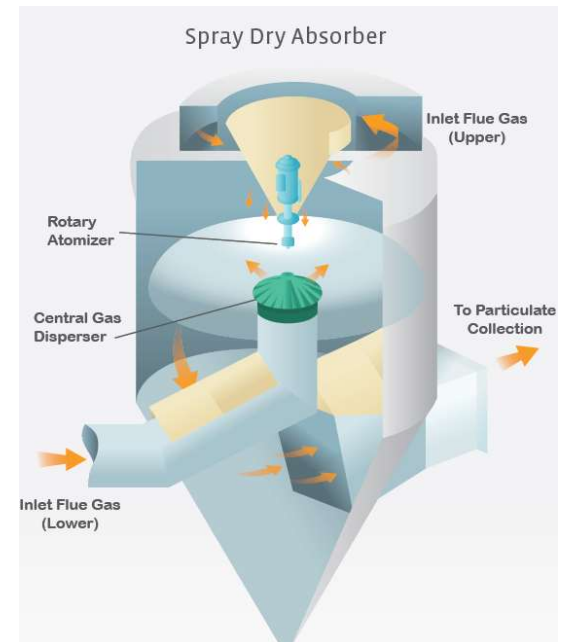
SO₂ Removal

Problem: We cannot increase reagent to our scrubber due to outlet temperature constraints.

- Outlet temperature controlled by approach to saturation
- Fixed in/out flue gas temps limits reagent slurry capacity
- At lower load, flue gas inlet flow and temp decrease

AdvX[®]-FLX

- Secondary air bypass results in less mass available for heat transfer, resulting in flue gas outlet temp increase.
- Increases flue gas temperature to scrubber, increasing the amount of slurry or humidity that can be injected.



SCRUBBER OPERATIONAL CONSTRAINTS, 2

Wastewater (process water) evaporation capacity

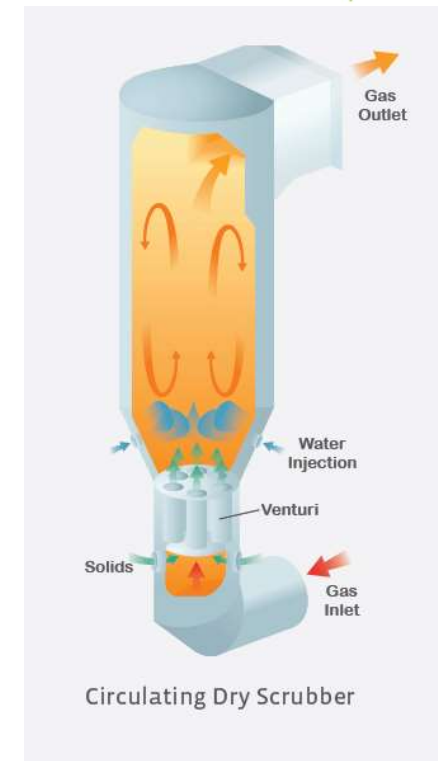
Problem: We cannot evaporate enough process water to maintain ZLD operation – requiring expensive treatment.

- Outlet temperature controlled by approach to saturation
- Fixed in/out flue gas temps limit water evap capacity
- At lower load, flue gas inlet flow and temp decrease

AdvX[®]-FLX

- Secondary air bypass results in less mass available for heat transfer, resulting in flue gas outlet temp increase.
- Increases flue gas temperature to scrubber, increasing the amount of process water that can be injected
- Effective at all loads if capacity needed at full load.

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SCRUBBER OPERATIONAL CONSTRAINTS, 3

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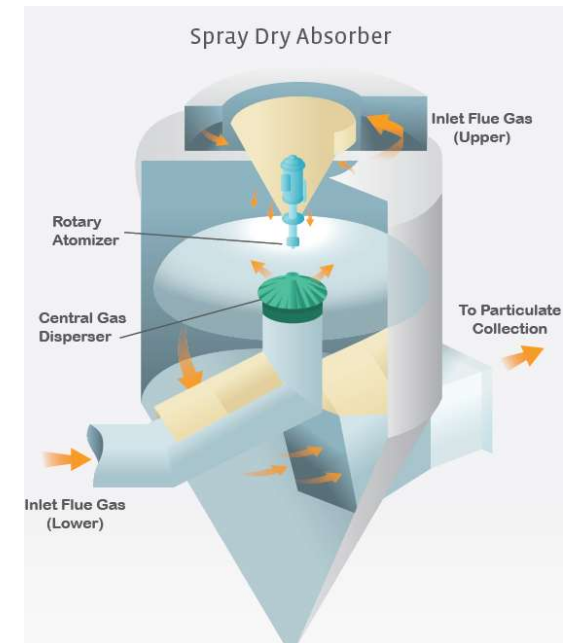
Minimum Load / Temperature / Flow

Problem: We cannot reduce our minimum load because we cannot bring our SDA/CDS online without sufficient temp or flow.

- SDA/CDS require a minimum load or temperature
- CDS require a minimum flow to keep the bed circulating
- At lower load, flue gas inlet flow and temp decrease

AdvX®-FLX

- Secondary air bypass results in less mass available for heat transfer, resulting in flue gas outlet temp increase.
- Increases flue gas temperature to scrubber, reducing the minimum load required to operate.
- Separate arrangement to increase gas flow available.



UNIT OPERATIONAL CONSTRAINTS, 1

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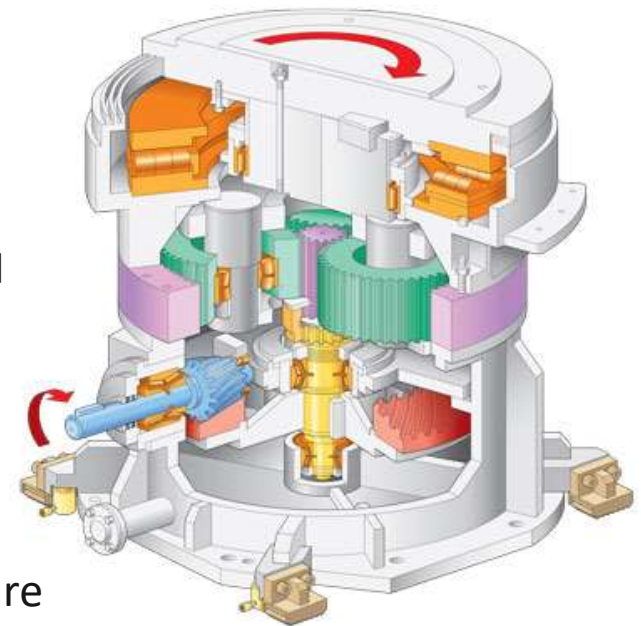
Coal Moisture / Mill Temperature

Problem: We have difficulty maintaining mill temperatures causing wet coal issues.

- At lower load, flue gas inlet flow and temp decrease
- Lower flue gas temp results in lower air temps from APH
- May not solely be a low-load issue or solution

AdvX®-FLX

- Secondary air bypass results in more heat transfer to primary air, resulting in increased primary air temperature
- Increases primary air temperature to mills, increasing coal drying and mill outlet temperature.



UNIT OPERATIONAL CONSTRAINTS, 2

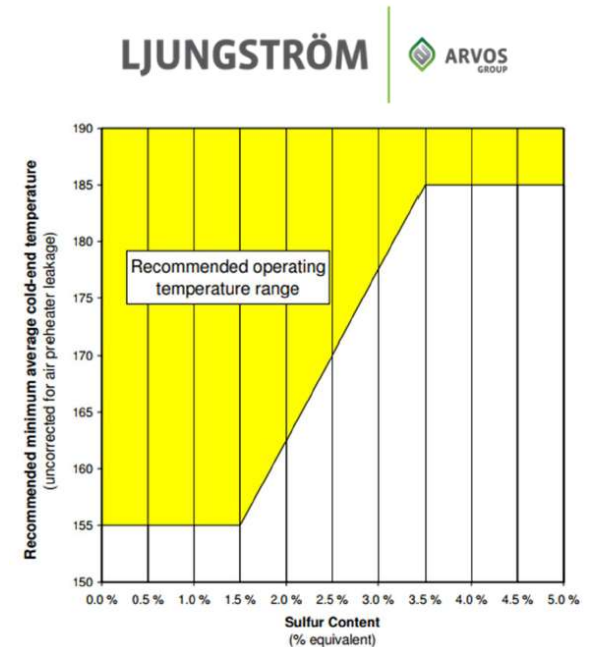
Average Cold End Temperature (ACET)

Problem: We are corroding our APH faster due to lower capacity factors.

- At lower load, flue gas inlet flow and temp decrease
- Lower flue gas temp results in lower APH gas out temps
- Lower gas outlet temps result in lower ACET

AdvX[®]-FLX

- Secondary air bypass results in less mass available for heat transfer, resulting in flue gas outlet temp increase.
- Increases APH gas outlet temperature, increasing average cold-end temperature.



$$ACET = \frac{Temp_{air-in} + Temp_{gas-out}}{2}$$

UNIT OPERATIONAL CONSTRAINTS, 3

Acid Dewpoint

Problem: We are corroding our ductwork and equipment downstream of the APH.

- At lower load, flue gas inlet flow and temp decrease
- Lower flue gas temp results in lower APH gas out temps
- Lower gas outlet temps can cause acid condensation

AdvX[®]-FLX

- Secondary air bypass results in less mass available for heat transfer, resulting in flue gas outlet temp increase.
- Increases APH gas outlet temperature, increasing acid dewpoint approach temperature.

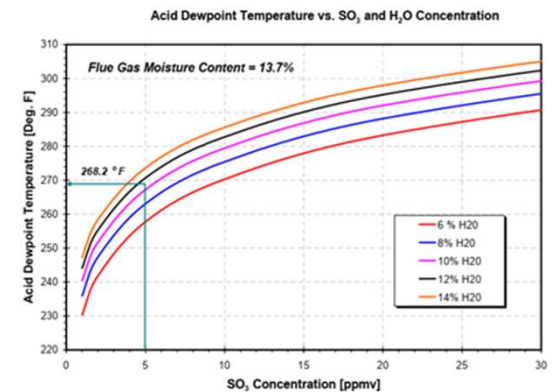


Figure 4-4s: Acid Dewpoint as a Function of SO₂ and H₂O Concentration in the Flue Gas

AIR PRE-HEATER (APH) 101

“Operation of a regenerative APH represents a compromise between performance and maintenance.” – Nenad Sarunac, PhD.

– Increasing Efficiency and Reducing Emissions of Coal-Fired Units, Energy Research Center, 2009

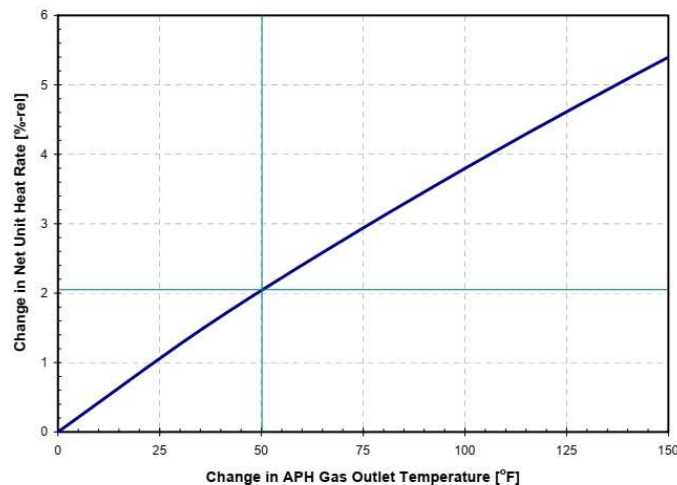


Figure 4-1: Effect of APH Gas Outlet Temperature on Net Unit Heat Rate

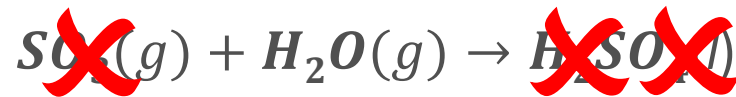
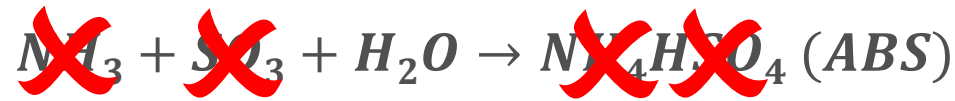
AdvX[®]-FLX

- Element upgrade
- Results in Fgo reduction
- 25°F change in Fgo = 1% HR change.
- Close bypass when not required to recover heat rate w/ APH upgrade.
- HRI may require ADP mitigation.

AIR PRE-HEATER (APH) 101. CLASS DISMISSED

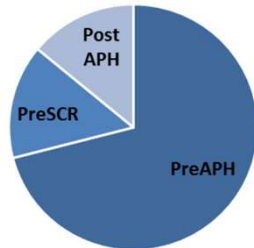
“No worries. Remove to improve.”

– Steven Kosler, (not-PhD.) 2019



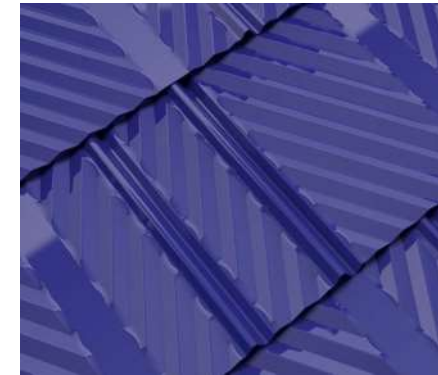
Hydrated Lime DSI for SO₃

By number of systems



~85% of hydrate DSI units feed prior to APH

Pre-SCR includes units expected to convert in next 6-18 months



Heat Rate Improvement Options

Heat Rate can be improved by:

1. improving boiler efficiency,
2. improving turbine cycle heat rate, and/or
3. reducing auxiliary power use.

- 1. Boiler efficiency can be improved by:
 - Reducing stack gas losses (using more heat from flue gas).
- 2. Turbine cycle heat rate can be improved by:
 - Reducing steam extraction from turbine cycle.
- 3. Auxiliary power use can be reduced by:
 - Improving equipment efficiency.

AdvX[®]-HRI improves all three.

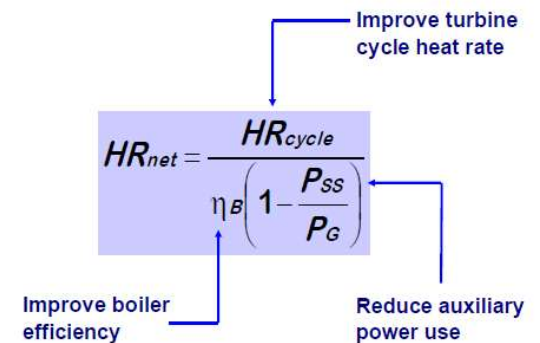


Figure 4: Options for Heat Rate Improvement

CASE STUDY 1

- Boiler efficiency can be improved by:
 - Reducing stack gas losses
- Unit recently relocated their SO₃ control upstream of APH
- Opens up APH upgrade to reduce stack gas losses.
- Max thermal upgrade – 44F GOT reduction
- \$2.5MM/yr/unit savings with APH upgrade alone.
- Acid dewpoint management and APH optimization remains an effective strategy for HRI that many have yet to implement

CASE STUDY 2

- PRB switch w/ >300F APH gas outlet
- Limited APH upgrade potential
 - DL7 for popcorn ash
 - No space for additional depth
 - Thermal upgrade – 2F GOT reduction
- Turbine cycle heat rate can be improved by:
 - Reducing steam extraction from turbine cycle.
 - Seasonal as steam not used in Summer.
 - Reducing steam coil lowers ACET
- What else can be done to reduce GOT and improve heat rate?

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AdvX[®]-HRI SYSTEM

Target Criteria

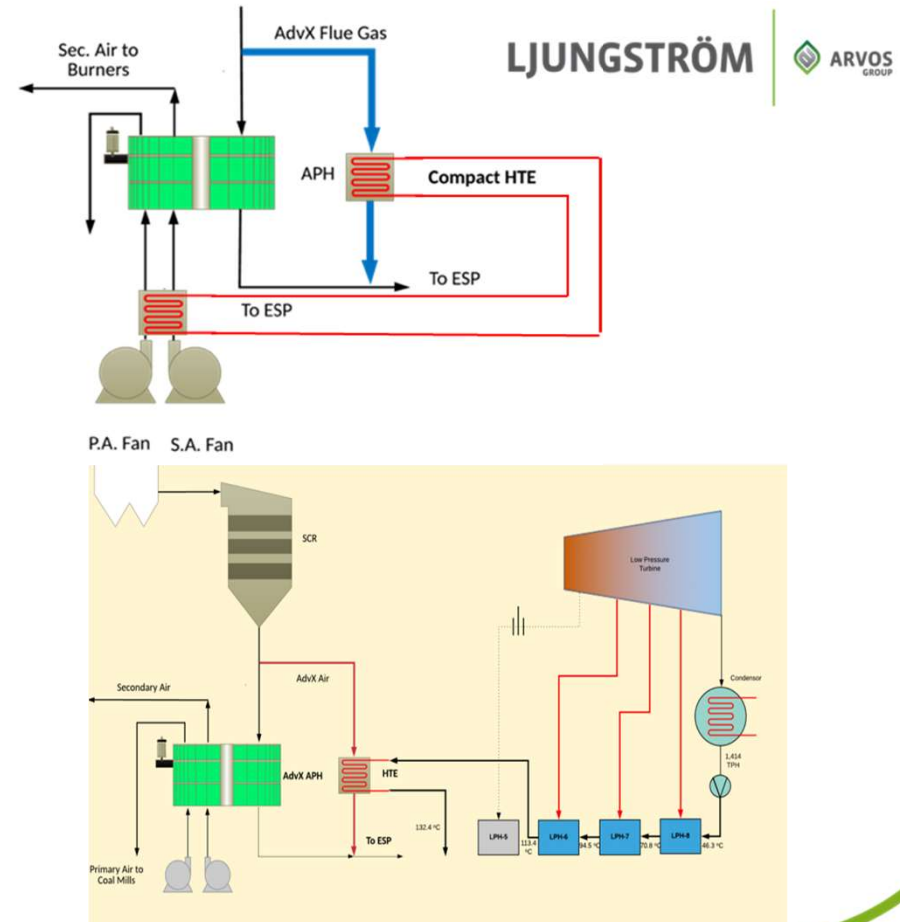
- High stack gas losses (>250F APH Gas Out)
- APH fouling / corrosion / sootblowing frequency (SO₃)
- APH thermally max or ACET/ADP limitations
- Recent SO₃ control relocation to upstream APH

Typical Scope of Work

- SO₃ optimization if nec.
- APH upgrade
- X-ratio shift
 - flue gas bypass duct
 - exp. joint(s) / damper(s)
- Energy application
 - Heat exchanger(s) loop (flue gas to BFW or SAH)
 - Replace/reduce extraction steam

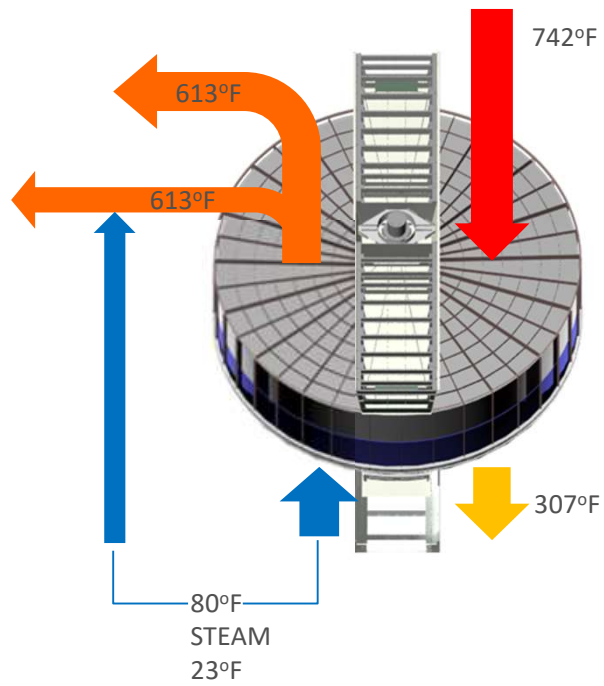
Value Proposition

- Smaller equipment than FGC
- Increases gas side effectiveness of APH
- Up to 3% HRI

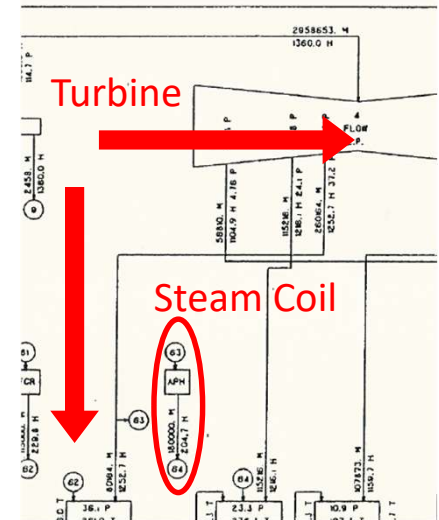
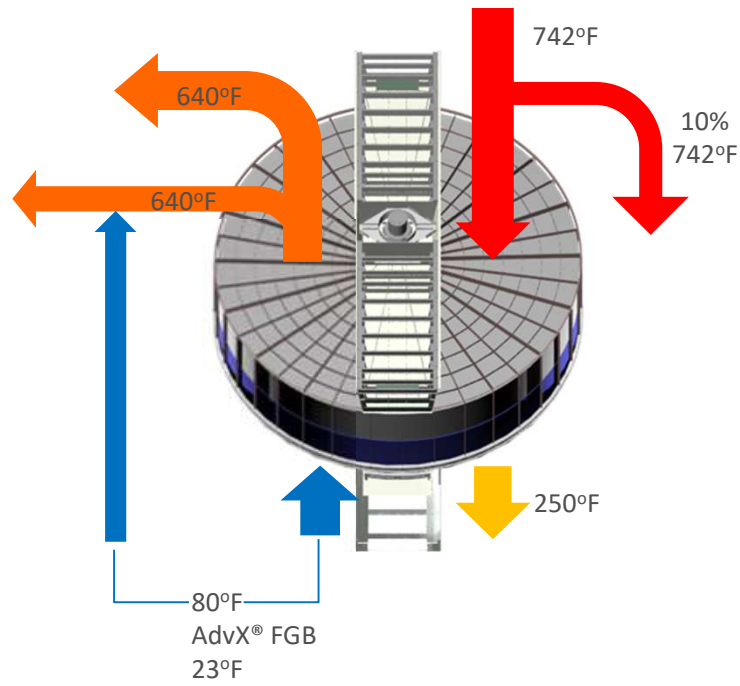


CASE STUDY – ADVX-HRI

ORIGINAL APH



AdvX®-HRI UPGRADE



40,000 kg/hr steam
+13MW generation

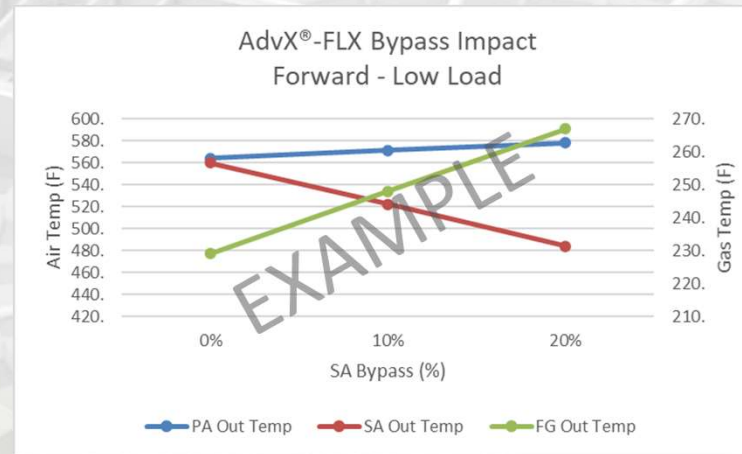
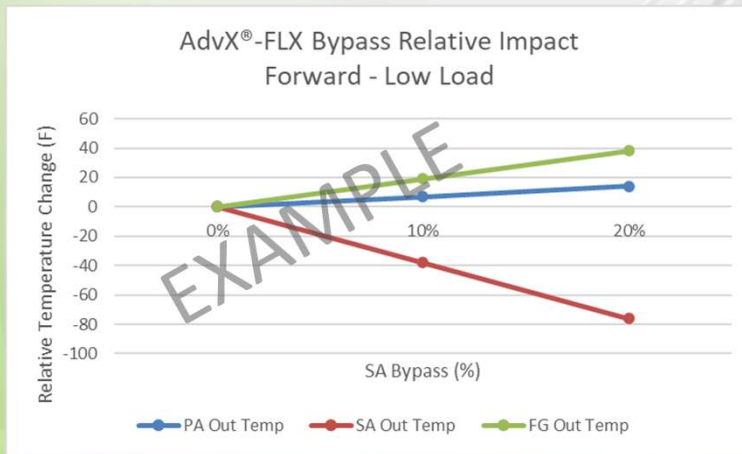
ADVX-HRI CASE STUDY CONTINUED...

- Boiler efficiency can be improved by:
 - Reducing stack gas losses
 - 307F to 250F
 - -5.5 klb/hr fuel
- Turbine cycle heat rate can be improved by:
 - Reducing steam extraction from turbine cycle.
 - 40,000 kg/hr steam
 - +13MW
- Auxiliary power use can be reduced by:
 - Improving equipment efficiency.
 - Flue gas volume
 - Fan / equipment power
- **3.0% “+” NUHR Improvement**

RESULTS SUMMARY	Baseline	AdvX [®] -HRI	
	100% Steam Extraction	0% Steam Extraction	
Max gross generation	660.04	673.04	MW
Increased Revenue Opportunity		\$ 4,159,486	\$/Year
Fuel Requirement	610.96	605.47	Klb/hr
Cost Savings Opportunity		\$ 1,198,430	\$/Year
Combined MW + Fuel Savings Benefit		\$ 5,357,916	\$/Year

Next Steps

1. **Contact LJUNGSTRÖM sales representative to discuss goals.**
2. **Develop assessment**



3. **Site visit for sizing and routing**
4. **Issue proposal**
5. **Bypass delivered in ~6months.**

Steven Kosler

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Get to the point

- 1. AdvX[®]-FLX can mitigate 6 operational constraints all in one simple, low-cost, system.***
- 2. Heat rate improvement when bypass closed via APH upgrade.***
- 3. LJUNGSTRÖM can design, manufacture and install AdvX[®]-FLX for a turn-key solution.***

Steven Kosler

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QUESTION & ANSWER

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