TURNING VANE WIND TUNNEL TEST RESULTS

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AIR COOLED CONDENSERS EXPERIENCE FAN VIBRATIONS RELATED TO AMBIENT CROSSWINDS. THE FAN VIBRATIONS CAN RESULT IN COSTLY AND POTENTIALLY DANGEROUS FAN BLADE BREAKAGE.

THE AXIAL WIND-TURNING VANE DESCRIBED IN THIS PRESENTATION IS DESIGNED TO ELIMINATE WIND-INDUCED AXIAL FAN BLADE BREAKAGE.

PREVIOUS ACCUG WIND TURNING VANE PRESENTATIONS:

Cuerdon, Martin J., P.E., ***Solving ACC Axial Fan Wind Related Problems,*** *http://acc-usersgroup.org/wp-content/uploads/2013/10/18-Cuerdon.ACCUG-Las-Vegas-Presentation-2013.pdf*

Cuerdon, Martin J., P.E., ***Axial Fan Wind Turning Vane Scale Model Test Results***, http://acc-usersgroup.org/wp-content/uploads/2014/10/Axial-Fan-Wind-Turning-Vane-Scale-Model-Test-Results.Martin-Cuerdon-Advanced-Analytical-Solutions.pdf

Copies of these presentation slides can be found on the ACCUG website,

http://acc-usersgroup.org/presentations/

ORIGINAL TEST APPARATUS PROVED AXIAL WIND TURNING VANE CONCEPT

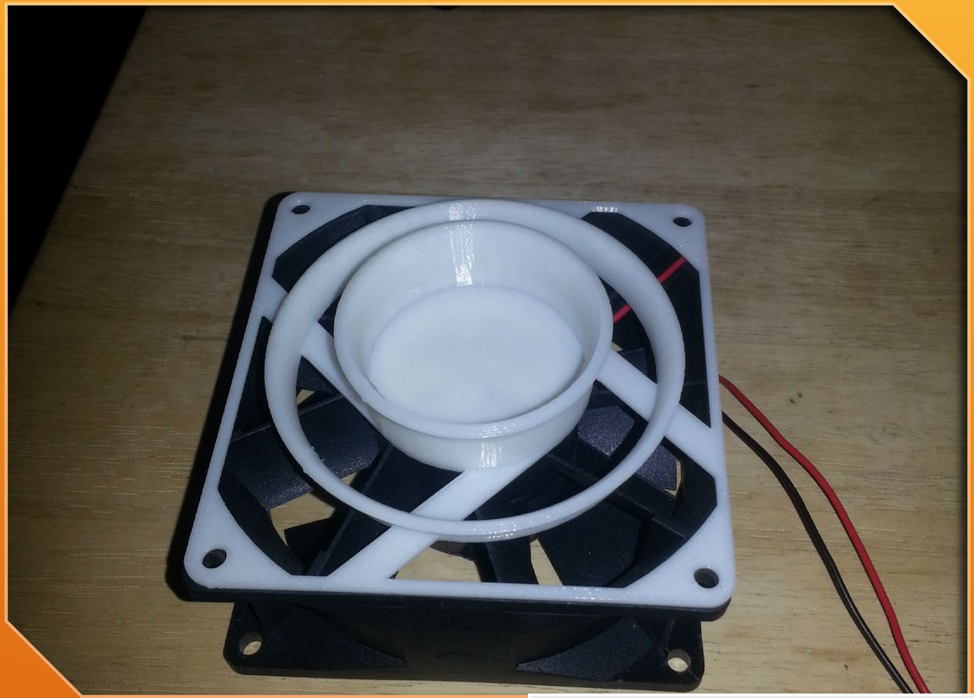
Previous test results demonstrated the axial fan output flow distribution was;

1. **Axisymetric bimodal (i.e., 2 Humped Camel shape) with no crosswnd,**
2. **Distorted axisymetric bimodal with a crosswind,**
3. **Significantly less distorted axisymmetric bimodal with a crosswind when the Axial Turning Vane was employed.**

ORIGINAL APPARATUS USED TO PROVE CONCEPT NOT PRECISE ENOUGH TO ANSWER QUANTIFICATION QUESTIONS

- **How much does the Axial Wind Turning Vane obstruct air flow when there are no crosswinds?**
- **Is there a break-even point where the axial fan air flow actually improves with the use of the Axial Wind Turning Vane?**
- **Can the Axial Fan aerodynamic imbalance be measured?**
- **How much does the Axial Wind Turning Vane reduce the Axial Fan aerodynamic imbalance?**

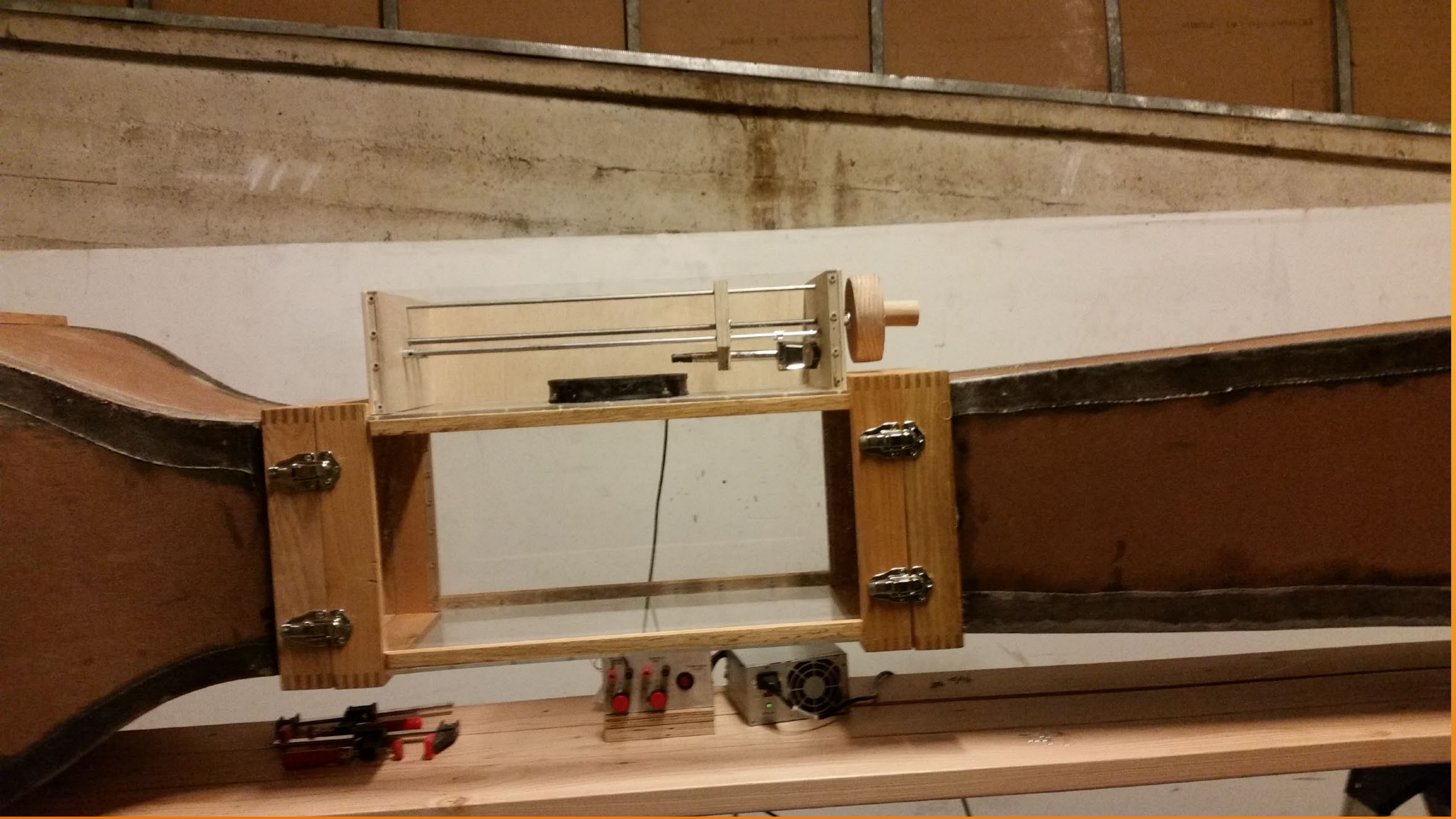
ORIGINAL FAN = 80 MM DIAMETER, 2 VANES
NEW FAN = 200 MM DIAMETER, 7 VANES



	Original Test Apparatus	Revised Test Apparatus
Fan Diameter	30mm	200mm
Measurement Interval	0.25"	.0625"
Measurements per Traverse	13	129
Crosswind Condition	Turbulent	Laminar
Crosswind Measurement	No	Yes
Crosswind Control	No	Yes
Ambient Air Temp Measurement	No	Yes
Ambient Air Pressure Measurement	No	Yes

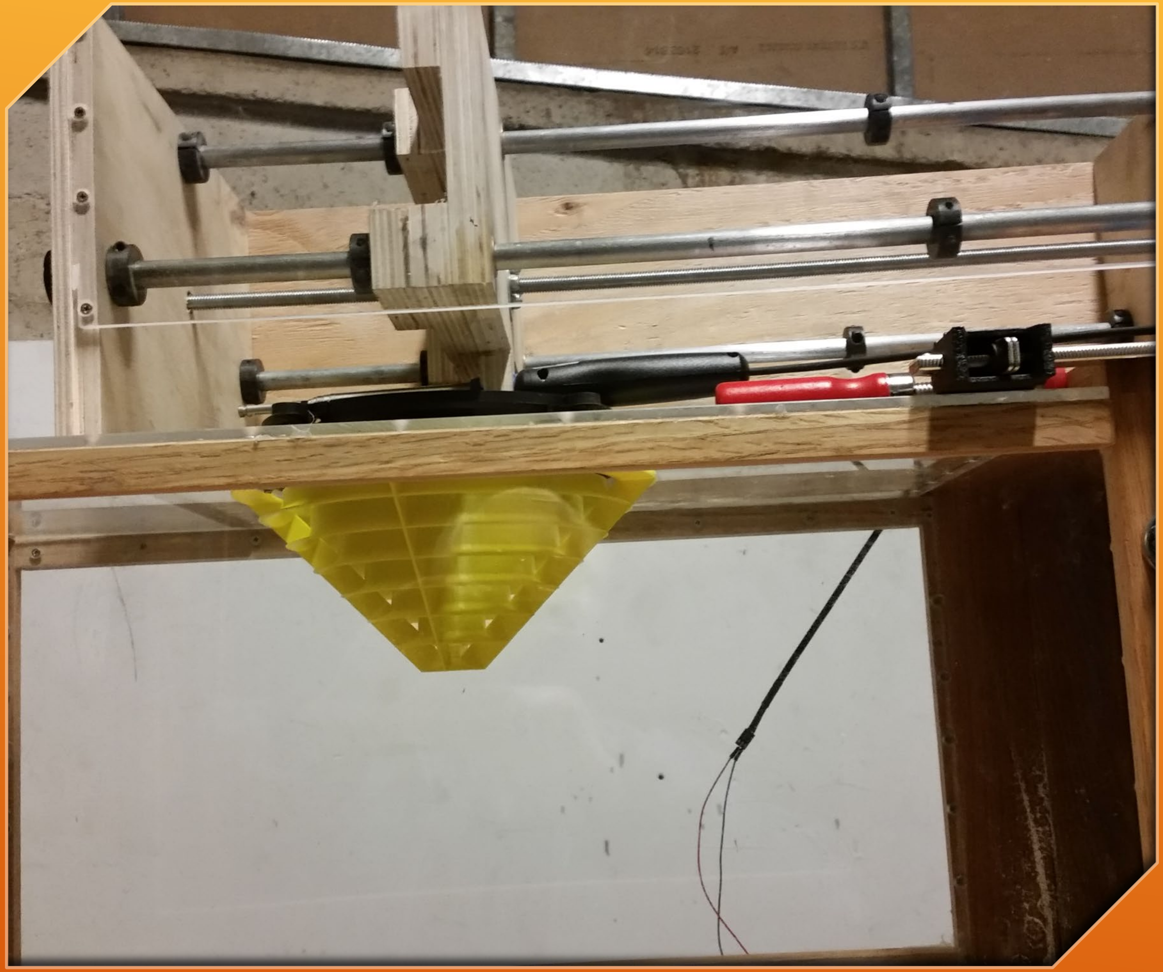
REVISED AXIAL TURNING VANE TEST WIND TUNNEL

- 10 foot long
- 2 foot x 2 foot Inlet
- 1 foot x 1 foot observation section
- 4 speed furnace fan
- guillotine outlet damper (Not Shown)



NEW TEST APPARATUS W/O AXIAL WIND TURNING VANE

Revised Test Apparatus Axial Fan mounted on Wind Tunnel measuring section. Axial Fan output air flow measured a with a hot wire Anemometer mounted on a sliding support indexed by a 3/8 '–16 threaded rod.

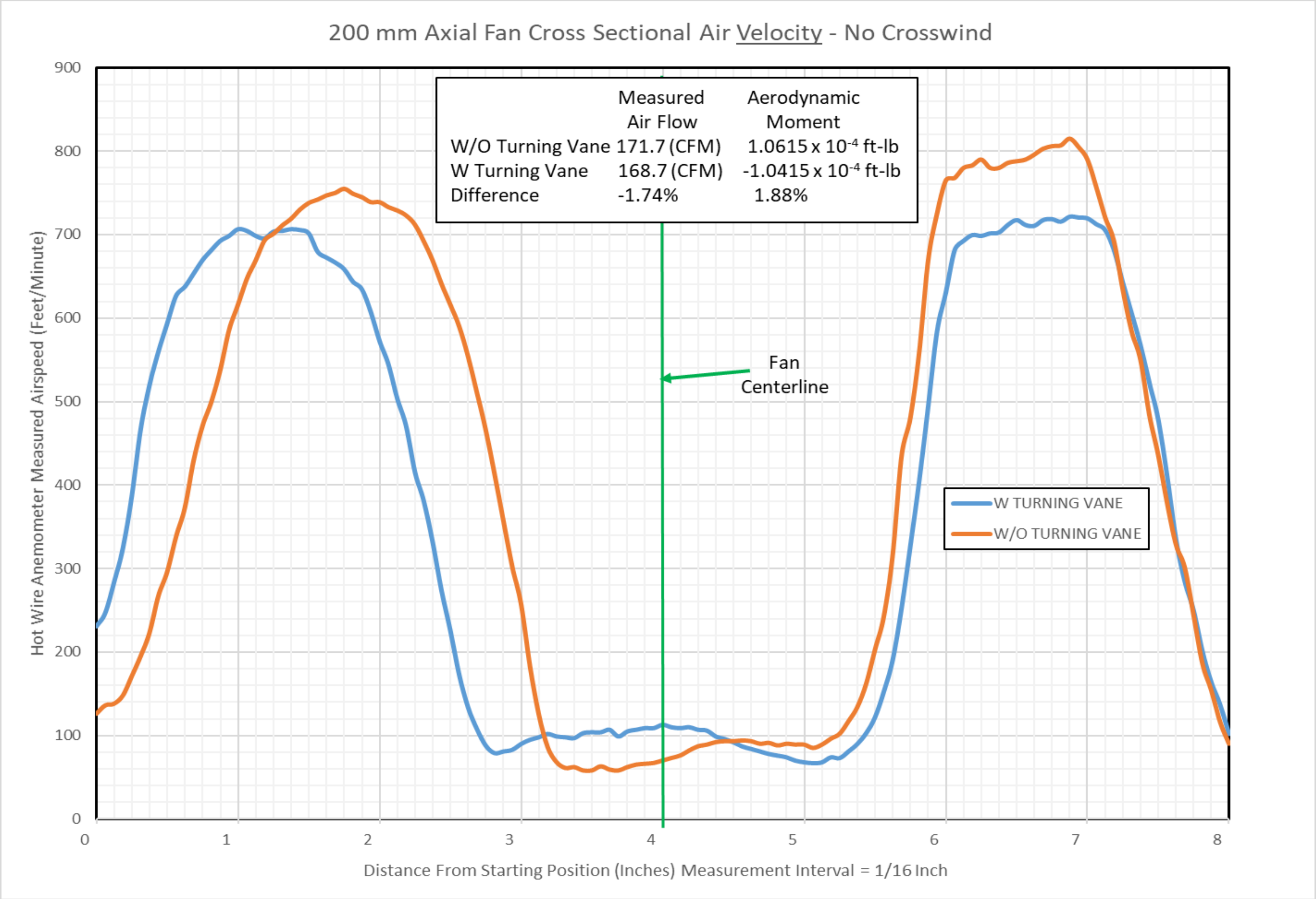


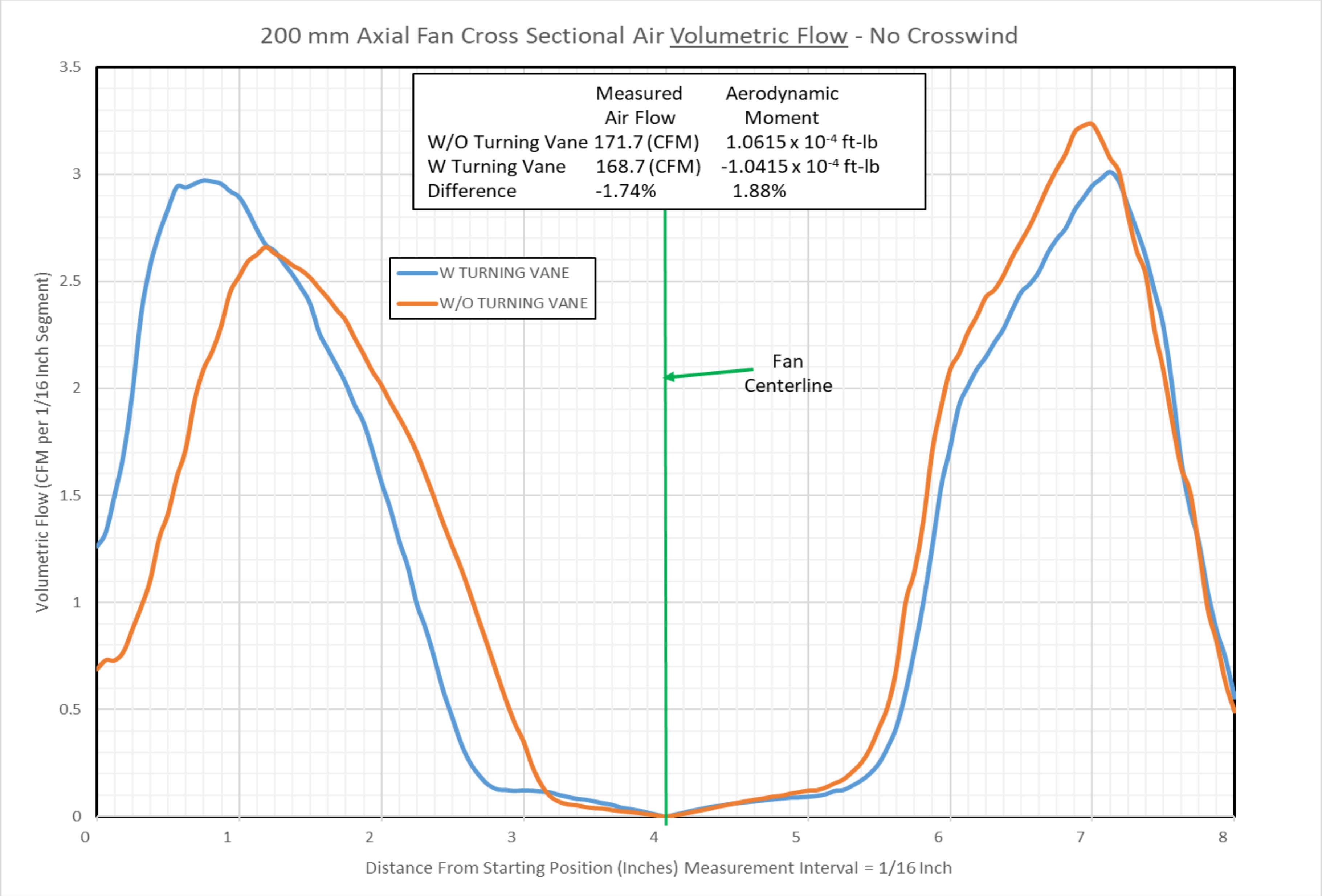
REVISED TEST APPARATUS WITH AXIAL TURNING VANE INSTALLED

Original number of measurement points per traverse = 13, interval = ¼", traverse length = 3". Measurements per traverse = 1300 (100 x 13).

Revised number of measurement points per traverse = 129, interval = 1/16", traverse length = 8" Measurements per traverse = 6,450 (50 x 129).

WIND TUNNEL MEASUREMENT RESULTS


200 mm Axial Fan Cross Sectional Air Velocity - No Crosswind
Measured Air Flow
Aerodynamic Moment
W/O Turning Vane 171.7 (CFM) 1.0615 x 10-4 ft-lb
W Turning Vane 168.7 (CFM) -1.0415 x 10-4 ft-lb
Difference -1.74% 1.88%
Fan Centerline
W TURNING VANE
W/O TURNING VANE
Hot Wire Anemometer Measured Airspeed (Feet/Minute)
Distance From Starting Position (Inches) Measurement Interval = 1/16 Inch
900
800
700
600
500
400
300
200
100
0
0
1
2
3
4
5
6
7
8


200 mm Axial Fan Cross Sectional Air Volumetric Flow - No Crosswind
Measured Air Flow
Aerodynamic Moment
W/O Turning Vane 171.7 (CFM) 1.0615 x 10^-4 ft-lb
W Turning Vane 168.7 (CFM) -1.0415 x 10^-4 ft-lb
Difference -1.74% 1.88%
W TURNING VANE
W/O TURNING VANE
Fan Centerline
Volumetric Flow (CFM per 1/16 Inch Segment)
Distance From Starting Position (Inches) Measurement Interval = 1/16 Inch
0
0.5
1
1.5
2
2.5
3
3.5
0
1
2
3
4
5
6
7
8

DERIVATION OF AERODYNAMIC MOMENT

Aerodynamic Moment is the sum of the unbalanced airflow mass pushing against the fan blades and creating a net bending moment against the Fan Shaft.

$$M_A = \left(\sum_{i=0''}^{1=8''} D_i \, AF_i\right)\left({}^{\rho}/_{\omega}\right)$$

Where:

M_A = Aerodynamic Moment (Ft. Lbs.)

i = Incremental Element (1/16" Measurement Increment)

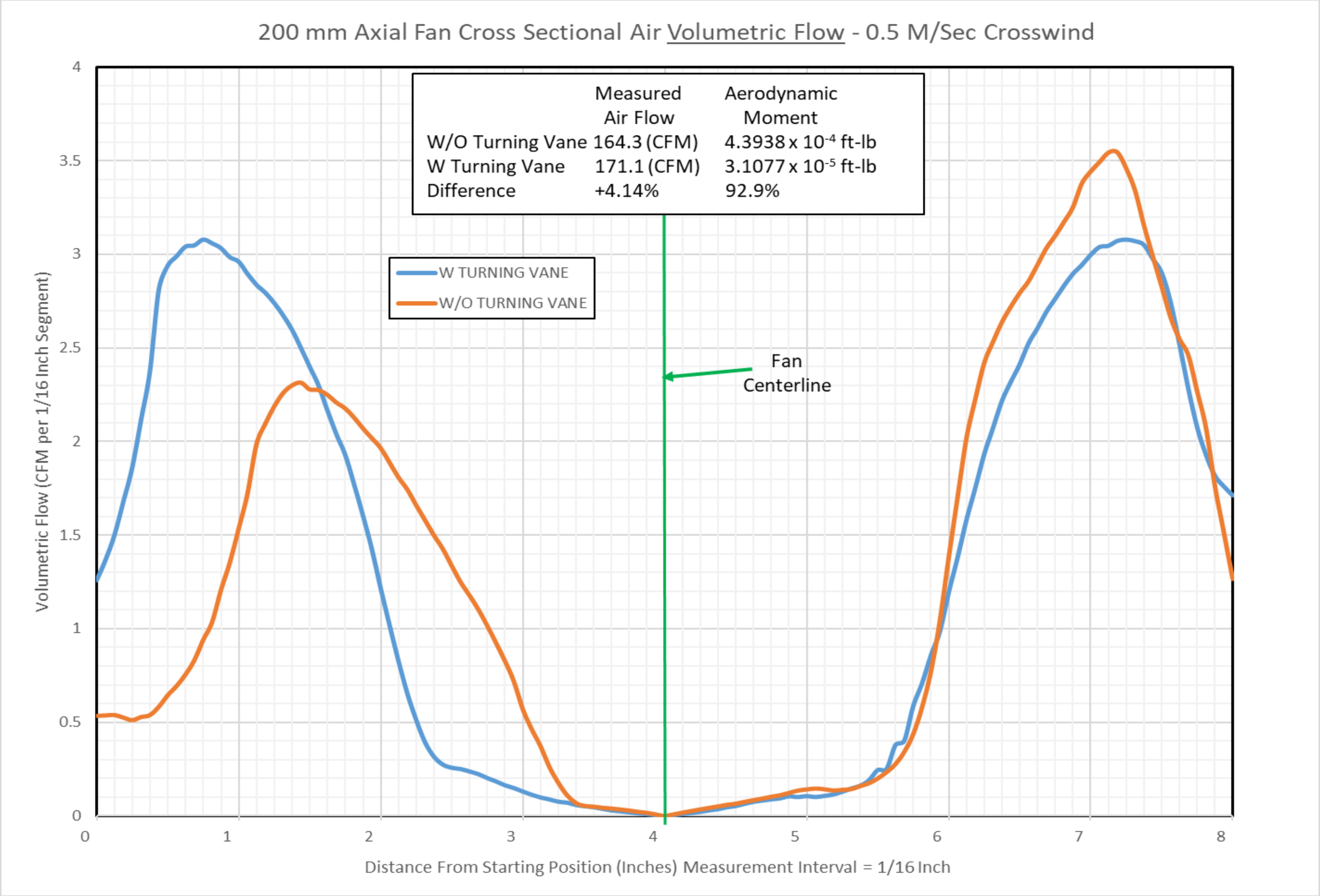
D_i = Distance from Element to Fan Centerline (Ft)

AF_i = Air Flow Through Element (Ft^3/Minute)

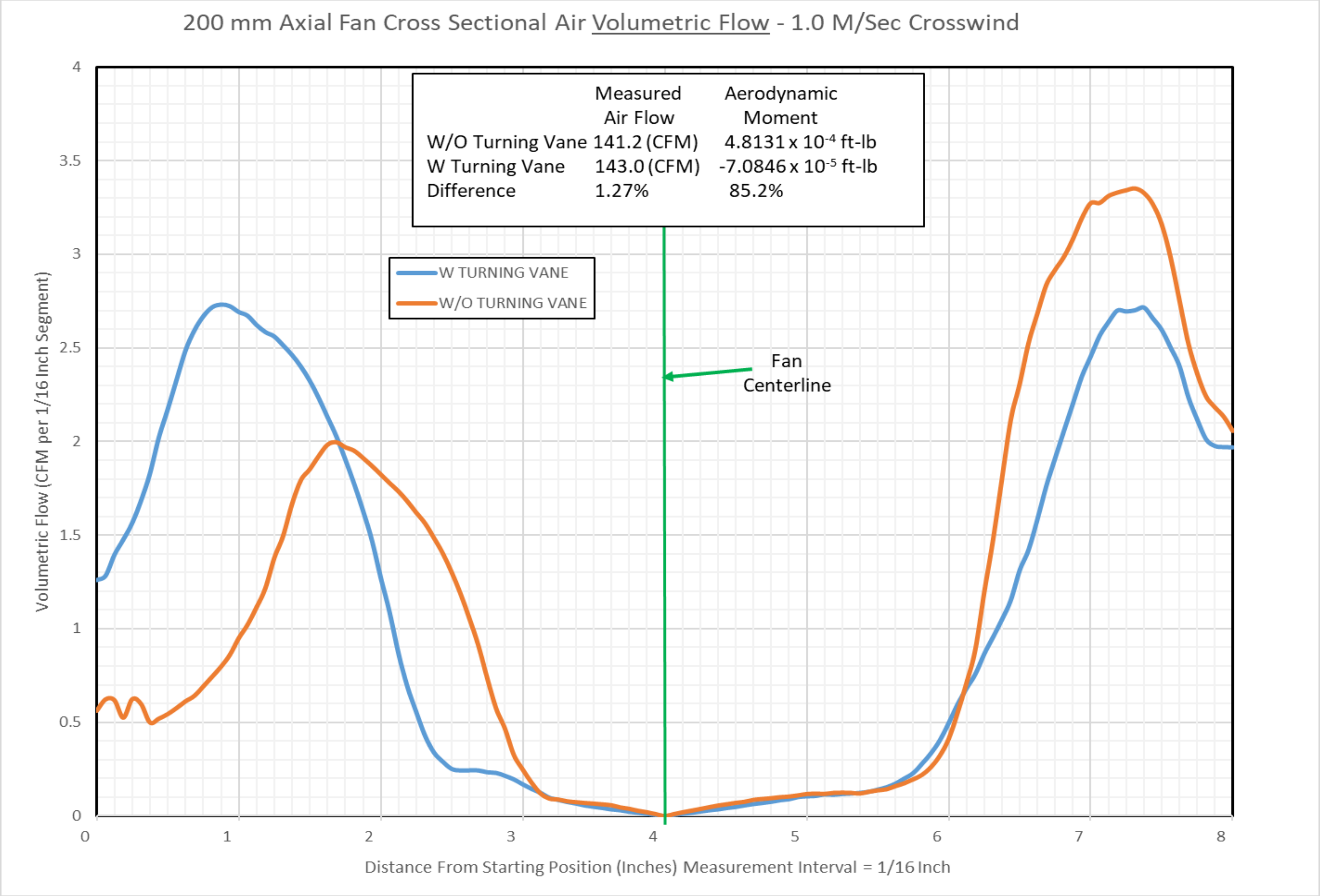
ρ = Air Density (Lbs./Ft^3)

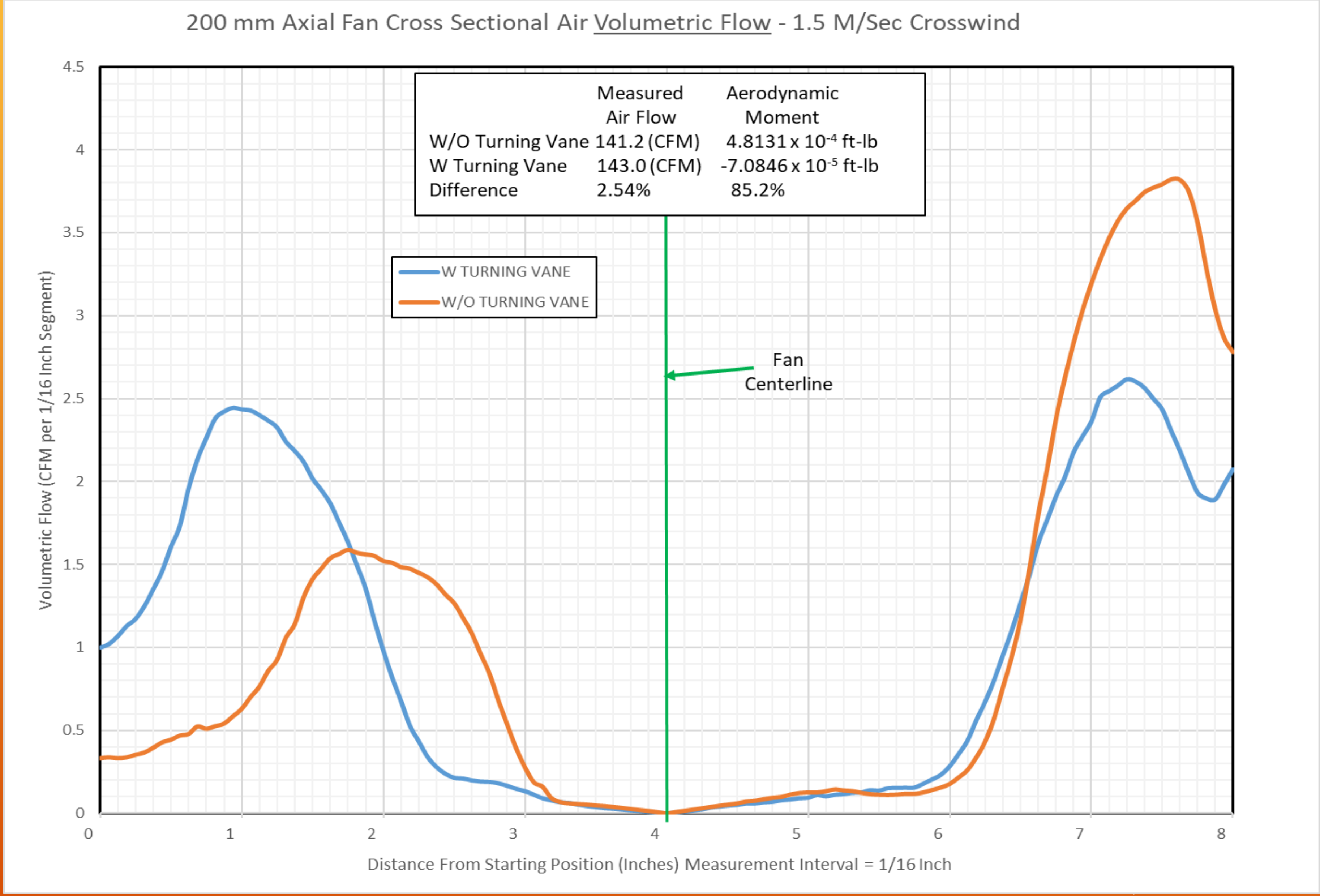
ω = Fan Speed (RPM)

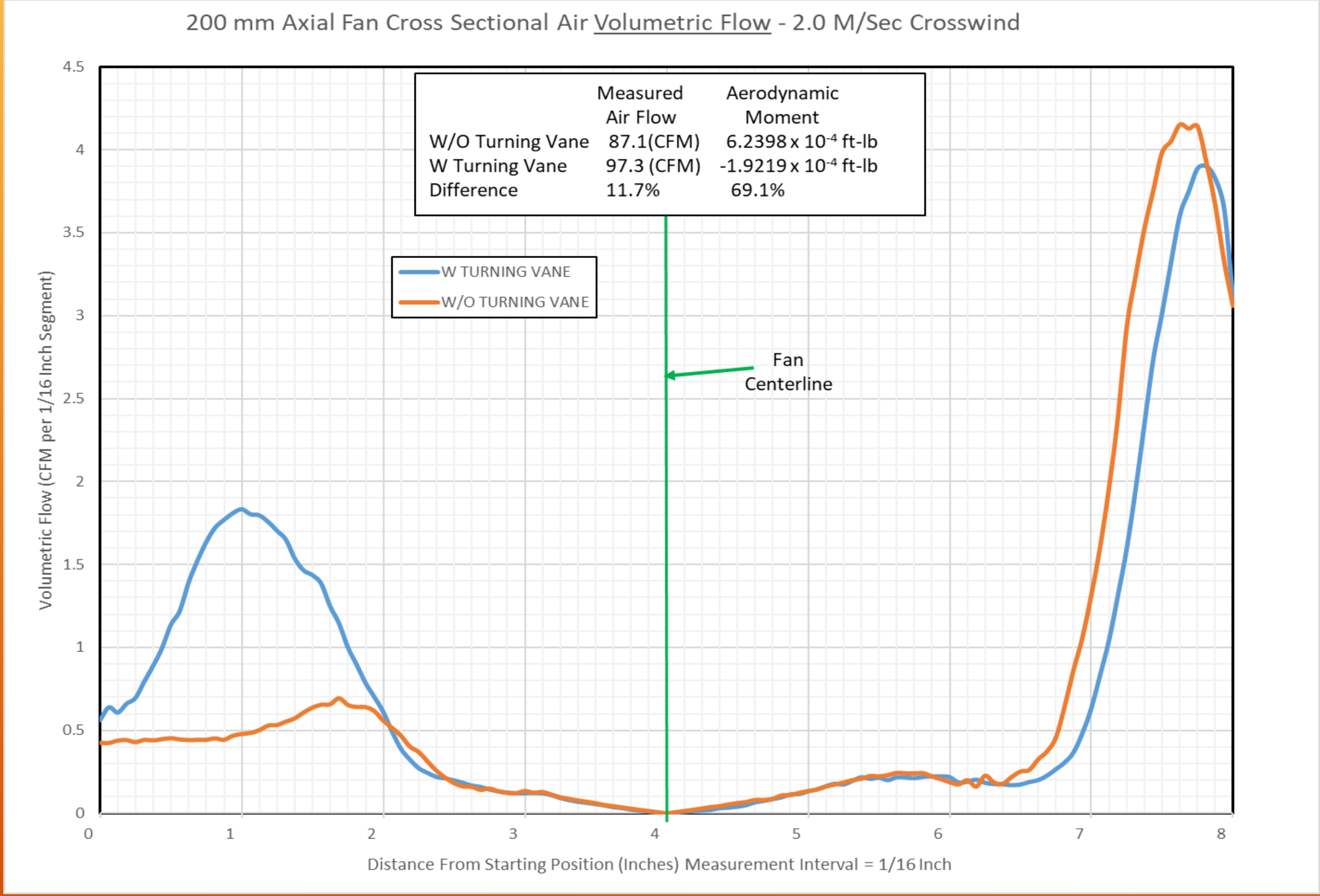
(Assumes an even bladed axial fan.)



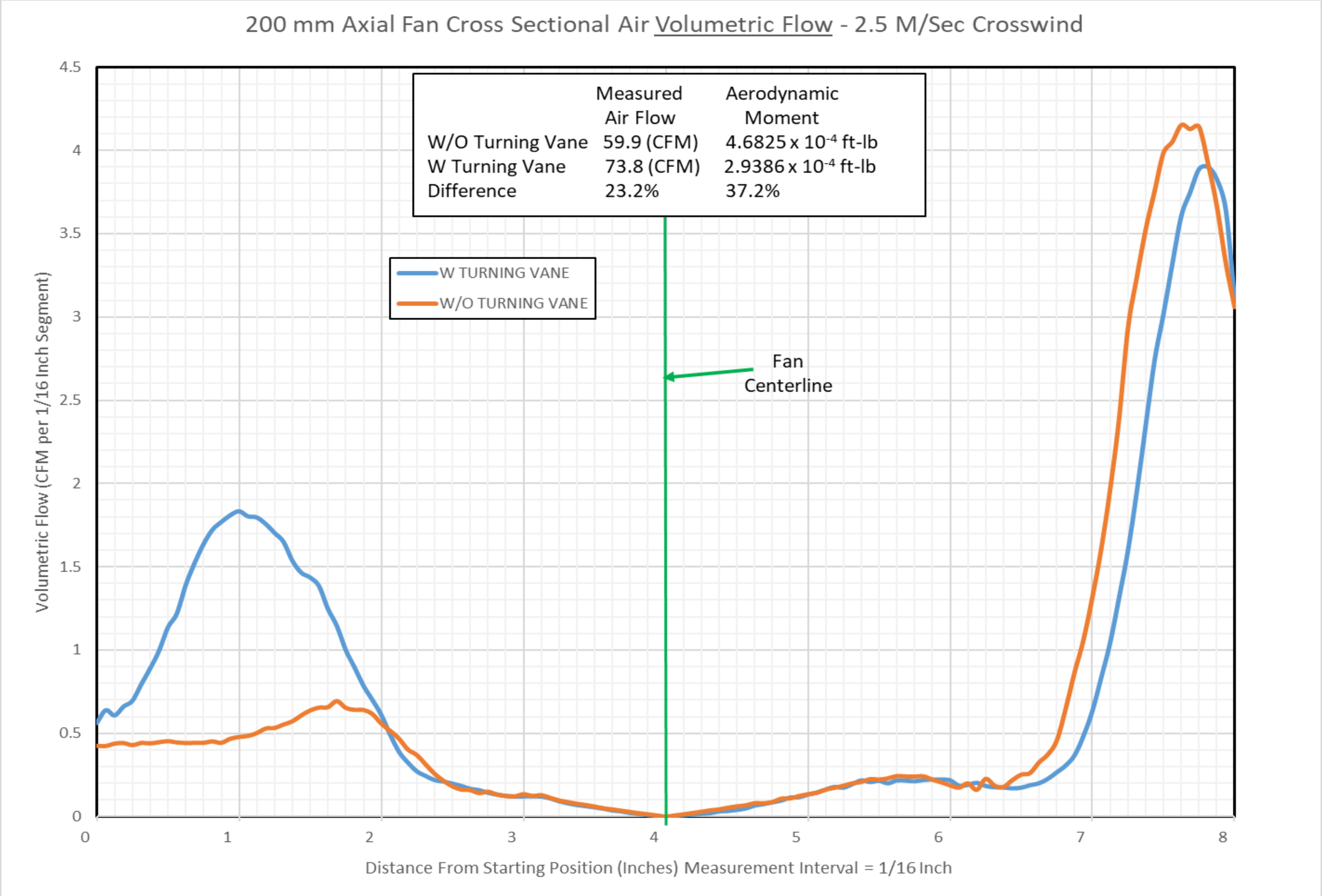
200 mm Axial Fan Cross Sectional Air Volumetric Flow - 0.5 M/Sec Crosswind
Measured Air Flow
Aerodynamic Moment
W/O Turning Vane 164.3 (CFM) 4.3938 x 10-4 ft-lb
W Turning Vane 171.1 (CFM) 3.1077 x 10-5 ft-lb
Difference +4.14% 92.9%
W TURNING VANE
W/O TURNING VANE
Fan Centerline
Volumetric Flow (CFM per 1/16 Inch Segment)
Distance From Starting Position (Inches) Measurement Interval = 1/16 Inch
0
0.5
1
1.5
2
2.5
3
3.5
4
0
1
2
3
4
5
6
7
8

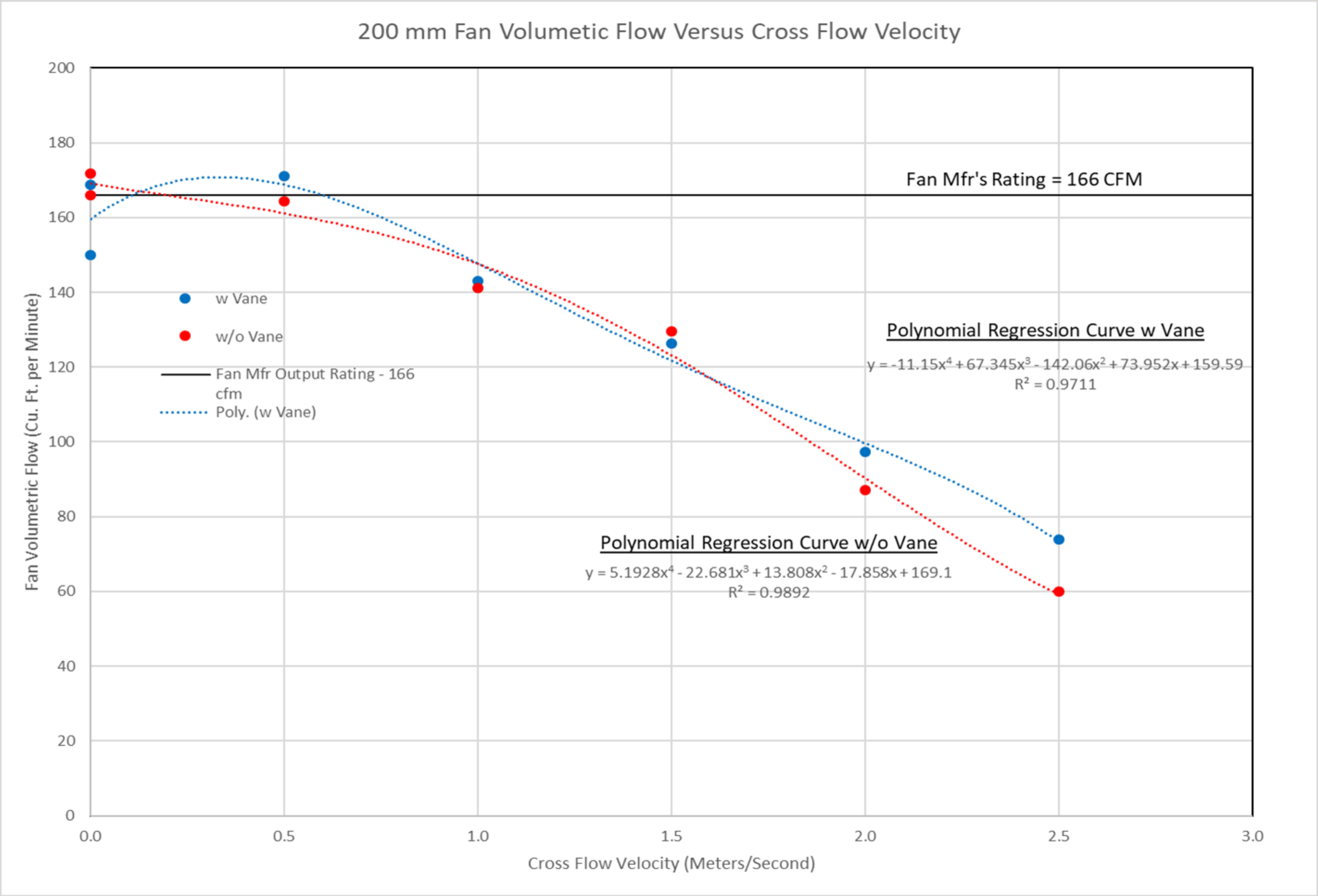

200 mm Axial Fan Cross Sectional Air Volumetric Flow - 1.0 M/Sec Crosswind
Measured Air Flow
Aerodynamic Moment
W/O Turning Vane 141.2 (CFM) 4.8131 x 10-4 ft-lb
W Turning Vane 143.0 (CFM) -7.0846 x 10-5 ft-lb
Difference 1.27% 85.2%
W TURNING VANE
W/O TURNING VANE
Fan Centerline
Volumetric Flow (CFM per 1/16 Inch Segment)
Distance From Starting Position (Inches) Measurement Interval = 1/16 Inch
0
0.5
1
1.5
2
2.5
3
3.5
4
0
1
2
3
4
5
6
7
8

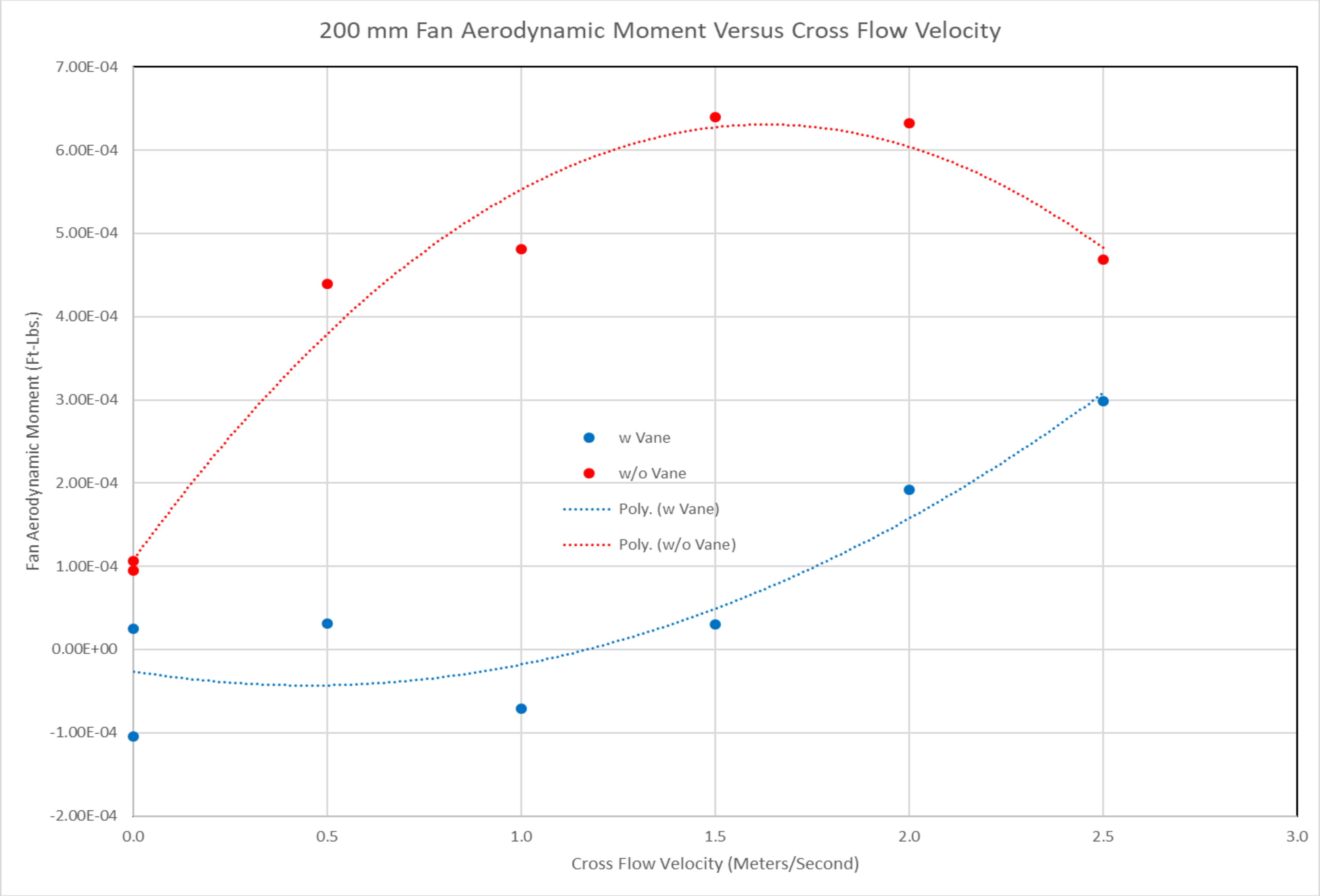

200 mm Axial Fan Cross Sectional Air Volumetric Flow - 1.5 M/Sec Crosswind
Measured Air Flow
Aerodynamic Moment
W/O Turning Vane 141.2 (CFM) 4.8131 x 10-4 ft-lb
W Turning Vane 143.0 (CFM) -7.0846 x 10-5 ft-lb
Difference 2.54% 85.2%
W TURNING VANE
W/O TURNING VANE
Fan Centerline
Volumetric Flow (CFM per 1/16 Inch Segment)
Distance From Starting Position (Inches) Measurement Interval = 1/16 Inch
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
0
1
2
3
4
5
6
7
8


200 mm Axial Fan Cross Sectional Air Volumetric Flow - 2.0 M/Sec Crosswind
Measured Air Flow
Aerodynamic Moment
W/O Turning Vane 87.1(CFM) 6.2398 x 10-4 ft-lb
W Turning Vane 97.3 (CFM) -1.9219 x 10-4 ft-lb
Difference 11.7% 69.1%
W TURNING VANE
W/O TURNING VANE
Fan Centerline
Volumetric Flow (CFM per 1/16 Inch Segment)
Distance From Starting Position (Inches) Measurement Interval = 1/16 Inch
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
0
1
2
3
4
5
6
7
8

17


200 mm Axial Fan Cross Sectional Air Volumetric Flow - 2.5 M/Sec Crosswind
Measured Air Flow
Aerodynamic Moment
W/O Turning Vane 59.9 (CFM) 4.6825 x 10-4 ft-lb
W Turning Vane 73.8 (CFM) 2.9386 x 10-4 ft-lb
Difference 23.2% 37.2%
W TURNING VANE
W/O TURNING VANE
Fan Centerline
Volumetric Flow (CFM per 1/16 Inch Segment)
Distance From Starting Position (Inches) Measurement Interval = 1/16 Inch
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
1
2
3
4
5
6
7
8


200 mm Fan Volumetic Flow Versus Cross Flow Velocity
Fan Volumetric Flow (Cu. Ft. per Minute)
Cross Flow Velocity (Meters/Second)
Fan Mfr's Rating = 166 CFM
w Vane
w/o Vane
Fan Mfr Output Rating - 166 cfm
Poly. (w Vane)
Polynomial Regression Curve w Vane
y = -11.15x⁴ + 67.345x³ - 142.06x² + 73.952x + 159.59
R² = 0.9711
Polynomial Regression Curve w/o Vane
y = 5.1928x⁴ - 22.681x³ + 13.808x² - 17.858x + 169.1
R² = 0.9892
200
180
160
140
120
100
80
60
40
20
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0


200 mm Fan Aerodynamic Moment Versus Cross Flow Velocity
Fan Aerodynamic Moment (Ft-Lbs.)
7.00E-04
6.00E-04
5.00E-04
4.00E-04
3.00E-04
2.00E-04
1.00E-04
0.00E+00
-1.00E-04
-2.00E-04
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Cross Flow Velocity (Meters/Second)
w Vane
w/o Vane
Poly. (w Vane)
Poly. (w/o Vane)

REVISED APPARATUS PROVIDES QUANTITATIVE ANSWERS

- How much does the Axial Wind Turning Vane obstruct air flow when there is no crosswind? **Answer: Cross sectional physical area of the Turning Vane is about 5%, the measured airflow with the Turning Vane mounted is a reduction of 1.74%**
- Is there a break-even point where the axial fan air flow actually improves with the use of the Axial Wind Turning Vane? **Answer: Break-even for the Wind Tunnel test apparatus is below 0.5 M/Sec. Axial Fan output air flow with the Turning Vane attached tracks closely to air flow of axial fan without the Turning Vane.**
- Can the Axial Fan aerodynamic imbalance be measured? **Answer: Yes provided ambient air temperature and pressure measurements are taken.**
- How much does the Axial Wind Turning Vane reduce the Axial Fan aerodynamic imbalance? **Answer: It varies with cross wind velocity but the Axial Wind Turning Vane reduces aerodynamic imbalance by as much as 92.9%.**

CONCLUSION:

THE AXIAL WIND TURNING VANE REDUCES AERODYNAMIC IMBALANCE BY AS MUCH AS 92.9%.

THE *AXIAL FAN INLET WIND-TURNING VANE ASSEMBLY WILL DRAMATICALLY REDUCE YOUR* ACC FAN WIND-RELATED VIBRATIONS.

AXIAL WIND TURNING VANE INTELLECTUAL PROPERTY RIGHTS

- **Axial Fan Inlet Wind-Turning Vane Assembly**, US Patent No. 9,593,885 B2, International Patent Application No. PCT/US2014/053353 (WIPO WO2015031723**)**, granted 2017-03-14.
- Chinese Patent Application Serial No. 201480059969.4 ***Axial Fan Inlet Wind-Turning Vane Assembly,*** Notification to Grant Patent Rights, July 9, 2018
- European Patent Office Intention to Grant a European Patent ***Axial Fan Inlet Wind-Turning Vane Assembly*** – Application No. 14 839 580.9 – 1008, granted 20 Aug 2018

Intellectual Property Rights Inquires – Contact: M. Cuerdon, 720-357-3786, Mcuerdon@aol.com