Solving ACC Axial Fan Wind Related Problems

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Axial Fan Design Attributes

Axial Fans efficiently move large volumes of air with relatively low pressure rise. These attributes would seem to make Axial Fans ideal for ACC service.

Unfortunately, Axial Fans with intake air flowing at right angles to the fan axis, i.e., crosswinds, violates a basic Axial Fan design assumption: Axisymmetric Intake Flow.

Modifying the Asymmetric Intake Flow is the key to minimizing ACC Fan Problems.

ACC Axial Fan Wind Related Problems

1. Degradation of Volumetric Flow above 3 m/sec
2. Fan Blade Vibrations caused by Aerodynamic Excitation due to Flutter and Stall Conditions
3. Structural Vibrations Transmitted to the Fan Bridge
4. Fan Blade Structural/Fatigue Failure
5. Fan Noise Accentuated
6. Plume Recirculation Issues

Issues 1 through 5 are not unique to ACC's; they are due to classic Axial Fan Inlet Flow Distortion and Asymmetry conditions. Issue 6 is ACC specific but is partially due to the decreased plume vertical velocity as a result of Issue 1.

Classic Axial Fan
Flow Distortion and Asymmetry

"Distorted flows arising from upstream air-turning circumstances are, however, unavoidable in many instances. For example, a fan taking air from the free atmosphere will be subjected to varying wind conditions, which **in the most severe case will be at right angles to the fan axis**."

Source: Wallis, R. Allen, "Axial Flow Fans and Ducts," John Wiley & Sons, 1983,

ACC Axial Fans are inherently operating with crosswinds of the "most severe case."

Classic Axial Fan
Flow Distortion and Asymmetry

"depending on the severity of the distortions (i.e., non-uniform inlet profiles) the fan blade can stall, accompanied by losses in aerodynamic efficiency and peak pressure rise, as well as blade vibrations."

Source: Bruneau, P. R. P,, The Design of a Single Rotor Axial Flow Fan for a Cooling Tower Application, MSc Thesis, Department of Mechanical Engineering, University of Stellenbosch, 1994

Classic Axial Fan
Flow Distortion and Asymmetry

"…the low pressure rise [Axial Fan] machine may be rendered impotent."

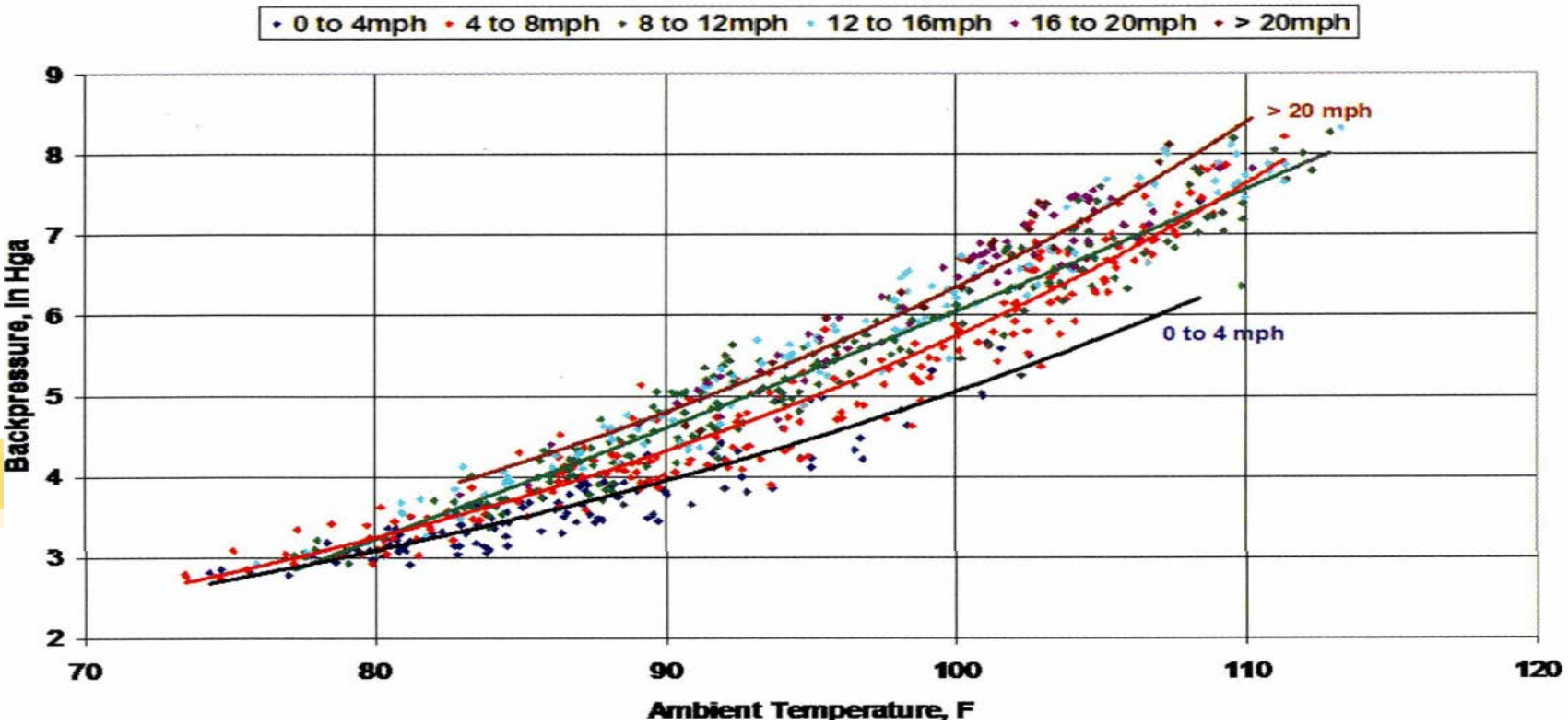
"Increasing design conservatism and greater blade rigidity must accompany a deteriorating flow situation. Lower design lift coefficients and greater blade cambers than the normal are ways in which this conservatism may be exercised…"

"Swirl control and the elimination of flow separation are important objectives . . ."

"The flows discussed herein may occasion result in blade flutter and subsequent [fan blade] fatigue failure."

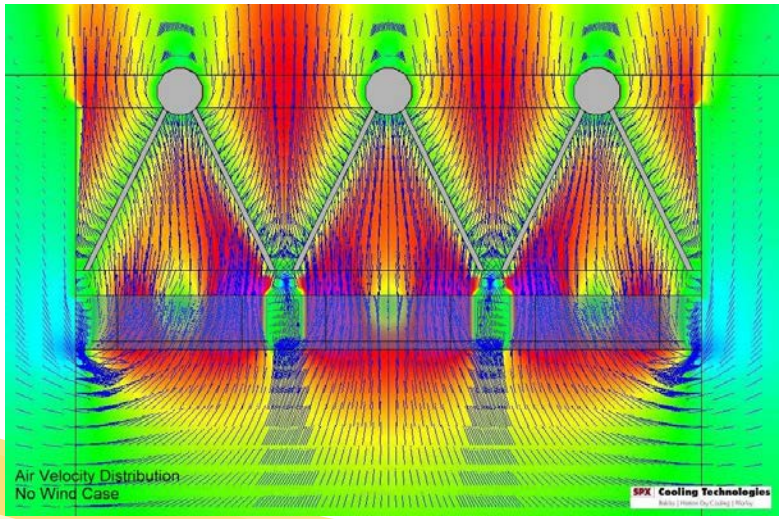
Source: Wallis, R. Allen, "Axial Flow Fans and Ducts," John Wiley & Sons, 1983

ACC Fan Performance Wind Related Thermal Performance Degradation

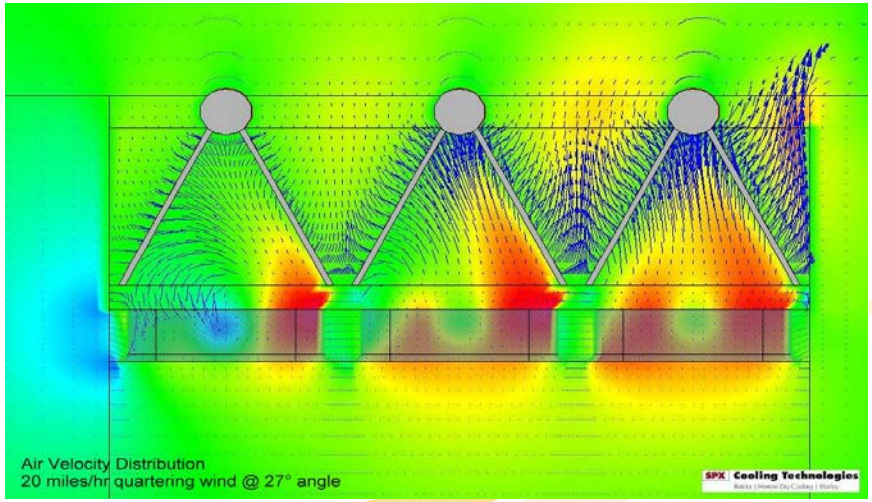


Source: Maulbetsch, J.S. & DiFilippo, M.N., "Wind Effects on ACC's", ACC User Group, San Francisco, September 19-20, 2011

ACC Axial Fan Performance – CFD Predicted Wind Related Degradation, Distortion & Asymmetry



Calm Winds



20 MPH Winds

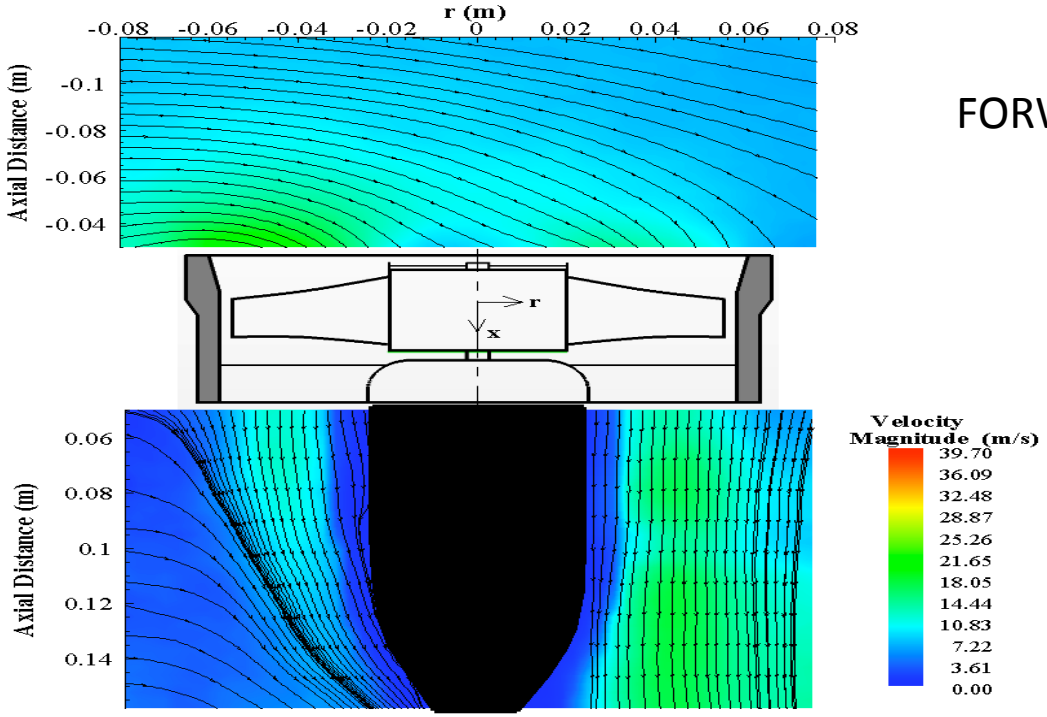
Source: **Improved Performance of an Air Cooled Condenser (ACC) Using SPX Wind Guide Technology at Coal-Based Thermoelectric Power Plants** [DEFC2606NT06549], Final Report 3/31/2011, **DOE Funding Opportunity, DE-PS26-08NT00233-01,** Principal Investigator: Ken Mortensen.

Detrimental Effects of Crosswinds is Not Related to the Large Diameter of ACC Axial Fans

". . .the performance of the ducted fan was highly affected . . .from the crosswind velocity. In crosswind, . . . a separation region that restricts the effective breathing area of the fan rotor, was always observed at the leading side of the ducted fan. That separation bubble has proven to affect the exit flow of the fan rotor."

This was one of the conclusions of a CFD study of a 5 Inch Diameter Axial Fan!

ACC Axial Fan Performance – Wind Related Degradation, Distortion & Asymmetry Not Limited To Large Diameter Fans



FORWARD FLIGHT
6 m/s

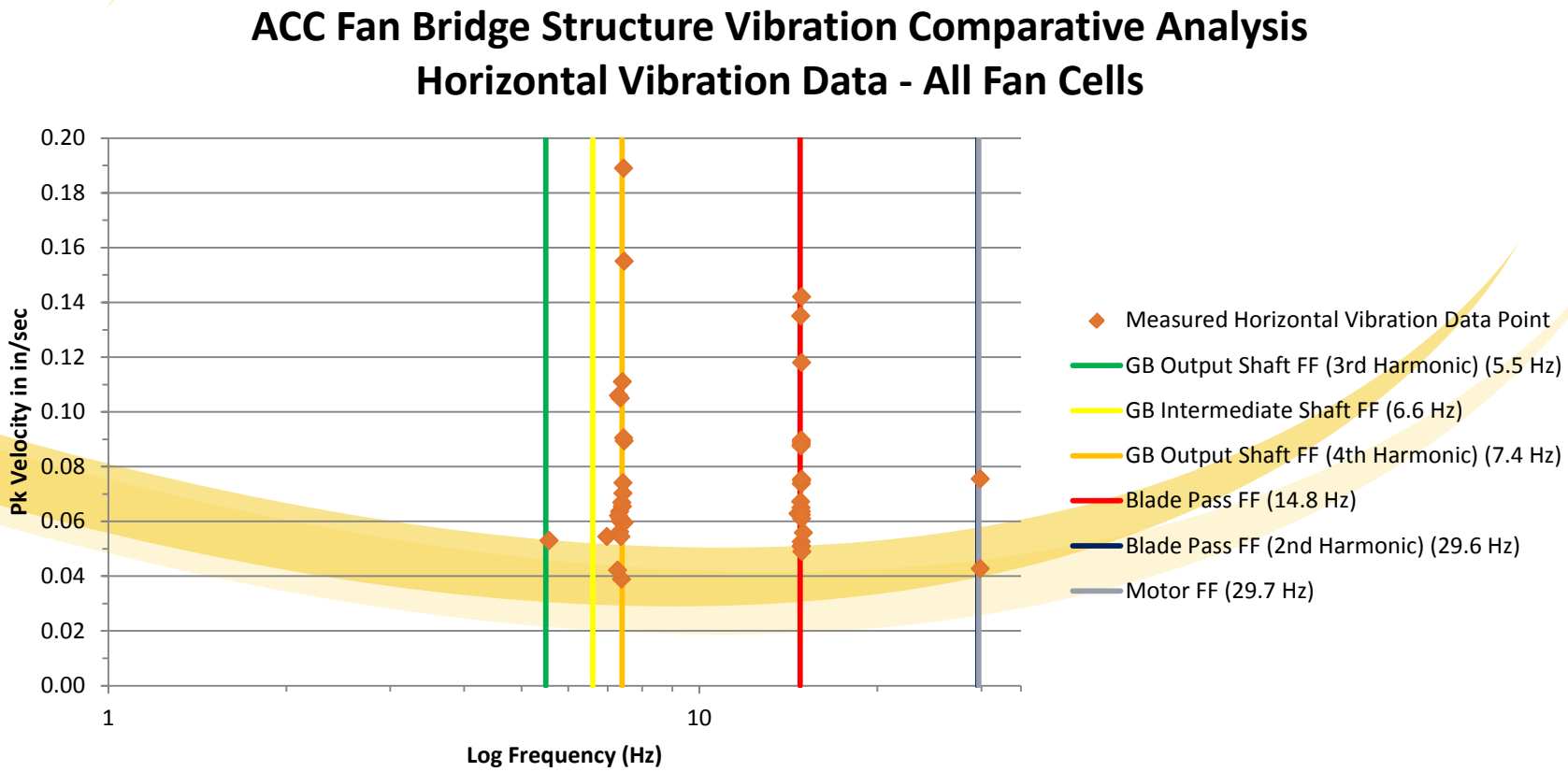
Source: Ali Akturk, Akamol Shavalikul and *Cengiz Camci, "***PIV Measurements and Computational Study of a 5-Inch Ducted Fan for V/STOL UAV Applications", AIAA 2009-332, 47th AIAA Aerospace Sciences Meeting and Exhibit, 5-8 January 2009, Orlando, Florida**

ACC Fan Blade Failures

Standard Corrective responses Include;

1. Strengthening & Stiffening Fan Blades,
2. Stiffening Fan Bridges to raise the structural natural frequency

ACC Vibration Analysis Indicated Dominant Structural Vibrations Correlated to Forcing Functions Frequencies



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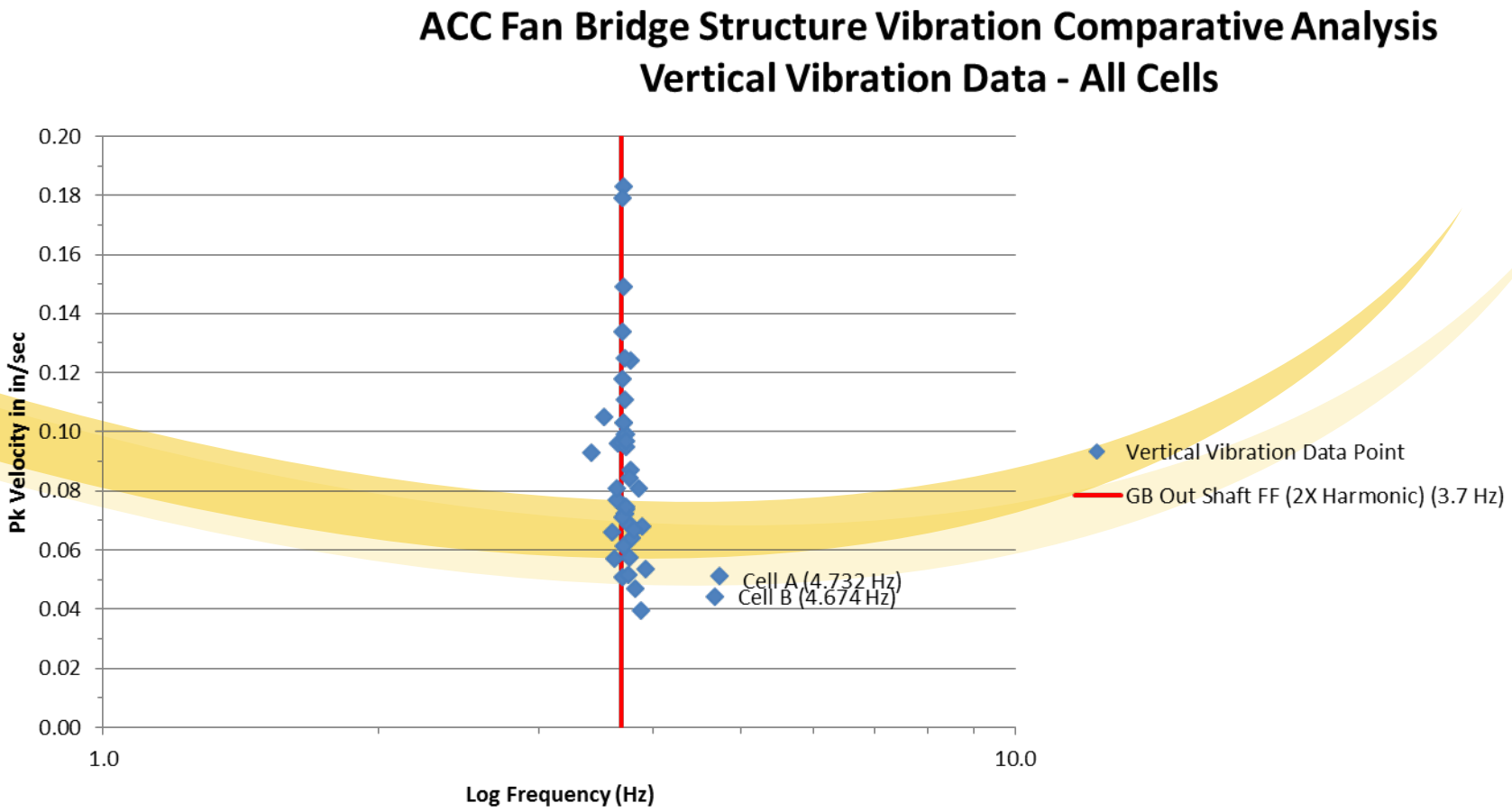


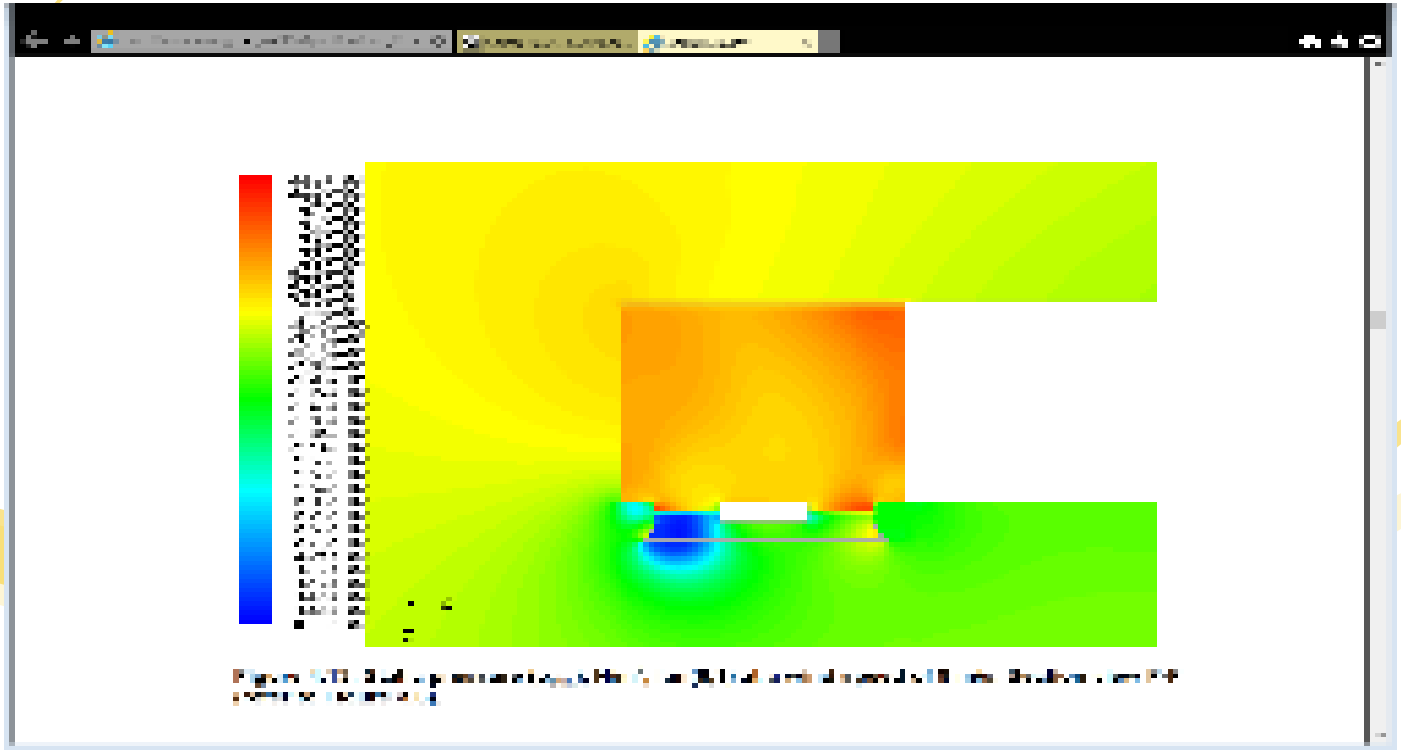
Effect of Standard Response to ACC Fan Blade Failures

1. Increasing the Separation of Natural Frequencies of the Fan Blades and the Steel Structure.
2. Subsequent Generations of Fan Blade Failures
3. Conclusion: Simple Harmonic Resonance Coupling of Fan Blade and Structural Natural Frequencies Does Not Appear to be the Dominate Root cause of Blade Failure.

ACC Fan Blade Failures

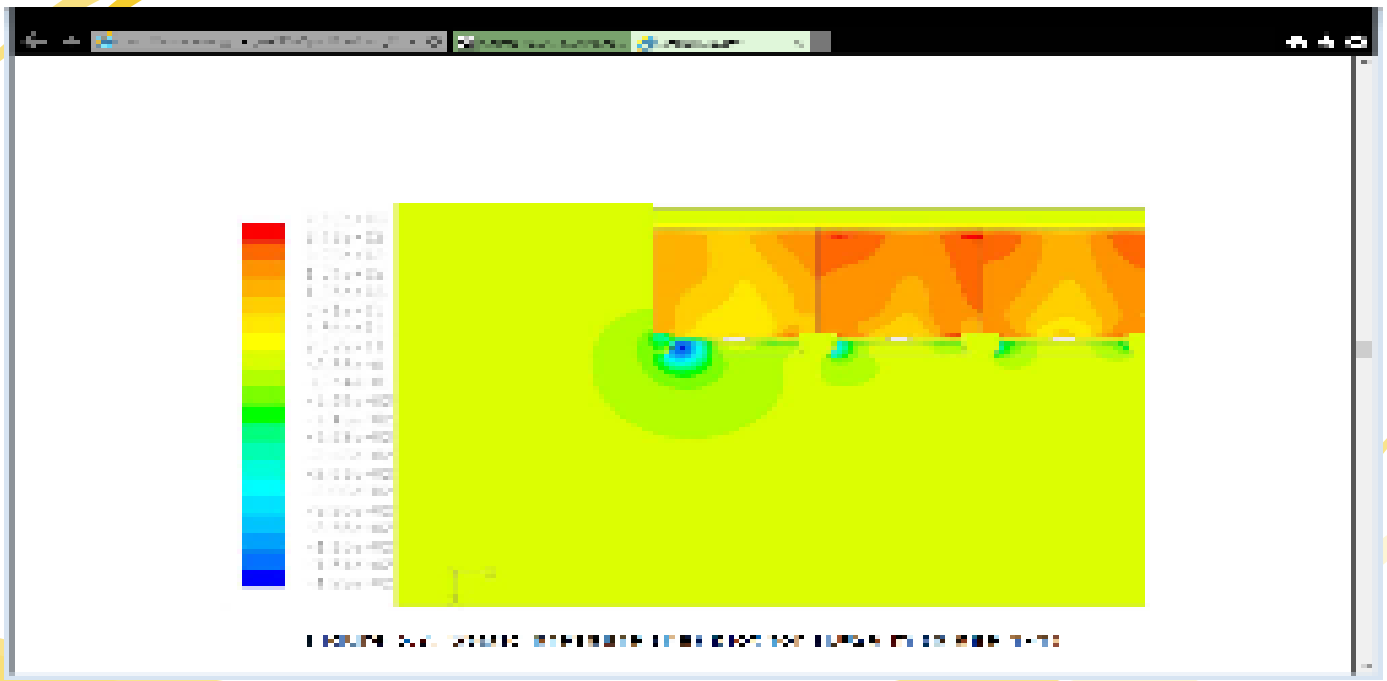
Question: If beefing up the fan blades and stiffening the structure doesn't seem to overcome the problems caused by wind induced distortions, why not minimize the wind induced distortions?

Distortion and Asymmetry on The Leading Edge of the Axial Fan Inlet



Source: “Numerical Investigation of Fan Performance in a Forced Draft Air-Cooled Steam Condenser” prepared for: California Energy Commission, prepared by J.R. Bredell and D.G. Kroger, University of Stellenbosch, South Africa www.energy.ca.gov/2007/publications/CEC-500-2007-124.pdf

ACC Fan Blade Failures



Cross sectional view of a multiple cell ACC. The distortion is clearly greatest at the outside fan cell which is consistent with observed high vibration and fan blade failure results.

ACC Fan Blade Failures

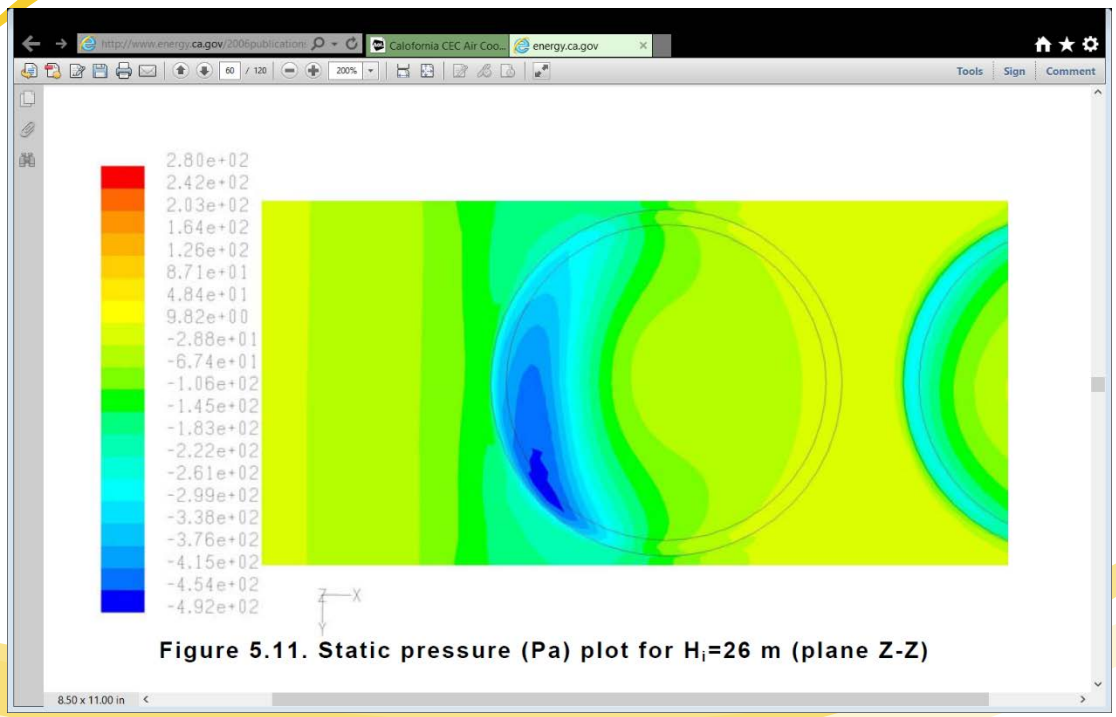
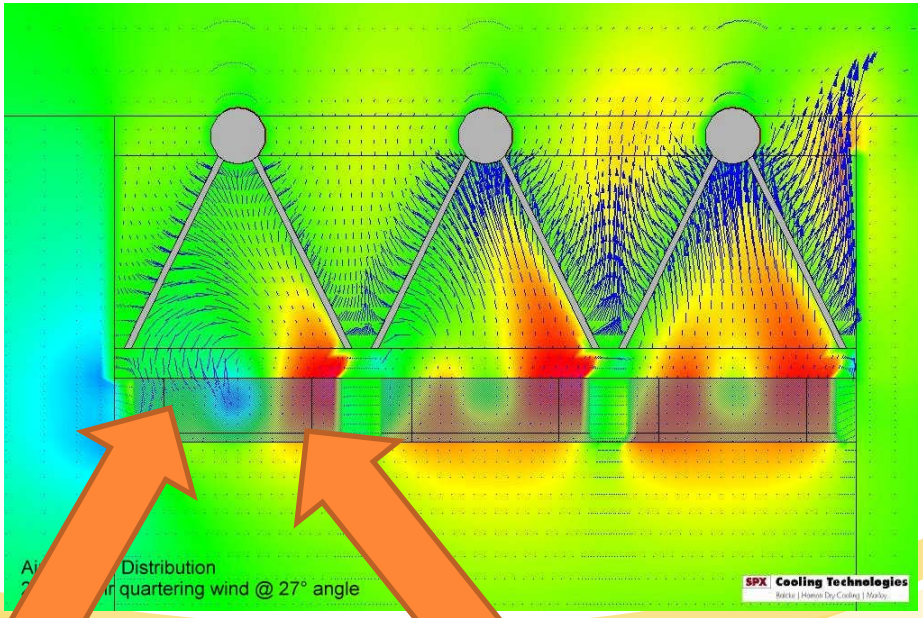


Figure 5.11. Static pressure (Pa) plot for H_i=26 m (plane Z-Z)

Plan view at the fan plane elevation. The blue pocket represents low pressure at the windward edge of the outside fan cell. The opposite side, (i.e., the leeward edge) is depicted with a yellow hue indicating an above ambient pressure result. Eliminating fan blade aerodynamic distortion requires adding pressure to the windward low pressure pocket while impeding air flow to the leeward pocket.

Conceptual Solution To Asymmetrical Inlet Air Conditions

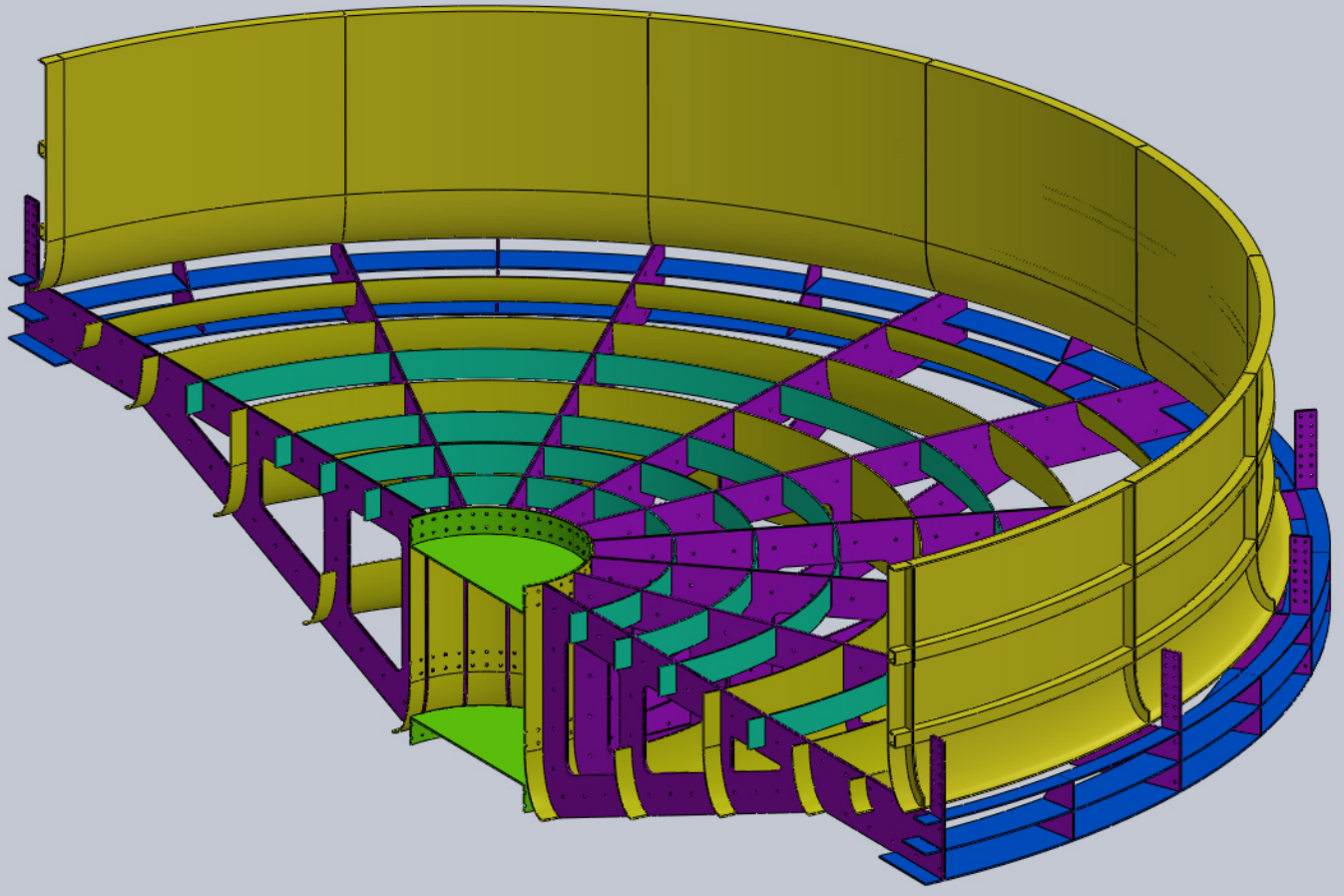


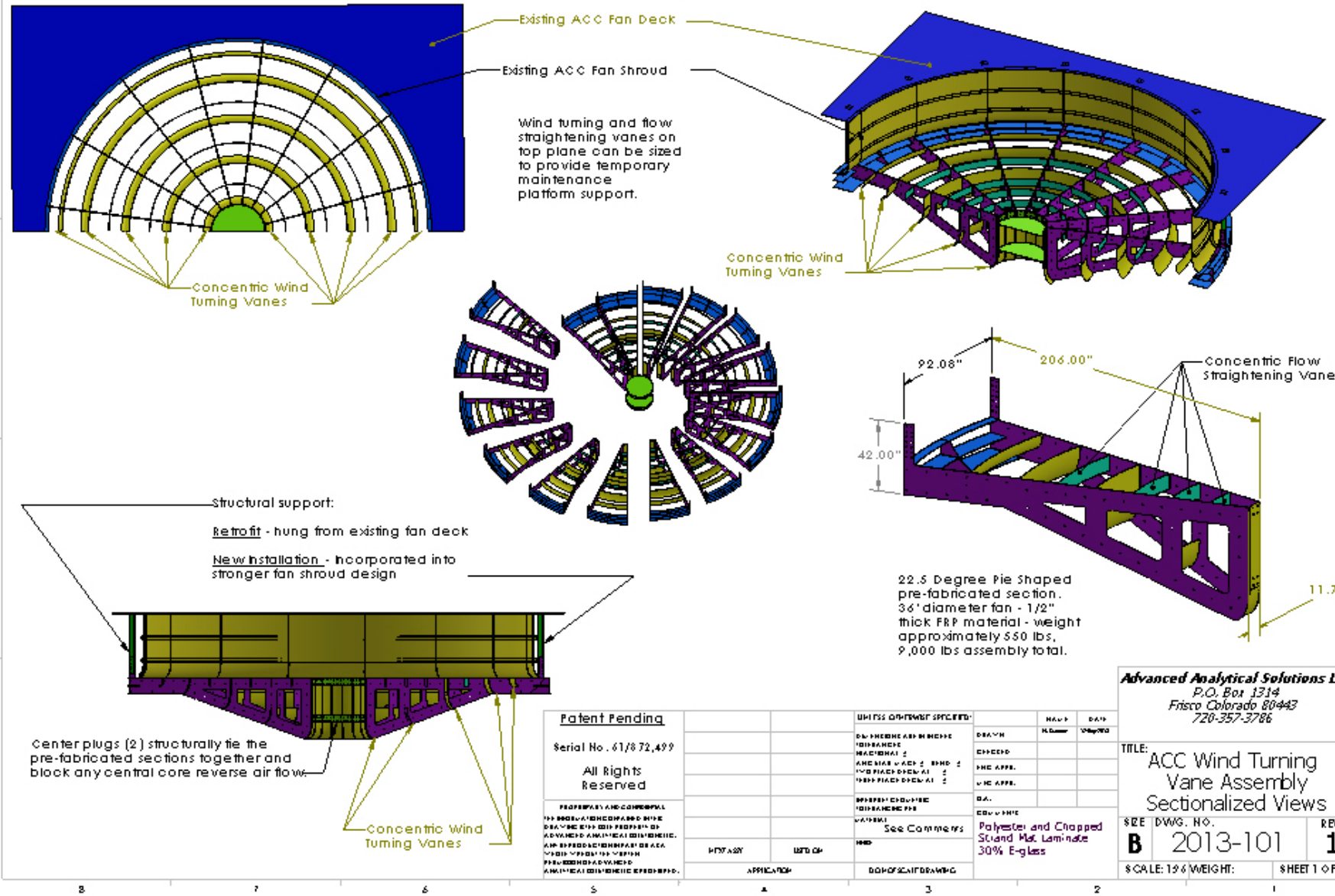
Add Air Flowing to Low Pressure Region

Deprive Air Flowing to High Pressure Region

Design Solution To Asymmetrical Inlet Air Conditions

Solution: Place a set of concentric turning vanes arranged conically under the fan shroud. This design will cause more air to turn into the low pressure windward pocket while causing the air flowing to the downwind side will be required to travel a longer distance and make more directional changes thus starving the high pressure pocket.




Existing ACC Fan Deck
Existing ACC Fan Shroud
Wind turning and flow straightening vanes on top plane can be sized to provide temporary maintenance platform support.
Concentric Wind Turning Vanes
Concentric Wind Turning Vanes
92.08"
206.00"
Concentric Flow Straightening Vanes
42.00"
11.70"
Structural support:
Retrofit - hung from existing fan deck
New Installation - incorporated into stronger fan shroud design
22.5 Degree Pie Shaped pre-fabricated section. 36' diameter fan - 1/2" thick FRP material - weight approximately 550 lbs, 9,000 lbs assembly total.
Center plugs (2) structurally tie the pre-fabricated sections together and block any central core reverse air flow.
Concentric Wind Turning Vanes
Patent Pending
Serial No. 61/872,499
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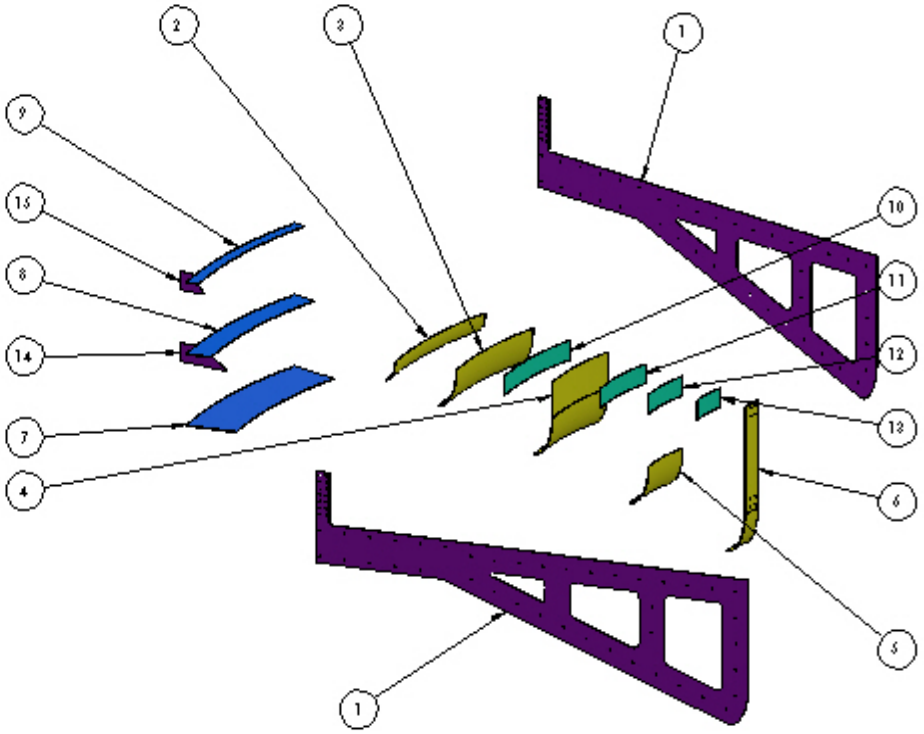
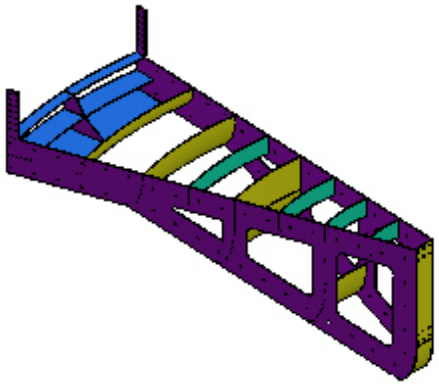
See Comments
Polyester and Chopped Strand Mat Laminate 30% E-glass
Advanced Analytical Solutions LLC
P.O. Box 1314
Frisco Colorado 80443
720-357-3786
TITLE:
ACC Wind Turning Vane Assembly Sectionalized Views
SIZE B
DWG. NO. 2013-101
REV 1
SCALE: 1/6 WEIGHT:
SHEET 1 OF 1

ITEM NO.	PART DESCRIPTION	DETAIL DRAWING NO.	QTY.
1	Side Panel	2013-201	2
2	Wind Turning Vane Number 1	2013-202	1
3	Wind Turning Vane Number 2	2013-203	1
4	Wind Turning Vane Number 3	2013-204	1
5	Wind Turning Vane Number 4	2013-205	1
6	Wind Turning Vane Number 5	2013-206	1
7	Horizontal Stiffener - Lower	2013-207	1
8	Horizontal Stiffener - Middle	2013-208	1
9	Horizontal Stiffener - Upper	2013-209	1
10	Straightening Vane Vertical Number 1	2013-210	1
11	Straightening Vane Vertical Number 2	2013-211	1
12	Straightening Vane Vertical Number 3	2013-212	1
13	Straightening Vane Vertical Number 4	2013-213	1
14	Vertical Stiffener - Lower	2013-214	1
15	Vertical Stiffener - Upper	2013-214	1





Patent Pending

Serial No. 61/872,499

See Comments

Polyester and Chopped Strand Mat Laminate 30% E-glass

Advanced Analytical Solutions LLC
P.O. Box 1314
Frisco Colorado 80443
720-357-3786

TITLE: ACC Wind Turning Vane Pre-Fab Exploded Section 22.5 Deg., 36' Fan Diameter

SIZE B | DWG. NO. 2013-102 | REV 1

SCALE: 1:48 WEIGHT: SHEET 1 OF 1

Expected Benefits of Concentric Conical Turning Vane Design

- Reduced Asymmetric Inlet Air Flow will reduce Fan Blade Aerodynamic Flutter and Stall conditions.
- Improved fan volumetric efficiency.
- Reduced Thermodynamic Performance Wind Related Degradation
- Reduced fan inlet air distortion should reduce fan blade noise generation.
- Increased volumetric efficiency also means higher plume vertical velocity and reduced tendency for plume recirculation.