

EPRI Condenser Technology Conference

Condenser Performance Meaningful Data with Minimal Instruments

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Cleanliness Factor Essential Parameters

- **Cooling Water Inlet Bulk Temperature**
- **Cooling Water Outlet Bulk Temperature**
- **Condenser Pressure**
- **Cooling Water Flow Rate or Condenser Duty**

*** Tube length, OD, gauge, material, passes**

Cleanliness Factor

Basic Equations

- $U^+ = Q / A \cdot \Delta T_{LM}$
- $Q = \dot{m} C_p \Delta T$
- $U^* = U_1 F_m F_w$
- $U_1: f(V_{tube}, OD_{tube})$
- $F_m: f(\text{Tube Material}, \text{Tube Gauge})$
- $F_w: f(T_{in})$
- $CF = U^+ / U^*$

Cleanliness Factor Sample Error

Unit Information:
330 MW, Coal-fired
Westinghouse Condenser, 165,000 sq.ft.

Parameter	Value	Error	Calculated Cleanliness Factor
Inlet Temperature	75	-0.5 / +0.5 °F	86.5 / 83.7
Outlet Temperature	94.5	-0.5 / +0.5 °F	80.8 / 89.7
Condenser Pressure	2.04	-0.1 / +0.1 inHgA	98.0 / 75.9
Circulating Water Flow	155,000	-5 / +5 % of reading	82.9 / 87.2
Cleanliness Factor	85%		69.2 / 108.2

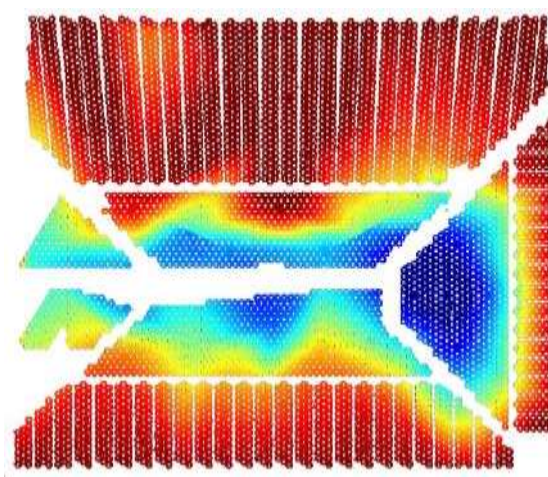
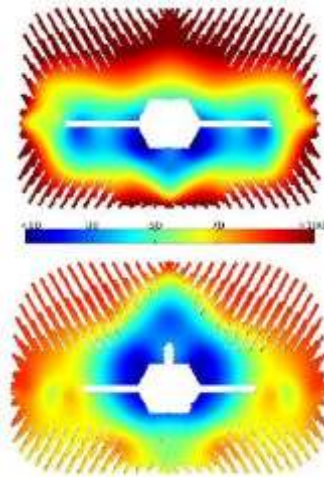
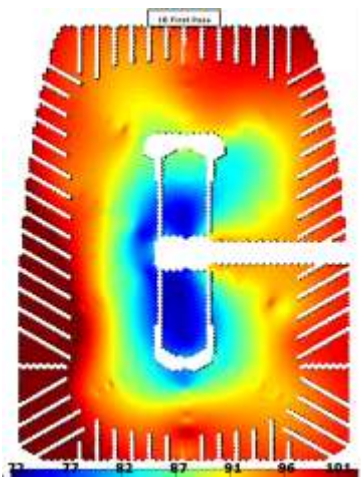
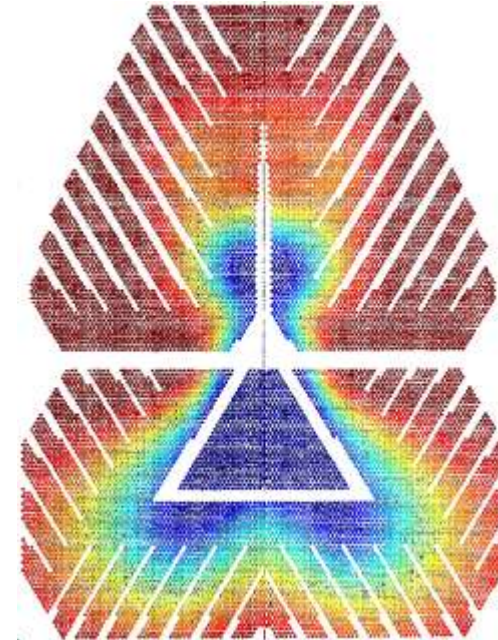
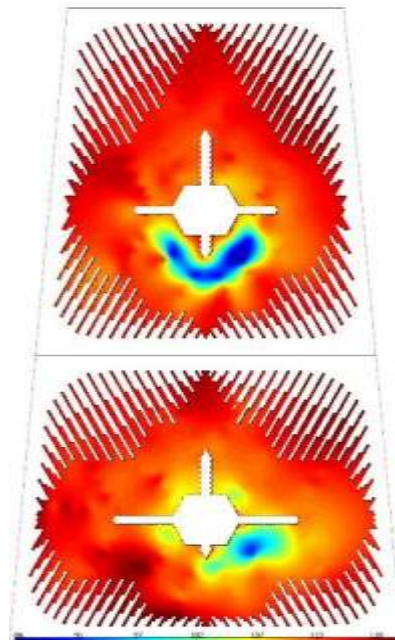
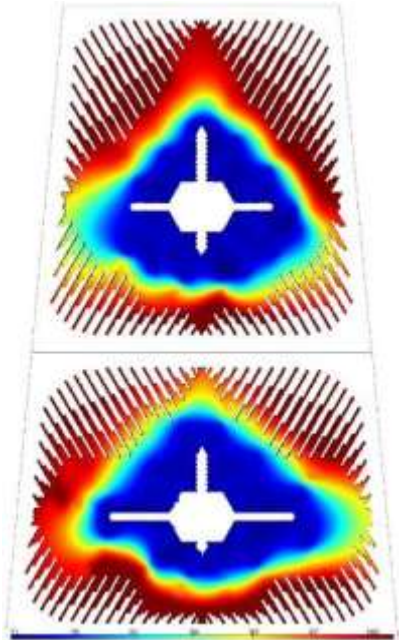
Cooling Water Inlet Bulk Temperature

- **PTC 12.2 Guidelines**
 - **Accuracy: $\pm 0.1^{\circ}\text{F}$**
 - **4-wire RTD is recommended; however, if the accuracy requirement is met then many other sensor styles are acceptable**
- **Common Issues**
 - **Instrument/calibration accuracy**

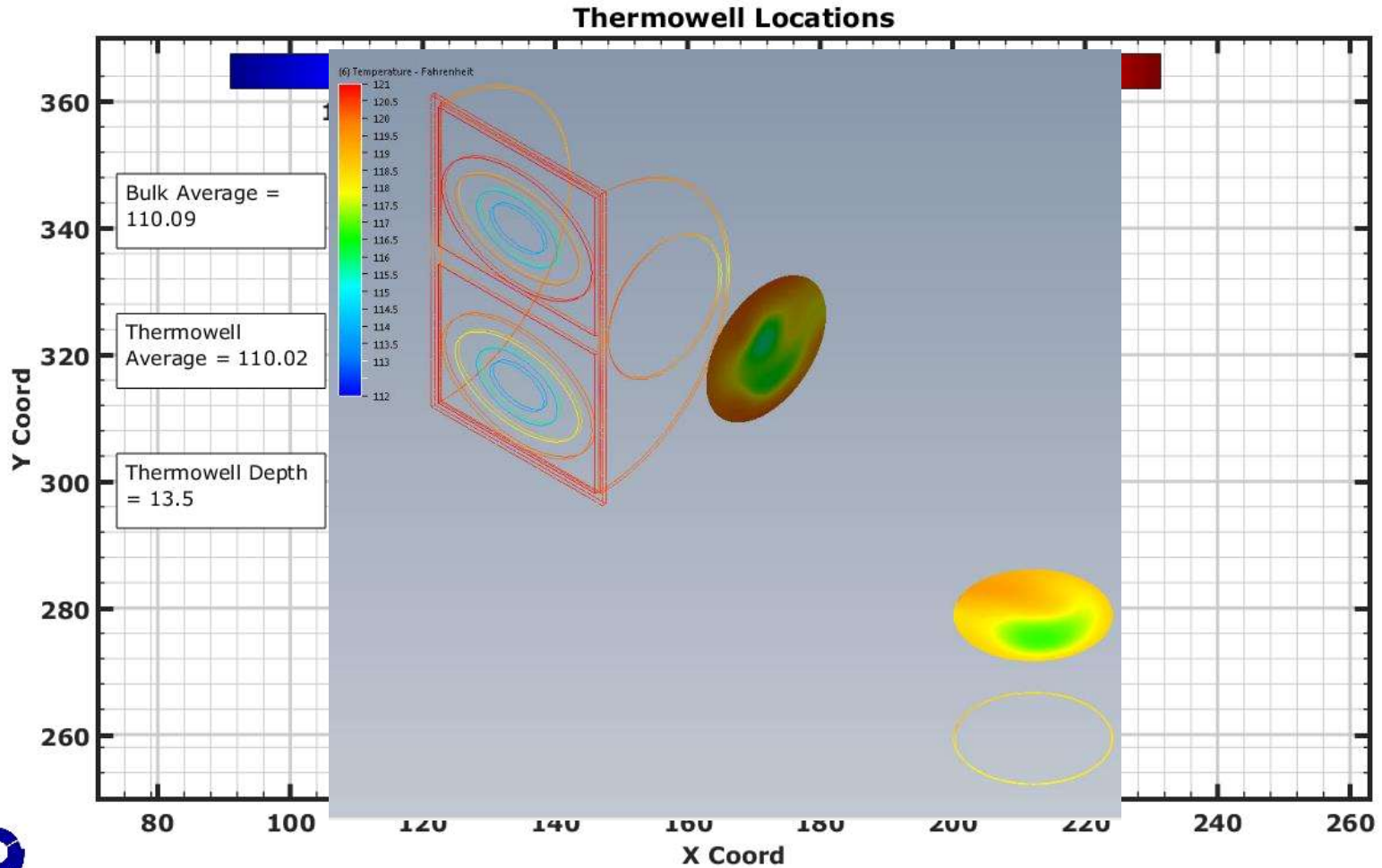
Cooling Water Outlet Bulk Temperature

- **PTC 12.2 Guidelines**
 - **Accuracy: Individual measurement $\pm 0.1^{\circ}\text{F}$, Overall measurement $\pm 0.3^{\circ}\text{F}$**
 - **Installed far downstream, less than 1,000 diameters (well-mixed), if available -or-**
 - **Array of measurements**
- **Issues**
 - **Instrument/calibration accuracy**
 - **Thermal stratification**

Cooling Water Outlet Bulk Temperature Thermal Stratification



Cooling Water Outlet Bulk Temperature Thermal Stratification



Condenser Pressure

- **PTC 12.2 guidelines**
 - Accuracy: ± 0.05 in. Hg
 - Static taps (ASME PTC 19.2), Basket tips, or guide plates
 - 1' to 3' above the tube bundle, multiple test points along the length of the condenser
 - Electronic absolute pressure transducer
- **Common Issues**
 - Unsuitable location
 - Transducer type
 - Transport tubing

Cooling Water Flow Rate

- **PTC 12.2 guidelines**
 - **Accuracy: $\pm 3\%$ (of reading)**
 - **Velocity traverse, tracer-dye dilution, ultrasonic time-of-travel**
- **Issues**
 - **One-time measurements (traverse, dilution)**
 - **Online Instrument availability**
 - **Instrument accuracy**

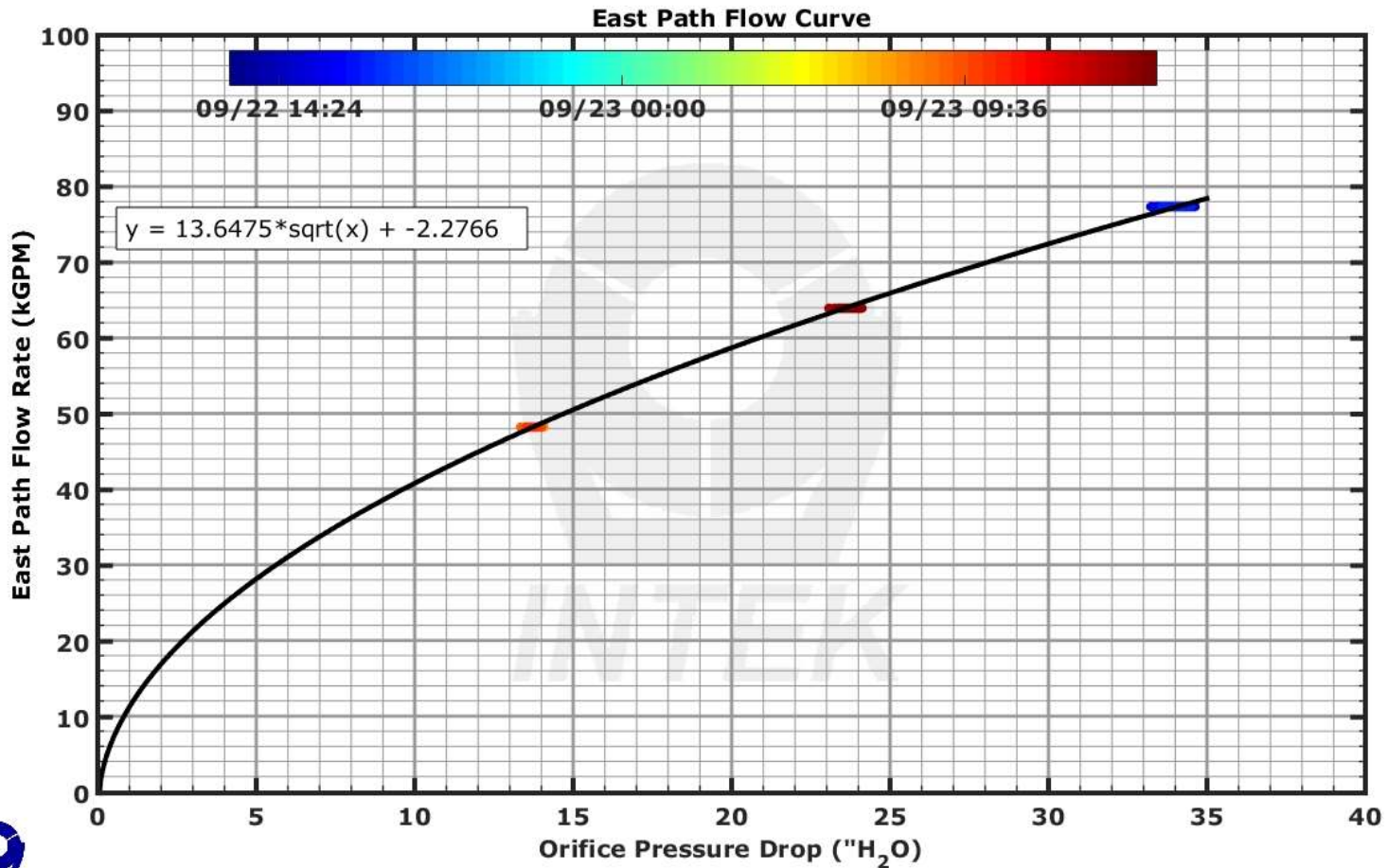
Cooling Water Flow Rate DP Meter

- **Existing differential pressure producing features in the circulating water piping**
 - **Waterbox-pipe orifice**
 - **Elbows**
- **Repeatable and measurable pressure drops can be correlated to circulating water flow rate**

Cooling Water Flow Rate DP Meter

- **Installation locations to avoid**
 - Near ball cleaning screens
 - Near butterfly valves
- **Special Considerations**
 - Compensation for remote seal fill fluid specific gravity difference and seal height
 - Calibration

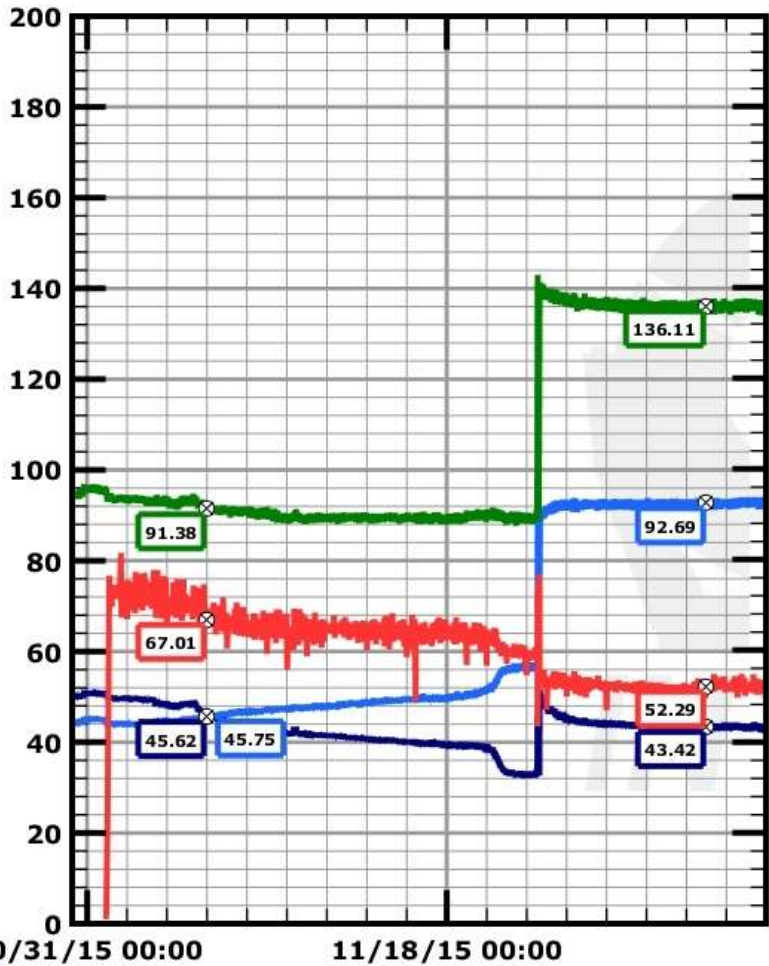
Cooling Water Flow Rate DP Meter



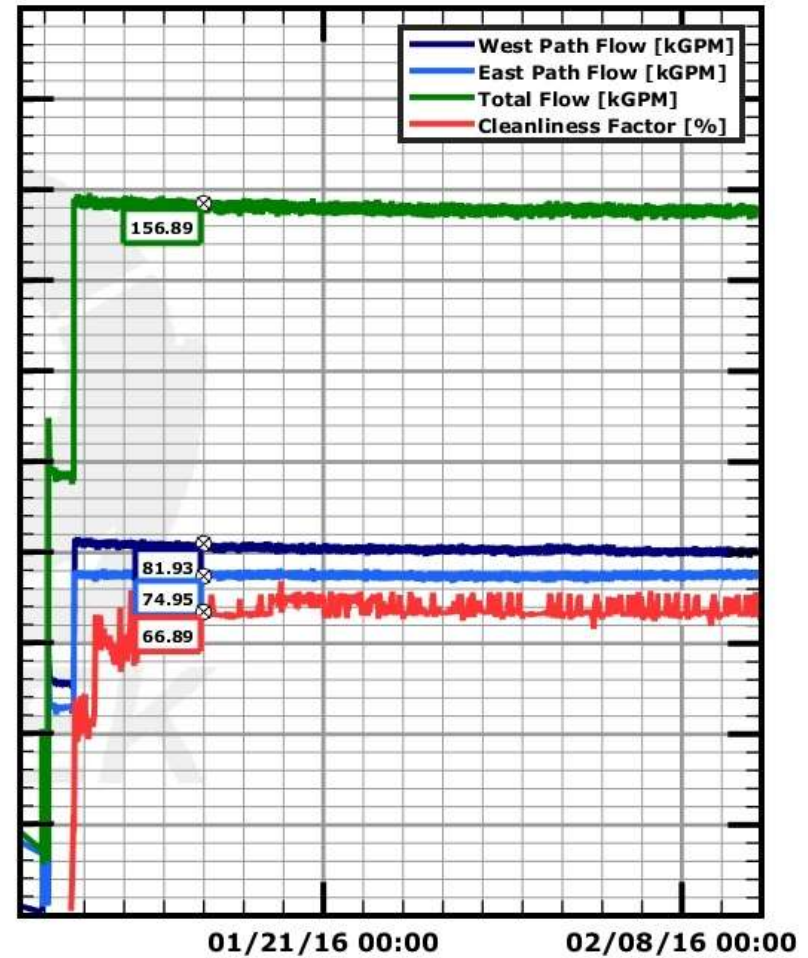
Case Study

- **Instruments installed**
 - **RTDs (Qty. 2): Measure circulating water temperature into each inlet waterbox.**
 - **RTDs (Qty. 8): Measure circulating water temperature out of each outlet waterbox. Four RTDs in each outlet circulating water pipe to account for thermal stratification. Far downstream location unavailable.**
 - **Condenser Pressure (Qty. 2): Measure condenser shell side steam pressure and temperature.**
 - **Differential Pressure (DP) meters (Qty. 2): Measure circulating water flow through each flow path. Calibrated via a pitot tube traverse on the cooling tower risers.**

Case Study



Initial Startup



Post-cleaning

