Air Cooled Condensers – Innovative Wind Mitigation

SPX Cooling Technologies, Inc. - Dry Cooling

GLOBAL INFRASTRUCTURE X PROCESS EQUIPMENT X DIAGNOSTIC TOOLS

Agenda

- Air Cooled Condensers – Innovative Wind Mitigation

Introduction

- SPX is a leader in Dry Cooling, with over 350 Air Cooled Condensers (ACCs) installed worldwide over the past 30+ years.
- The typical ACC is the forced draft A-Frame configuration.
- ACCs serve power plants of various sizes and types, from 20MW Biomass Plants to > 600MW Coal Plants
- ACCs range in size from two(2) modules to over one-hundred(100) modules

- “Small” three (3) module ACC

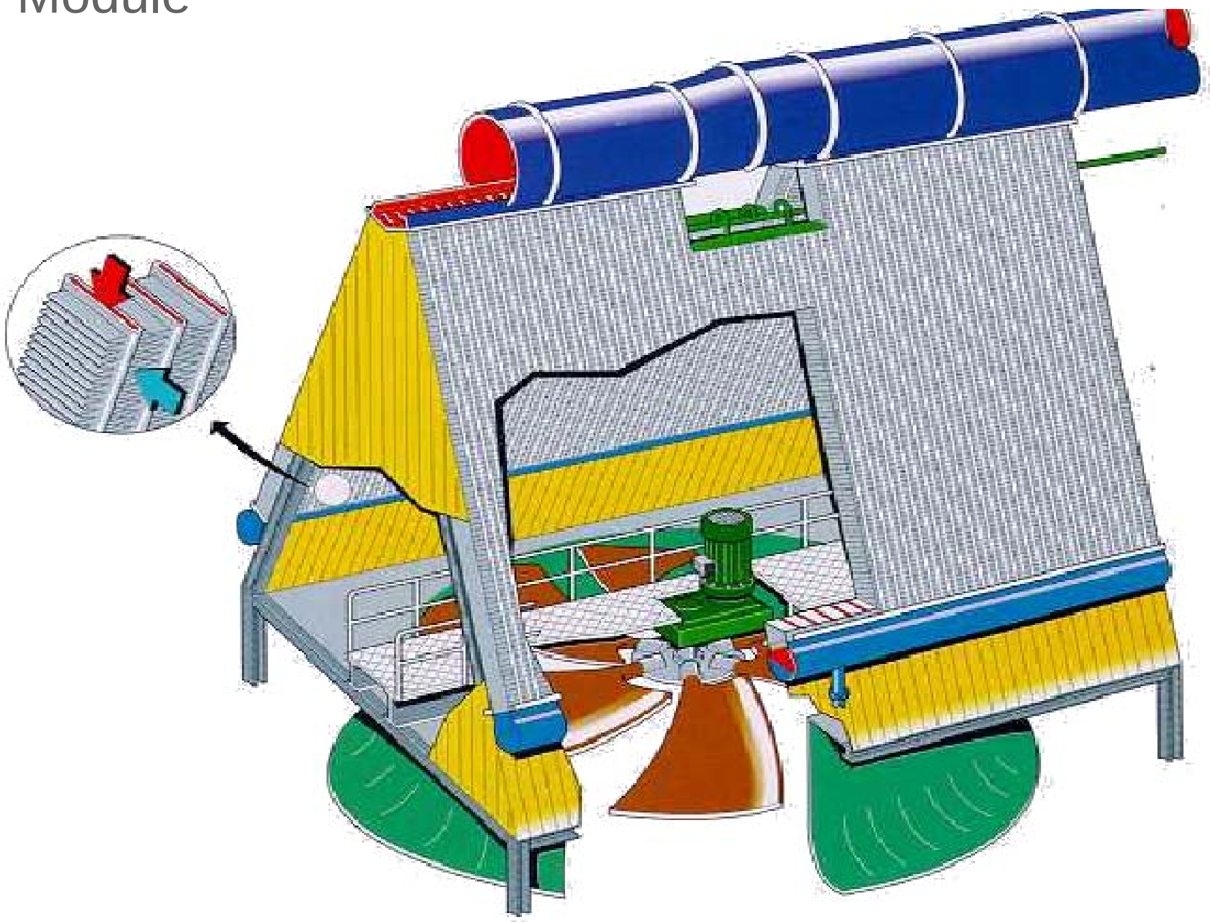
Introduction

- “Medium” thirty-five (35) module ACC

- THE FOCUS OF THIS PRESENTATION IS TO:
  - Illustrate the operational challenges that wind poses to ACCs and Power Plant operations
  - Recognize previous efforts to illustrate the effects of wind
  - Quantify the effects of wind on ACC performance
  - Review existing solutions to mitigate the effects of wind on ACC performance
  - Promote new, innovative solutions to mitigate the effects of wind on ACC performance

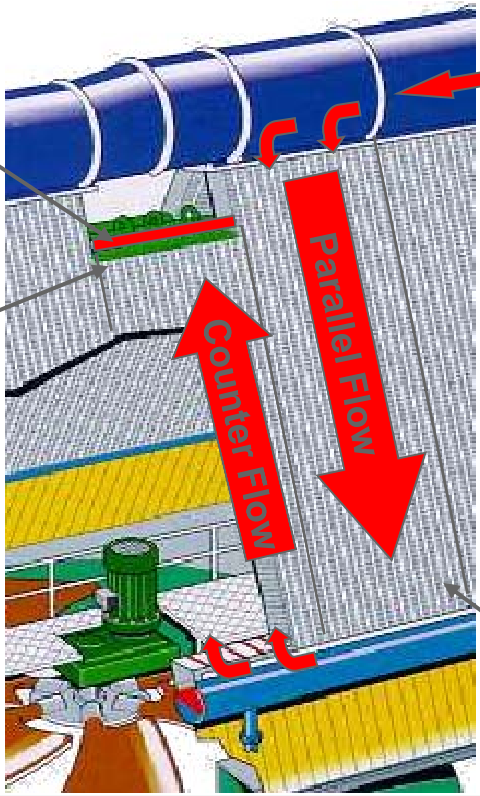
Condensing Process

- ACC Module



Condensing Process

- Two Stage Condensing Process
  - Mitigate Sub-Cooling
  - Effective Extraction of Non-Condensibles



- BASIC THERMODYNAMIC PRINCIPLES

$Q_{\text{condensation}} = Q_{\text{air}}$

$$\mathbf{m\ (h_{\text{turbine exhaust}} - h_f) \approx U\ A\ (T_{\text{sat. steam}} - T_{\text{air}})}$$

Therefore . . . .

If T air ↑ . . . . then $T_{\text{sat. steam}}$ ↑ (Backpressure↑)

If U (Overall HTC) ↓ . . . then $T_{\text{sat. steam}}$ ↑ (Backpressure ↑)

If Backpressure ↑ . . . . . . MW_e ↓ , $ Revenue ↓ (Herein the 'Rub")

ACC PERFORMANCE DERATE

- Given the preceding equation, for a given ACC with a constant steam flow condition, ambient air temperature and fan state, the leading factors that could contribute to an “instantaneous” backpressure increase are:
  - “Instantaneous” Change in Cooling Air Temperature
  - “Instantaneous” Change in Heat Transfer Coefficient

- ACC PERFORMANCE DERATE
  - Instantaneous Change in Cooling Air Temperature
    - An instantaneous change in inlet air temperature is generally caused by hot air recirculation.
    - A typical ACC, with perimeter siding (discharge), for the most part, hot air recirculation is predominantly mitigated.
    - ACCs without perimeter siding (few and far between) are prone to recirculation related performance issues.
    - ACCs with unique site arrangement may also be at risk to recirculation.
    - Generally speaking, however, recirculation is not the driving ACC performance issue.

ACC PERFORMANCE DERATE

- Instantaneous Change in Heat Transfer Coefficient (U)
  - An instantaneous change in heat transfer coefficient is almost exclusively caused by wind effect on fan (airflow) performance
  - ACC fans are typically operate at a “High Volume” / “Low Static Pressure” working point
  - Seemingly small increases in static pressure lead to notable decreases in volumetric cooling air flow
  - Notable decrease in ACC air flow leads to reduced “U” resulting in an increase in ST Backpressure and a decrease in ST Generator MW_e output

ACC PERFORMANCE TEST CODES

- As wind effects have been recognized by Owners, Operators, EPCs, Academicians, Testing Companies and OEMs, ACC performance test codes have followed suit with their wind speed design standard:
  - VDEW WD-0285-1965 – Max. Velocity ≤ 7.0 m/s
  - VGB-R 131 M e -1997 – Ave. Velocity ≤ 3.0 m/s
    Max. Velocity ≤ 6.0 m/s
  - ASME PTC 30.1-2007 – Ave. Velocity ≤ 5.0 m/s
    Max. Velocity ≤ 7.0 m/s
  - CTI ATC107 – Pending – Ave. Velocity ≤ 4.5 m/s
    Max. Velocity ≤ 7.0 m/s

General Considerations

- MARKET DEMAND
  - Mitigate the recognized effects of wind on ACC performance
  - Reasonable initial cost / High lifetime operational value
  - Easily integrated into new ACCs
  - Capability to retrofit of existing ACCs
  - No wind direction dependency
  - Reduced ACC fan power electrical consumption
  - Improved ACC Performance / ST Backpressure
  - More consistent backpressure / power generation

TECHNICAL PAPERS & PRESENTATIONS

- Investigations of wind effects have been commissioned by Owners, Academicians and Technical Organizations depicting specific wind induced issues with individual ACCs:
  - Adrian Melhuish BSc & Simon Melhuish - Installation of Galebreaker Windshield at Kings Lynn Power Station, 2006
  - Chuck McGowin & Kent Zammit EPRI, John Maulbetsch (Maulbetsch Consulting) - Field Testing of Wind Effects Presentation, EPRI, June 2008
  - J.A. van Rooyen, University of Stellenbosch - Performance Trends of an Air-Cooled Steam Condenser Under Windy Conditions, J. Eng. Gas Turbines Power - March 2008

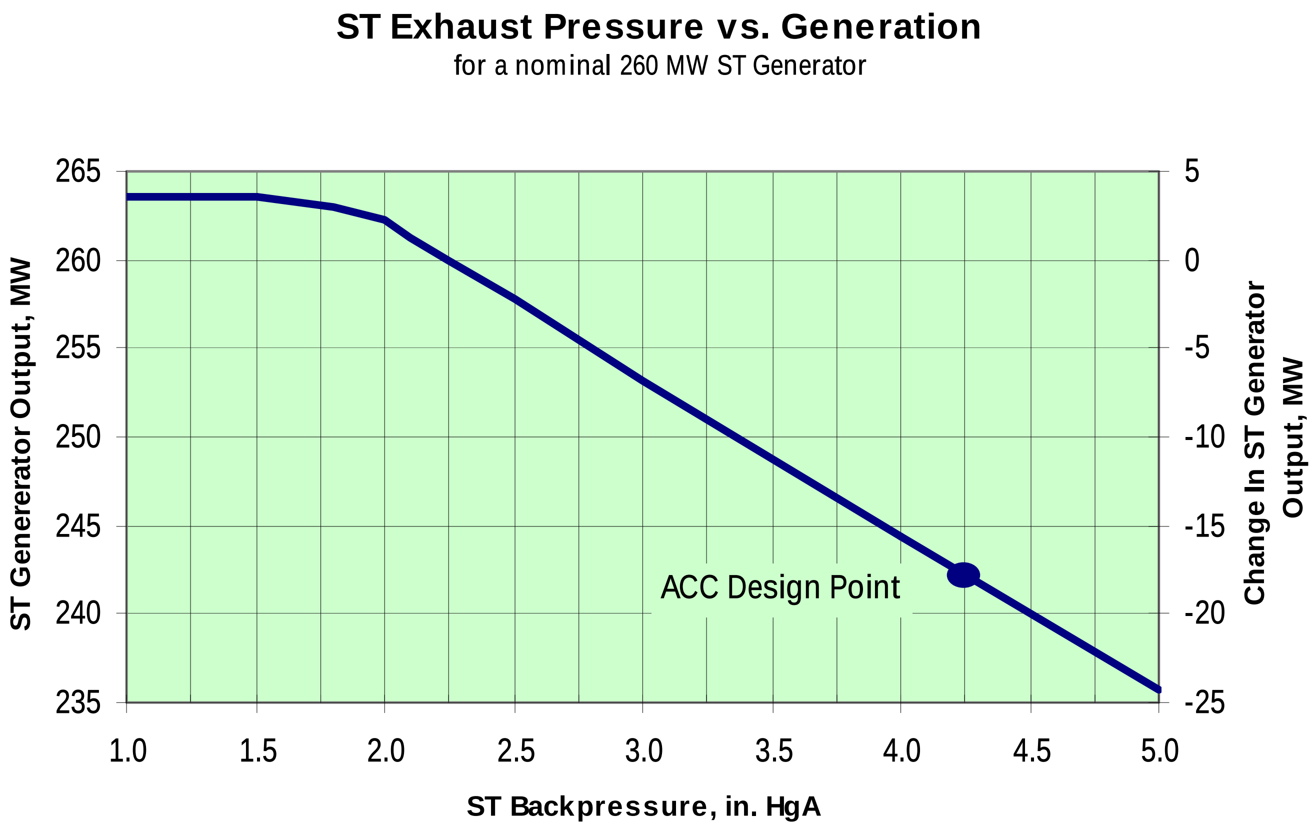
General Considerations

- TECHNICAL PAPERS & PRESENTATIONS
  - These various investigations, as well as SPX's own experience in recent years, yields the following general indications:
    - For an increase in wind from 3 m/s to 4 m/s, an increase in steam turbine backpressure of 0.1"Hg to 0.5"Hg can be expected
    - For an increase in wind from 3 m/s to 9 m/s, an increase in steam turbine backpressure of 0.5"Hg to 1.5"Hg can be expected
    - Very Important . . . Wind effect on ACC performance is unique to each and every ACC, due to site arrangement, ACC arrangement, thermal design conditions, equipment selection and other factors.

- ACC LIMITING STEAM TURBINE GENERATOR OUTPUT
  - Mainly, curtailment of capacity due to increased backpressure is only a concern when the ambient temperature and wind speed are at increased levels
    - All ACC fans already at full speed – No “Reserve” Capacity
    - Incremental increase in backpressure causes a notable decrease in STG MW_e output or . . . ST Alarm/Trip!
  - At reduced air temperatures, all ACC fans may not be at full speed and/or backpressure is reduced.
    - Backpressure excursions due to wind are typically automatically handled by the “inconspicuous” increase of the ACC fan(s).

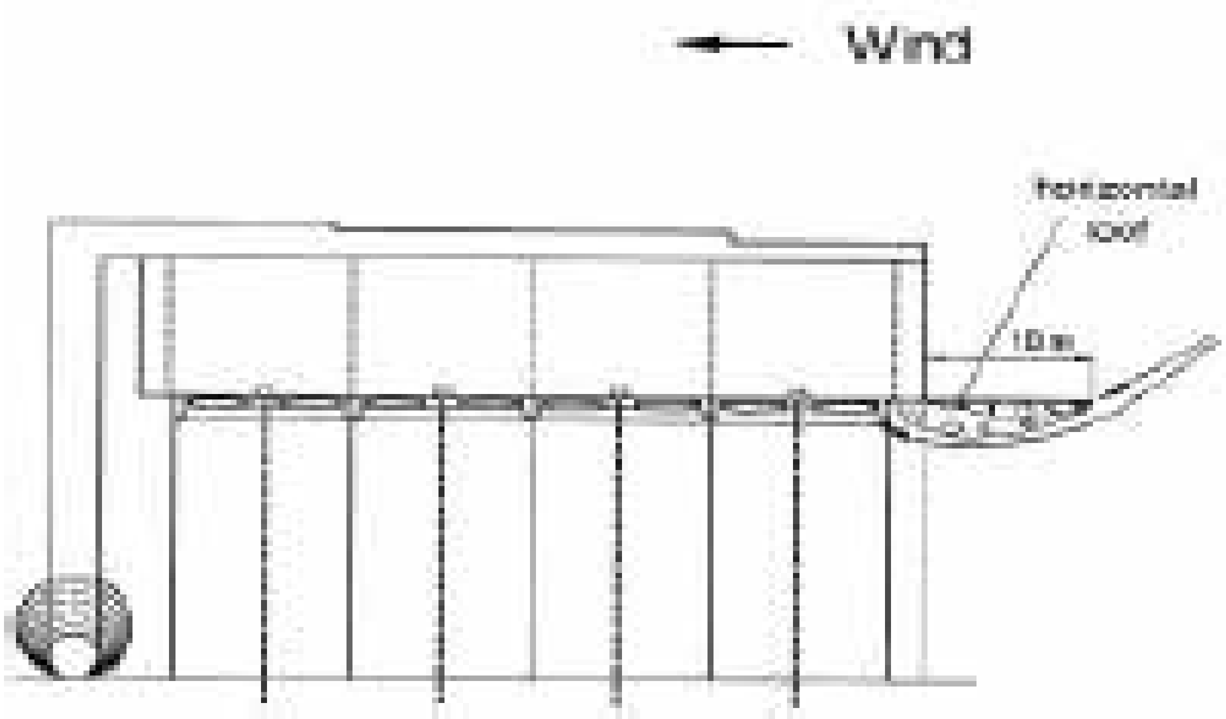
General Considerations

- ACC LIMITING STEAM TURBINE GENERATOR OUTPUT
  - 0.5”Hg Backpressure ~ 5 MWe



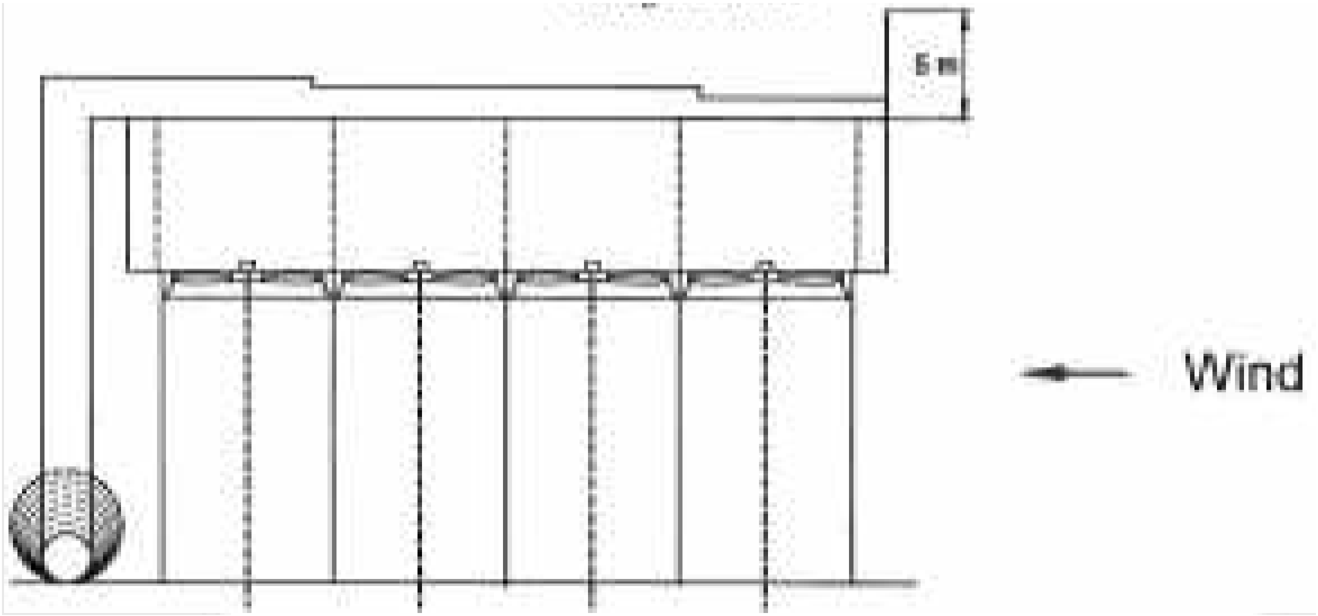
Wind Mitigation Options

- HORIZONTAL EXTENSIONS
  - Improves flow attachment at perimeter fans
  - Effective w/ >10 m extensions
  - Becomes less effective as wind speed increases



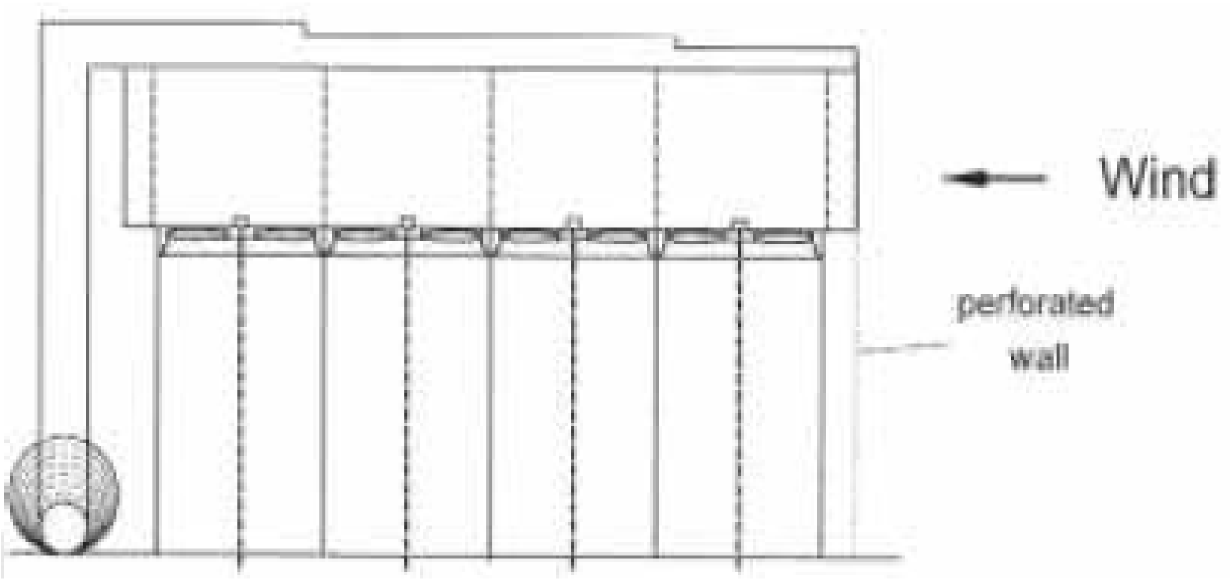
Wind Mitigation Options

- VERTICAL PERIMETER SIDING EXTENSIONS
  - Little effect with 5 m extension
  - Negligible effect on fan inlet conditions



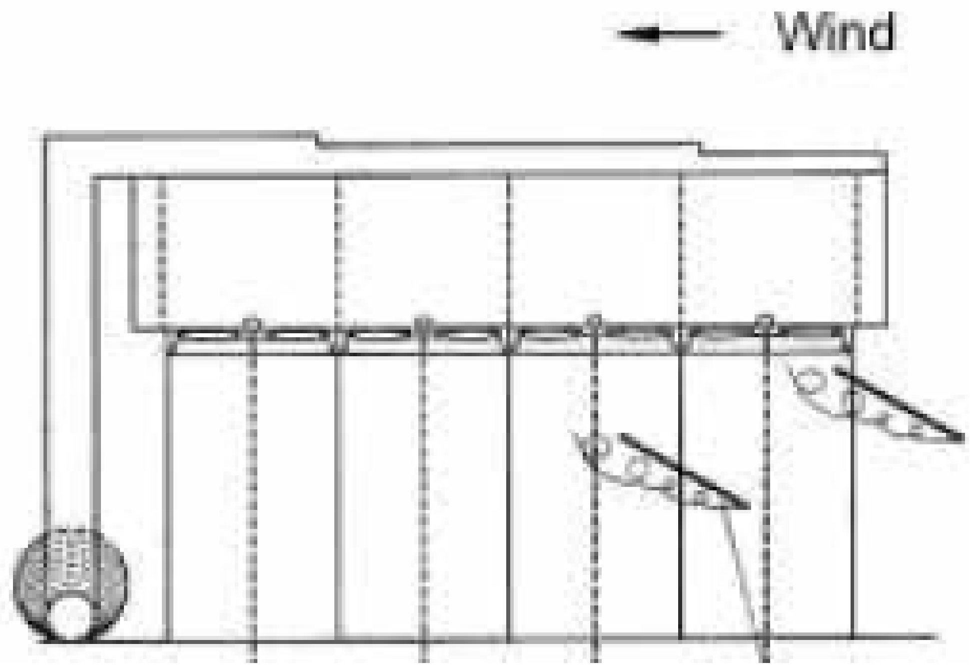
Wind Mitigation Options

- PERFORATED WALL
  - Increased ACC height and/or fan power
  - Negligible effect on fan inlet conditions
  - Wind direction dependent



Wind Mitigation Options

- MIXER PLATES / BAFFLE
  - Inlet Air Flow "Stabilization"
  - Wind direction dependent

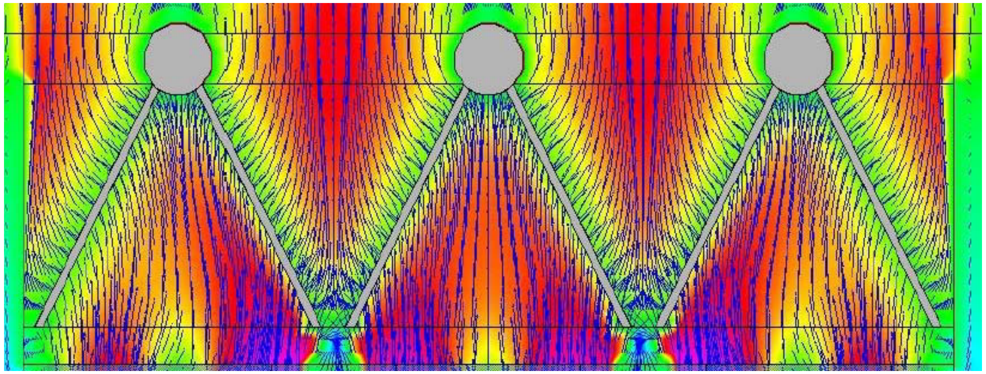


Innovative Solution

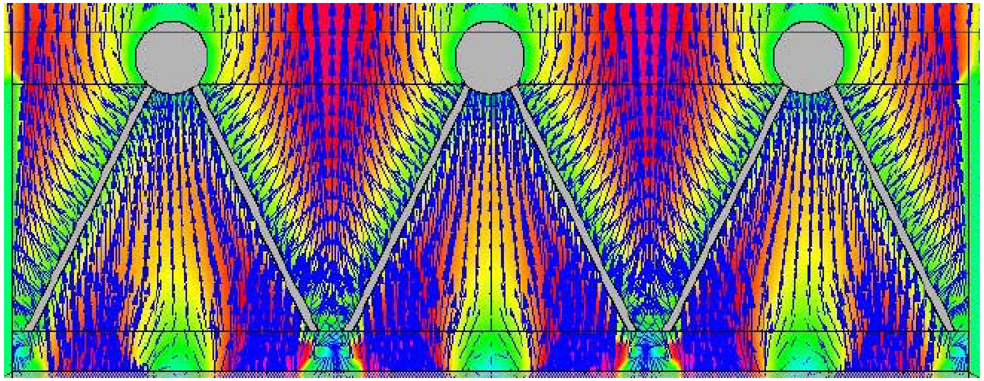
- SPX's INNOVATIVE WIND MITIGATION
  - Developed over the past years, coupling intuitive design process and detailed CFD modelling
  - CFD models demonstrate improved/increased airflow at design wind conditions, without increase in fan power
  - CFD models demonstrates significantly reduced airflow degradation at wind speeds up to 9 m/s (20 mph)
  - Details regarding the physical attributes remain confidential until further physical testing is complete as to validate CFD predictions
  - Validation testing currently in progress

CFD RESULTS

- Mitigation Features Improve Airflow at 3 m/s to 0 m/s Wind
- 2% to 7% Increase in Airflow
- 0.1 to 0.3”Hg Backpressure Decrease
- 1 to 3 MWe STG Improvement
- $ Generation Increase

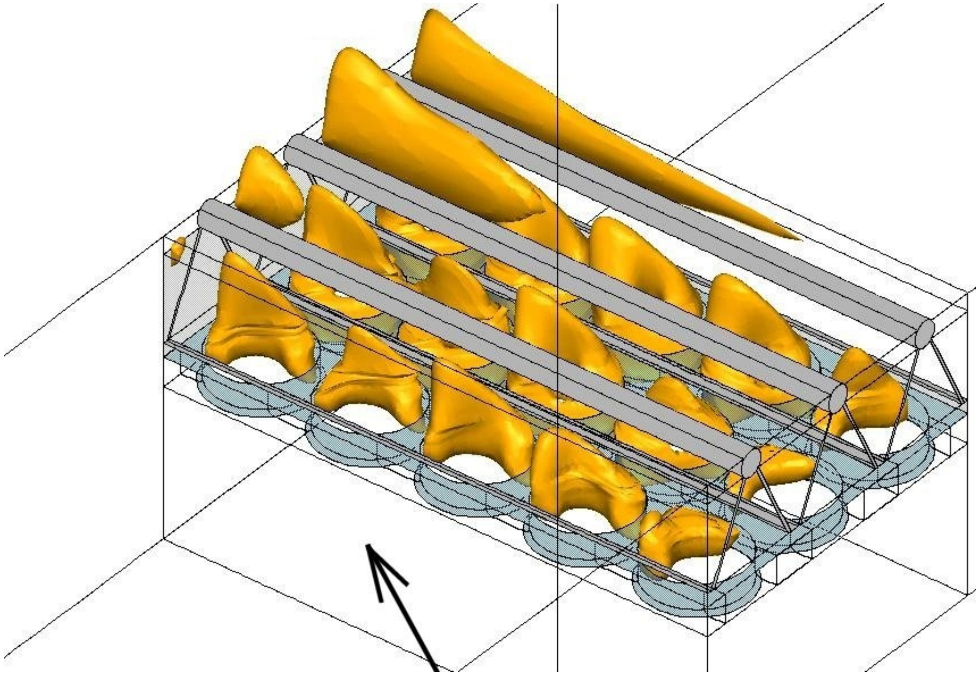


Without Wind Mitigation



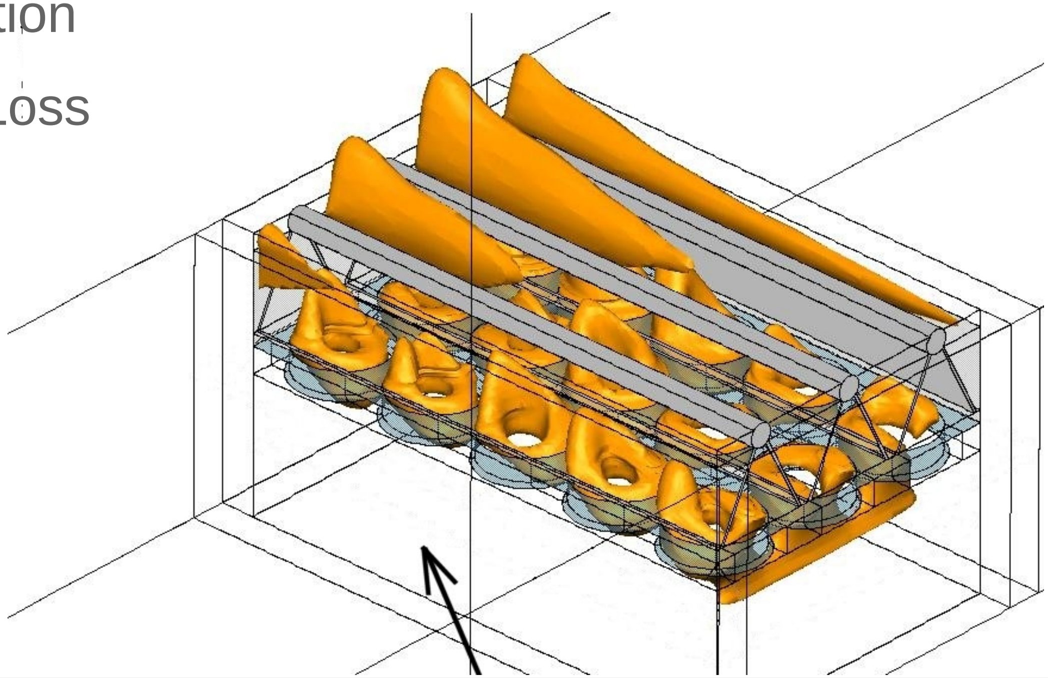
With Wind Mitigation

- CFD SIMULATION RESULTS
  - Without Wind Mitigation Features / 9m/s Quartering Wind
  - 15% to 20% Reduction in Airflow
  - 0.5 to 0.7”Hg Backpressure Increase
  - 5 to 7 MWe STG Reduction
  - $ Notable Generation Loss



Innovative Solution

- CFD SIMULATION RESULTS
  - With SPX's Wind Mitigation Features / 9m/s Quartering Wind
  - Only a 4% to 9% Reduction in Airflow
  - 0.2 to 0.4"Hg Backpressure Increase
  - 2 to 4 MWe STG Reduction
  - $ Reduced Generation Loss



Conclusions

- The mal-effect of wind on ACC performance has been recognized for some time.
- ACC Performance Test Codes have evolved to account for increased wind speeds, however, they still need account for wind conditions that are reasonable to provide for a mutually acceptable, verifiable ACC performance level.
- Over the years, various solutions have been studied and or implemented by various parties with varying degrees of success.
- All ACCs and sites are different. Thorough CFD analysis for each unique is required to provide for the optimal wind mitigation result.
- By coupling its ACC experience and R&D expertise and resources, SPX strives to respond to the market's expressed needs and to provide defined solutions to improve ACC performance under wind conditions.

Conclusions

Thank you for your attention and participation . . . .