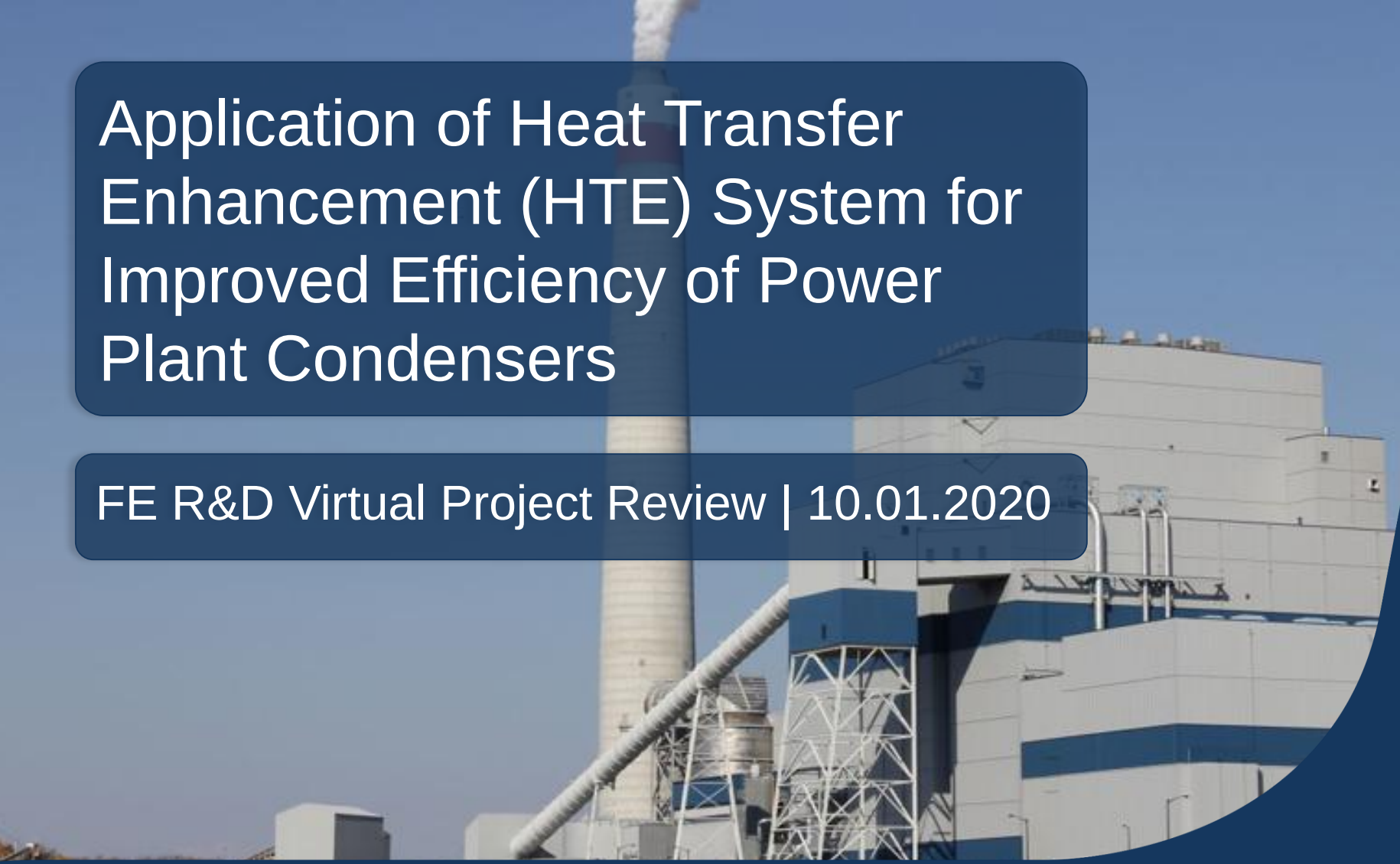
Application of Heat Transfer Enhancement (HTE) System for Improved Efficiency of Power Plant Condensers

FE R&D Virtual Project Review | 10.01.2020



U.S. DEPARTMENT OF ENERGY

NATIONAL ENERGY TECHNOLOGY LABORATORY

INTERPHASE MATERIALS

Project Description

- **Purpose:** Demonstrate increased condenser efficiency and reduced continuous feed water treatment for coal-fired power plants
- **Approach:** Application of Interphase Material's heat transfer enhancement technology (HTE)
- **Fossil Energy Objective 2.2:** Advance technologies to improve the efficiency, reliability, emissions, and performance of existing fossil-based power generation

Project Description

- **Driving question:** Can Interphase technology increase heat transfer and reduce fouling on large-scale heat exchangers?
- **2018 Status:** Bench-top validation in laboratory setting
- **2020 Status:** Demonstrated success across HVAC chillers, industrial heat exchangers, engine cooling, and a power plant condenser

INTERPHASE MATERIALS

THERMOPHASE

2018 → 2020

HTE System → THERMOPHASE

Chillers → PF HX → Condenser

Technology Benchmarking

"The condenser can make or break your efficiency and power goals"

- Condenser performance based on heat transfer from steam to cooling water
- A condenser that can maintain a better vacuum results in higher cycle efficiency and higher potential power output
- Condenser heat transfer often greatly hampered by fouling of heat transfer tubes

Current state of the art:

Chemical Treatment of Cooling Water

Mechanical Cleaning of Condenser

Project Update – Input & Challenges

PLANT INPUT

- **Experimental Design:** from benchtop to field, incorporated feedback to make work relevant
- **Application Method:** balanced practicality, cost, and risk
- **Data Analysis:** both approach and success metrics for the condenser and skid
- **Risk:** mitigation and assessment throughout

CHALLENGES

- **COVID-19 Pandemic:** project progress delayed by site access limitations
- **Scale-Up:** Power plant system over 100 times larger than any system previously treated; technical scale-up and application logistics posed significant challenges

Current Status

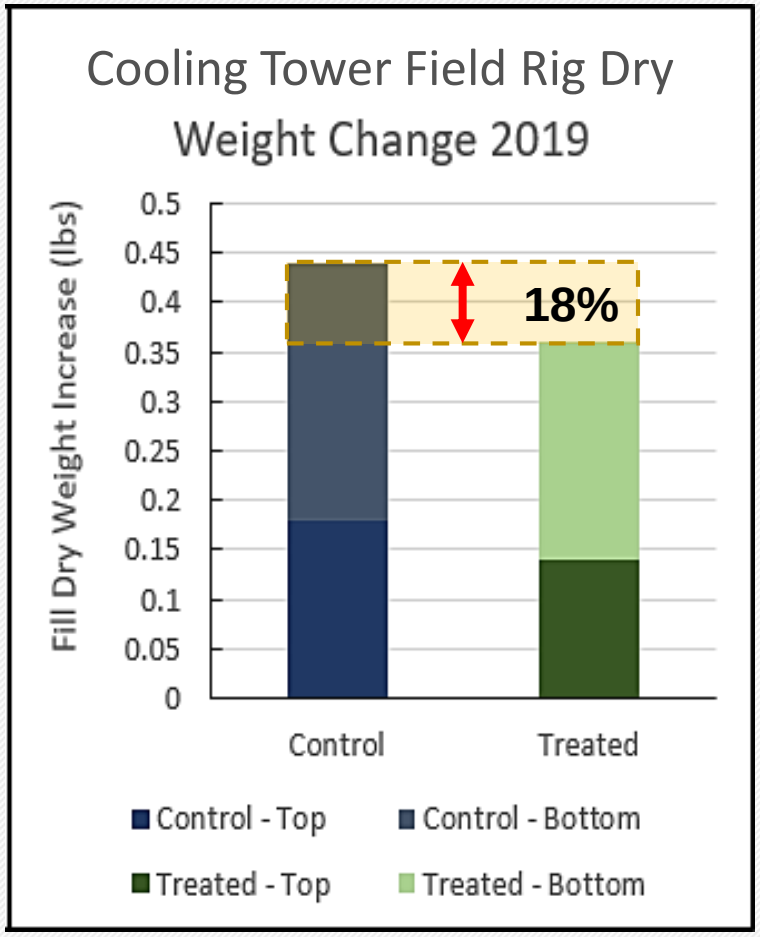
Objectives:

1) Improve heat transfer properties and therefore efficiency of the condenser.
2) Reduce the use of continuous feed water treatment technologies.
3) Decrease fouling on critical cooling systems, such as cooling towers and the condenser.

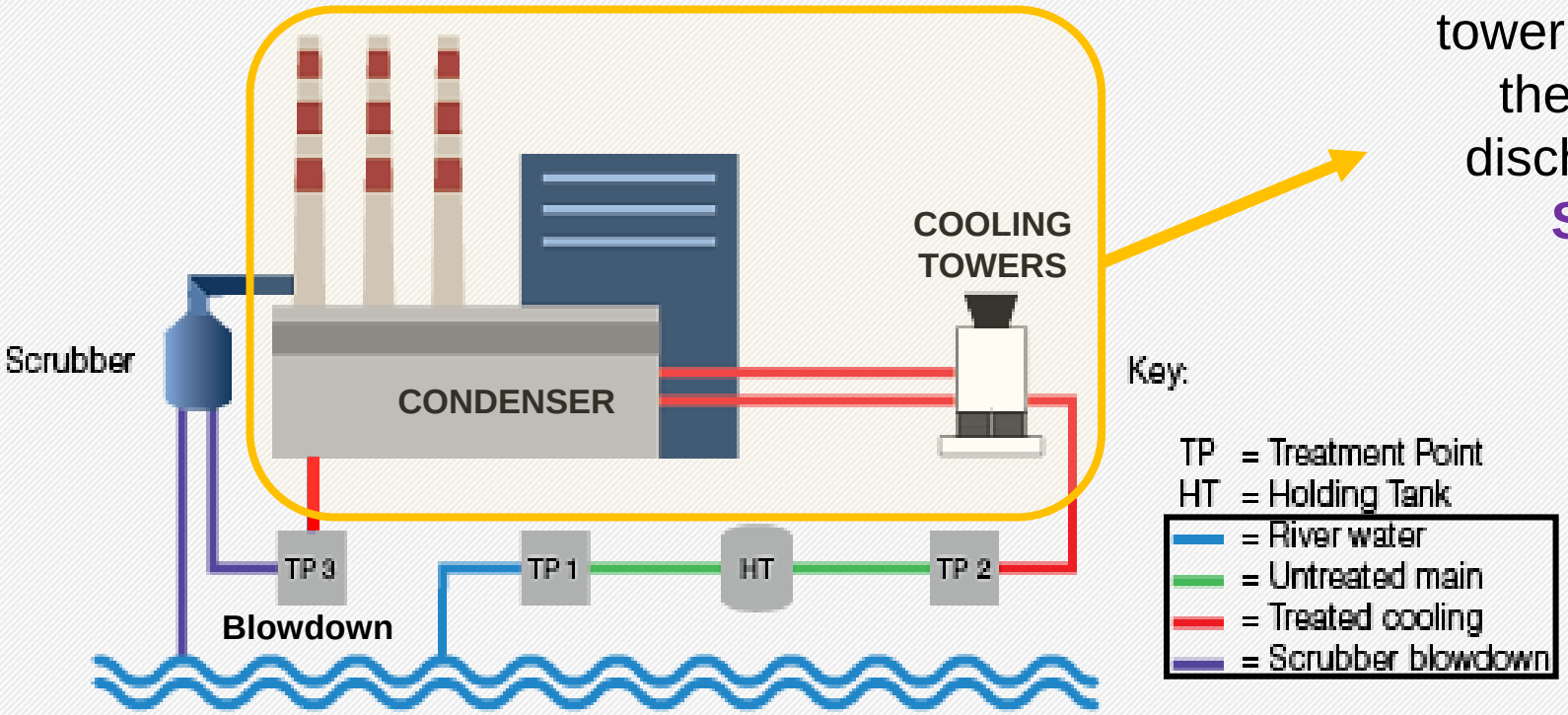
Key Results	Completion
Demonstrate increase in heat transfer coefficient in laboratory testing	Successful in 2018
Decrease in dry weight of cooling tower fouling in field rig testing	Successful in both 2018 and 2019
Evaluate economic and environmental impact of condenser application, including backpressure and heat rate	(Ongoing) Began September 2020

Project Update – Cooling Towers

- Small-scale cooling towers installed at water treatment station, circulating raw untreated water over the fouling season
- Towers treated with Interphase technology showed increased fouling resistance, accumulating 18% less dry weight fouling over the 2019 season
- At scale, this could translate to over 360 pounds less fouling annually on a typical power plant cooling tower
- Opportunity for further research and investigation



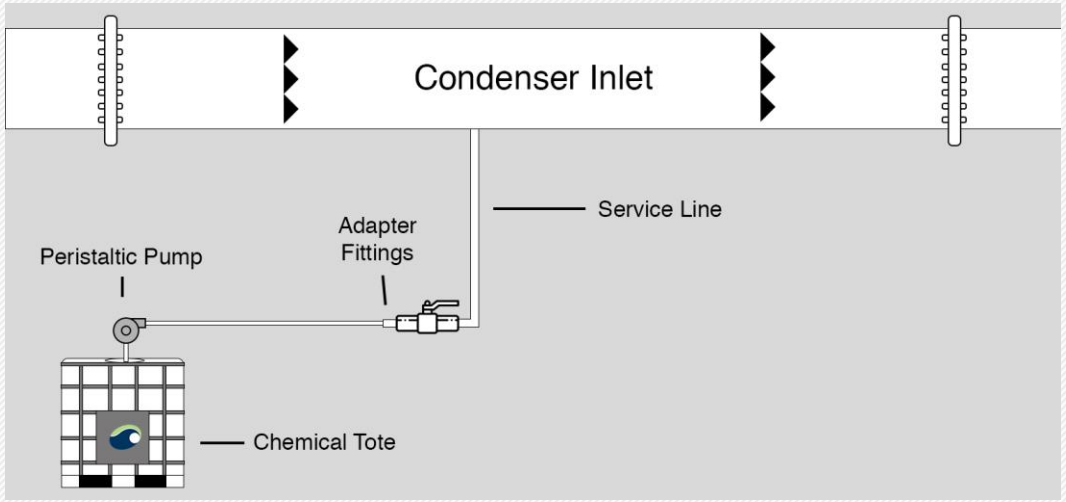
Project Update - Treatment



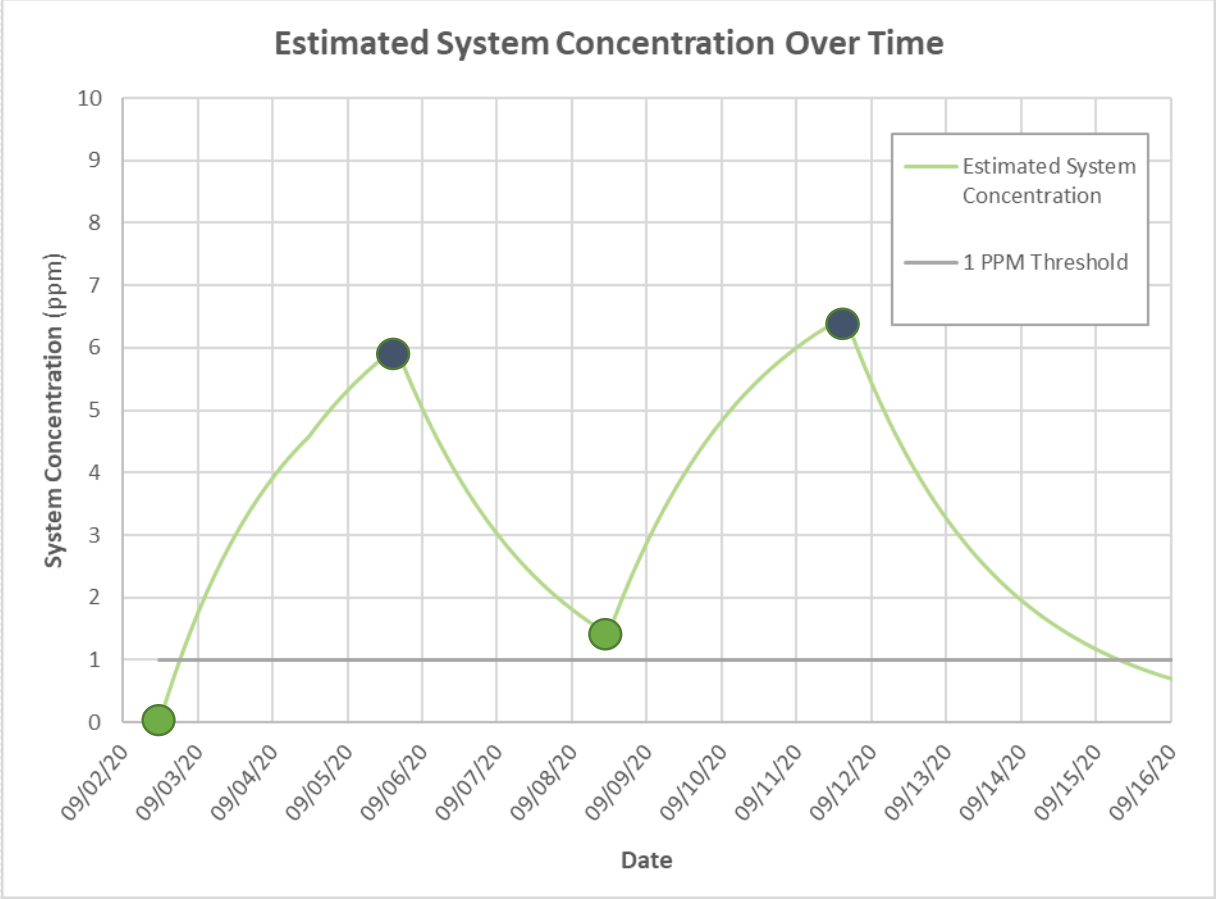
Fall 2020: Condenser and cooling tower application is occurring in the **Treated cooling** loop, discharging primarily through **Scrubber blowdown**

Project Update - Treatment

- Chemical tote connected to service line prior to condenser water box
- Material injected via peristaltic pump at 86 GPD
- Two treatments conducted over one week each

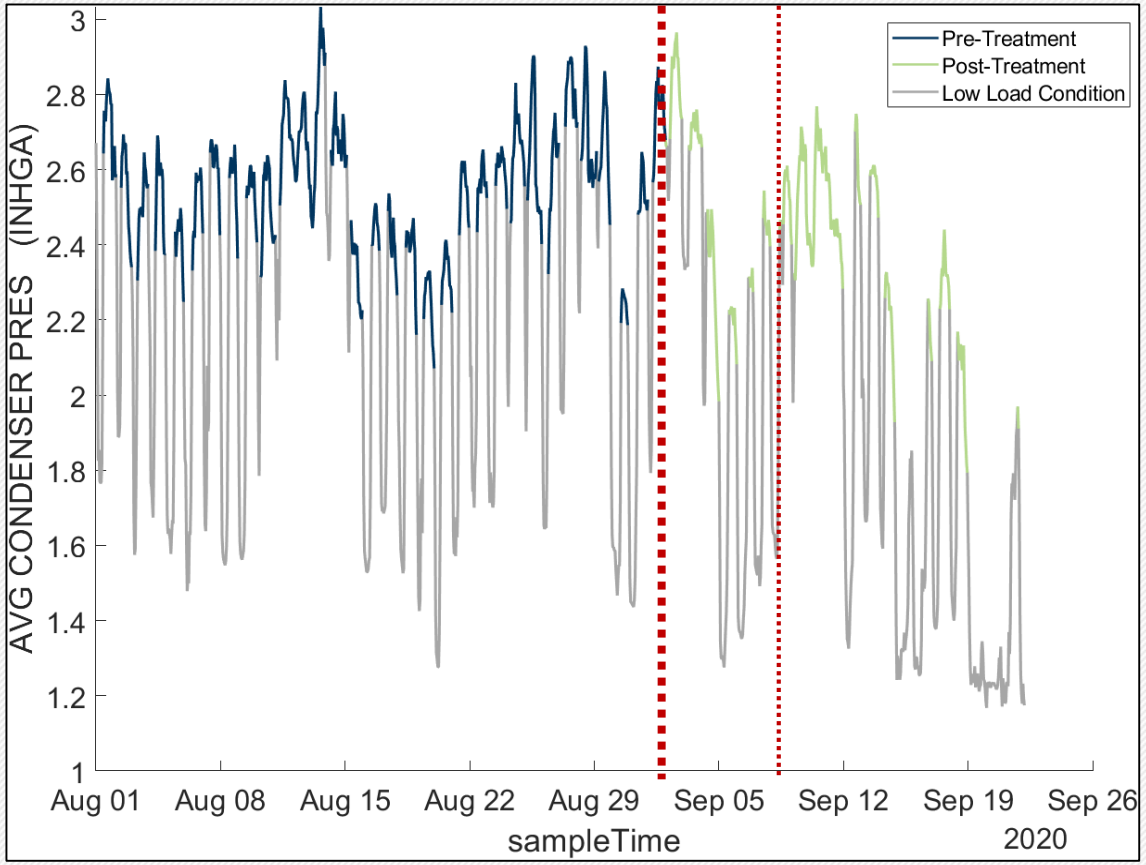


Visual diagram of injection method at condenser inlet port. Material circulated though cooling water loop.

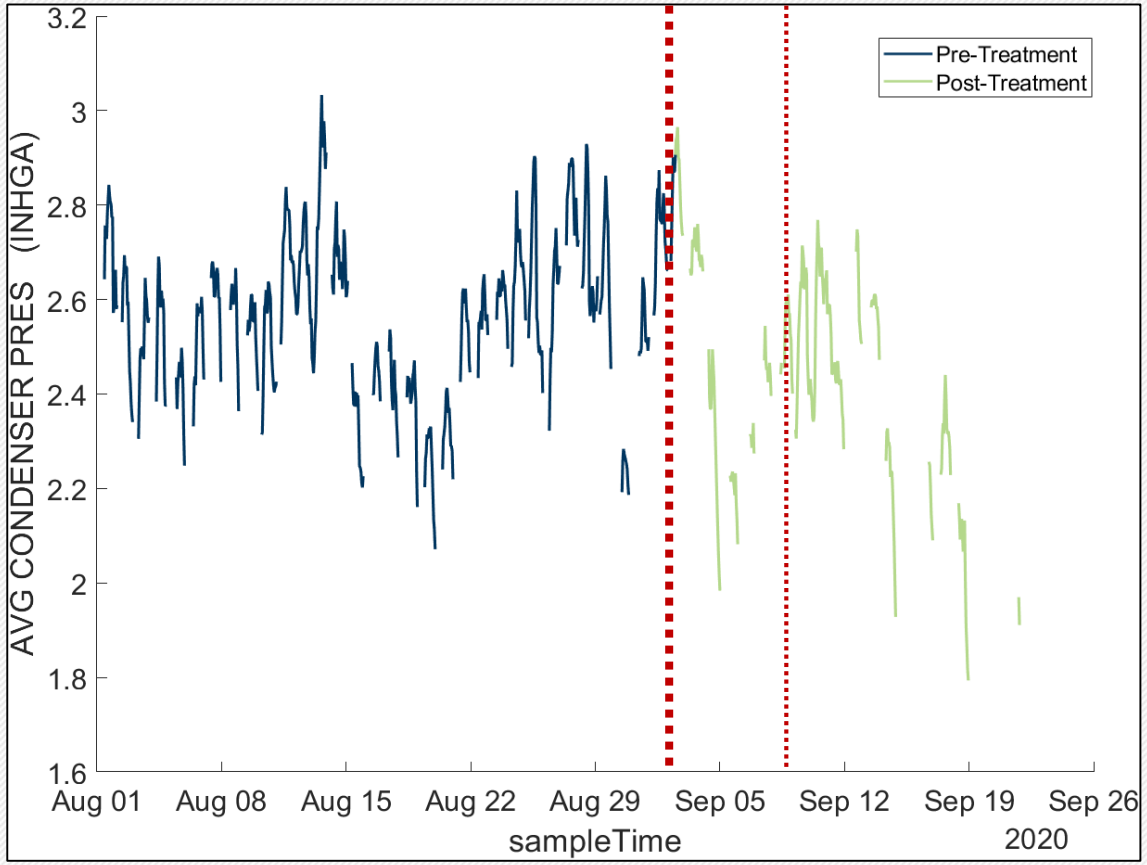


Project Update - Treatment

Unfiltered: Condenser pressure since 8/1, Interphase treatment on 9/2 and 9/8

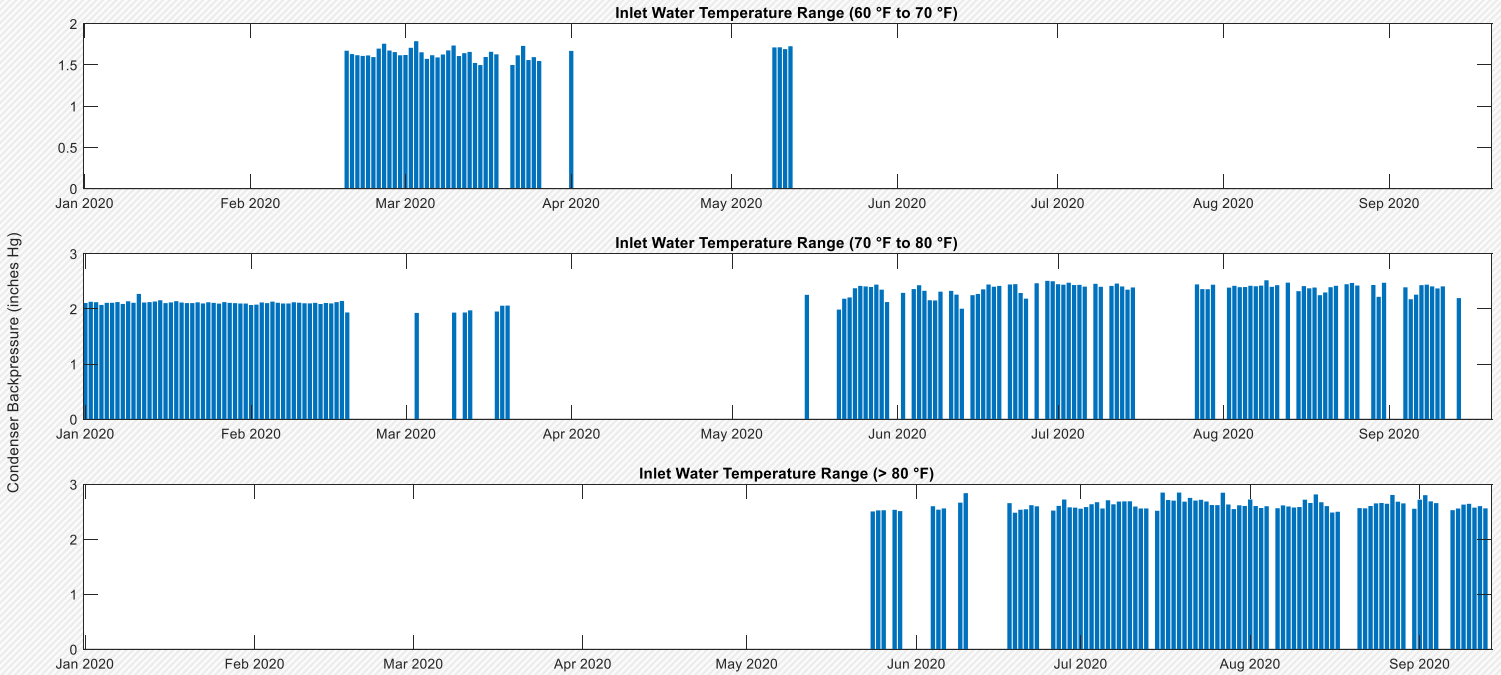


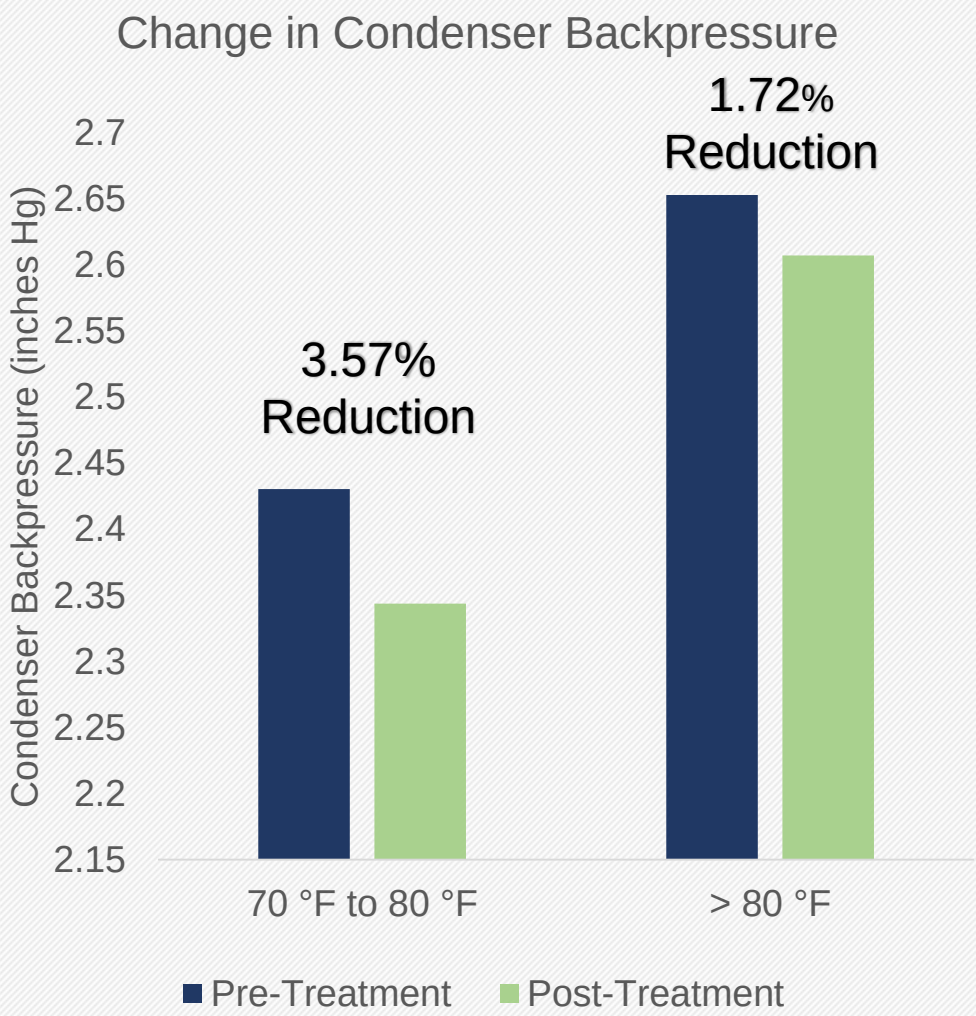
Data filtered: Condenser pressure when plant is operating at full load condition (>750 MW)



Filtering for plant load reduces noise in backpressure from +/- 0.7 inhga to +/- 0.2 inhga!

Project Update - Treatment

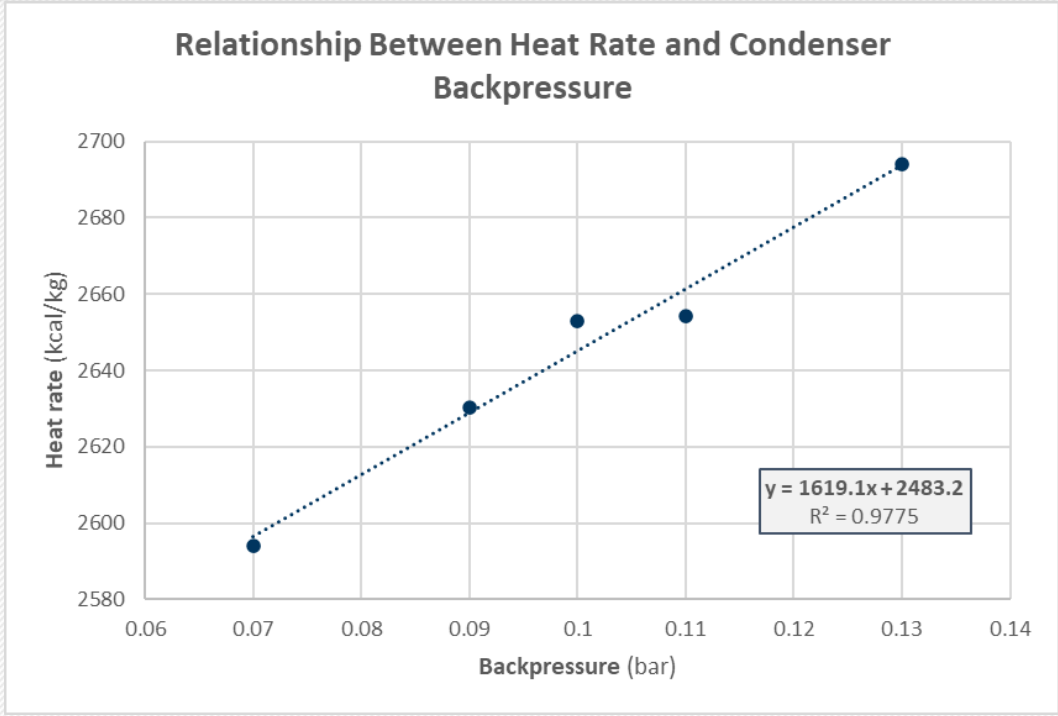




- To eliminate confounding variables, data filtered by power output, CW flow, and CW inlet temperature.
- Results are preliminary and more time is needed to validate the trend, however initial dosing has improved condenser backpressure in the current data set

Preparing Project for Next Steps

- **Market benefits:**
  - **A ~3.6% reduction in backpressure reduces heat rate by 0.2%, saving estimated $190k in fuel costs alone annually and 12,800 less tons CO_2 produced**
  - Across the fossil energy fleet of 1,800 natural gas and 400 coal plants nationwide, this translates to ~$158M in reduced fossil energy consumption and ~7.6M less tons CO_2 produced
  - Additionally, fouling protection on condenser tubes can reduce pressure increase over time
  - Fouling protection on cooling towers could also:
    - Prevent loss of heat rejection abilities due to fouling
    - Extend useful life of fill before failure



Sources:

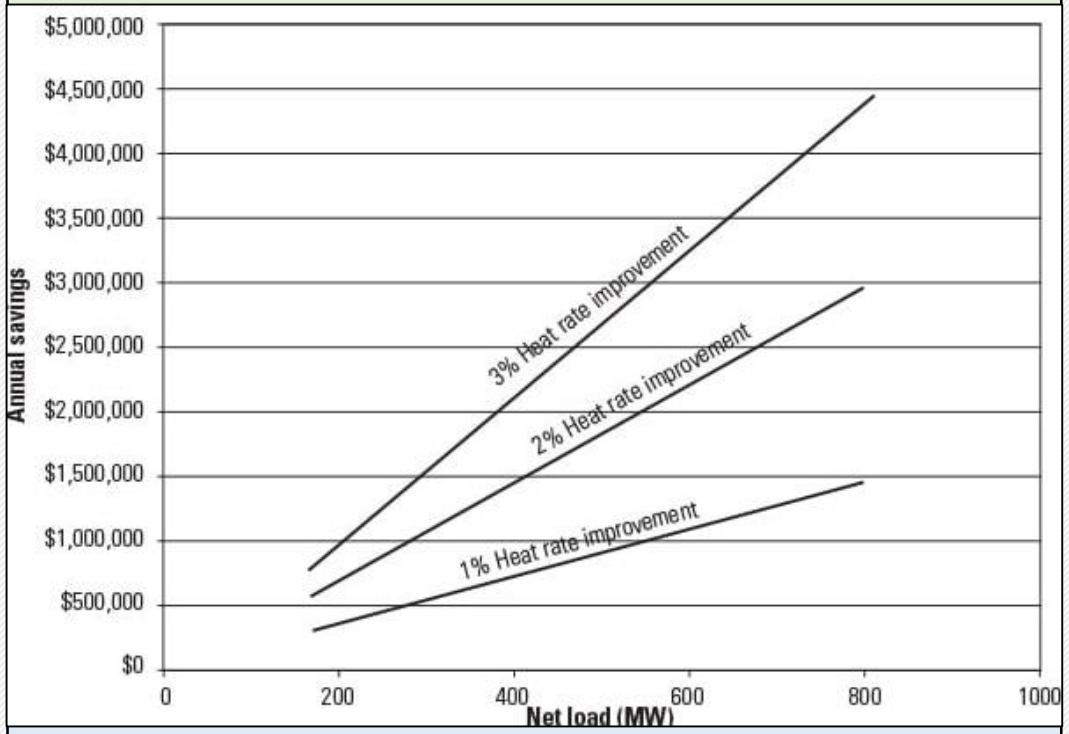
Korellis, S. “Coal-Fired Power Plant Heat Rate improvement Options, Part 1”. *Power Magazine.* 2014. <https://www.powermag.com/coal-fired-power-plant-heat-rate-improvement-options-part-1/>.

Bhoi, R. et al. “Effect of Condenser Backpressure on Power Plant Heat Rate and Thermal Efficiency”. *IJSRD*, 3(03). 2015. ISSN: 2321-0613.

Market size and energy prices from U.S. Energy Information Administration

Preparing Project for Next Steps

Coal Power Plant Annual Cost Savings Given Power Output and Heat Rate Change



Given an energy cost of $2.50/MMBtu; figure reproduced from Power Magazine courtesy of EPRI

- **Technology-to-market plan:**
  - Integrate with existing industry partners such as condenser cleaning service providers to apply technology post-cleaning for optimal gains
  - Study longevity of treatment and determine re-application schedule to fully quantify economic benefits to the fossil energy portfolio and beyond
  - Perform additional research on cooling tower fouling prevention to optimize technology and quantify potential economic and environmental gains

Concluding Remarks

- Improvements to condenser heat exchange increases overall plant efficiency and lowers CO2 emissions, directly supporting FE strategic Goal 2.2
- Opportunity to translate technology to power plant condensers across the wider energy generation portfolio
- Opportunity to translate technology to other heat exchangers and thermal management systems within FE portfolio
- **Key Challenge & Next Steps:** integrate technology offering into existing industry frameworks by collaborating with key partners.

2.2 Advance technologies to improve the efficiency, reliability, emissions, and performance of existing fossil-based power generation

Links to Sources

- **Best Practices for Maximizing Condenser Efficiency**
- https://www.powermag.com/best-practices-for-maximizing-condenser-efficiency/

- **How Deficient Preventative Maintenance Impacts Power Plants**
- https://www.goodway.com/hvac-blog/2017/12/how-poor-preventative-maintenance-measures-impact-power-plants/

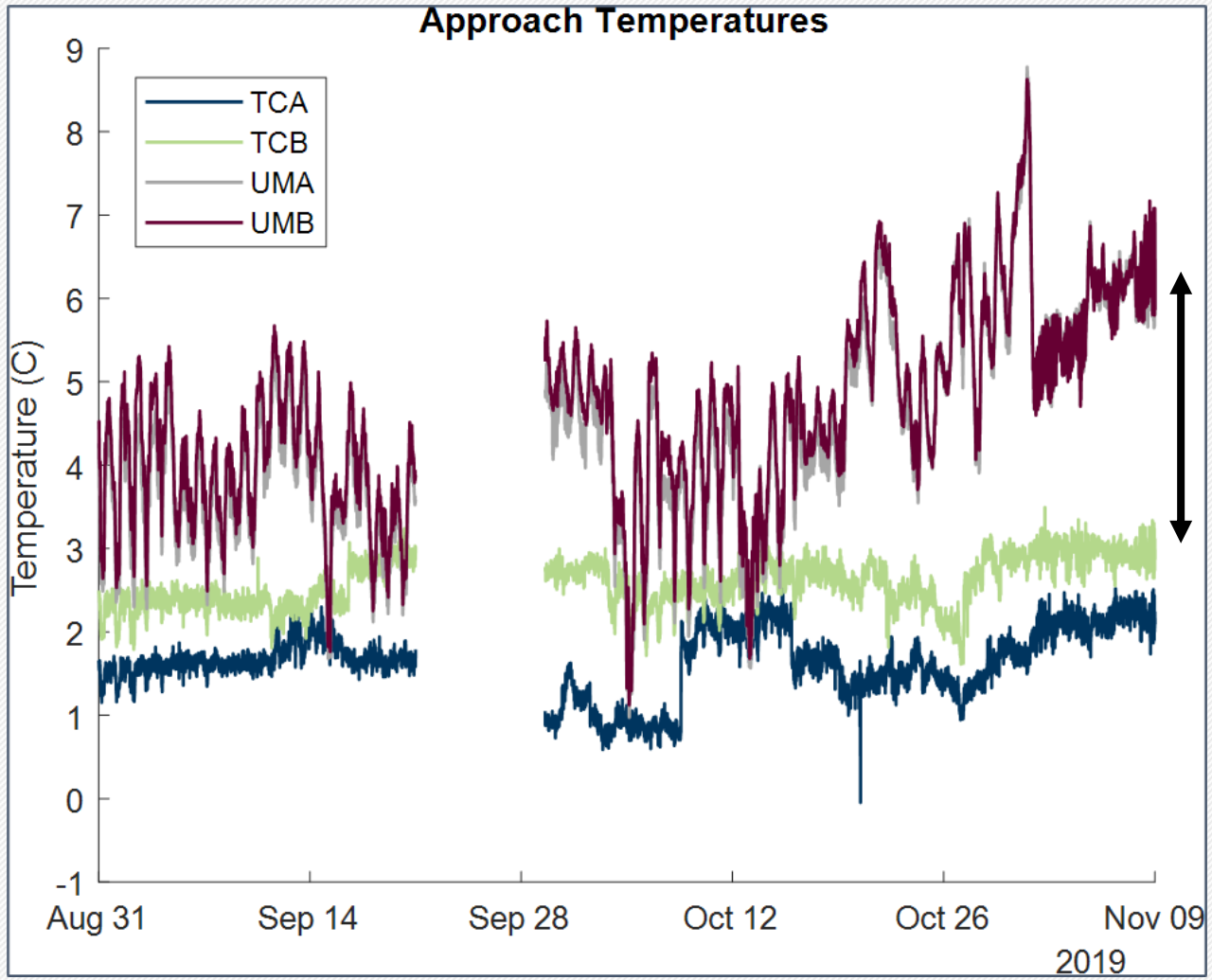
- **Effect of Condenser Backpressure on Power Plant Heat Rate and Thermal Efficiency**
- http://www.ijsrd.com/articles/IJSRDV3I30093.pdf

- **Coal-Fired Power Plant Heat Rate Improvement Options, Part 1**
- https://www.powermag.com/coal-fired-power-plant-heat-rate-improvement-options-part-1/

Appendix

- List of Tasks
  - Task 1: Project Management and Planning
  - Task 2: Laboratory Scale Testing with Longview Water
  - Task 3: Skid Design, Fabrication, Installation, and Application of HTE System
  - Task 4: Data Collection and Risk Assessment
  - Task 5: Application of HTE System to Longview Condenser
- Skid data (next slide)

Project Update – Water Treatment Efficacy



- The onset of fouling is evidenced by increases in the approach temperature and fouling weight
- $T_{approach} = T_{hot\ out} - T_{cold\ in}$
- The increase in approach temperature in the untreated main water supply compared to treated cooling suggests the onset of fouling in both banks of HXs in the less treated water, which is matched in the dry weight change of the skid's cooling tower fill