DESTINATION 2050

POWERGEN INTERNATIONAL®

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ORANGE COUNTY CONVENTION CENTER
ORLANDO, FLORIDA, USA
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OFFICIAL HOST UTILITY: OUC The Reliable One®

Demonstrating Heat Transfer Improvement and Fouling Reduction in the Condenser and Cooling Tower at a 770MW Power Plant

Power Gen 2023 – February 21, 2023

Jason Wilburn – CFO of Pittsburgh Chemical Solutions, LLC
Dr. Noah Snyder, President & CEO of Interphase Materials

Introduction

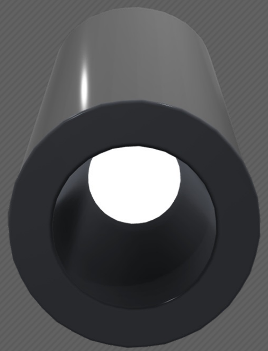
THERMOPHASE Mechanism of Action

Condenser tube heat transfer is proportionate to:

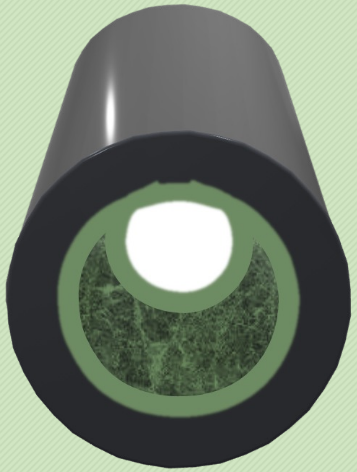
Material Resistance R_M

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 either reducing fouling or the boundary layer.

Introduction

THERMOPHASE Development History

2015 – 2016 – 2017 – 2018 – 2019 – 2020 – 2021 – 2022

Awarded Phase I Navy SBIR

Interphase Materials (IPM) was founded

Awarded Phase II Navy SBIR

First commercial application of THERMOPHASE on land-based chiller

First marine engine application on M-80 Stiletto

First application to an operating powerplant main condenser

First application to marine chiller on USTS Kennedy

THERMOPHASE, in development since Interphase Materials was founded in 2015, was 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.

Introduction
THERMOPHASE On Operating Heat Exchanger - Chiller

Pittsburgh Chemical Solutions

Fouling Reduction in Operating Tube Heat Exchanger Onboard the USTS Kennedy using Interphase Materials Proprietary THERMOPHASE Product

Clarity of Tube Rifling Emphasizes Cleanliness of ***THERMOPHASE*** treated system

Untreated Tubes Show Increased Presence of Fouling Debris and Loss of Ability to Visualize Tube Rifling

This demonstration occurred using a 1 hr flush of THERMOPHASE product on the USTS Kennedy's HVAC chillers. These chillers are fed raw seawater without treatment. The duration of this demonstration 4 months based on the ships schedule. A reduction in fouling observed here will provide significant benefits to the operation of the system and in costs/time associated with system maintenance.

Next Key Milestone

Demonstrate Performance on Operating Power Plant

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).

The next key technical milestone for THERMOPHASE was demonstrated performance improvement in an operating power plant.

THERMOPHASE – DOE/NETL Project

NATIONAL ENERGY TECHNOLOGY LABORATORY

NETL Mission

To drive innovation and deliver solutions for an environmentally sustainable and prosperous energy future

The U.S. Department of Energy (DOE)/Fossil Energy's (FE) Crosscutting Research Program FOA (DE-FOA-0001686)

To bridge between basic and applied research by targeting concepts that offer the potential for transformational breakthroughs and step-change benefits in the way energy systems are designed, constructed, and operated.

INTERPHASE MATERIALS

Interphase Materials Mission

To restore and reinforce global biological needs with sustainable biointerfaces

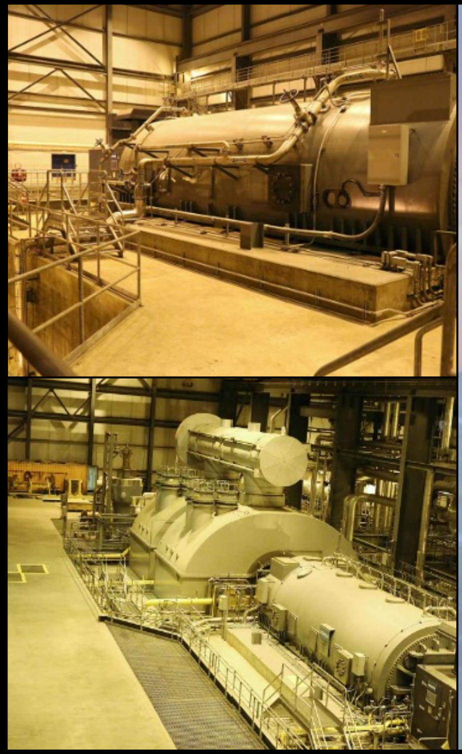
Project Objective (DE-FE0031561)

To determine the condenser efficiency improvements coal-fired power plants could realize by utilizing the Recipient's HTE system* as well as the reduction of continuous feed water treatment technologies

This project was funded via the U.S. Department of Energy (DOE)/Fossil Energy's (FE) Crosscutting Research Program (DE-FOA-0001686).

*THERMOPHASE was referred to as the HTE System at the time Interphase Materials' submitted the original proposal.

Longview Power Plant Overview



Generator
Siemens
SGen6-3000W

Turbine System
Siemens HMNN
770 MW
4 Turbines

Condenser

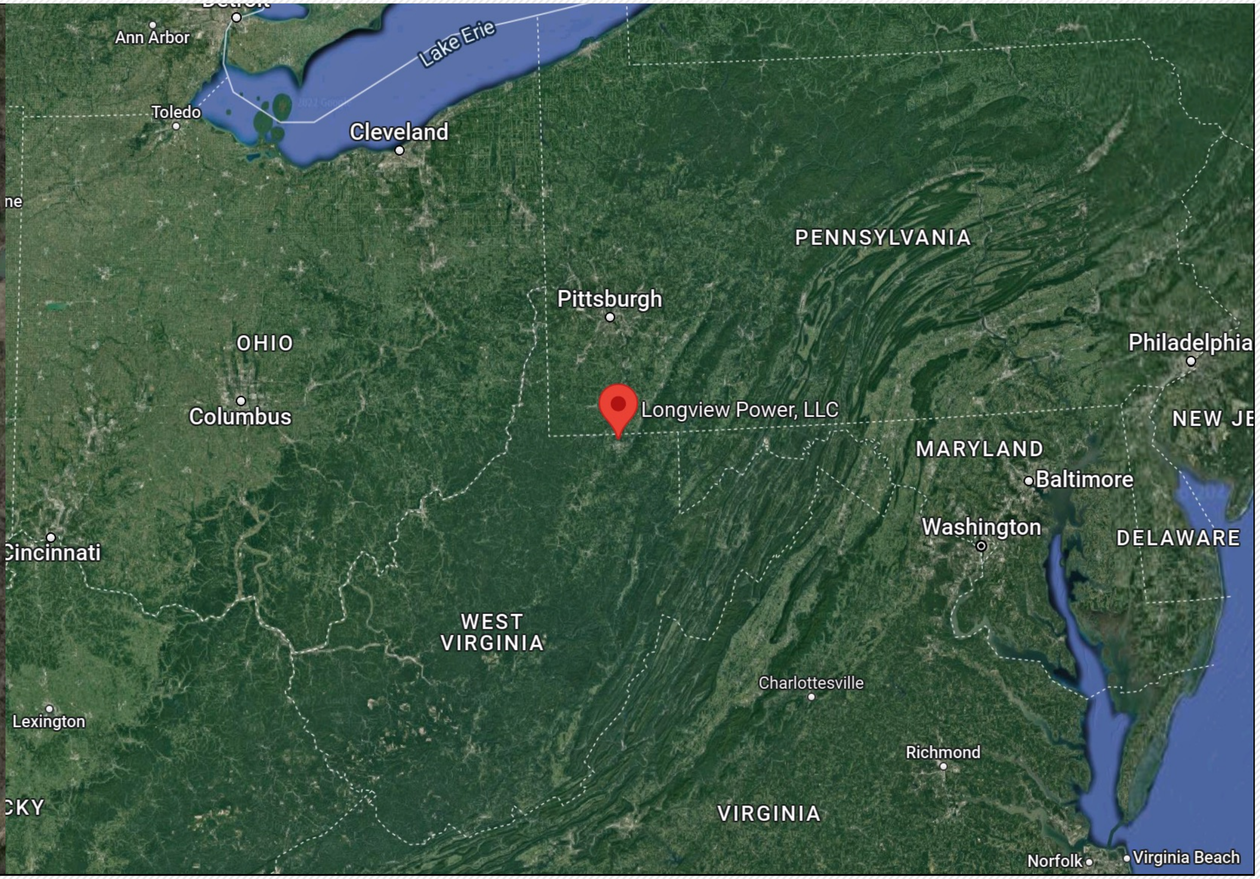
Siemens
SCon6000

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

Longview Power Plant Location



The Longview Power Plant is located in Maidsville, WV.

THERMOPHASE Applications

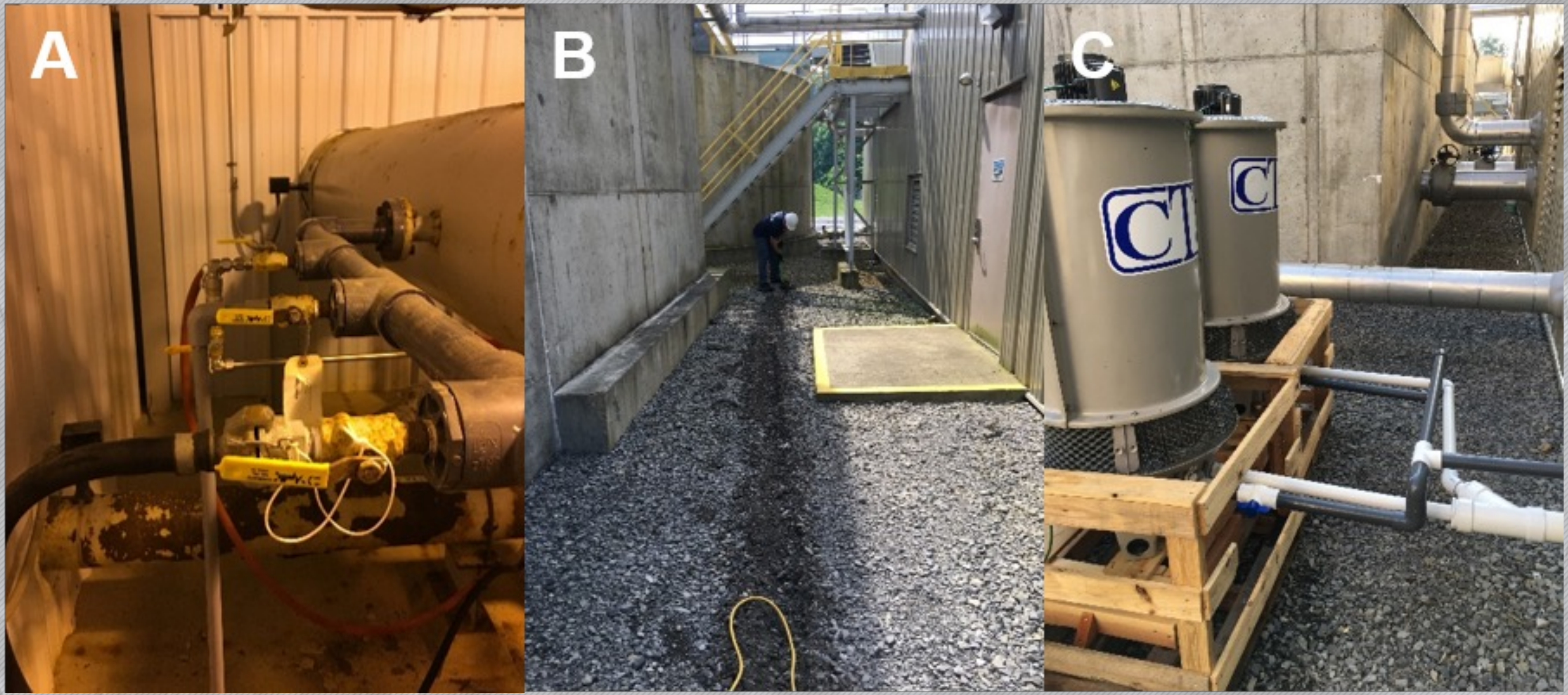
Pittsburgh Chemical Solutions

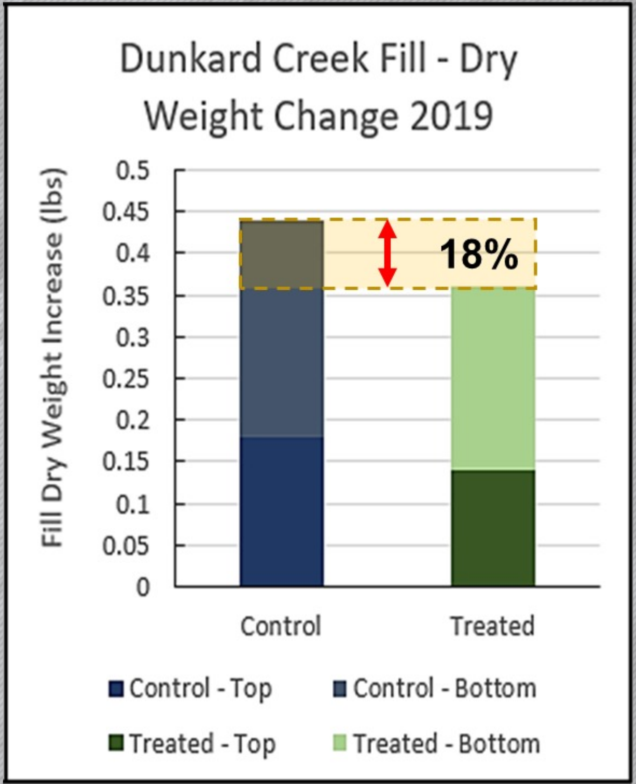
Application 1 on September 2nd, 2020

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.

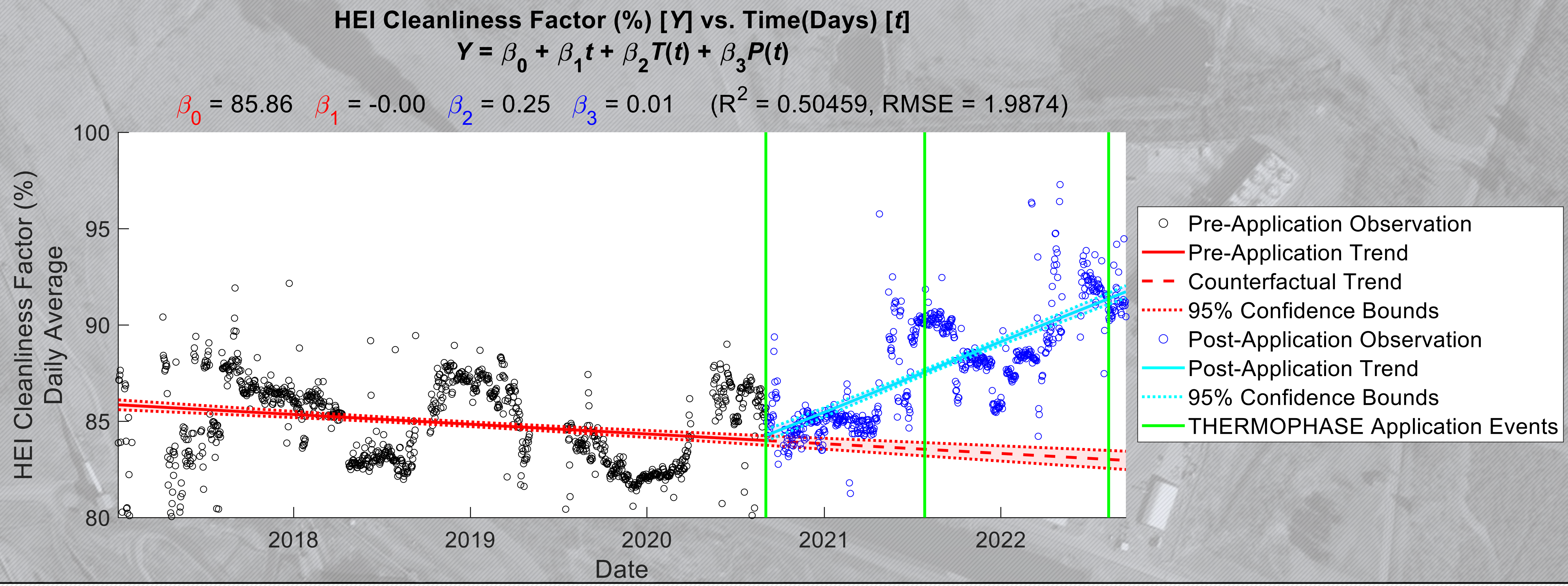
THERMOPHASE Cooling Tower Fill Reduction





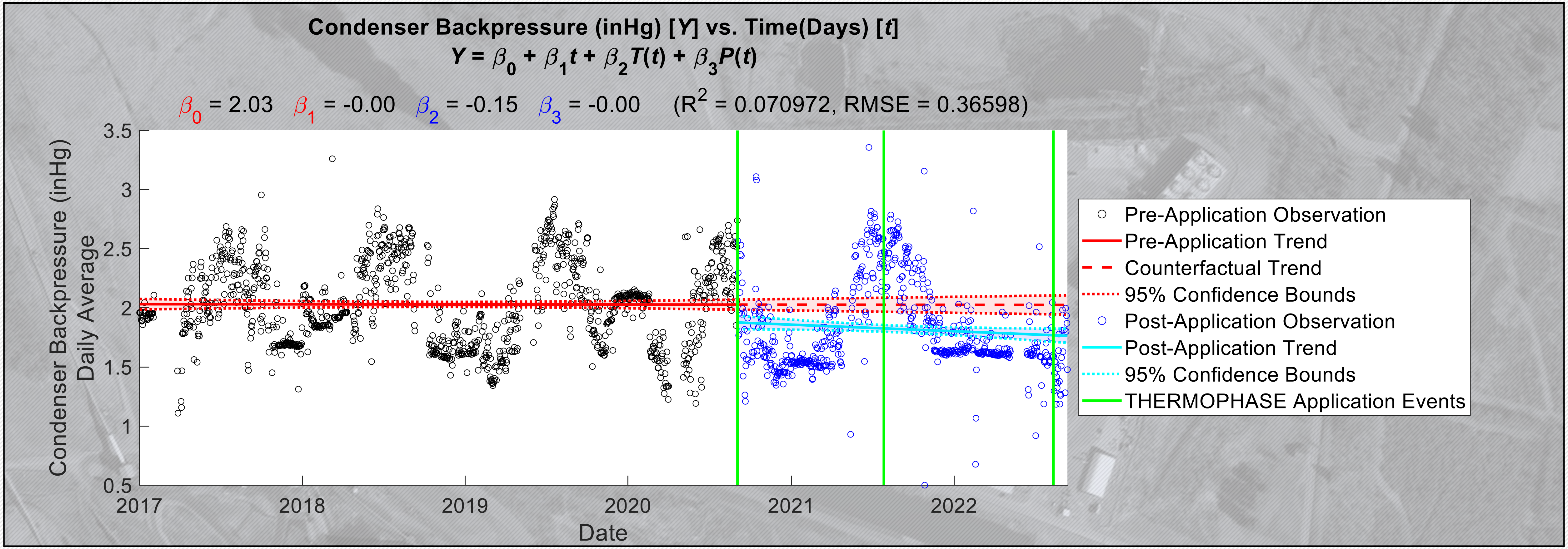
THERMOPHASE treatment reduced dry weight by 18%. Small-scale cooling towers installed at water treatment station, circulating raw untreated water over the 2019 fouling season. Towers treated with Interphase technology showed increased fouling resistance, accumulating 18% less dry weight fouling.

HEI Cleanliness Factor



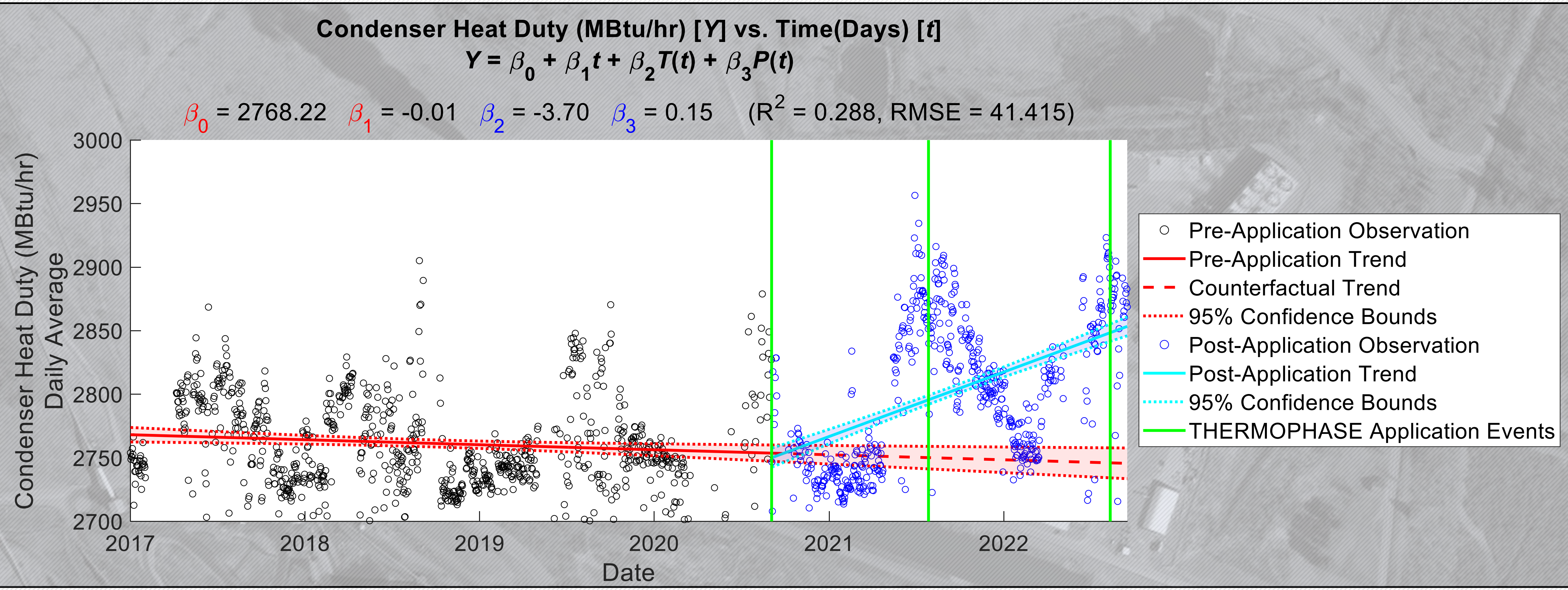
The daily average of the HEI Cleanliness Factor is plotted above through September 16th, 2022. The HEI Cleanliness Factor is a historian calculation recorded in the Longview Power historian (variable 1OPM.CONDENSER:Cleanliness). The HEI Cleanliness Factor is defined as $\frac{U_{\text{Observed}}}{U_{\text{Expected}}}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

Condenser Backpressure



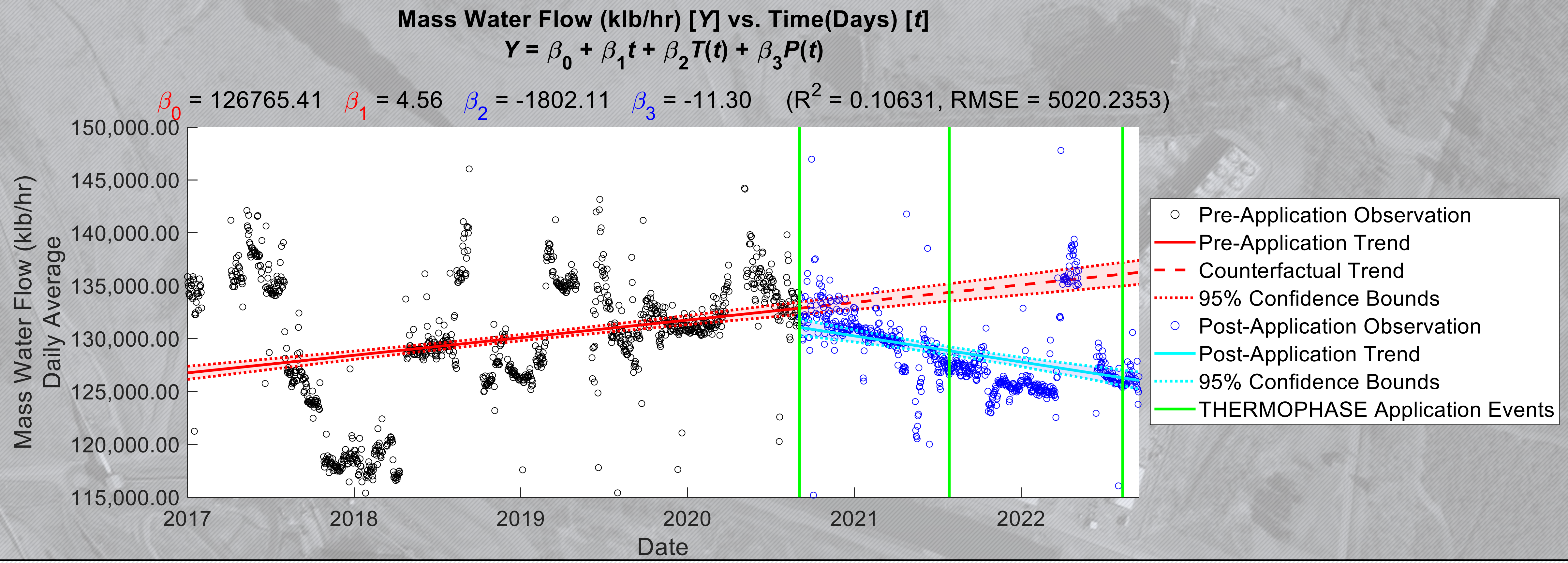
The daily average of the condenser backpressure is plotted above through September 16th, 2022. The condenser backpressure is an instrument value recorded in the Longview Power historian (variable 10MAG10CP002.XQ01).

Condenser Heat Duty



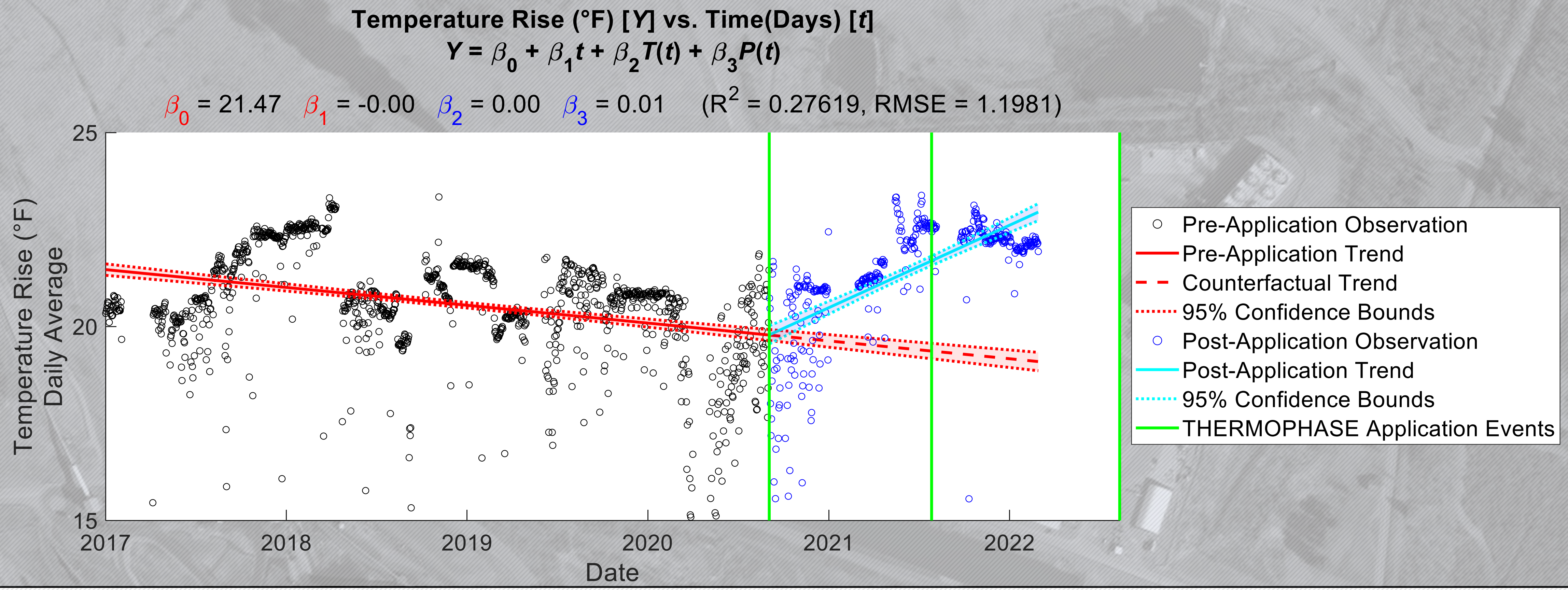
The daily average of the condenser heat duty is plotted above through September 16th, 2022. The condenser heat duty is an historical calculation recorded in the Longview Power historian (variable 1OPM.CONDENSER:DUTY).

Water Flow



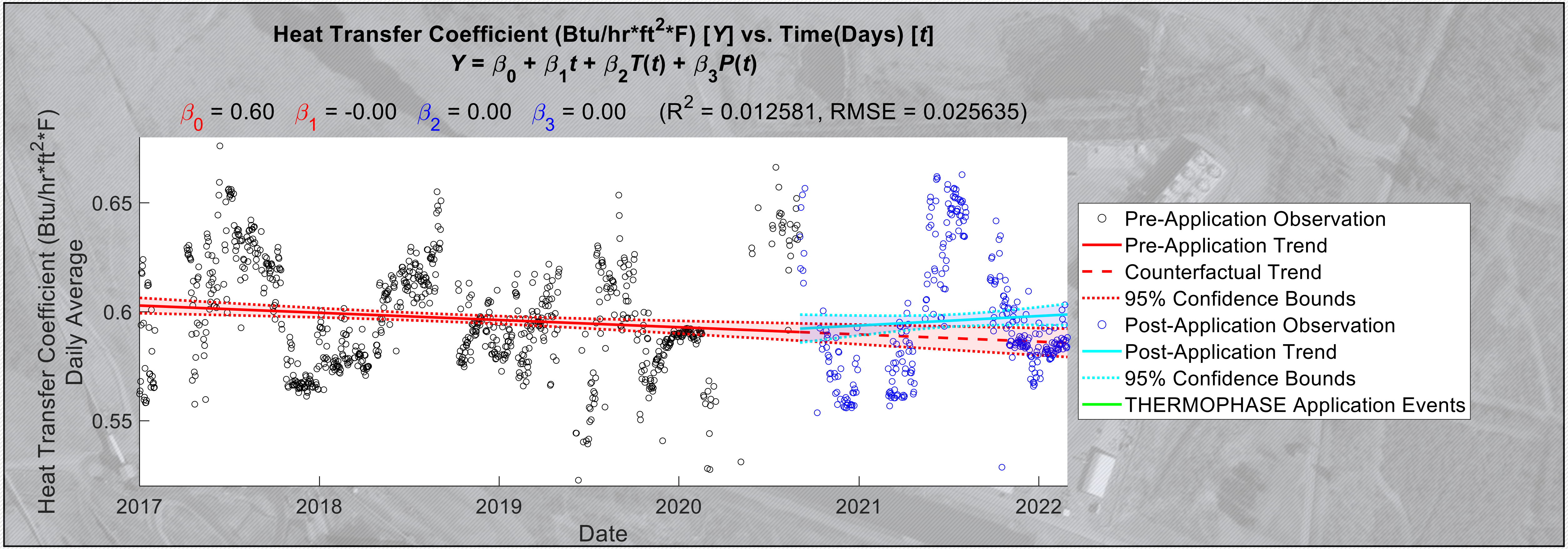
The daily average of the mass circulation water flow is plotted above through September 16th, 2022. The mass circulation water flow is a historian calculated value recorded in the Longview Power historian (variable 1OPM.CIRC_WATER_IN:FLOW).

Temperature Rise



The daily average of the temperature rise is plotted above through February 12th, 2022. The temperature rise is an offline calculation. The temperature rise (TR) is defined as, $TR = T_{CW_{out}} - T_{CW_{in}}$.

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

Longview Plant and Other Comparison Plants

THERMOPHASE 2-Year Savings per Plant					
	Estimate ± 95% C.I.				
Savings Type	Longview Power Plant	Average Coal Plant	Average Natural Gas Plant	All U.S. Coal Plants	All U.S. Natural Gas Plants
Water Withdrawl	1,287 ± 750.8 Mgal	972 ± 486.1 Mgal	29 ± 14.4 Mgal	222,622 ± 111,311 Mgal	58,094 ± 29,047 Mgal
CO_2 Emissions	136 ± 79.3 Mlbs	103 ± 51.3 Mlbs	10 ± 5.0 Mlbs	23,504 ± 11,752. Mlbs	20,176 ± 10,088 Mlbs
Fuel Cost (in Millions)	$3.35 ± 1.68	$2.53 ± 1.27	$0.53 ± 0.26	$579.76 ± 289.88	$1,062.15 ± 531.08

Note: There are 229 coal plants with an average combined annual output of 800 million MWh and there are 2,020 natural gas plants with an average annual output of 1,600 million MWh. Longview Power Plants annual output is estimated to be ~ 5.4 million MWh and is more efficient than the average plant by 15%.

- Heat Transfer Coefficient Improvements at Longview (4%); consistent with laboratory results (5.8%)
- Immediate and Sustained Backpressure improvements are consistent with condenser performance improvements (TTD, U, and HEI CF%)
- Based on net decrease of 0.26 inHg after two years (13% reduction), 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

COST SAVINGS EXPECTED (Not quantified in Longview Presentation)

Pittsburgh Chemical Solutions

Longview Power data quantified fuel savings, water usage savings and reduced CO2 emissions. Additional cost savings not quantified but will be realized:

- Cost savings from reduced water reductions
  - Pump savings
  - Chemical treatment savings from less water requires
  - Discharge savings from less water usage
  - Potential reduced chemical treatment savings for operational reasons
- Cost savings due to reduced SOx (less fuel burned) – lime, water, auxiliary load
- Cost Savings due to reduced NOx (less fuel burned) – ammonia, auxiliary load, potential credit sale
- Cost Savings due to reduced Hg (less fuel burned) – activated carbon, auxiliary load
- Cost Savings due to less ash disposal
- Potential Environmental Credits – CO2
- Less need for Condenser Cleaning

Preliminary EPRI Validation

- Interphase Materials was asked by the Electric Power Research Institute (EPRI) to include samples of THERMOPHASE in a project to evaluate coatings for condenser tubes.
- During the first phase of testing, THERMOPHASE was ranked the highest compared to 5 other coatings being evaluated on a basis of hydrophobicity (ASTM D7334), thermal conductivity (ASTM E1461), adhesion (ASTM C1624), and abrasion (ASTM G133) testing.
- THERMOPHASE was shown to increase the heat transfer coefficient by 1.8% when compared to clean, unmodified tubes. Over a month later, the improvement increased to 2.4% (presumably due to fouling on the unmodified tubes).
- These results are preliminary and will likely be incorporated into an EPRI report in Q1 2023.

Summary

THERMOPHASE has been demonstrated on marine engines, chillers, heat exchangers and multiple years at in full scale power applications.

THERMOPHASE results, reviewed/validated by DOE/NETL & EPRI.

Thank You!