Balance of Plant (BOP) Heat Exchanger NDE and Performance Programs Symposium – July 2025

Pittsburgh Chemical Solutions

THERMOPHASE

What is THERMOPHASE?

THERMOPHASE is a chemistry that provides a nanocoating on surfaces. It provides the following:

- Prevention of Fouling
- Improved Heat Transfer

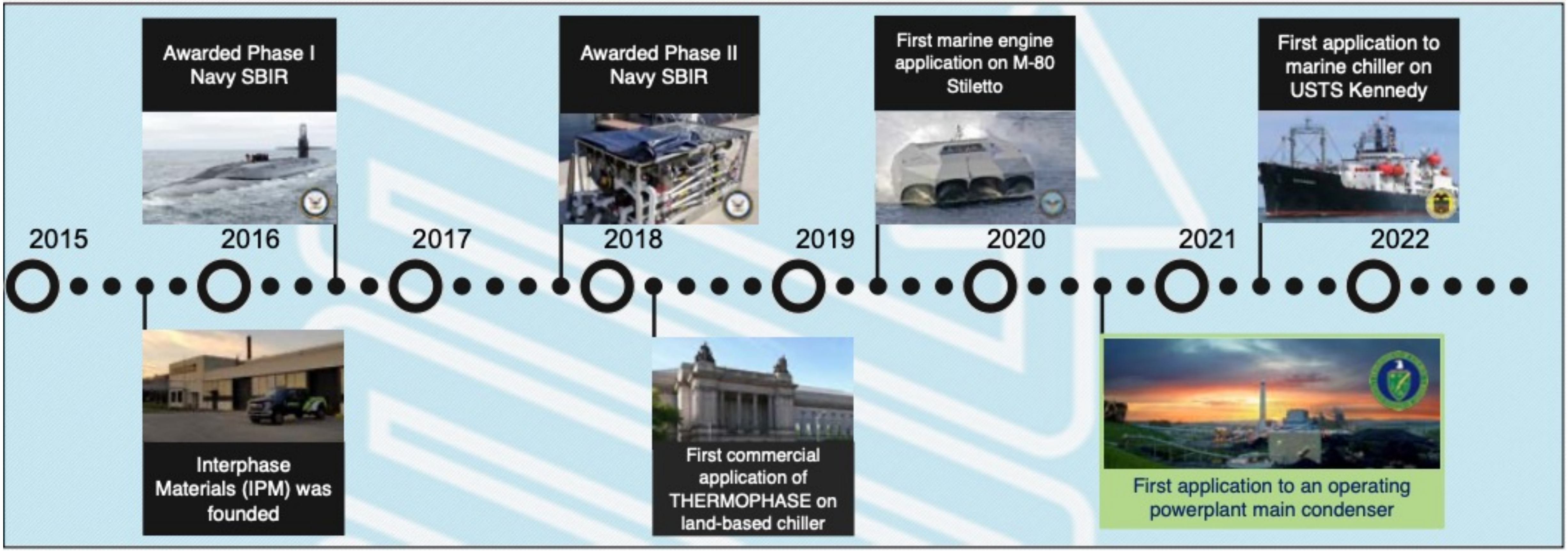
Benefits include:

- Improved efficiency (energy savings, fuel savings, etc.)
- Reduction of required maintenance
- Improved operation capability
- Reduction of emissions
- Reduced water usage
- Non-Hazardous/Non-biocide
- Non-Toxic
    - LC50 for fish and Daphnids
    - Sustainability Prize from the University of Southern California (funded third party toxicity testing with results showing no toxic effect of the technology on any of the test organisms including maritime vertebrae and invertebrae species)

Product has been used in various industries (condensers, chillers, various types of heat exchangers, cooling towers, etc) including:

- Power Plants
- Hospitals
- Universities
- Industrial Facilities
- Marine Engines

THERMOPHASE Development History



- THERMOPHASE has been in development since Interphase Materials was founded in 2015 and has been funded from a variety of sources including the U.S. Navy Small Business Innovation Program (SBIR), the Rapid Reaction Technology Office (within the Department of Defense), the U.S. Department of Transportation Maritime Administration (MARAD) and the Department of Energy. THERMOPHASE has been available commercially for building cooling systems since 2018.

THERMOPHASE Mechanism of Action

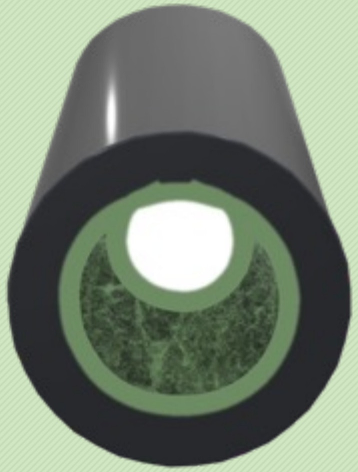
Condenser tube heat transfer is proportionate to:

Material Resistance R_M

Fouling Resistance R_F

Boundary Layer R_B ***Resistance***

Tube Fouling over time increases the Fouling Resistance (R_F)



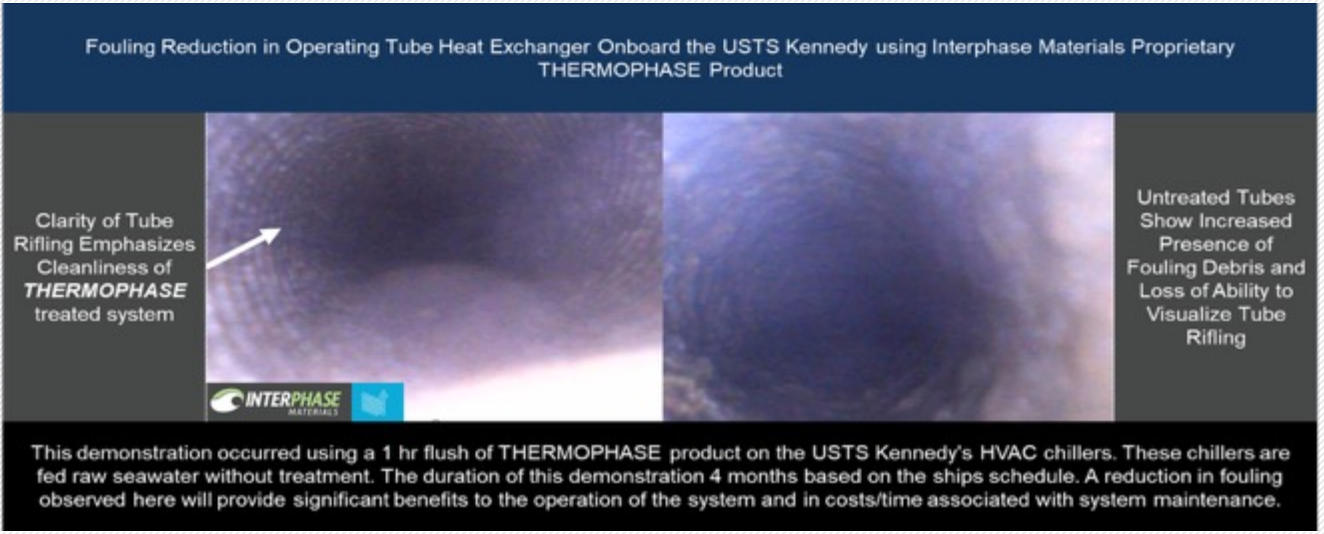
THERMOPHASE Reduces the Fouling Resistance (R_F) and Boundary Layer Resistance (R_B)

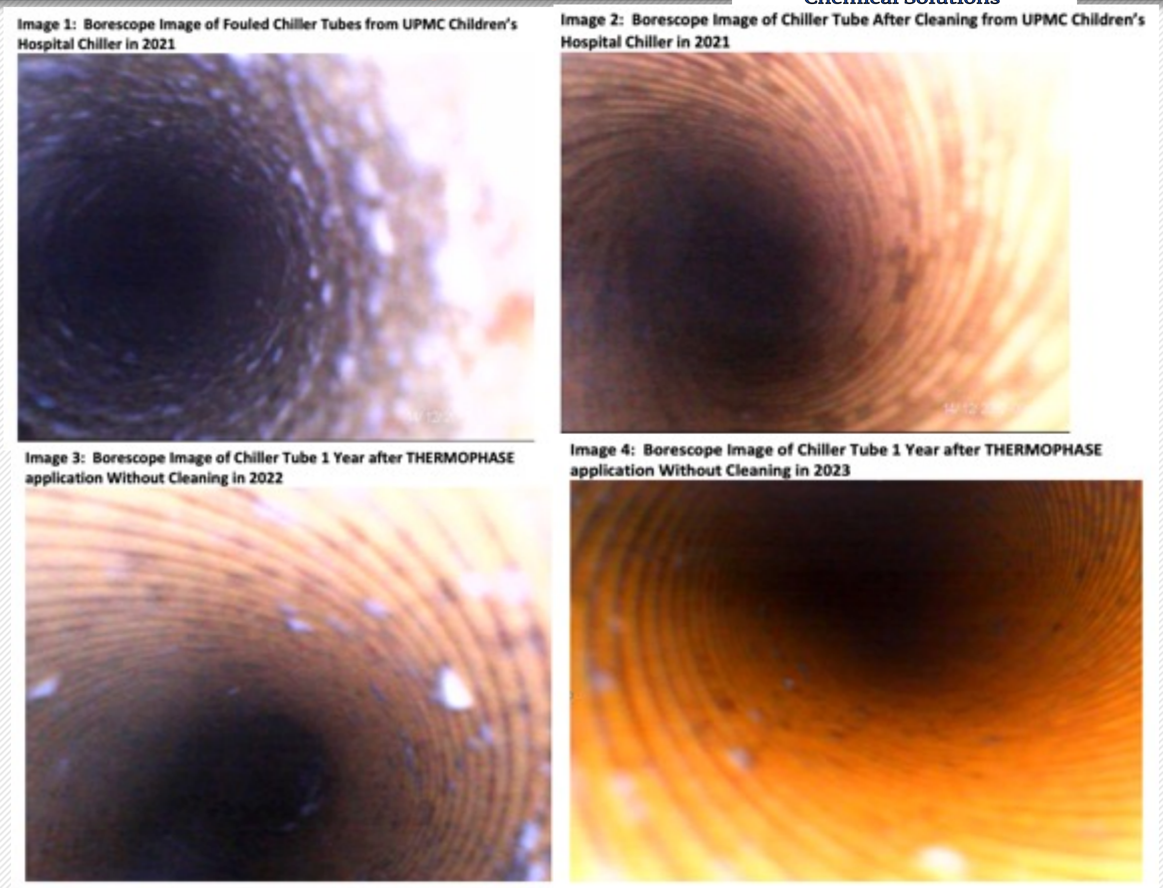
- Increase Power Plant Efficiency
- Backpressure Decrease
- Increase Condenser Heat Transfer
- Lower Boundary Layer and Fouling Thermal Resistances

THERMOPHASE is an advanced material technology applied to the inside of heat exchanger components, such as condenser tubes, to lower the thermal resistance of the material by reducing fouling and/or the boundary layer.

Fouling

THERMOPHASE *Results - Fouling*





- THERMOPHASE reduced chiller tube fouling on the USTS Kennedy (DOT MARAD Project #693JF71850005, https://www.maritime.dot.gov/sites/marad.dot.gov/files/2022-09/Interphase%20Materials%20MMA%20Final%20Report.pdf).

THERMOPHASE was applied by circulating it through the offline chiller. The chillers were treated between February and March of 2021. Without any cleaning, the chiller tubes were borescoped the following year in January/February 2022. This was duplicated in 2023 and tubes no longer clean the tubes. In 2024 and now 2025 inspections, with multiple years without cleaning and THERMOPHASE annual application the tubes remains clean. Yearly Eddy current testing by the plant is being moved to every 3 years.

Heat Transfer Improvements

Heat Transfer

THERMOPHASE

Heat Transfer Improvements have been excellent (examples):

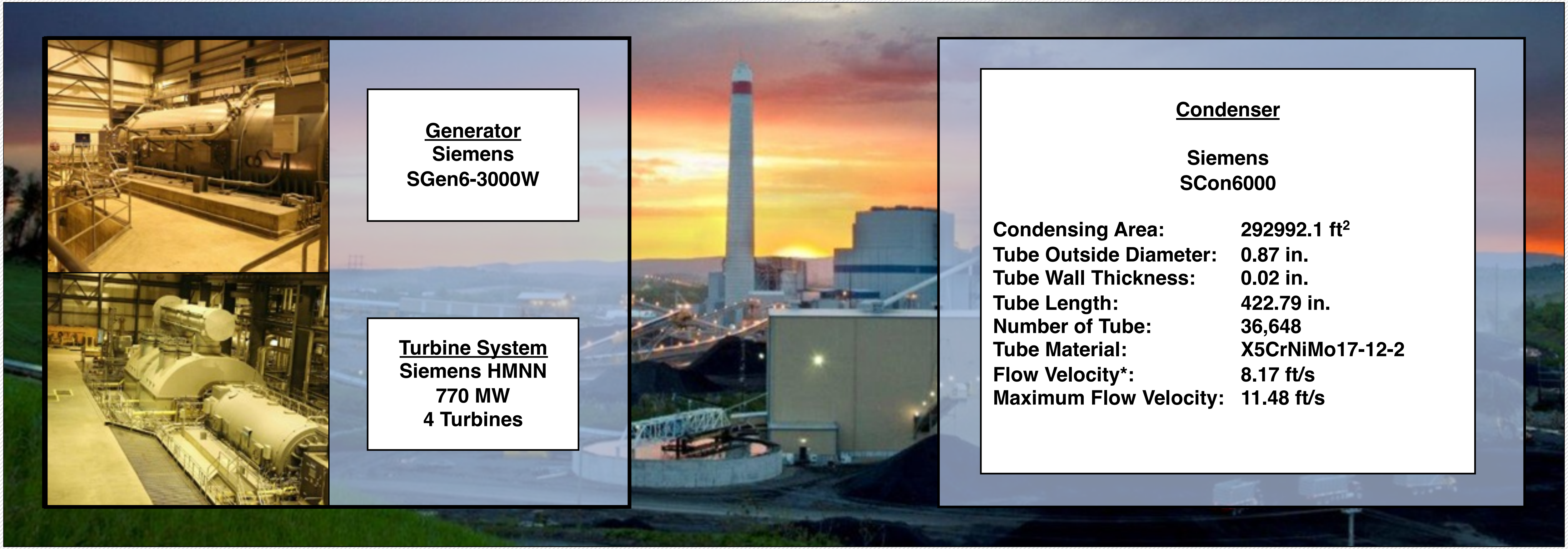
- Baseline lab results 5.8%
- 770MW results 4%
- 900MW results approximately 7% on condenser heat transfer coefficient and approximately 15% on heat exchangers effectiveness
- EPRI test results on new tubes 2.4% and increasing before test ended

Electric Power Research Institute (EPRI) Validation

- THERMOPHASE was provided at the request of EPRI in a project to evaluate coatings for condenser tubes.
- During the first phase of testing, THERMOPHASE was tested hydrophobicity (ASTM D7334), thermal conductivity (ASTM E1461), adhesion (ASTM C1624), and abrasion (ASTM G133). THERMOPHASE performed excellent in all categories.
- THERMOPHASE was shown to increase the heat transfer coefficient by 1.9% when compared to clean, unmodified tubes. A month later, the improvement increased to 2.4% and was improving when test was stopped. The test was a short duration and THERMOPHASE was the only internal coating that showed improvement during the test time frame.
- Data is consistent with the DOE/NETL two-year program at Longview and other installations of THERMOPHASE

Full Scale Power Plants

Longview Power Plant Overview



Generator
Siemens
SGen6-3000W

Turbine System
Siemens HMNN
770 MW
4 Turbines

Condenser

Siemens
SCon6000

Condensing Area:	**292992.1 ft^2**
Tube Outside Diameter:	**0.87 in.**
Tube Wall Thickness:	**0.02 in.**
Tube Length:	**422.79 in.**
Number of Tube:	**36,648**
Tube Material:	**X5CrNiMo17-12-2**
Flow Velocity*:	**8.17 ft/s**
Maximum Flow Velocity:	**11.48 ft/s**

*Flow velocity at rated temperature rise

Source: The Future of Reliable Clean Coal Power. Retrieved December 13, 2022, from https://longviewpower.com/clean-coal-power

THERMOPHASE Applications

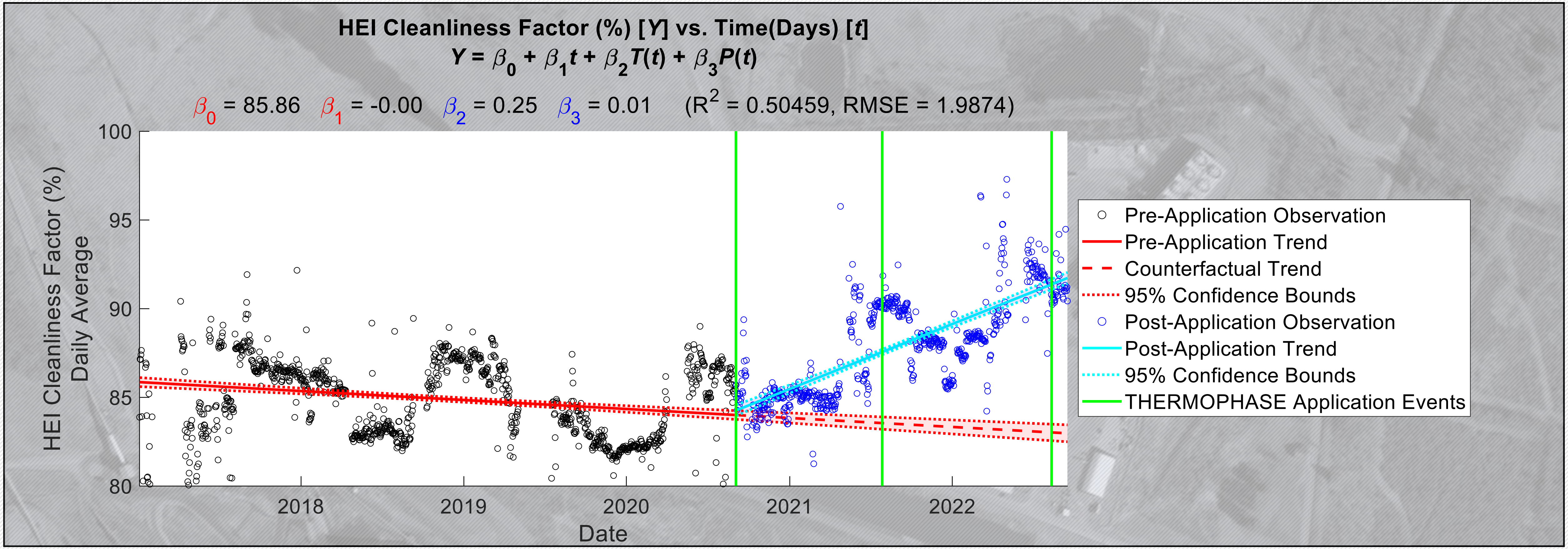
Pittsburgh Chemical Solutions

Application 1 on September 2nd, 2020

Application 2 on July 27th, 2021

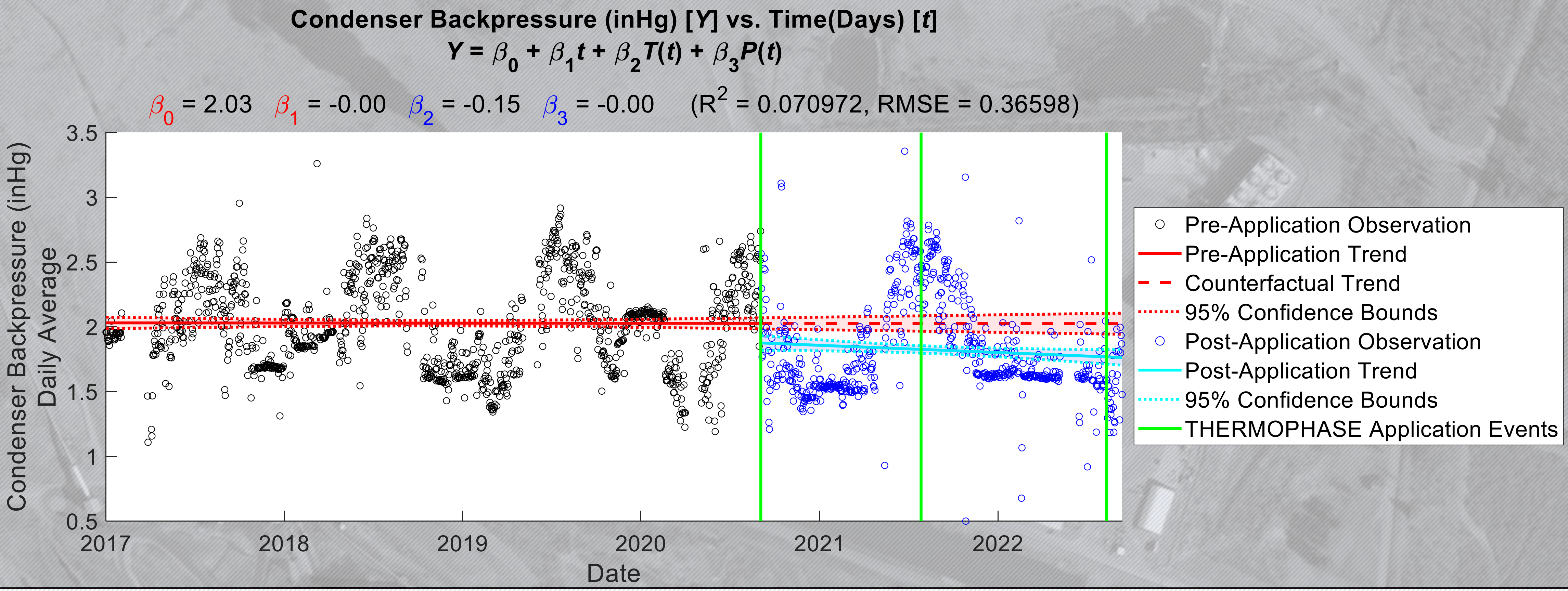
THERMOPHASE was applied to the Longview Power plant beginning on September 2nd, 2020. The second and third applications were on July 27th, 2021, and August 11th, 2022. In the first application, THERMOPHASE was slowly added over two weeks with the system concentration not exceeding 6 ppm (based on an estimated 2 million-gallon system volume). The second and third applications were performed by adding the material directly into the cooling tower sump with a peak concentration of ~ 25 ppm. The tubes of the condenser were not cleaned before or after THERMOPHASE application.

HEI Cleanliness Factor



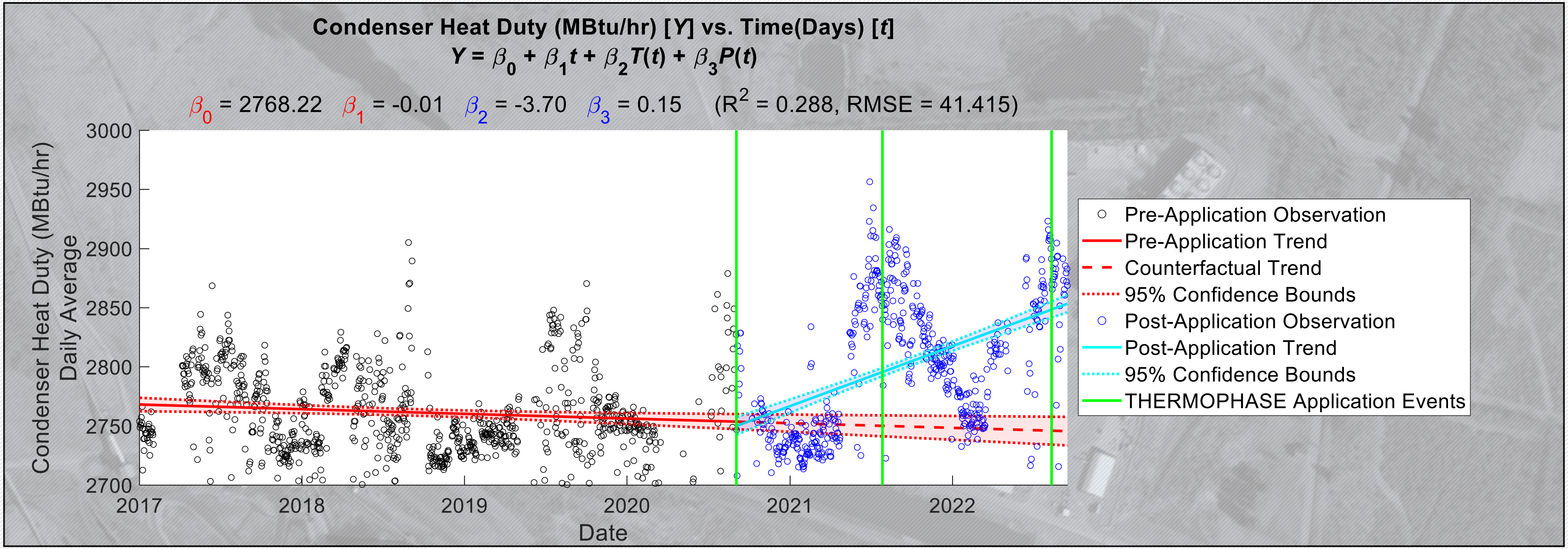
The daily average of the HEI Cleanliness Factor is plotted above through September 16th, 2022. The HEI Cleanliness Factor is a historian calculation recorded in the Longview Power historian (variable 1OPM.CONDENSER:Cleanliness). The HEI Cleanliness Factor is defined as $\frac{U_{\text{Observed}}}{U_{\text{Expected}}}\times 100$.

Condenser Backpressure



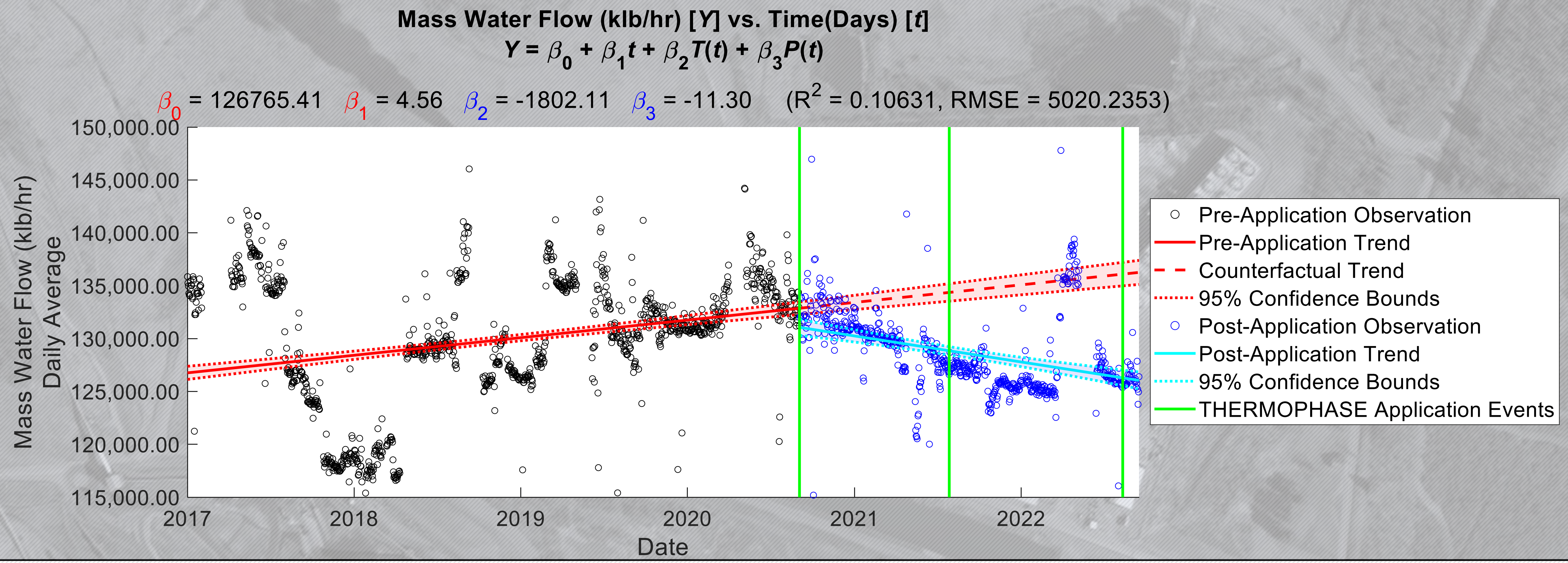
The daily average of the condenser backpressure is plotted above through September 16th, 2022. The condenser backpressure is an instrument value recorded in the Longview Power historian (variable 10MAG10CP002.XQ01).

Condenser Heat Duty



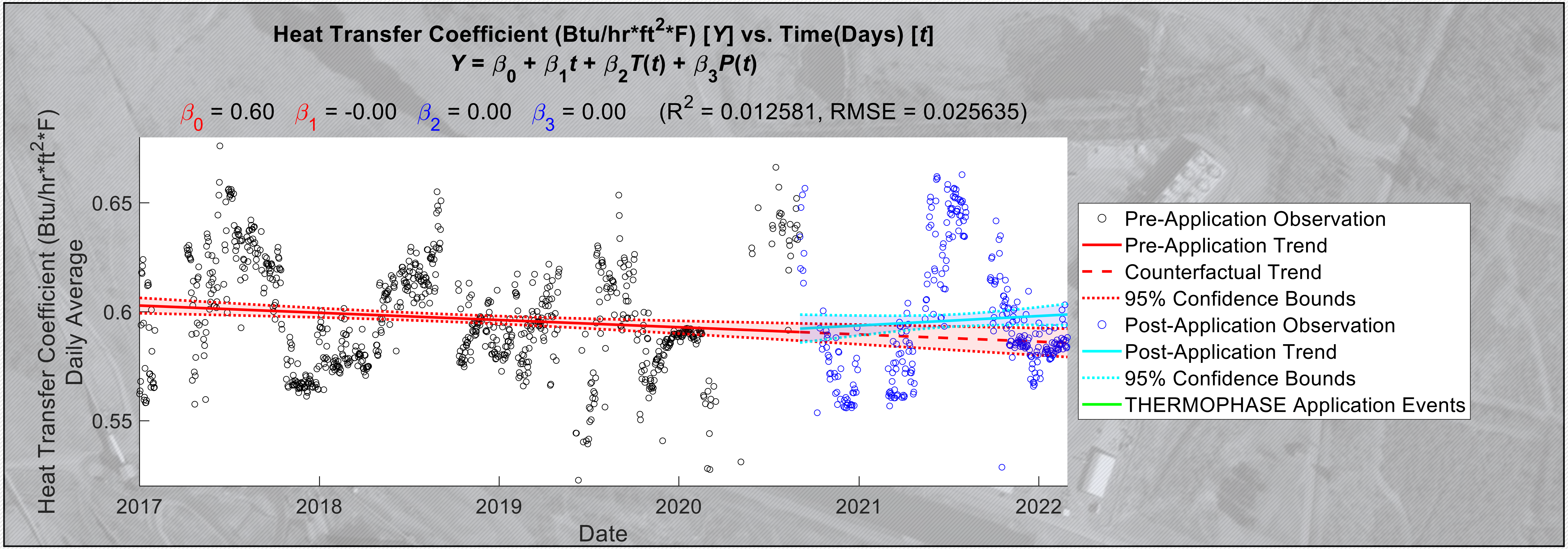
The daily average of the condenser heat duty is plotted above through September 16th, 2022. The condenser heat duty is an historical calculation recorded in the Longview Power historian (variable 1OPM.CONDENSER:DUTY).

Water Flow



The daily average of the mass circulation water flow is plotted above through September 16th, 2022. The mass circulation water flow is a historian calculated value recorded in the Longview Power historian (variable 1OPM.CIRC_WATER_IN:FLOW).

Heat Transfer Coefficient



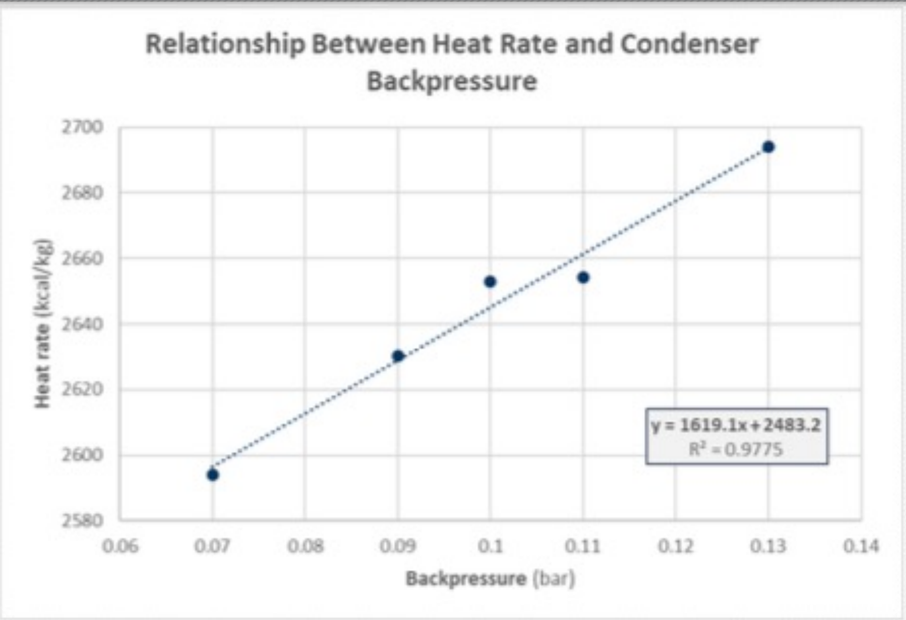
The daily average of the heat transfer coefficient is plotted above through September 12th, 2022. The heat transfer coefficient is an offline calculation. The heat transfer coefficient (U) is defined as, $U = \frac{Q}{A \cdot LMTD}$.

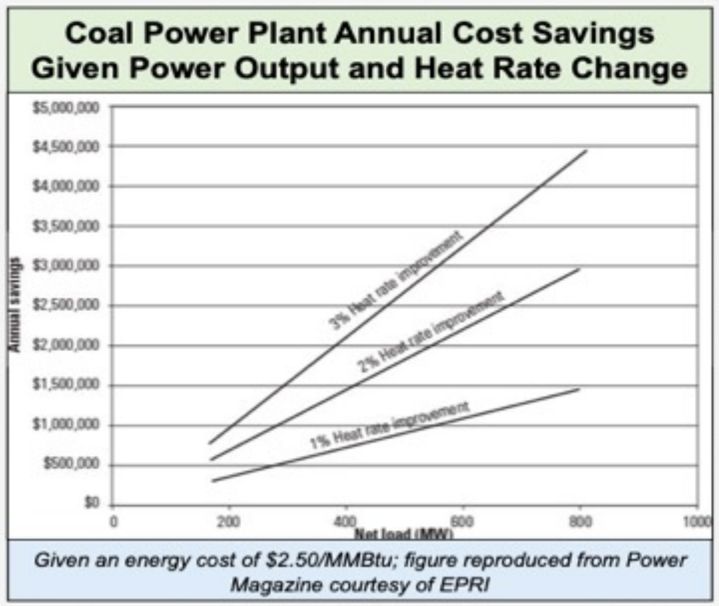
Data From Over 2 Years Validates THERMOPHASE

Data provided to DOE/NETL and presented that validates THERMOPHASE Benefits include:

- HEI Cleanliness Factor
- Condenser Backpressure
- Terminal Temperature Difference
- Condenser Heat Duty
- Temperature Rise
- Log-Mean Temperature Difference
- Heat Transfer Coefficient
- Water Flow
- Condenser Water Outlet Temperature
- Condenser Water Inlet Temperature
- Wet Bulb Temperature/Dry Bulb Temperature
- Cooling Tower Approach Temperature

Operational Savings (Partial List)





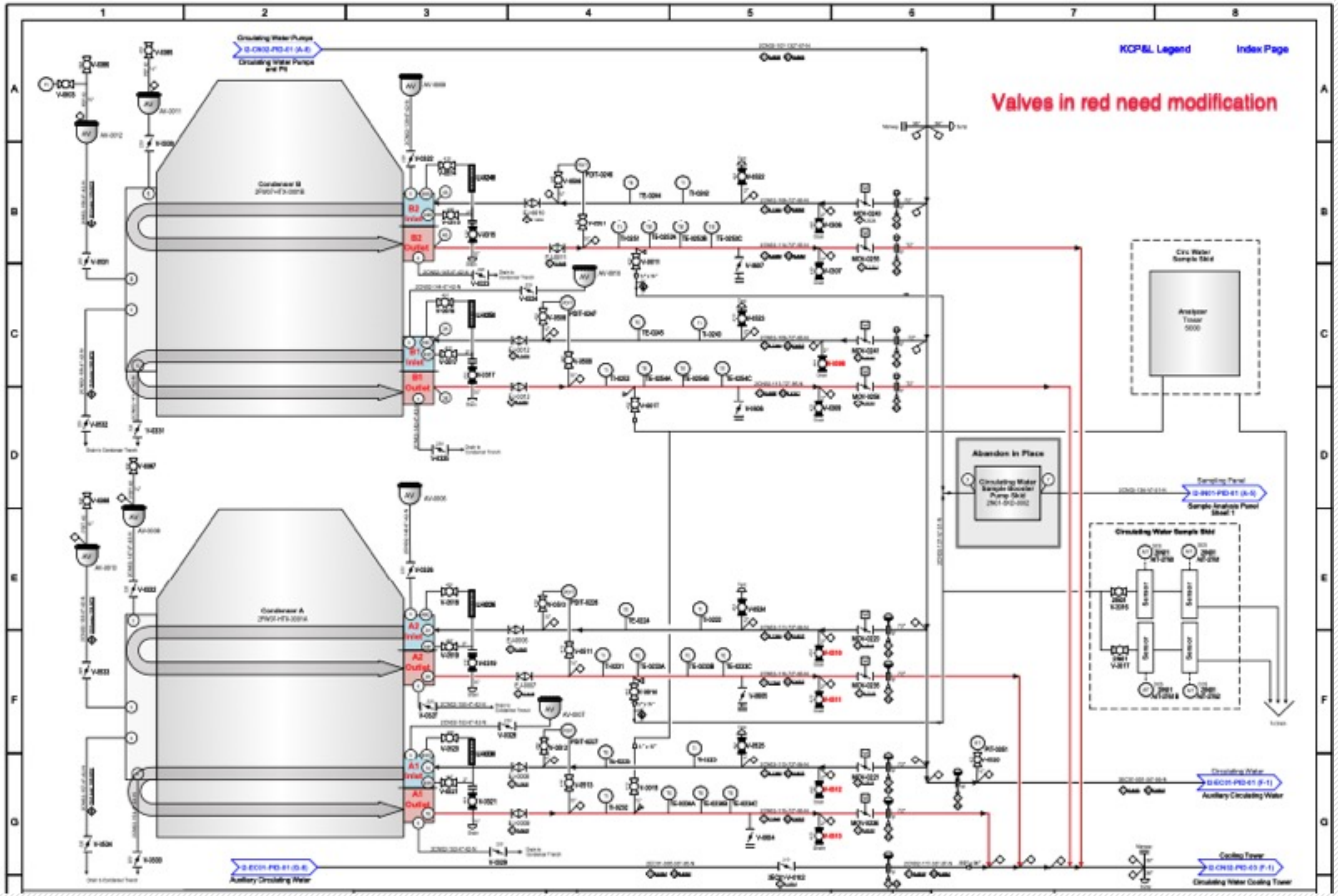
THERMOPHASE 24-Month Savings

Savings Type	
Water Withdrawl	1.287 billion gallons
CO2 Emissions	136 million lbs
Fuel Usage Reduced	40,000 Tons

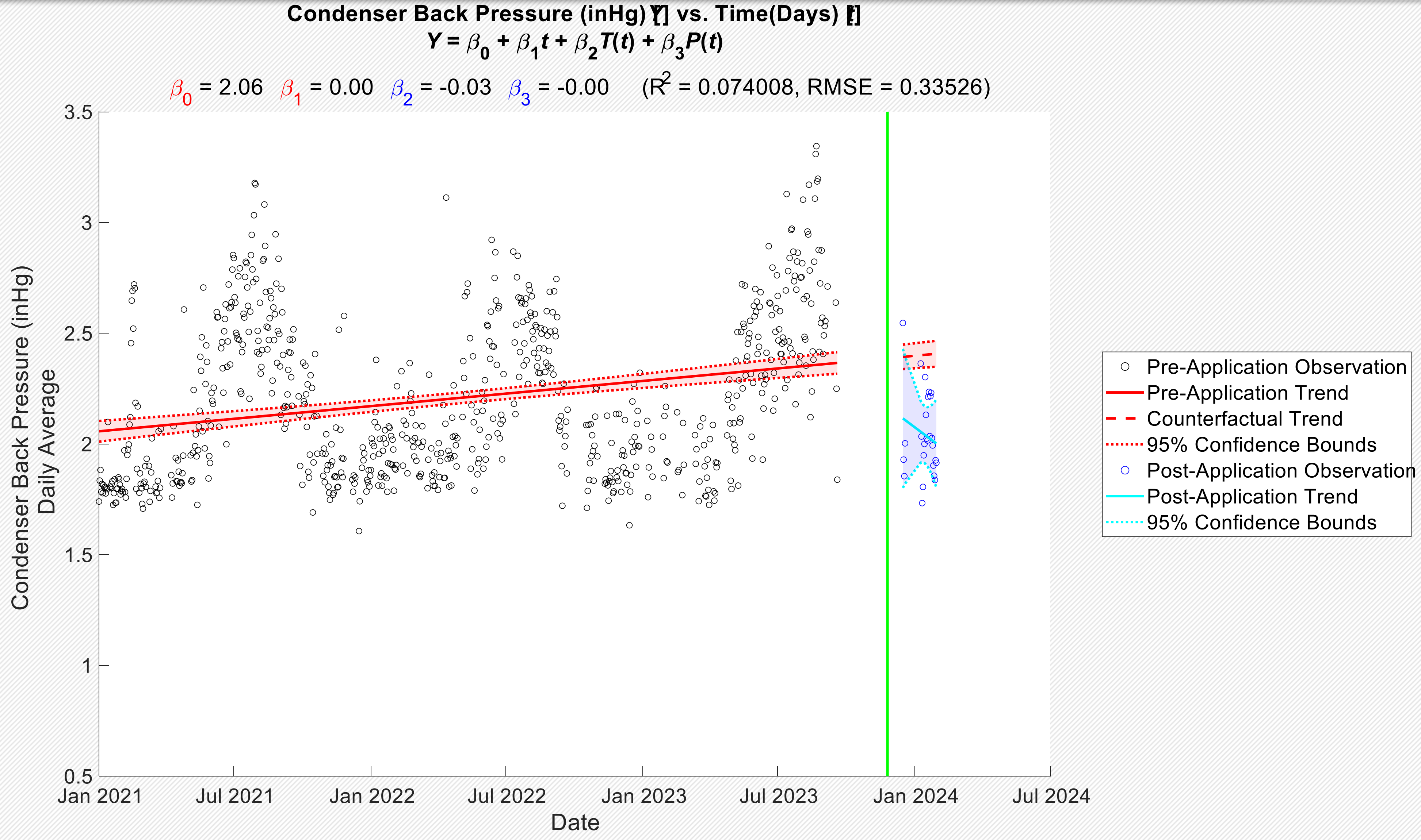
- Heat Transfer Coefficient Improvements at Longview (4%) were consistent with laboratory results (5.8%)
- Immediate and Sustained Backpressure improvements are consistent with condenser performance improvements (TTD, U, and HEI CF%)
- Based on a net decrease of 0.26 inHg after two years (13% reduction), the water, emissions, and fuel cost savings are significant and in support of the DOE/NETLs mission to provide solutions for an environmentally sustainable and prosperous energy future

900MW Unit

900MW Unit
Condenser P&ID

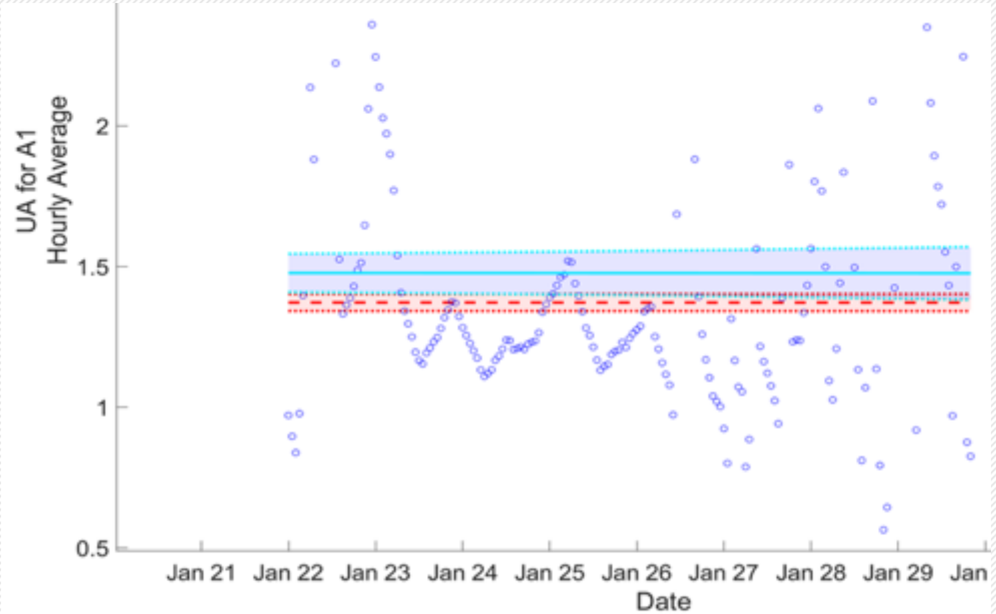


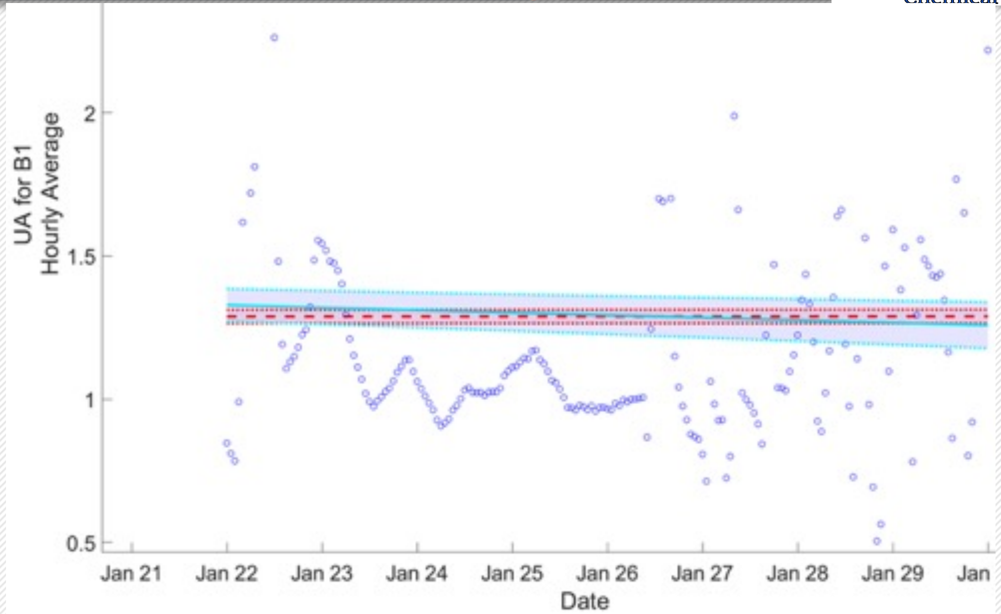
900MW Unit
Condenser Analysis – Back Pressure

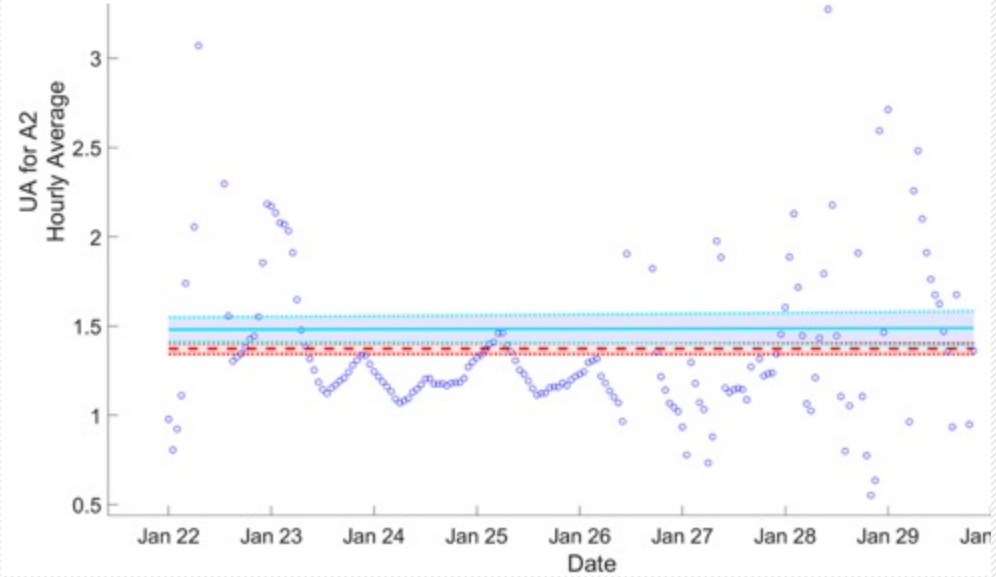


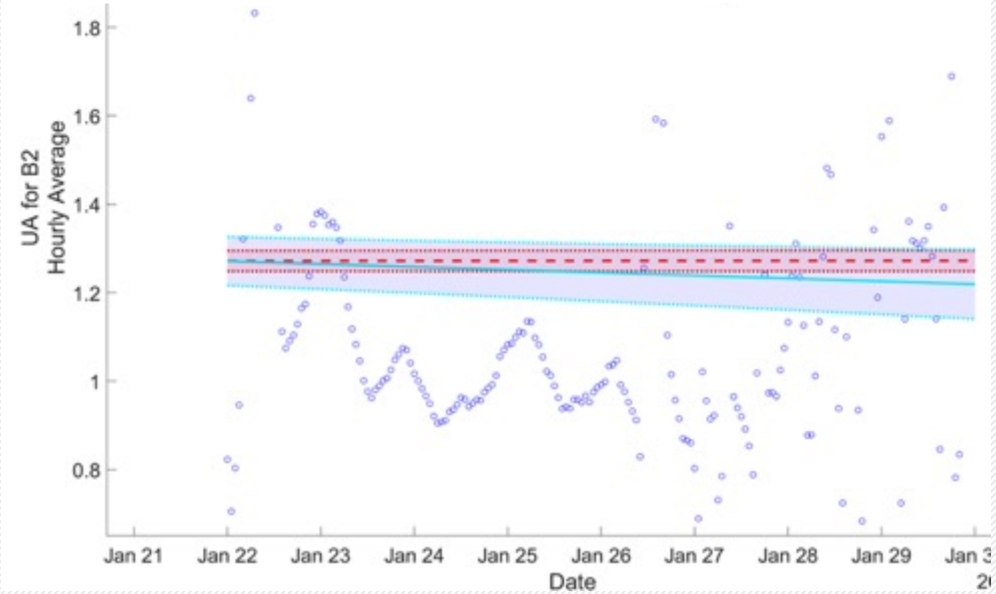
900MW Unit

Condenser Heat Transfer Coefficient (THERMOPHASE Treated vs Untreated)









900MW Unit

Condenser Analysis – Back Pressure – 4 Year June Monthly Comparison

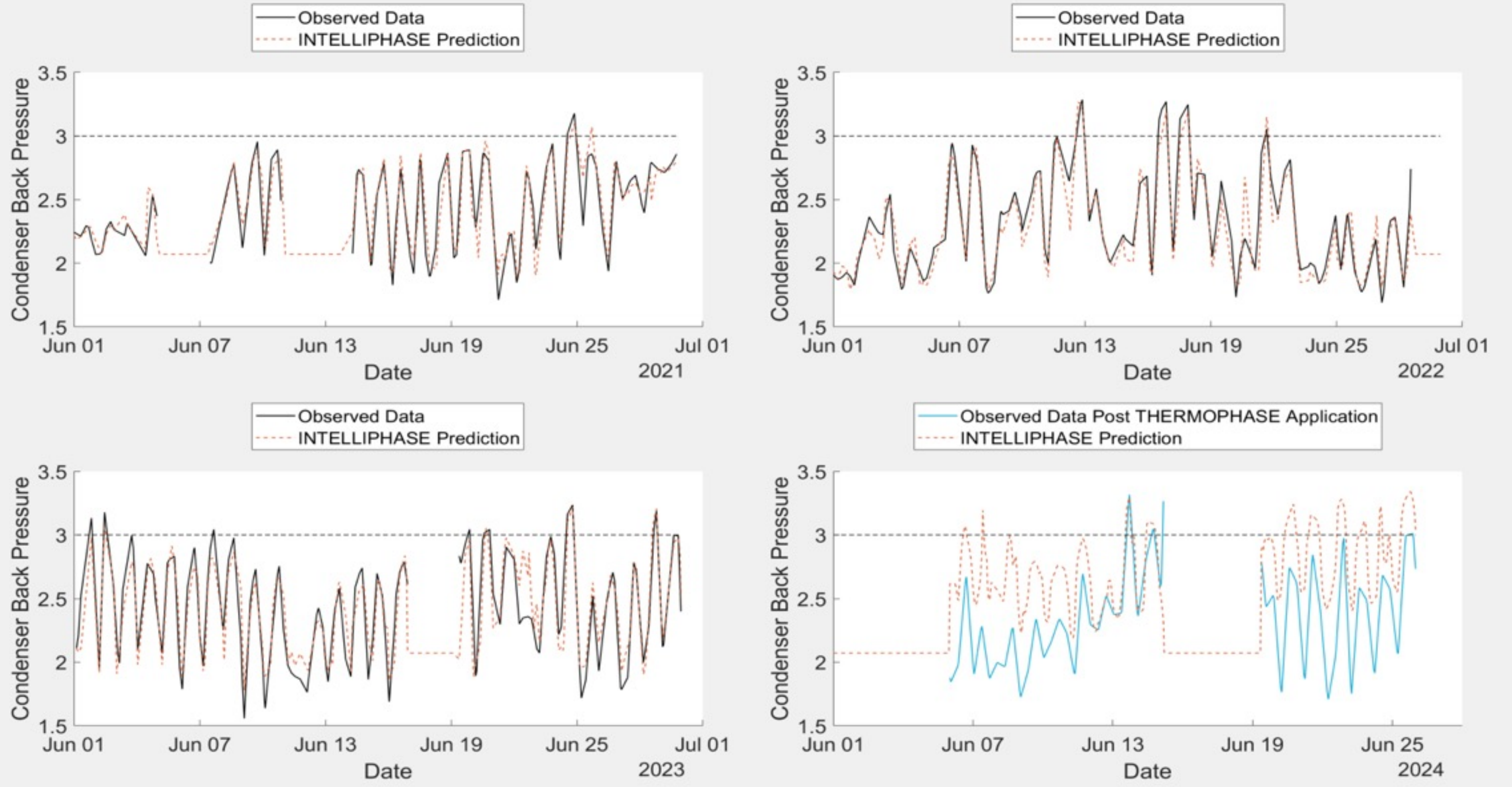
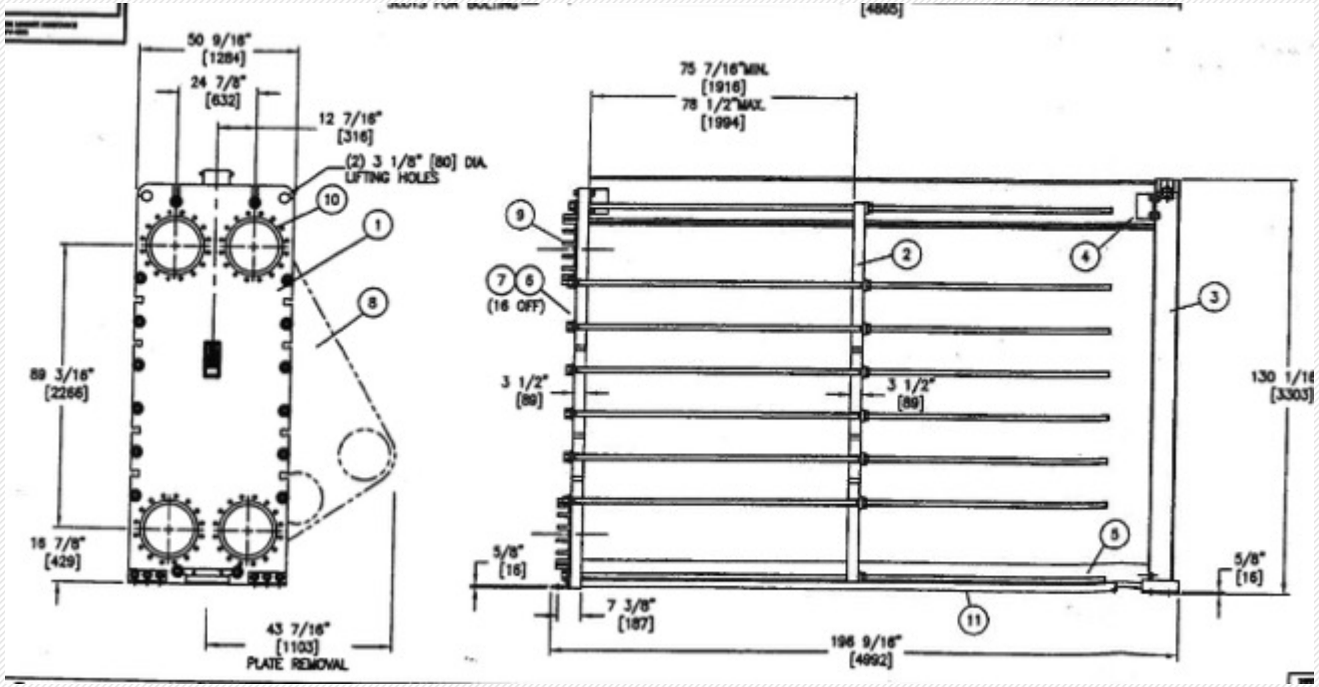


Plate & Frame Heat Exchangers
900MW Unit

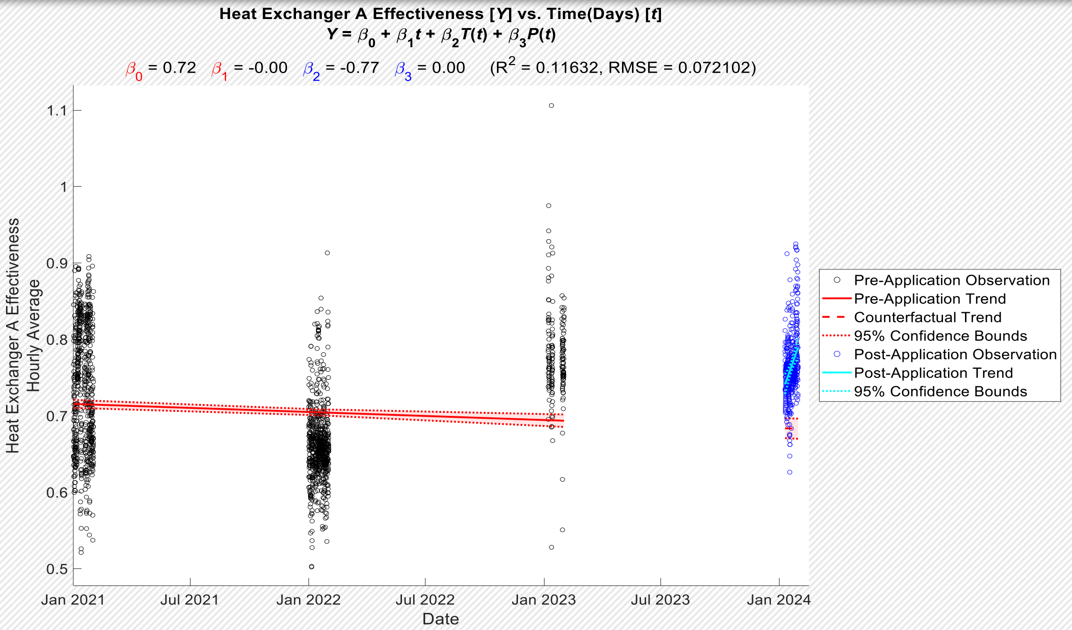
CCW Plate & Frame Heat Exchangers (900MW Unit)

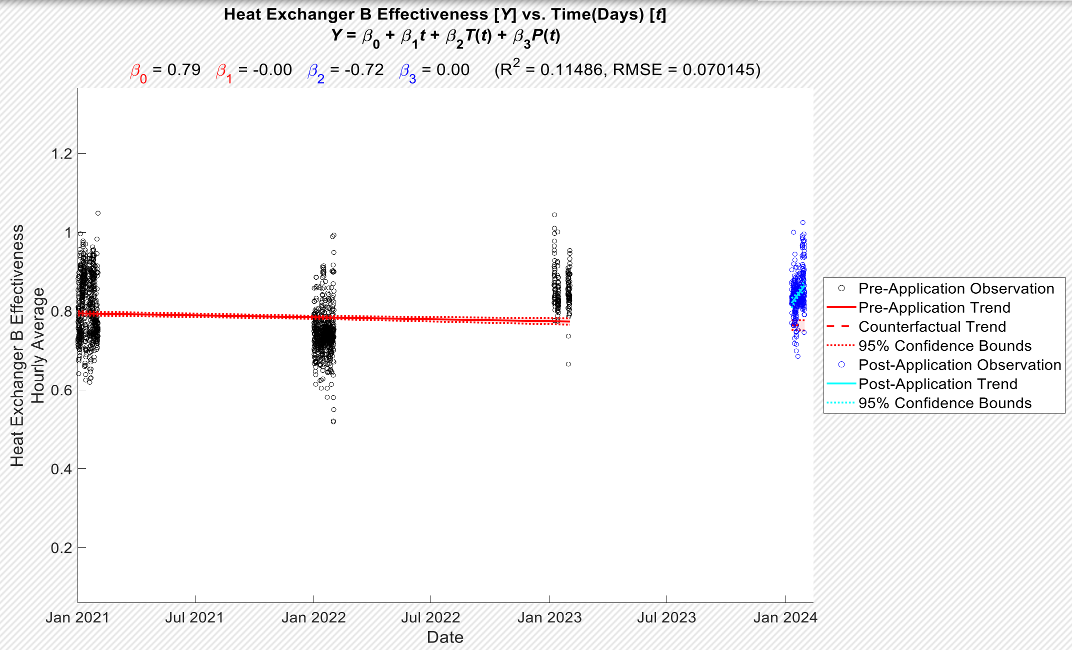
Pittsburgh Chemical Solutions

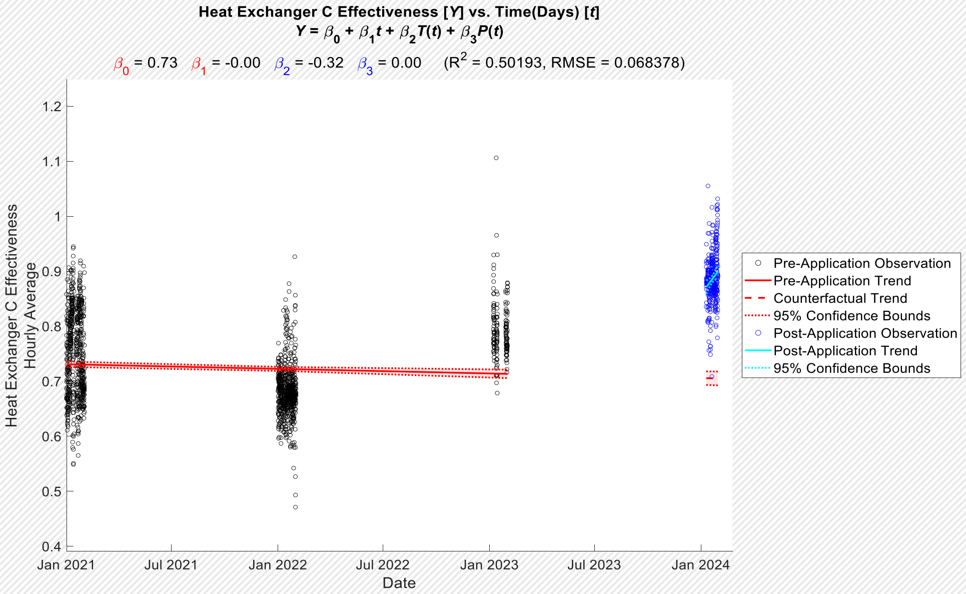


CCW Plate & Frame Heat Exchangers (900MW Unit)

Heat Exchanger Effectiveness

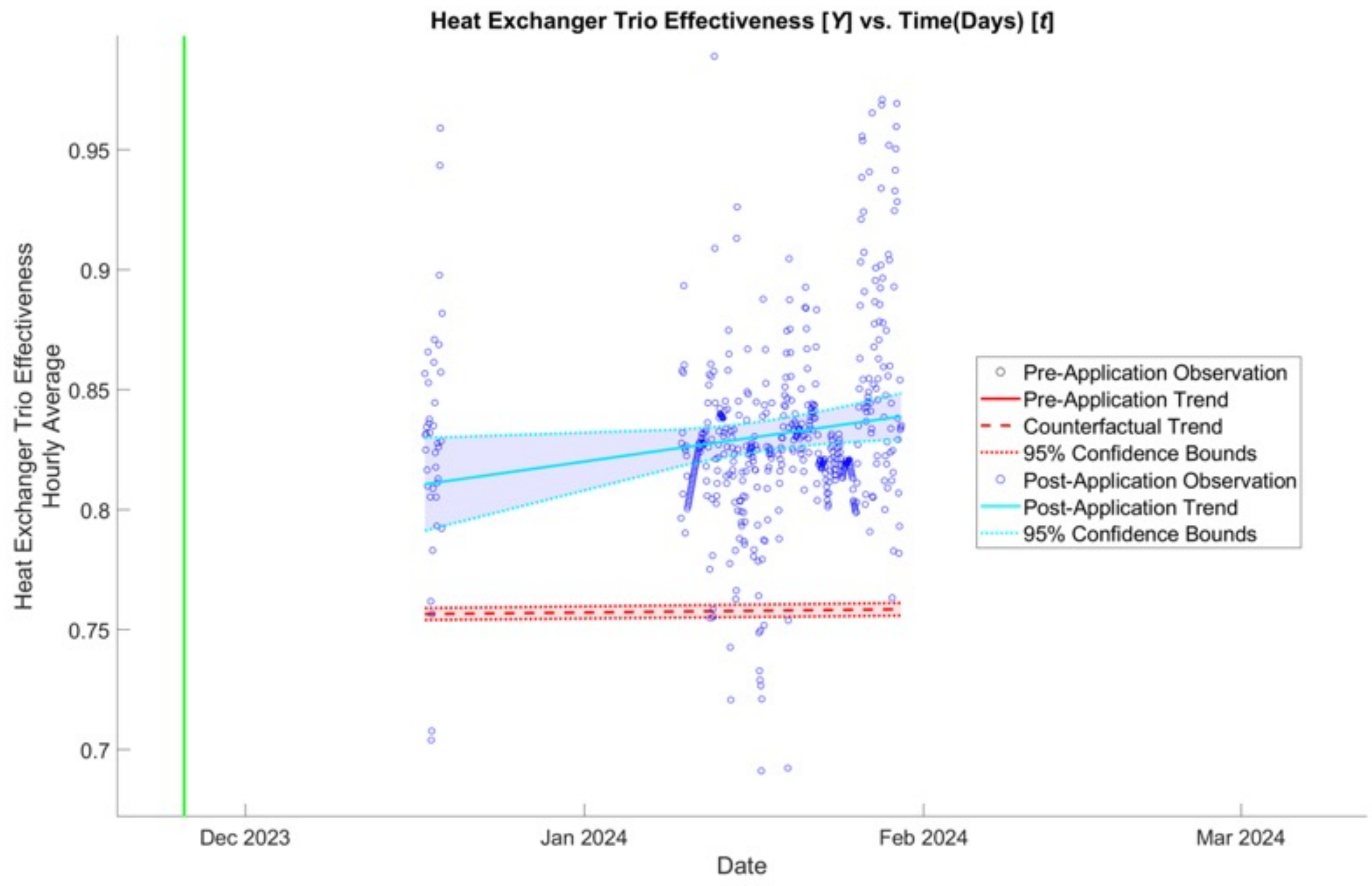






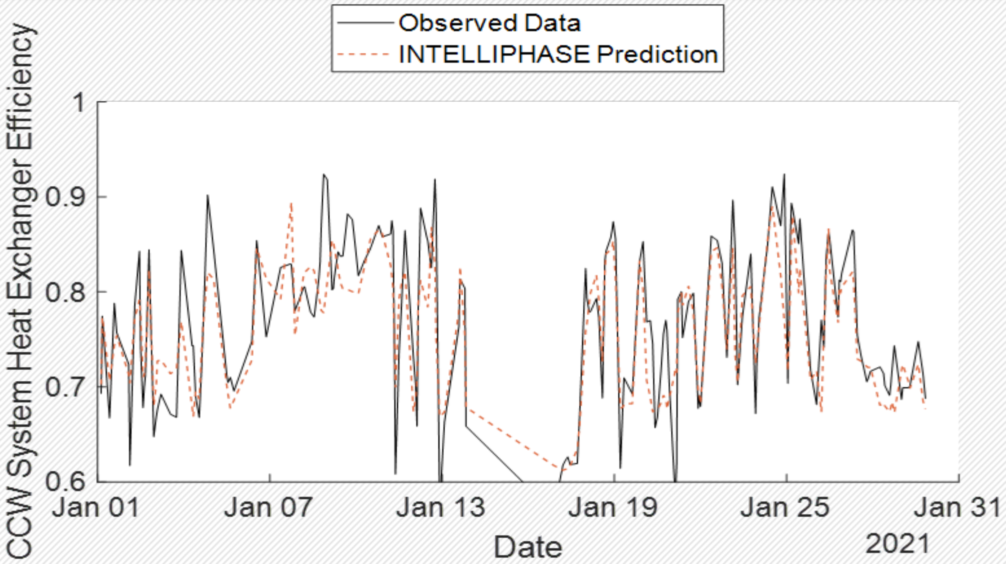
Pittsburgh Chemical Solutions

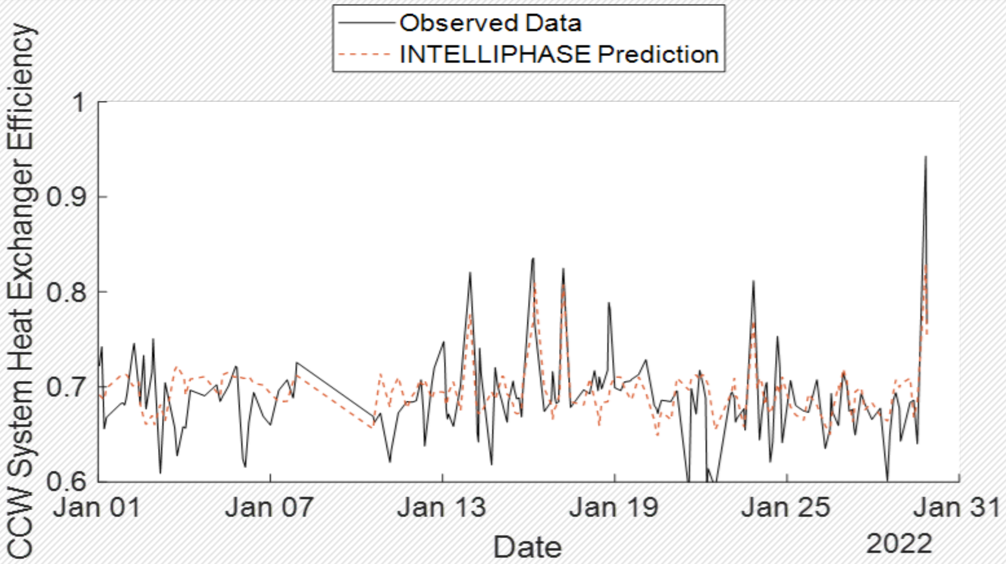
CCW Plate & Frame Heat Exchangers (900MW Unit)
Total Combined Heat Exchangers Effectiveness

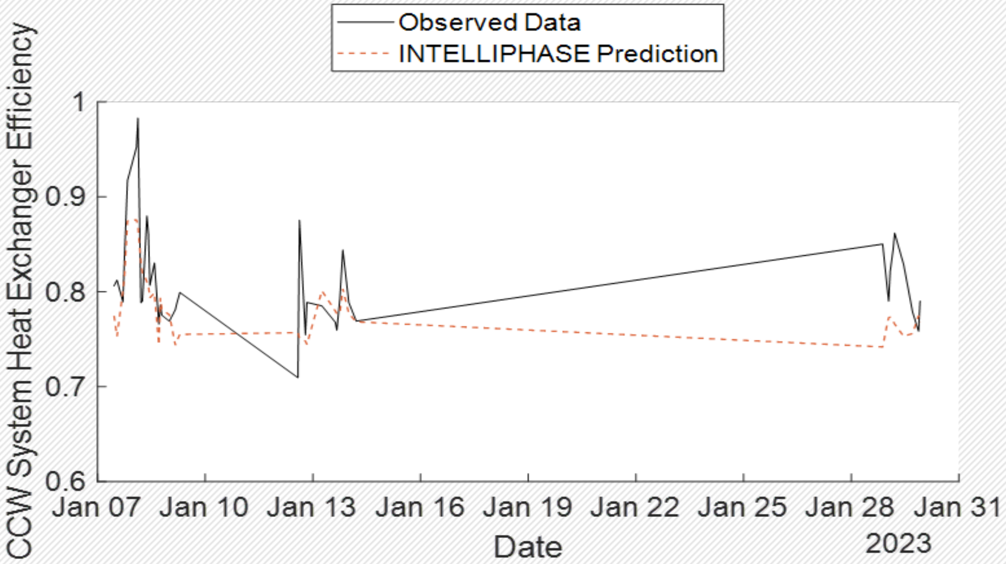


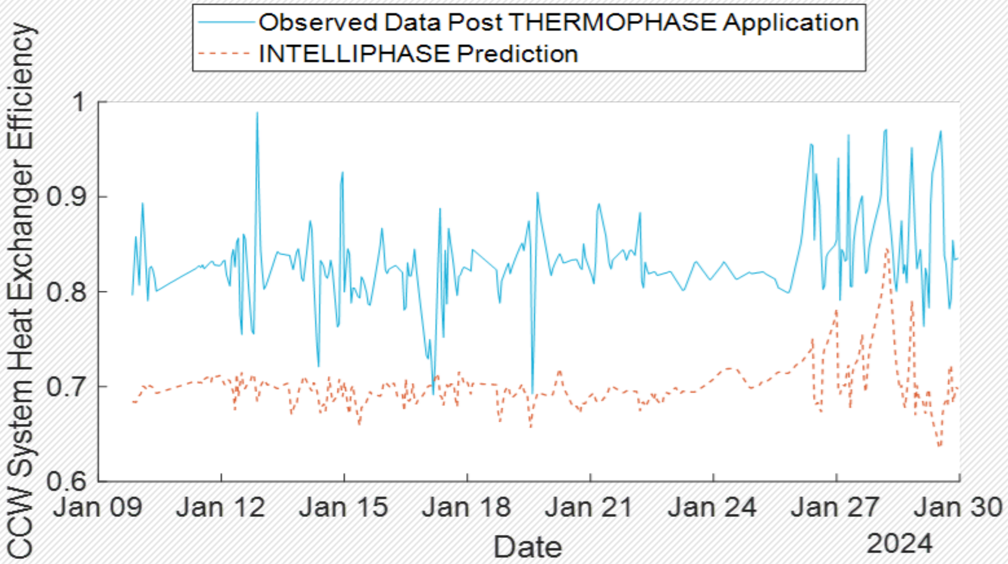
CCW Plate & Frame Heat Exchangers (900MW Unit)

Total Combined Heat Exchangers Effectiveness – 4 Year January Monthly Comparison



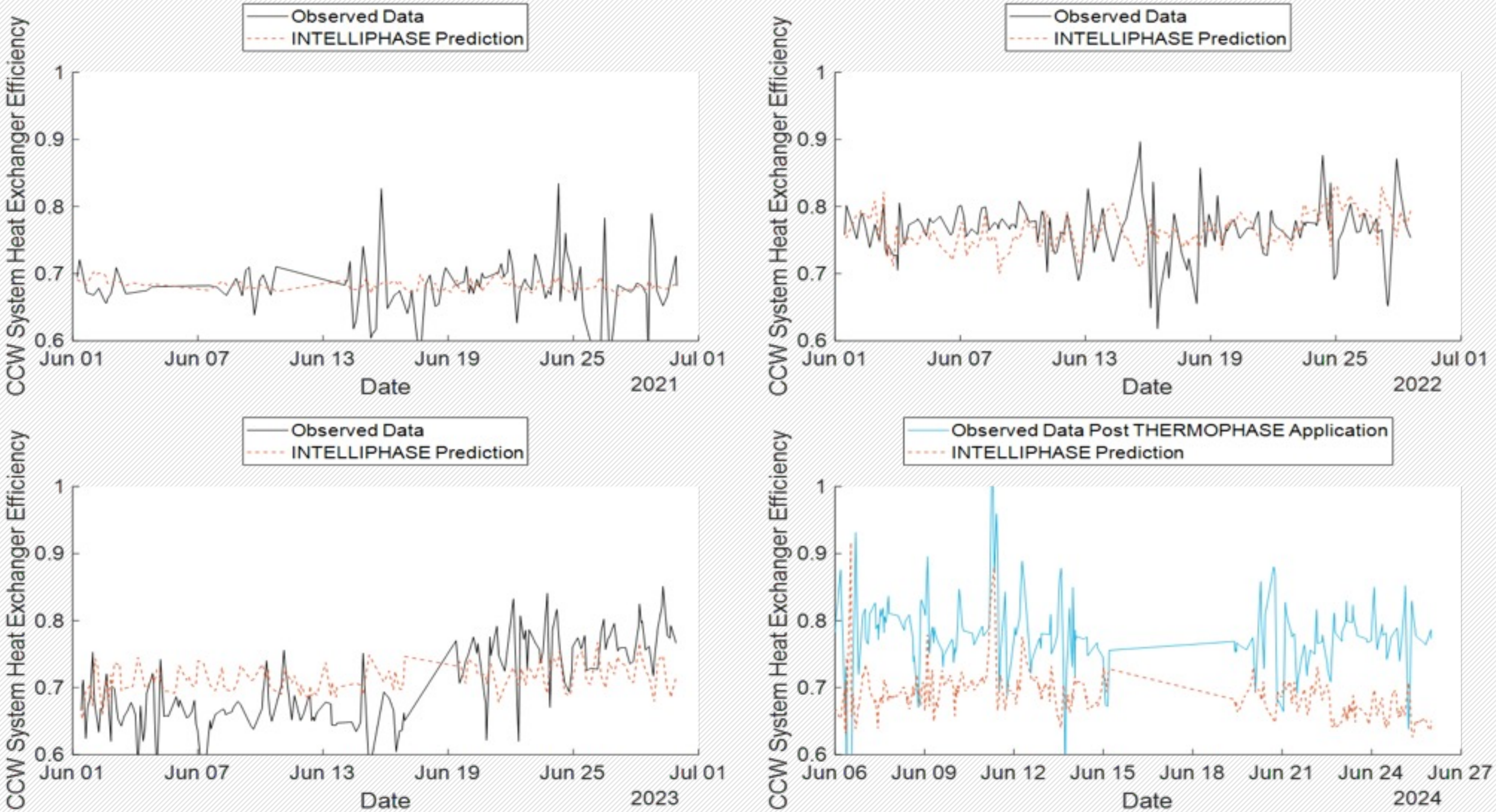






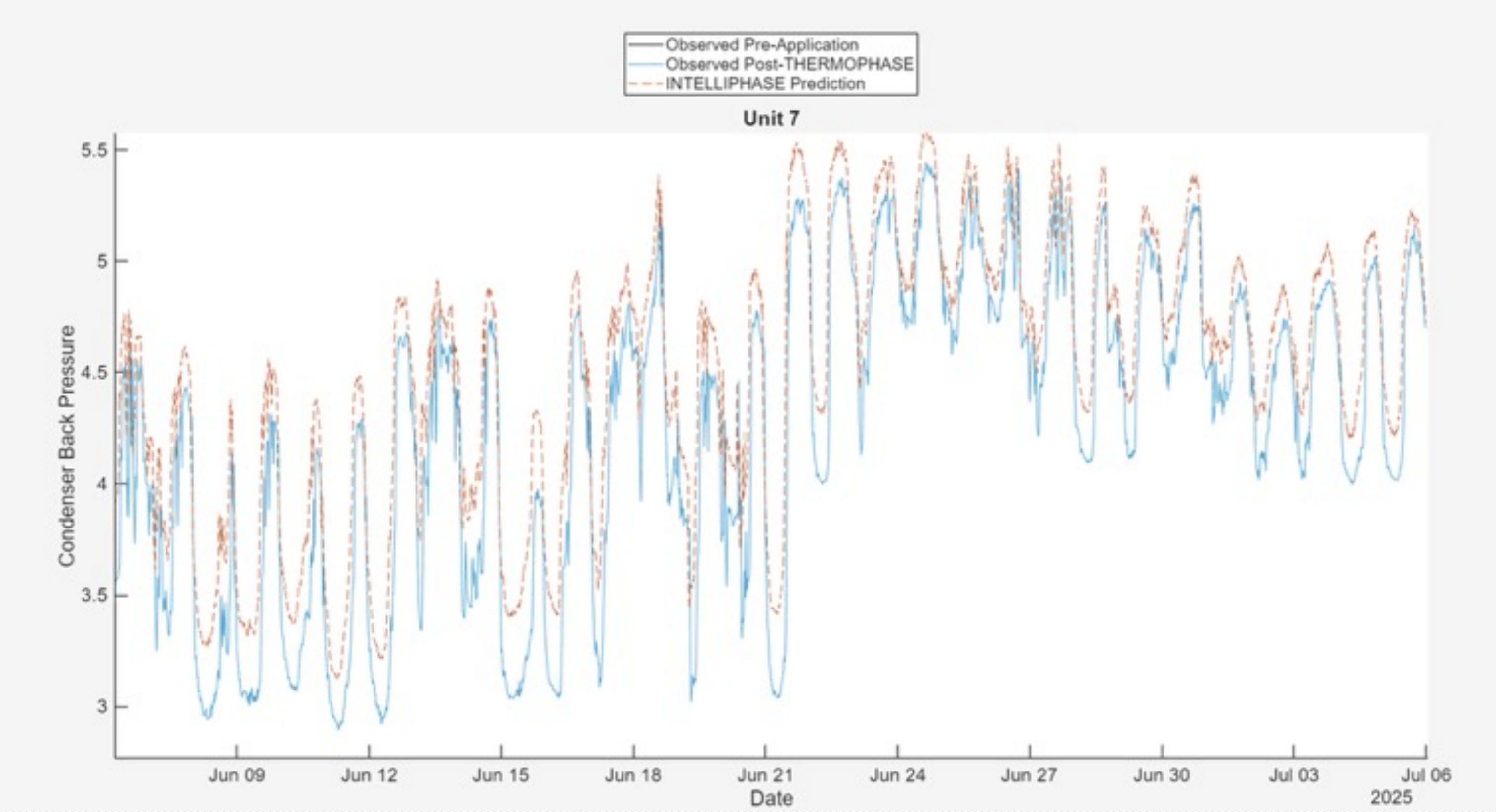
CCW Plate & Frame Heat Exchangers (900MW Unit)

Total Combined Heat Exchangers Effectiveness – 4 Year June Monthly Comparison



560MW Unit

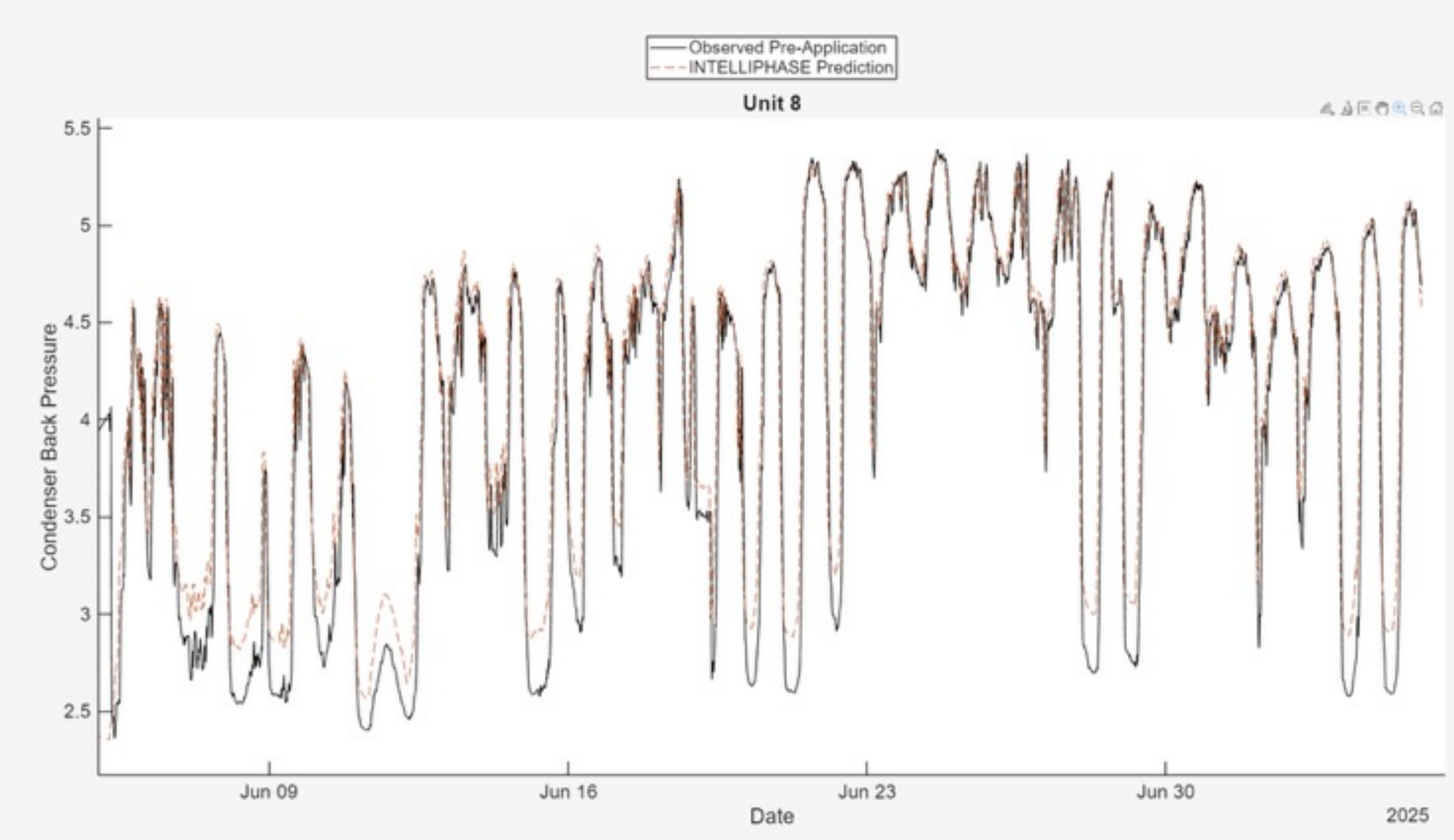
Condenser Backpressure Unit 7



Condenser 7: Substantial Improvement

Following THERMOPHASE treatment, Condenser 7 shows a **reduction in back pressure of approximately 0.2 to 0.3 inches Hg** compared to expected values without treatment. This is a meaningful improvement, especially considering that overall back pressure values are typically around 4 inches Hg.

Condenser Backpressure Unit 8



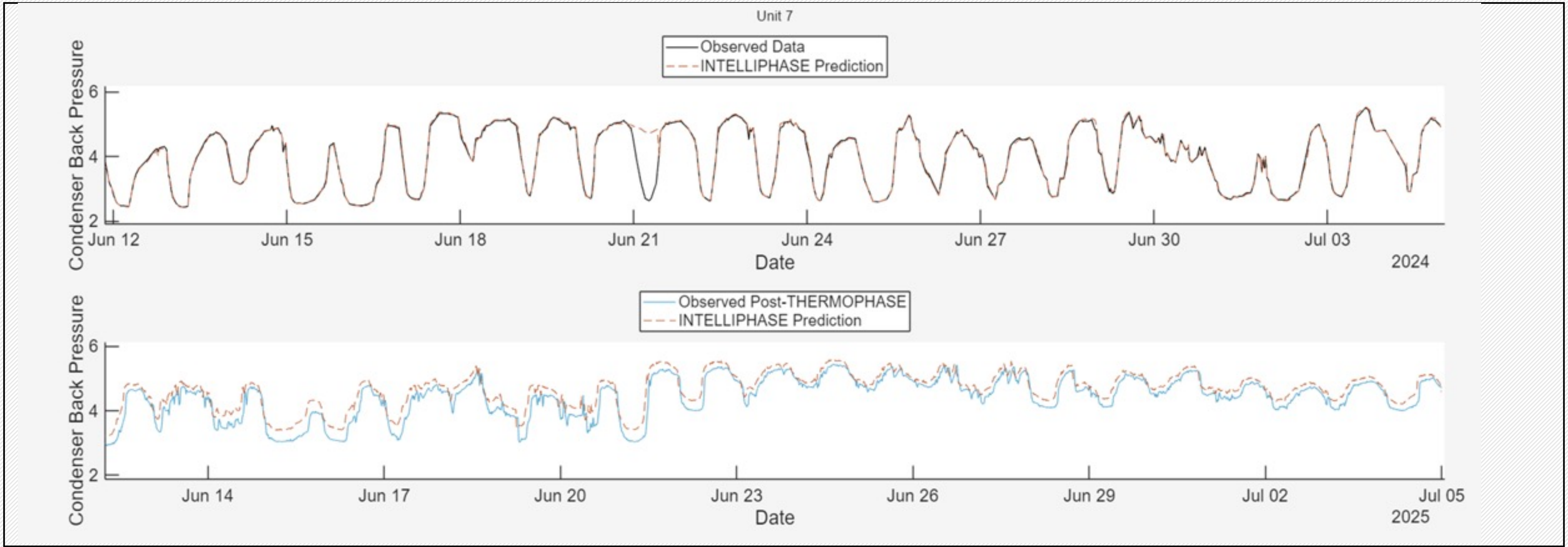
Condenser 8: Control Case Validates Methodology

In contrast, **Condenser 8**, which did not receive THERMOPHASE treatment but was cleaned, showed only a **modest improvement of 0.03 to 0.07 inches Hg**. This aligns closely with our predicted values for an untreated but cleaned unit.

Condenser Data & INTELLIPHASE

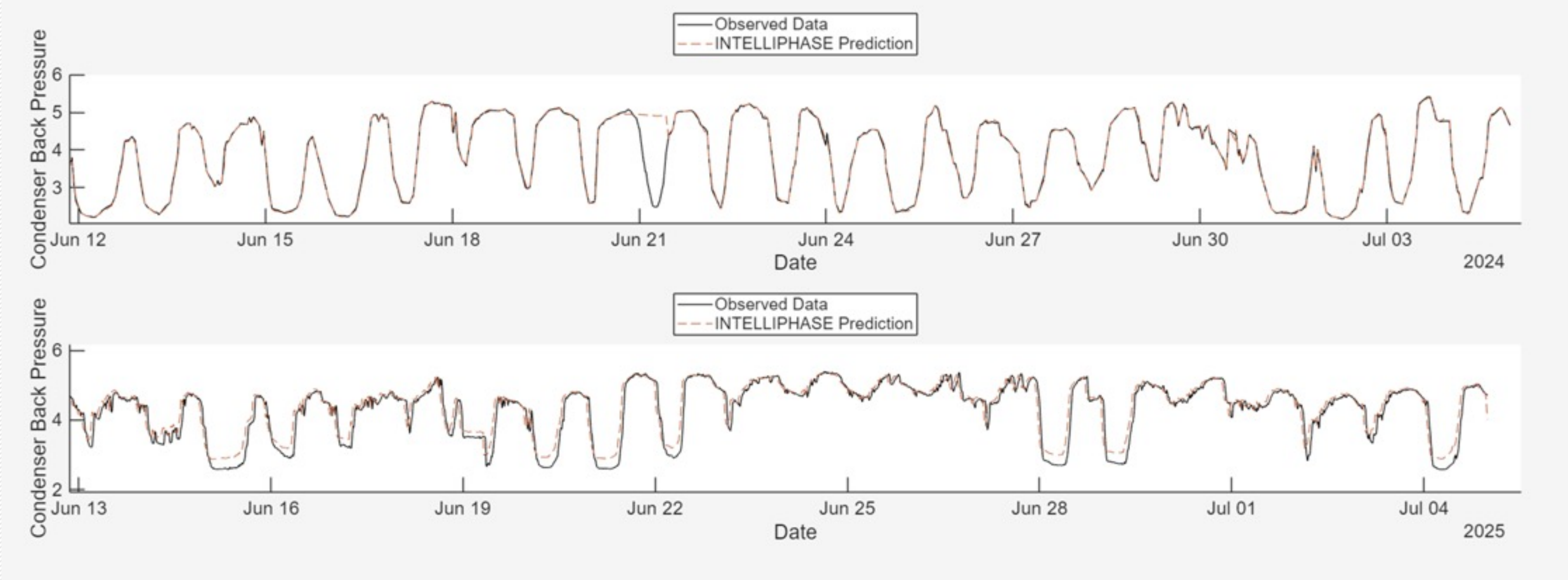
What makes these results particularly compelling is the performance of **INTELLIPHASE**, our AI-guided sensor fusion model. INTELLIPHASE not only accurately predicted the summer performance of Condenser 8, but also successfully modeled the **historical back pressure behavior** of both Condenser 7 and Condenser 8 prior to the shutdown. This dual validation, both forward-looking and retrospective, demonstrates that INTELLIPHASE is reliably capturing the underlying thermodynamic behavior of the system.

Unit 7 - Condenser Backpressure Observed and Predicted in 2024 (Top) and 2025 (Bottom)



This modeling accuracy is critical. It confirms that the observed post-treatment improvements in Condenser 7 are not anomalies or artifacts of data noise, but rather the result of **THERMOPHASE fundamentally altering the heat transfer characteristics** of the condenser system. The model's ability to predict untreated behavior so precisely gives us high confidence that the deviations observed in the treated unit are real, significant, and attributable to the treatment itself.

Unit 8 - Condenser Backpressure Observed and Predicted in 2024 (Top) and 2025 (Bottom)



The fact that INTELLIPHASE correctly modeled Condenser 8's behavior gives us high confidence in the methodology behind backpressure predictions. This, in turn, makes the performance gains observed in Condenser 7 even more compelling—because they are not just improvements, they are improvements **beyond what our validated model predicted**.

THERMOPHASE IMPACT & SUMMARY

Impact: While plant engineers and PCS personnel can likely extrapolate the operational savings from these results on their own, it's worth highlighting the potential impact. Based on this article, Enhance Condenser Back Pressure and Turbine Efficiency - Bionetics Corporation, a **0.1 inch Hg increase in back pressure can result in a 0.17% increase in heat rate**. Applying this to a 525 MW plant, a **0.3 inch Hg reduction** in back pressure (as observed in Condenser 7) translates to an estimated **2.68 MW of power gain or can be correlated directly to significant cost savings**.

And this only reflects the **initial heat transfer enhancement**. It does not yet account for the **longer-term benefits** of THERMOPHASE, such as reduced biofouling, lower maintenance costs, and sustained performance over time.

Summary

- **Condenser 7 (THERMOPHASE-treated):** 0.2–0.3 in Hg lower back pressure than predicted and observed in previous years historical data.
- **Condenser 8 (untreated, cleaned):** 0.03–0.07 in Hg lower back pressure, consistent with model, and likely due to condenser cleaning.
- **INTELLIPHASE** accurately predicted both historical and current performance for untreated units, validating the methodology and strengthening the case for THERMOPHASE's effectiveness.
- **Estimated impact:** 2.68 MW power gain or can be correlated directly to significant cost savings for a 525 MW plant, based on initial performance improvements alone.

Summary

Entity Validation of THERMOPHASE

- United States Department of Energy (DOE)
- National Energy Technology Labs (NETL)
- Electric Power Research Institute (EPRI)
- U.S. Department of Transportation Maritime Administration (MARAD)
- United States Navy
- Multiple Installations

THERMOPHASE has been demonstrated on marine engines, chillers, heat exchangers, condensers and cooling towers.

Recent tests show product is effective on membrane filters (more production and less DP) with filter life extension likely of 2.5 times baseline filter.

Thank You!