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COMMITTEE
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NOV 8 – 14, 2019

CONFERENCE
NOV 11 – 14, 2019
EXHIBITION
NOV 10 – 13, 2019

Salt Lake City, Utah

Latest Status of the Rimrock, AZ WINDGRABBER® Prototype Field Test Unit

IMECE Paper 13039

WINDGRABBER®

A Wind Energy Power Enhancer System Technology

By BCK Consulting, LLC
Brett C. Krippene, PE; Presenting

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Latest Status of the Rimrock, AZ WINDGRABBER® Prototype Field Test Unit

Co-Author Presenter

Mr. Brett C. Krippene, BSME, PE
ASME Life Fellow Member
Owner/President
BCK Consulting, LLC
Inventor; WINDGRABBER®
Systems & Technology
7 WINDGRABBER® Patents
3 Clean Coal/LNB Combustion Patents

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IMECE Paper 13039

WINDGRABBER®
A Wind Energy Power Enhancer System Technology

Latest Status of the Rimrock, AZ WINDGRABBER® Prototype Field Test Unit

Opening Statement

As a graduate Marine Engineer from the United States Merchant Marine Academy at Kings Point, Long Island, New York, Class of 1961, and former merchant mariner, sailing as a US Coast Guard-licensed Second Marine Engineering officer on Steam and Motor Vessels of any Tonnage or Horsepower and who maintained such USCG issued license for some 50 years in time, well out into a semi-retirement age of 65 years reached in 2004, and who has spent over that time period, up into present time, working in all phases of the power & process industries in various capacities such as starting up, operating, designing, inventing and trouble-shooting various and differing types of fossil & waste fuel fired, as well as currently emerging and renewable energy conversion systems, I feel that I am uniquely qualified to speak out about the current status of Wind Energy Development in both the United States of America and around the World; especially as to how wind is currently perceived and practiced as a land-based energy conversion system, as well as to how it will continue to be viewed out into the near term future.

Any small sail boat enthusiast, such as myself, who has ever sailed a tall boat in either a spinnaker (Drag) or tacking (Lift) mode before or up into a stout wind and in a following and open sea, can strongly attest to the pure joy that comes with personally experiencing the instantaneous conversion of the raw and available energy in the wind into a truly graceful, cost effective and highly efficient manner of motive power production which has become widely and socially acceptable to many of those who have ever had the actual pleasure of being any part of that exhilarating experience.

This is my true Vision for all aspects of wind energy conversion that I currently have in my mind at this time, and that I will continue to hold in that manner well out into the future.

With these thoughts in mind, I offer the following technical presentation to you today where I will try to explain to you why I have become so obsessed with all types of wind energy conversion systems in general up through this time, and why I have also been trying so diligently to try to influence its future research & development efforts in a more socially friendly direction within these United States.

Following this presentation, I will remain available to anyone who might be interested in sharing their thoughts with my wife and myself concerning the future development of small and intermediately sized wind as a reliable and widely utilized and highly harvestable natural resource, that is on at least a par with that as is currently being experienced by the current solar radiation techniques that are in wide practice around the world and in present time.

Those desiring a flash drive file copy of my power point presentation (i.e.92 MB in size) can share their available flash drive with me now, while I am at the conference, to obtain such a copy, or, those who so wish can obtain a PDF version (i.e. 7.6 MB in size) of my technical presentation by E mail by either picking up a copy of my business card after my presentation, and personally contacting me at some future time and/or by providing me with their current business card or cards. I will send them such a copy by E mail attachment no later than the end of this coming week or before December 1, 2019, latest.

(END)

Lead InTo Technical Presentation

At present, after trying three separate times to acquire adequate Federal grant funding via three separate proposals submitted to the National Science Foundation, and in collaboration with West Texas A & M University, over the years from 2013 through 2015, to conduct an applied research project on WINDGRABBER® that could be financed and conducted at a reasonable scale up of both pilot and demonstration plant system rated sizes so as to be truly and directly scalable to full commercial sizes. I finally gave up on my ability to acquire such adequate government funding and/or technical support and decided to instead proceed forward from that point onward in early 2017 with conducting and accomplishing whatever progress I could make on my WINDGRABBER® technology on my own, working solely with my very supportive wife, Karin, of some 55 years in marriage, to see what we could achieve by ourselves, utilizing our own personal retirement investments, to both finance and conduct the overall endeavor.

This technical presentation today , therefore, largely represents what my wife and I have been able to accomplish with that primary objective in mind, and while working with others as we could afford and/or entice to get involved with us towards that ultimate and end objective.

In Summary, the largest single obstacle that I have personally discovered related to man's being able to truly develop a small or intermediately sized wind energy conversion system, which will be widely received by the general public in a truly socially acceptable manner is with obtaining a better understanding of the air viscosity issues effecting both the resistance to air flow as is experienced within the surrounding WINDGRABBER® like enclosures and duct work and/or within a building or other such enclosure, which might be utilized as a WINDGRABBER® type enclosure, as well as with the boundary layer effects actually experienced both between the surrounding atmosphere and any associated ground clutter effects and the actual wind conversion system or systems being utilized and which actually harvests the available energy from the naturally occurring winds flowing in the ambient environment as well as the ensuing air flows as are captured within the specific wind energy conversion system of interest and as actually flows through and around the actual wind turbine rotor and air bladed system being utilized, as well as within the associated air blades of any specific design, shape and configuration as may be incorporated therein.

November, 2019

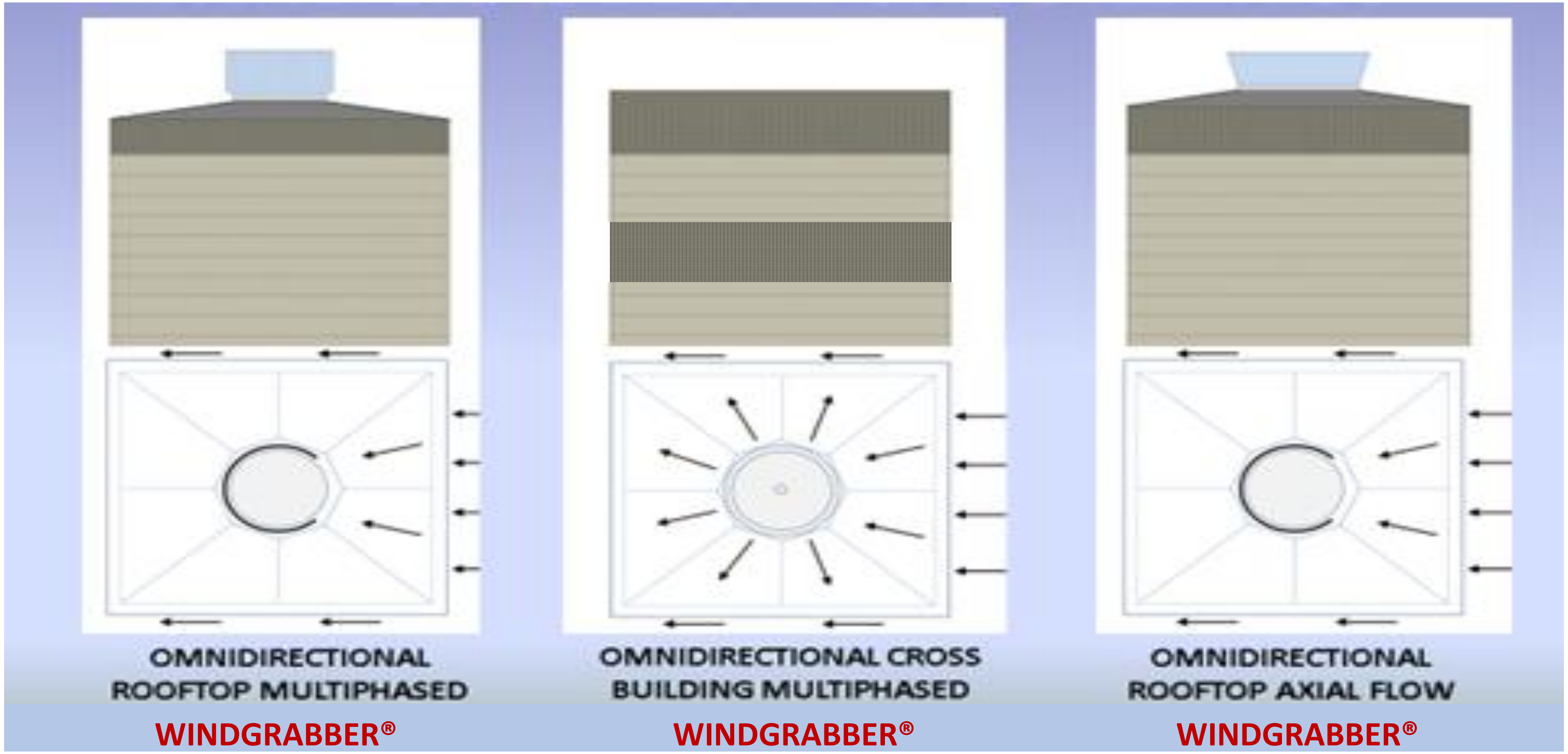
Brett C. Krippene, BSME, PE

ASME Life Fellow

What Is WINDGRABBER® ?

A USPTO Patented Wind Turbine Enclosure System Technology!

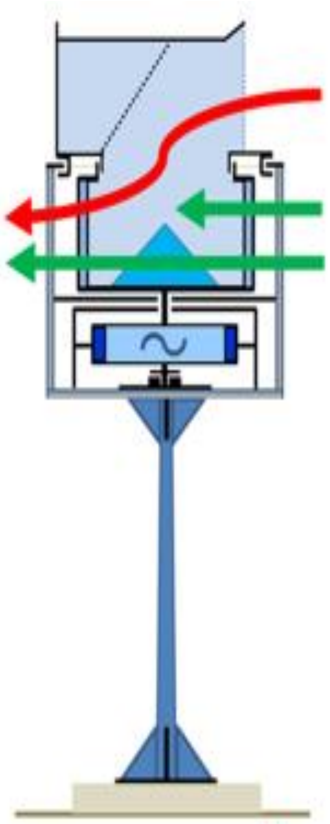
WINDGRABBER® For Large Buildings



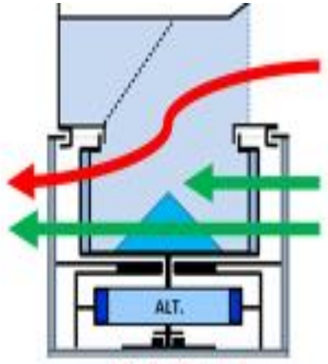
What Is WINDGRABBER® ?

A USPTO Patented Wind Turbine Enclosure System Technology!

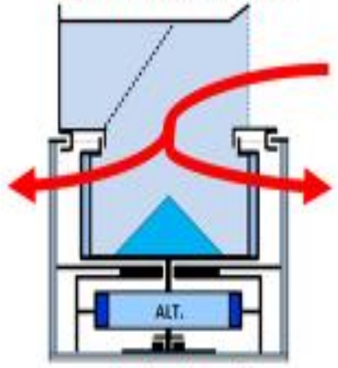
WINDGRABBER® For Homes & Small Office Buildings



Open WINDGRABBER®

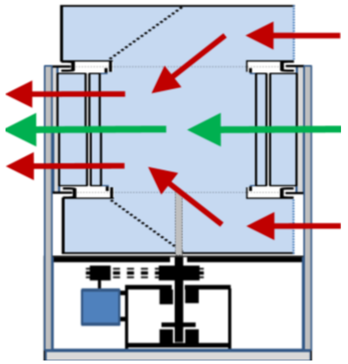


Multi-Phased
Open WINDGRABBER®

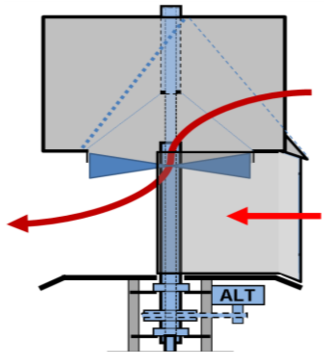


Single Phased
Open WINDGRABBER®

Enclosed WINDGRABBER®



Dual Inlet Multi - Phased
Open WINDGRABBER®



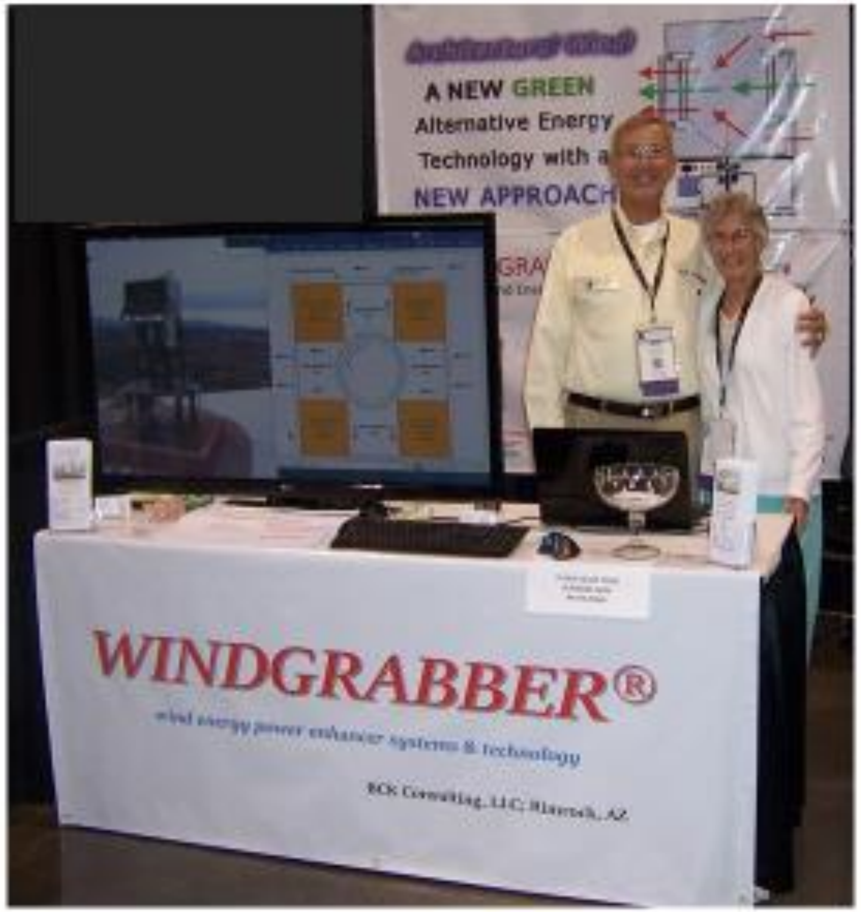
Propeller - Axial Flow
Open WINDGRABBER®

Why WINDGRABBER® ?

- **Environmentally Friendly** – No Fuel Combustion - Wind Energy is the Only Consumable
- **Socially Engineered** - Engineered to Blend into the Background Environment and, Thus, Addresses Most Social Issues Related to Wind
- **Offers Bird Life Protection** - Screened-in Inlet to Enclosure
- **Architecturally Pleasing** – Compatible & Integral with the Building's Design Structure
- **Visual & Audible Impacts Minimized** – Low Speed Moving Components Physically Shielded From View
- **Quiet & Safe Operation** – A Product of the Above
- **Easy to Permit & Install** – Another Product of the Above

Brett & Karin Krippene at the ASME 2019 TURBO EXPO Conference & Exhibition, Phoenix, AZ

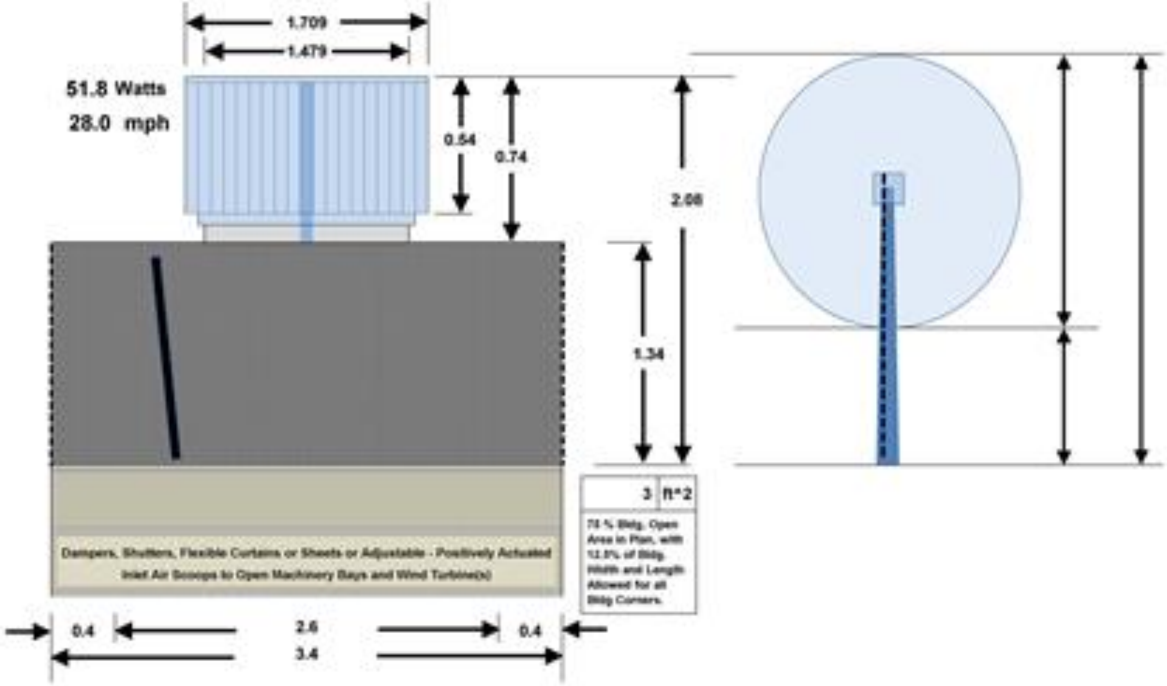
WINDGRABBER®
Is NOT a
Wind Turbine!

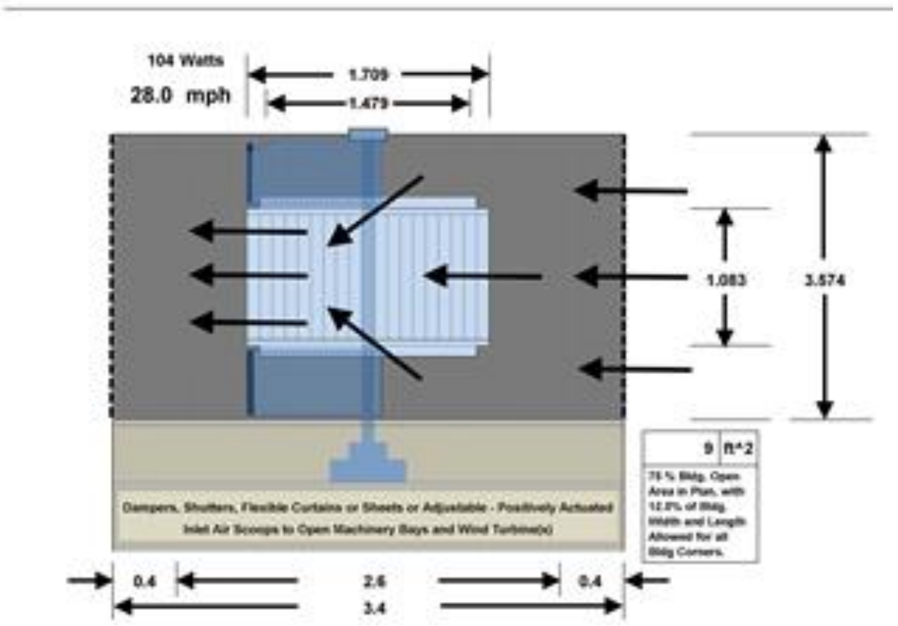


BCK Consulting, LLC

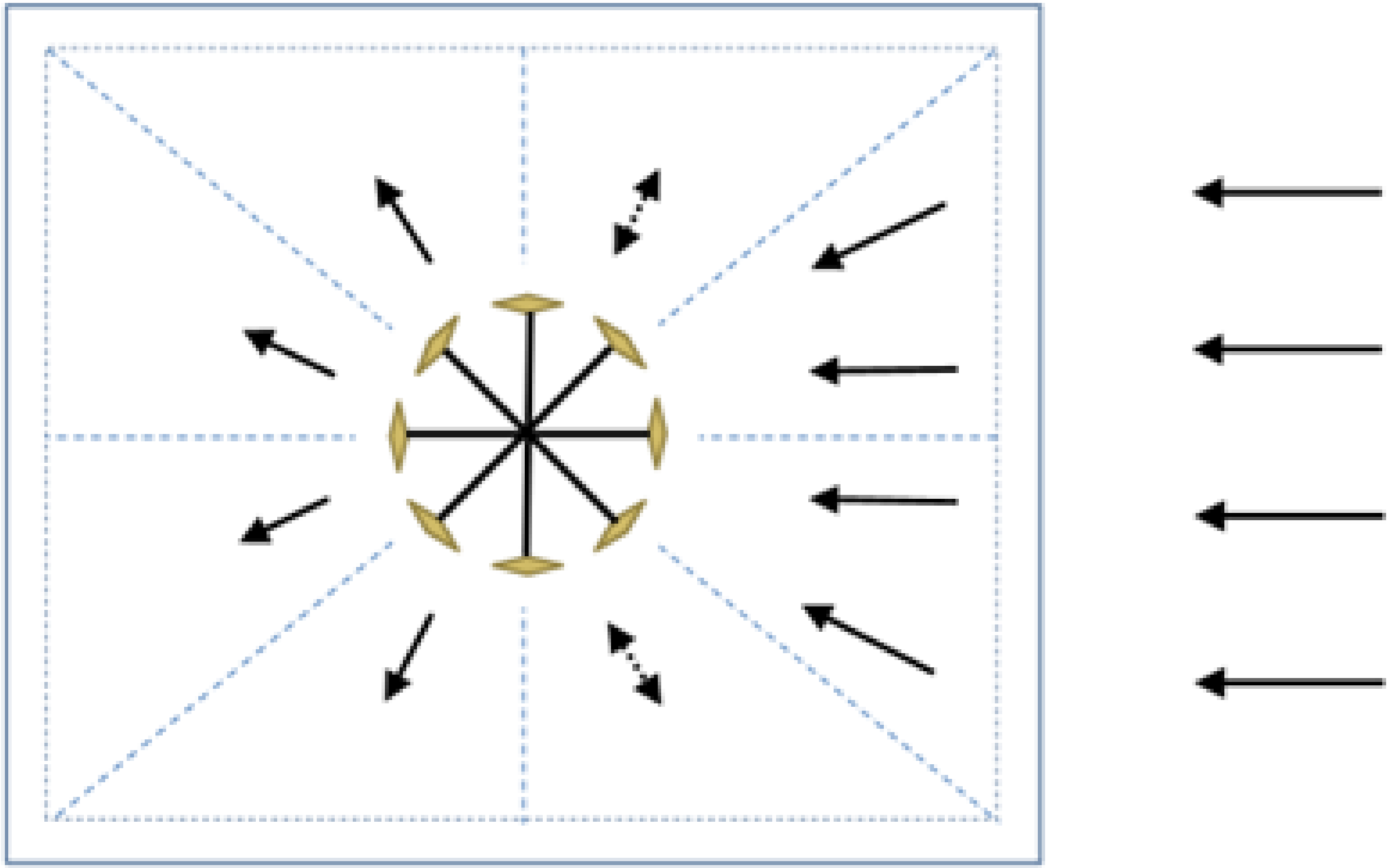
Ever Continuing to Look
For that Special
WINDGRABBER® Wind
Turbine System R & D
Engineer & Designer
at Turbo Expo 2019!

WINDGRABBER® For Centrifugal –Squirrel Cage; Reverse Air or Radial Outflow Type WINDGRABBER® Wind Turbine Systems

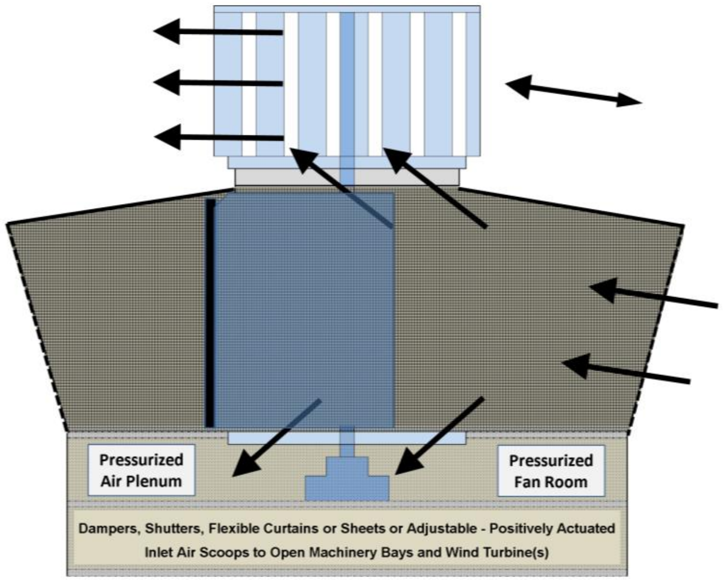




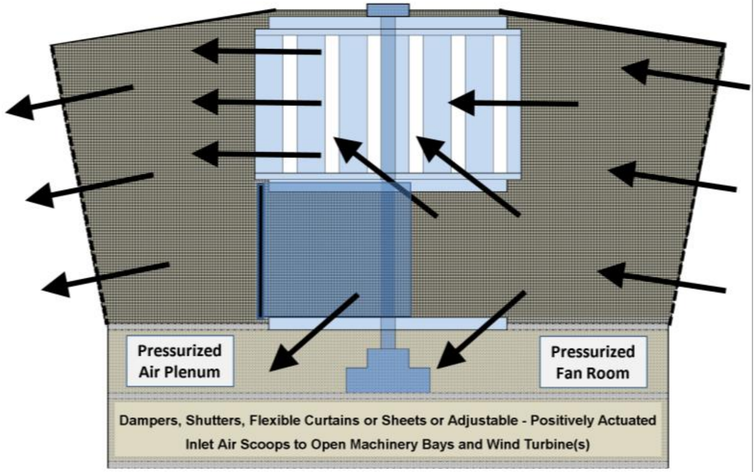
WINDGRABBER® For Advanced H – Rotor Savonius, Darrieus or Giro Mill Type WINDGRABBER® Wind Turbine Systems



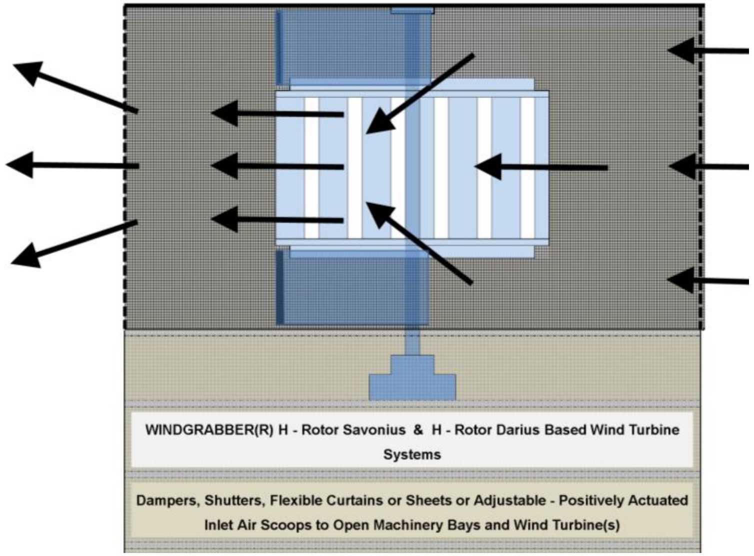
WINDGRABBER® For Advanced H – Rotor Savonius, Darrieus or Giro Mill Type WINDGRABBER® Wind Turbine Systems



Dampers, Shutters, Flexible Curtains or Sheets or Adjustable - Positively Actuated Inlet Air Scoops to Open Machinery Bays and Wind Turbine(s)

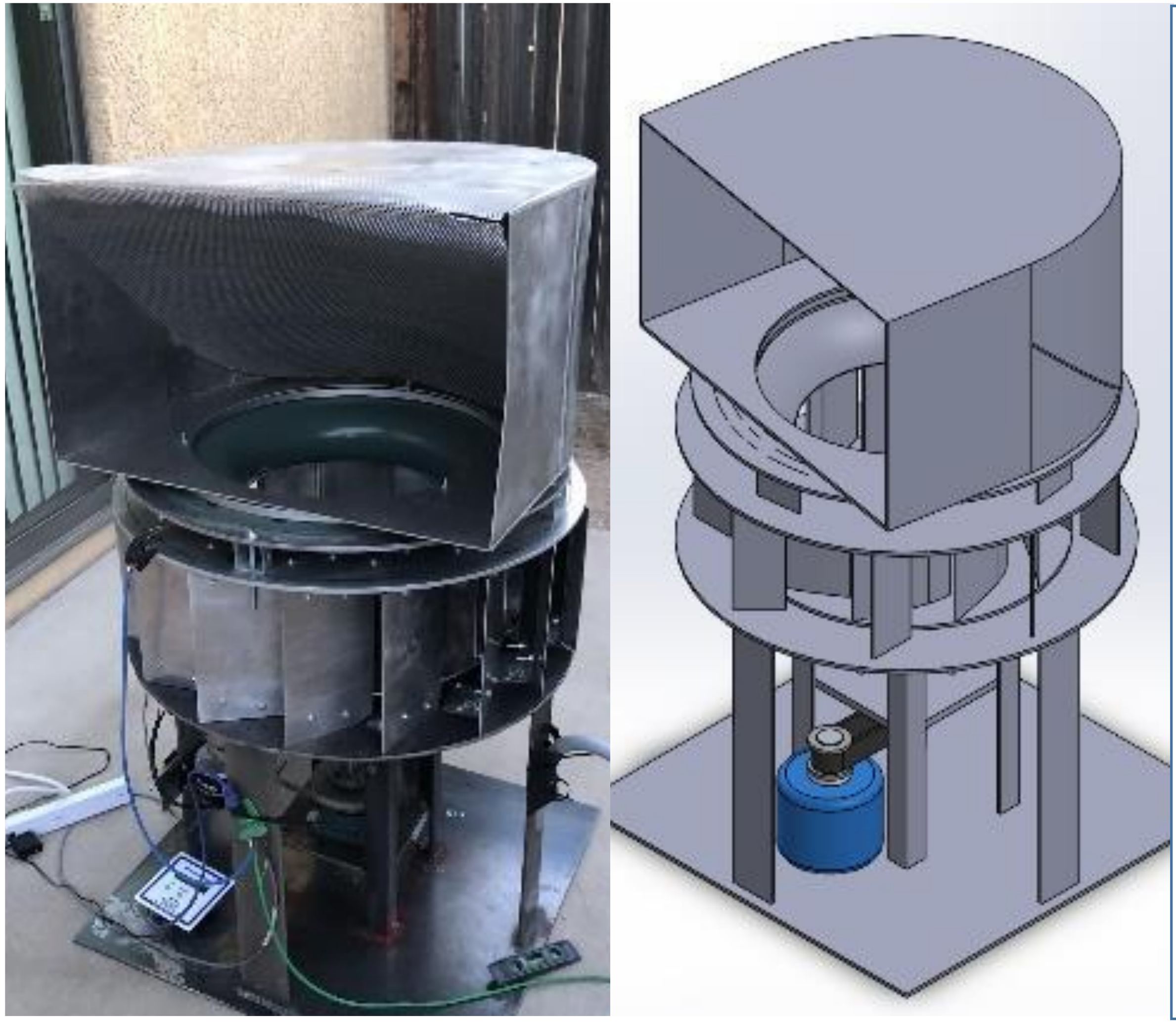


Dampers, Shutters, Flexible Curtains or Sheets or Adjustable - Positively Actuated Inlet Air Scoops to Open Machinery Bays and Wind Turbine(s)



Dampers, Shutters, Flexible Curtains or Sheets or Adjustable - Positively Actuated Inlet Air Scoops to Open Machinery Bays and Wind Turbine(s)

University of Arizona Senior Capstone Project



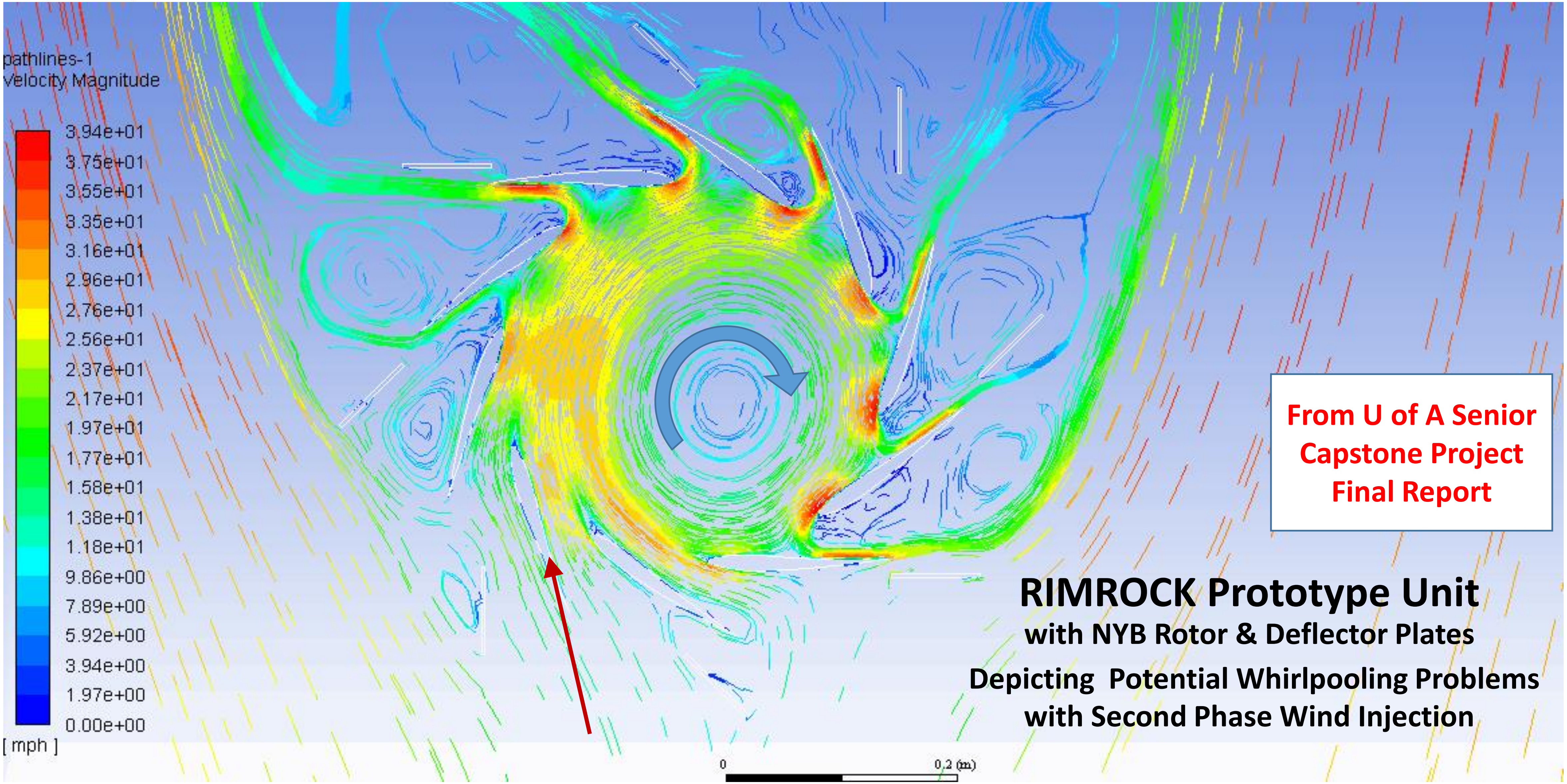
Summary Objective: (Project Conducted 9/1/2017 to 5/1/2018)

- **Design, Fabricate, Start Up and Test a Small U of A Team WINDGRABBER® Conceptually Designed Pilot Plant.**
- **Perform Wind Turbine Rotor and Air Blade Design Studies and Select a Best Design for Pilot Plant Demonstration.**
- **Optimize & Test the Resulting WINDGRABBER® Enclosure and Wind Turbine System for Best Operation & Performance.**

Summary Conclusion:

- **The Results Did Not Meet all the U of A Team's Expectations in terms of Power Production and Other Metrics.**
- **With Better Resources and More Start Up Time (i.e. Better WIND!) Made Available, the U of A team Would Have Achieved all of the Original Goals & Objectives.**
- **This Project, However, Did Provide a Better Foundation for BCK Consulting LLC to Continue on with a Final Phase of WINDGRABBER® Math Modeling and R & D Field Testing as Subsequently Conducted at the Rimrock, AZ Home Test Site.**

WINDGRABBER® *Wind Energy Power Enhancer Systems & Technology*



From U of A Senior Capstone Project Final Report

RIMROCK Prototype Unit

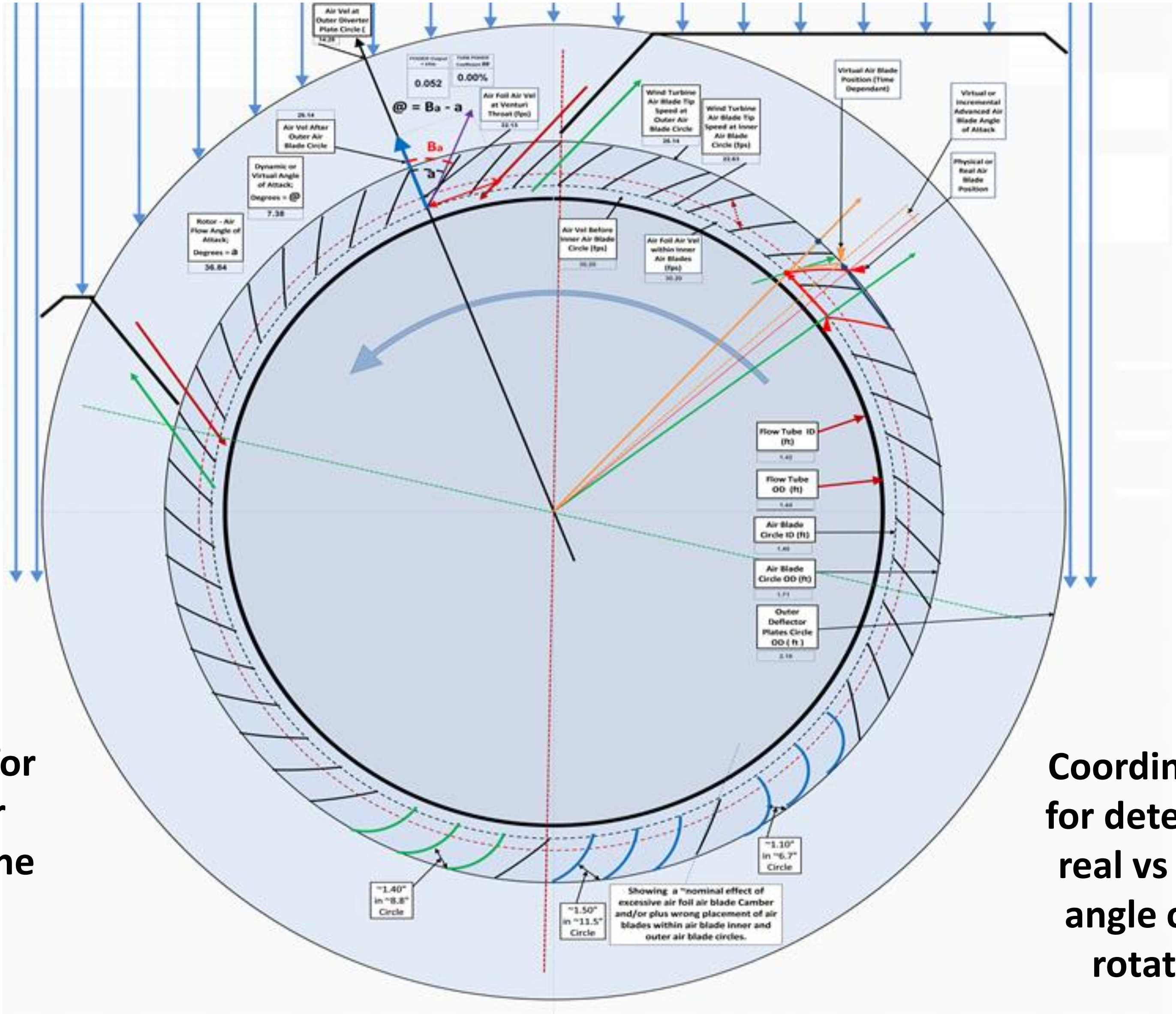
with NYB Rotor & Deflector Plates

Depicting Potential Whirlpooling Problems with Second Phase Wind Injection

WINDGRABBER® *Wind Energy Power Enhancer Systems & Technology*

WINDGRABBER®

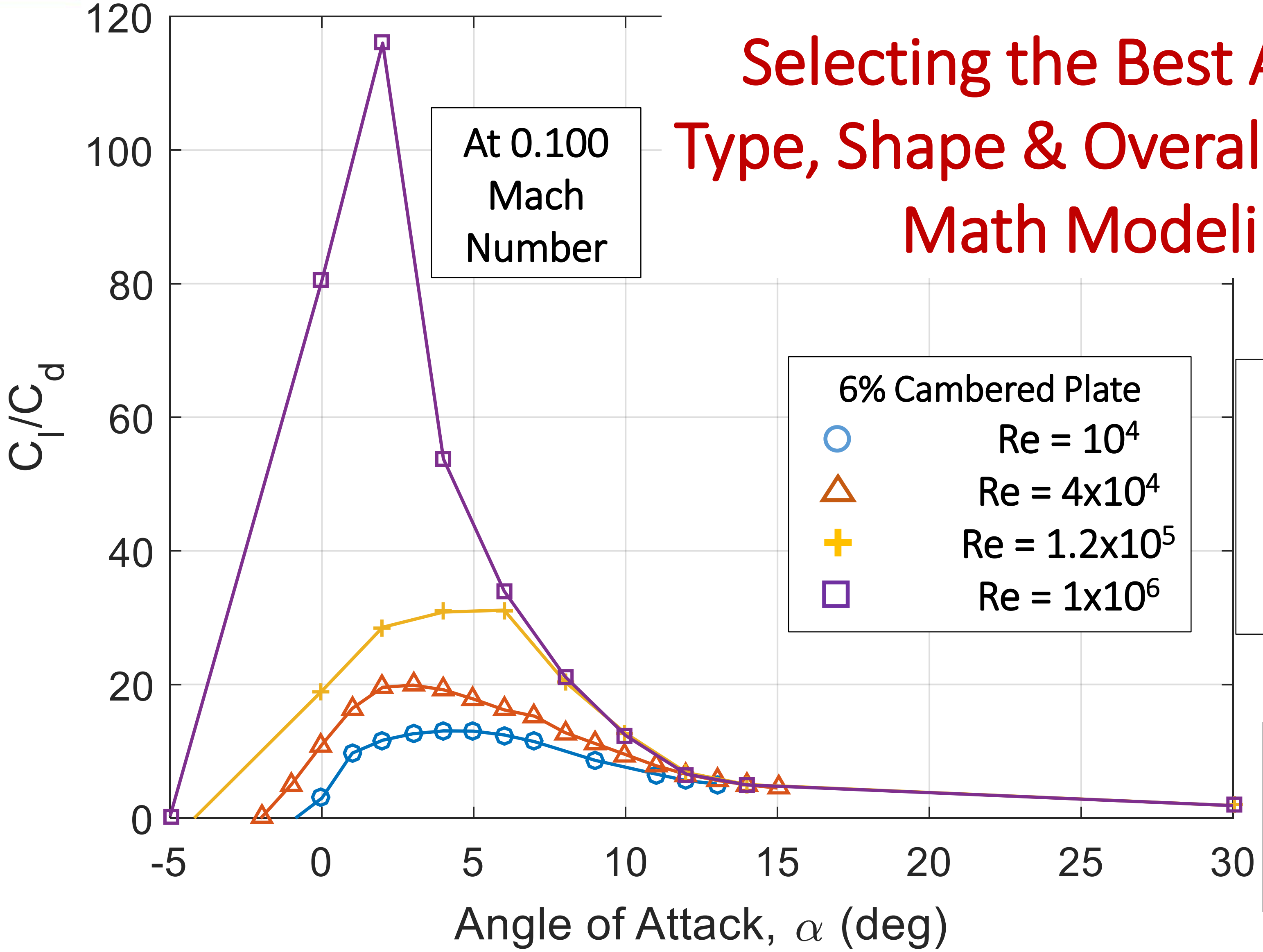
Reverse Air Flow or Radial Outflow Type Wind Turbine Rotor Design with an Air Foil Air Blade Design and Depicting the Virtual Angle of Attack



Coordinating with Czero for Setting the turbine rotor outer tip speed equal to the exiting air velocity to eliminate "fan" effects.

Coordinating with Czero for determination of the real vs virtual air blade angle of attack for the rotating air blades.

Selecting the Best Air Foil Air Blade Type, Shape & Overall Design for Future Math Modeling Studies



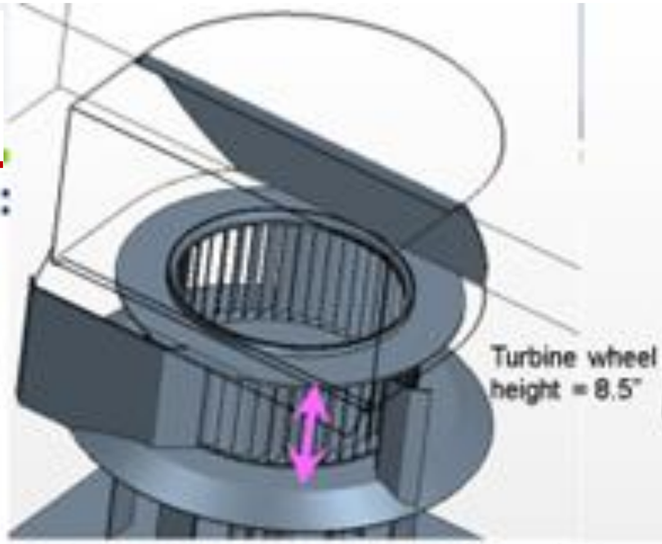
6% Cambered Plate
50 watts WG
100 watts WG
1,000 watts WG
67 kWe WG

Basic Understanding of Airfoil Characteristics at Low Reynolds Numbers (104–105)
Justin Winslow,∗ Hikaru Otsuka,† Bharath Govindarajan,‡ and Inderjit Chopra§
University of Maryland, College Park, Maryland 20742
DOI: 10.2514/1.C034415

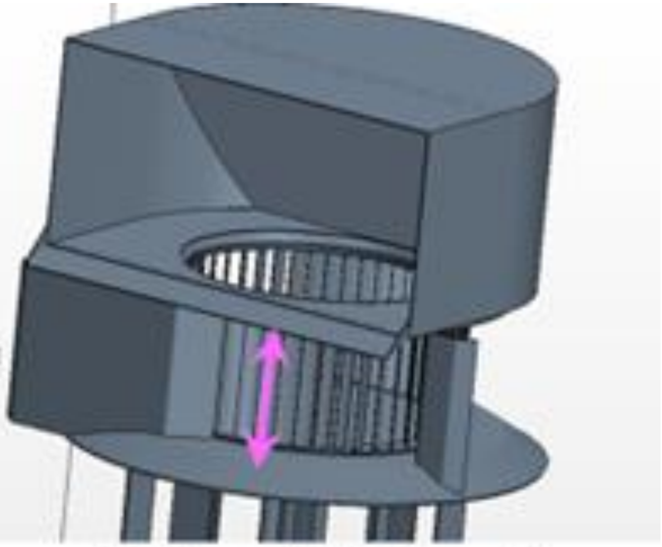
Czero’s Math Modeling Work for WINDGRABBER®

Rotating Frame of Reference CFD: Curved Thin Flat Plate Geometry

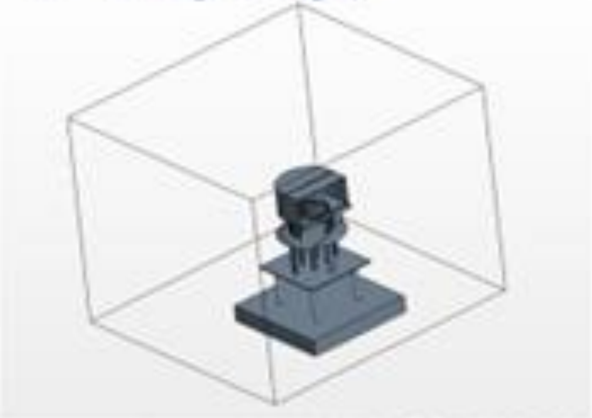
- Model geometry for CFD
- 48 blade rotor, CCW rotation.
    - ID = 17.75"
    - OD = 20.5"
    - Height = 8.5"
- 2 diverter plates
    - 0 deg to left
    - 80 degree to right



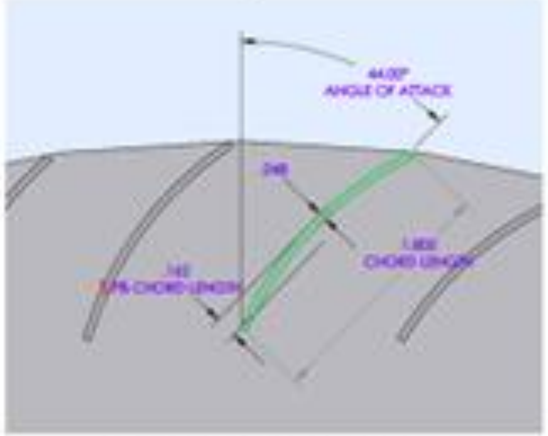
Internal porous deflector plate and turbine



Turbine and diverter walls

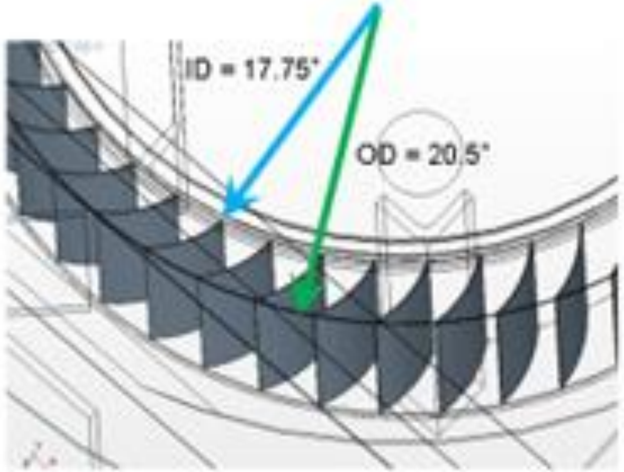


Outside envelope with WINDGRABBER inside



Turbine blade geometry

@ 9% Camber



Static CFD results

- Blade geometry performance
  - Geom 1: Torque = 4.89 N*m
  - NACA 1: Torque = 4.76 N*m
  - Curved Plate: Torque = 6.52 N*m
- Enclosure geometry performance
  - Total flow
    - Geom 1: 1.58 kg/s
    - NACA 1: 1.88 kg/s
    - Curved Plate: 1.79 kg/s
  - Primary flow
    - Geom 1: 1.19 kg/s
    - NACA 1: 1.264 kg/s
    - Curved Plate: 1.273 kg/s
  - Secondary flow
    - Geom 1: 0.39 kg/s
    - NACA 1: 0.619 kg/s
    - Curved plate: 0.523 kg/s

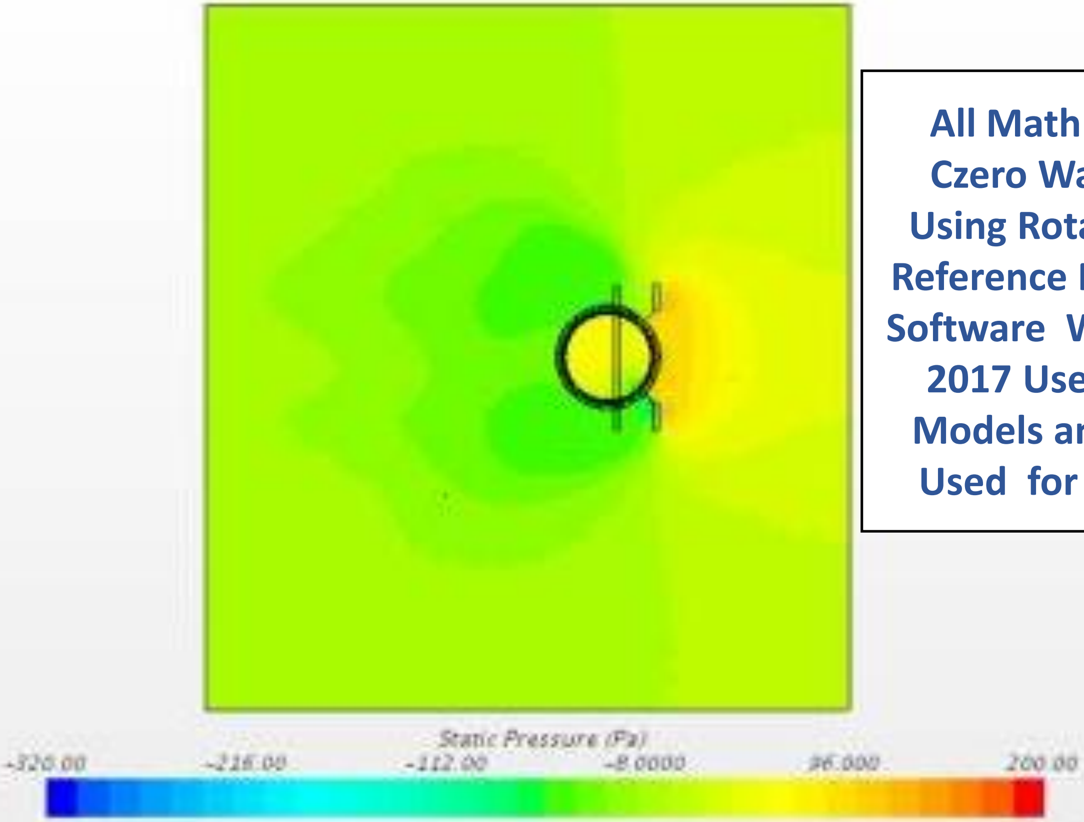
P = Power Calculation
(At most efficient rps point)

P = 2*pi*N*T
T = 2.957 N*m (torque)
N = rev/s = 3.5
P = 65.0 W

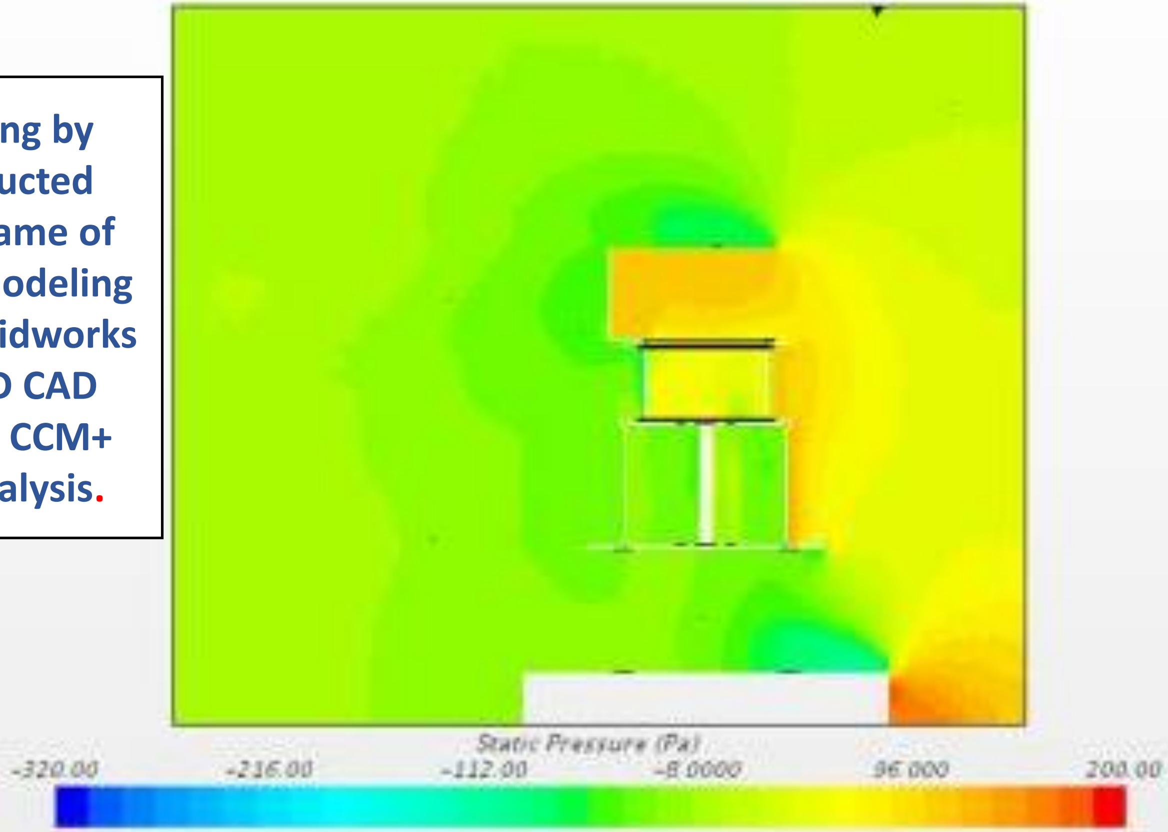
Rotating Frame of Reference CFD results

- Torque and Power
  - Curved Plate 3.0 RPS: 3.4189 N*m (64.4 W)
  - Curved Plate 3.5 RPS: 2.957 N*m (65.0 W)
  - Curved Plate 4.77 RPS: 2.0112 N*m (60.3 W)
- Mass Flow
  - Total flow
    - Curved Plate 3.0 RPS: 1.688 kg/s
    - Curved Plate 3.5 RPS: 1.668 kg/s
    - Curved Plate 4.77 RPS: 1.656 kg/s
  - Primary flow
    - Curved Plate 3.0 RPS: 1.359 kg/s
    - Curved Plate 3.5 RPS: 1.3738 kg/s
    - Curved Plate 4.77 RPS: 1.428 kg/s
  - Secondary flow
    - Curved Plate 3.0 RPS: 0.3286 kg/s
    - Curved Plate 3.5 RPS: 0.2944 kg/s
    - Curved Plate 4.77 RPS: 0.2277 kg/s

Results – Static Pressure Contours



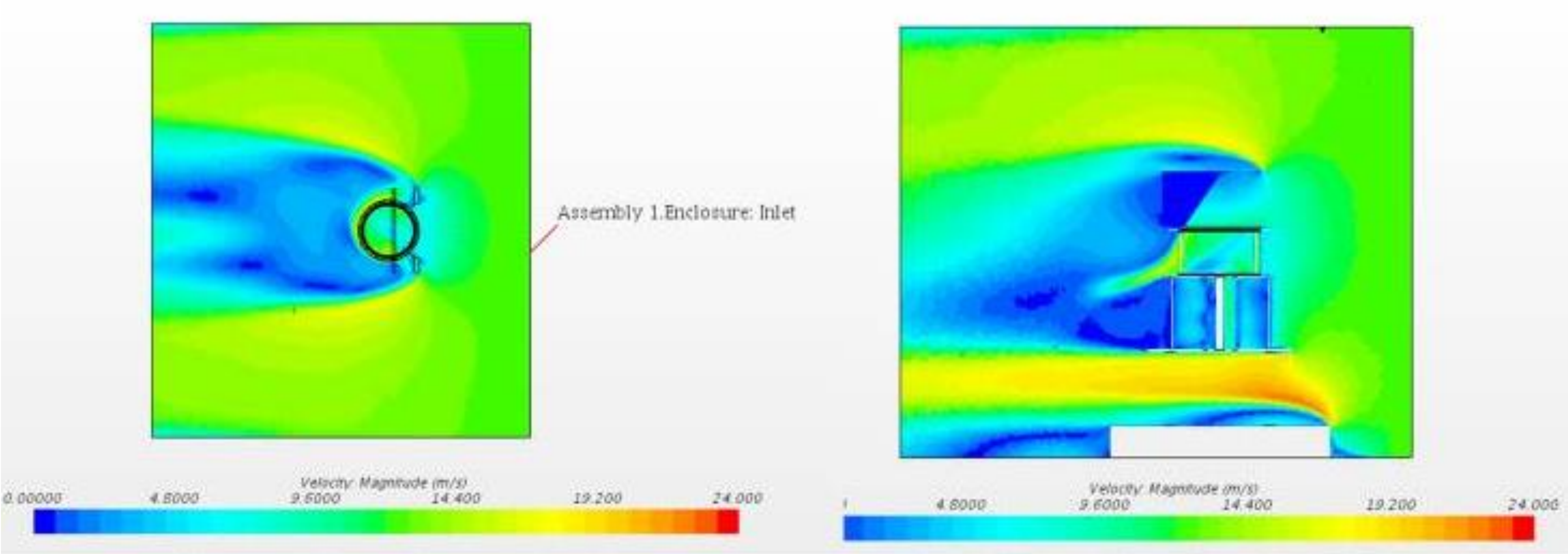
All Math Modeling by Czero Was Conducted Using Rotating Frame of Reference Math Modeling Software With Solidworks 2017 Used for 3D CAD Models and STAR CCM+ Used for CFD Analysis.



Horz. cut through center of rotor

Vertical cut through center of windgrabber

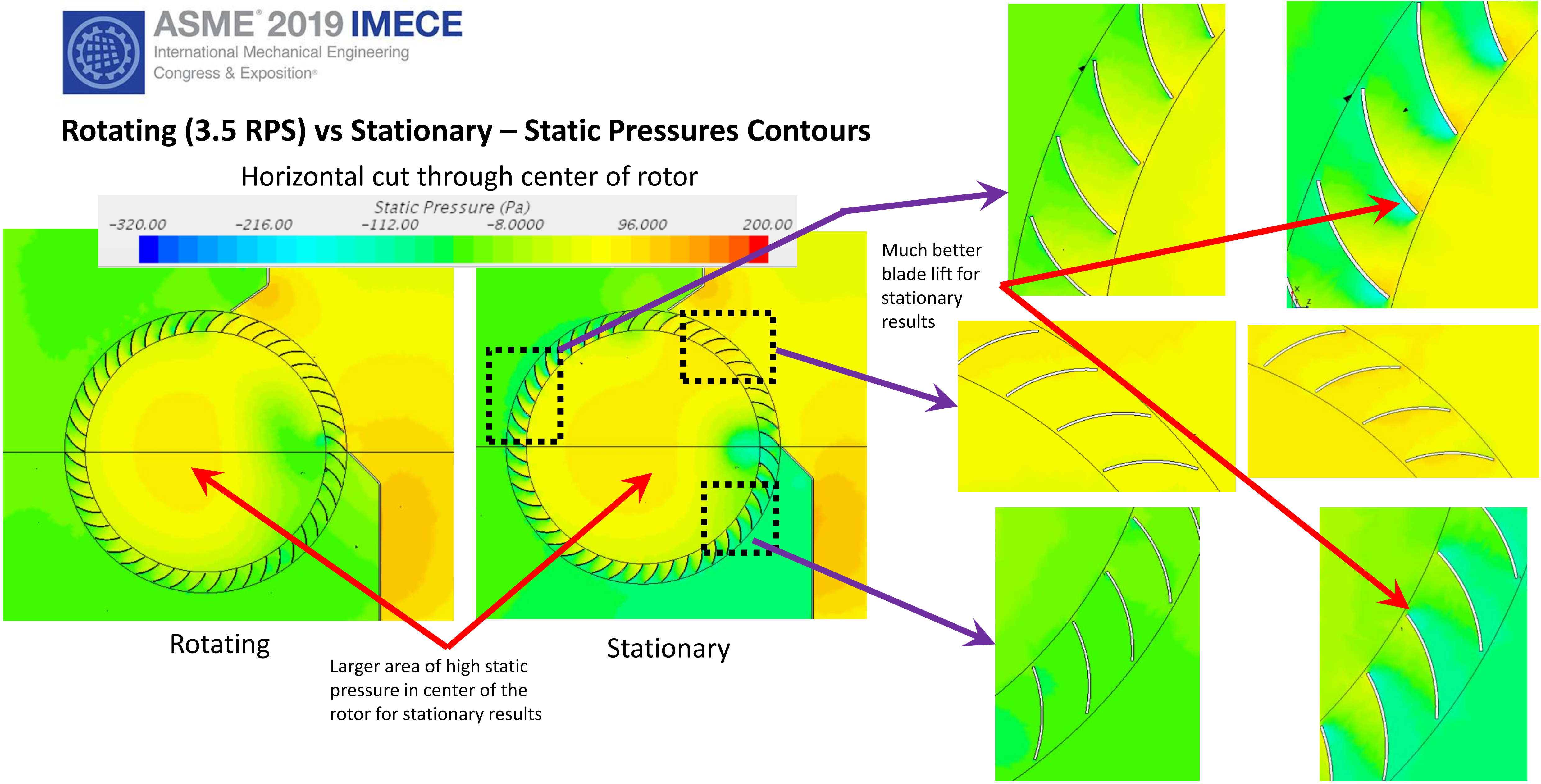
Results – Velocity Contours



Horz. cut through center of rotor

Vertical cut through center of windgrabber

Rotating (3.5 RPS) vs Stationary – Static Pressures Contours



Horizontal cut through center of rotor

Rotating

Stationary

Larger area of high static pressure in center of the rotor for stationary results

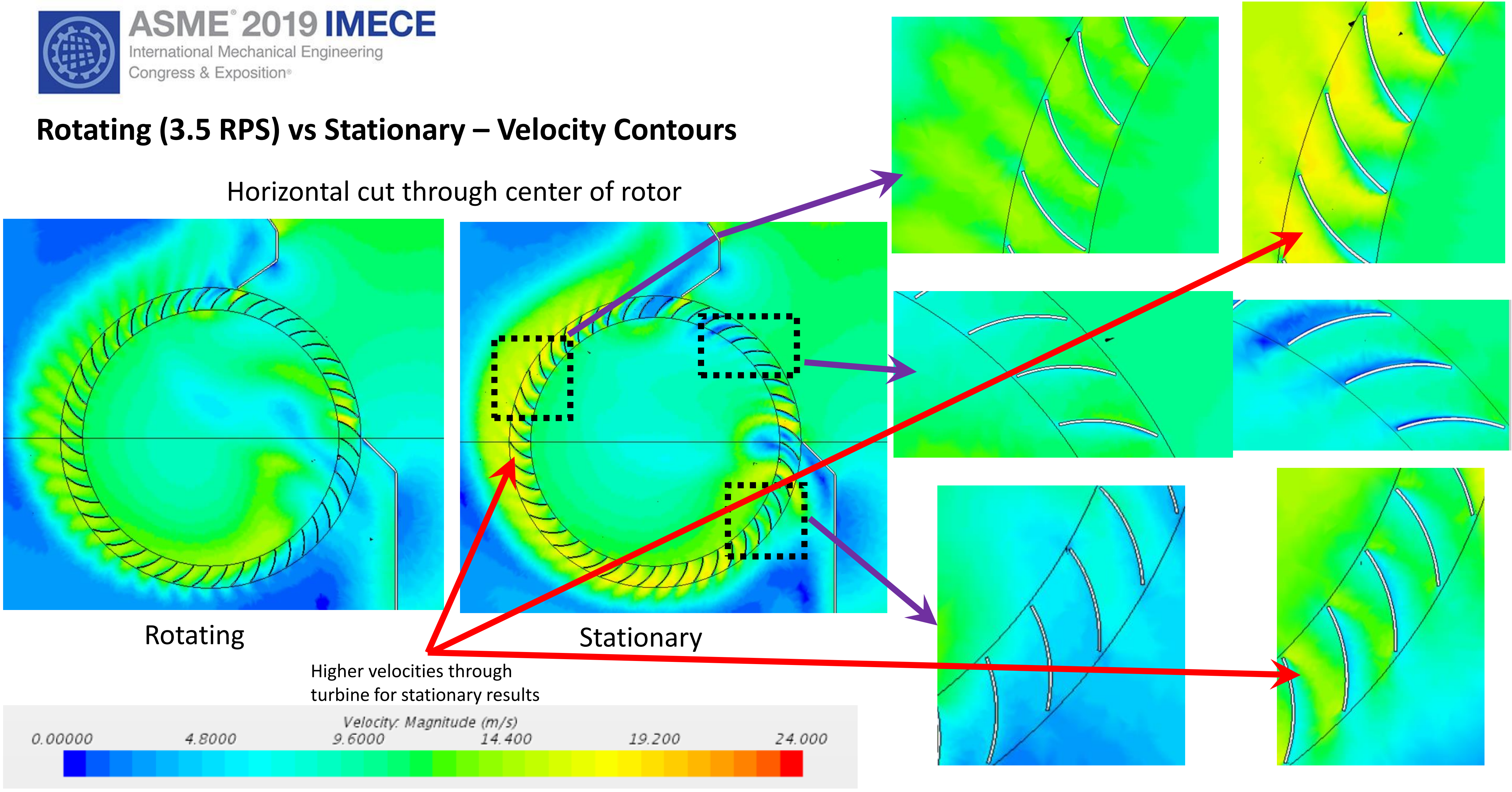
Much better blade lift for stationary results

Details around blades

Rotating

Stationary

Rotating (3.5 RPS) vs Stationary – Velocity Contours



Horizontal cut through center of rotor

Rotating

Stationary

Higher velocities through turbine for stationary results

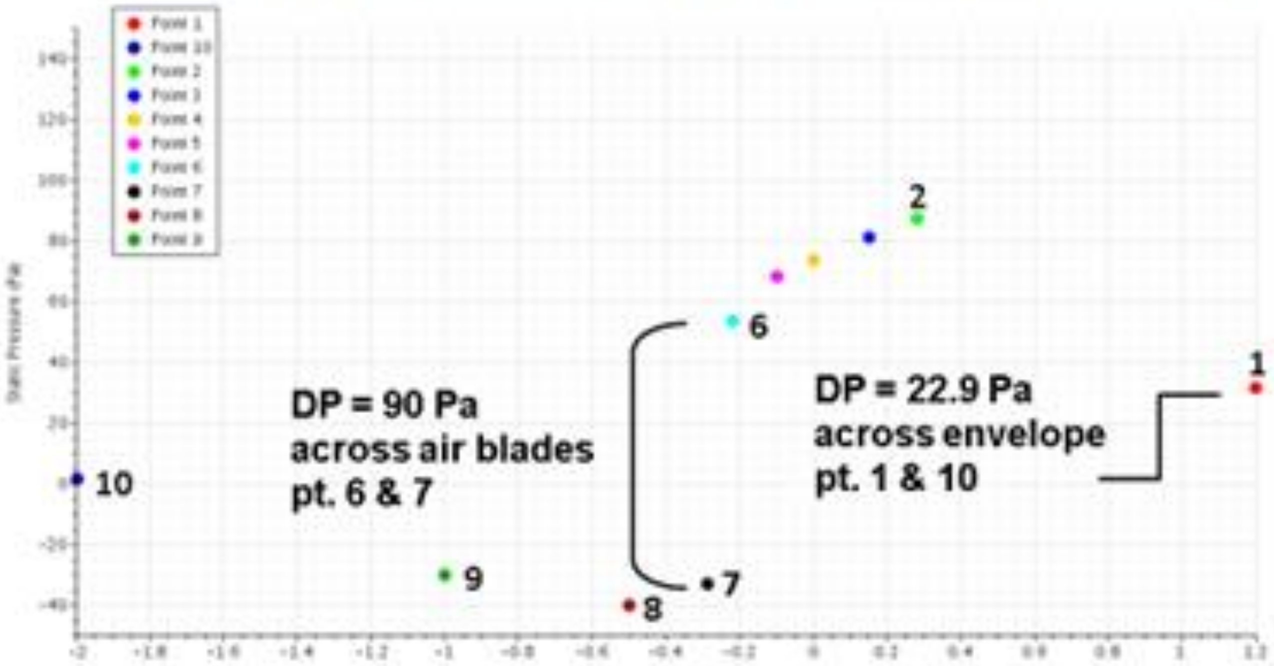
Details around blades

Rotating

Stationary

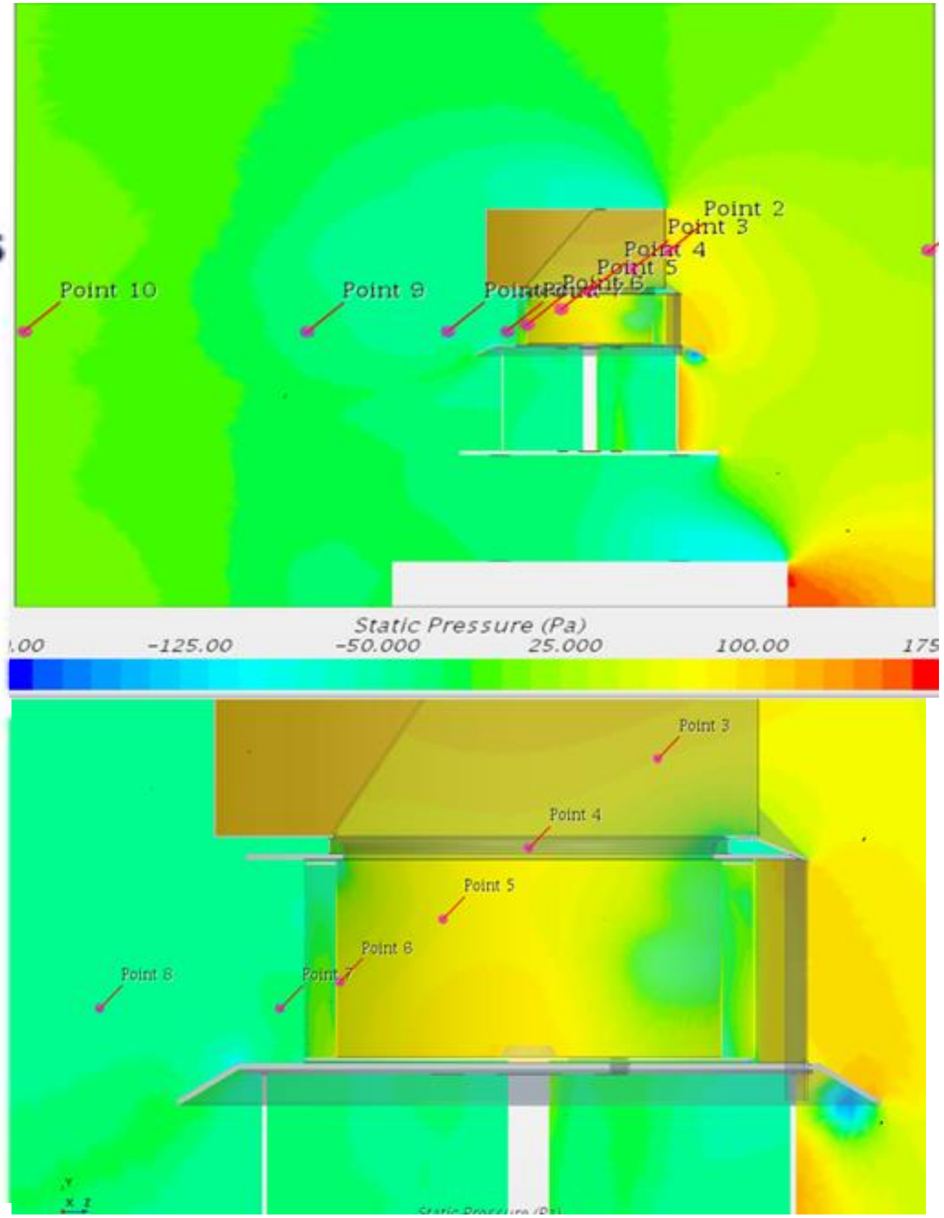
Rotating Case 2c Results – Static Pressures @ 3.5 rps

Pressures at specified points along the WINDGRABBER centerline



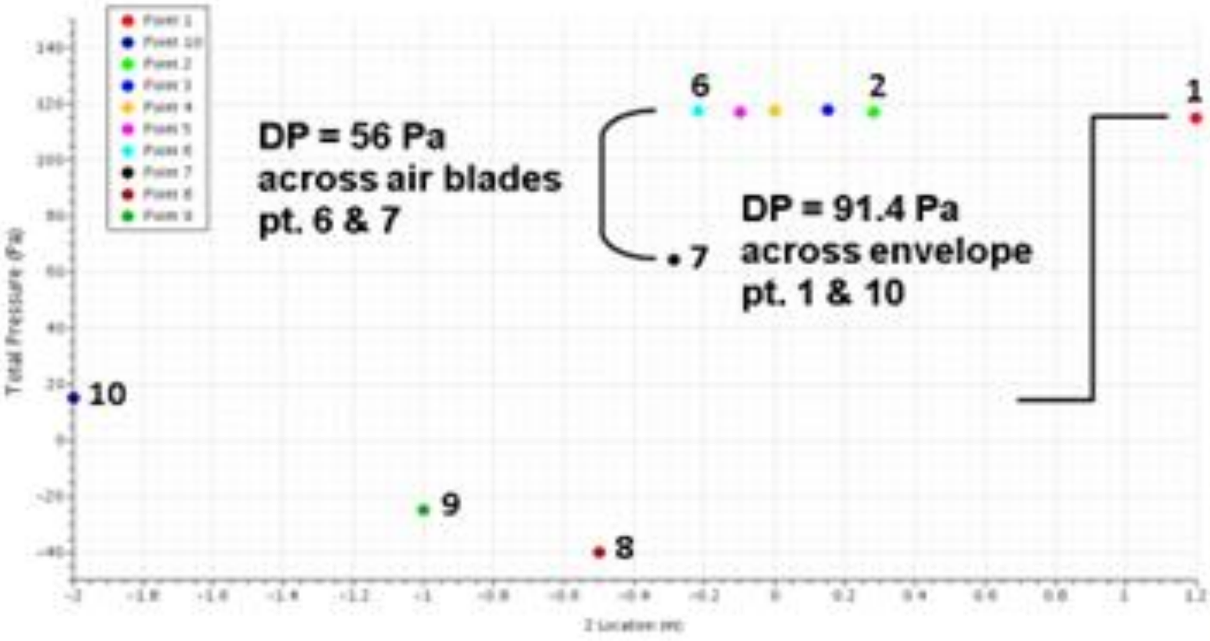
DP = 90 Pa across air blades pt. 6 & 7

DP = 22.9 Pa across envelope pt. 1 & 10



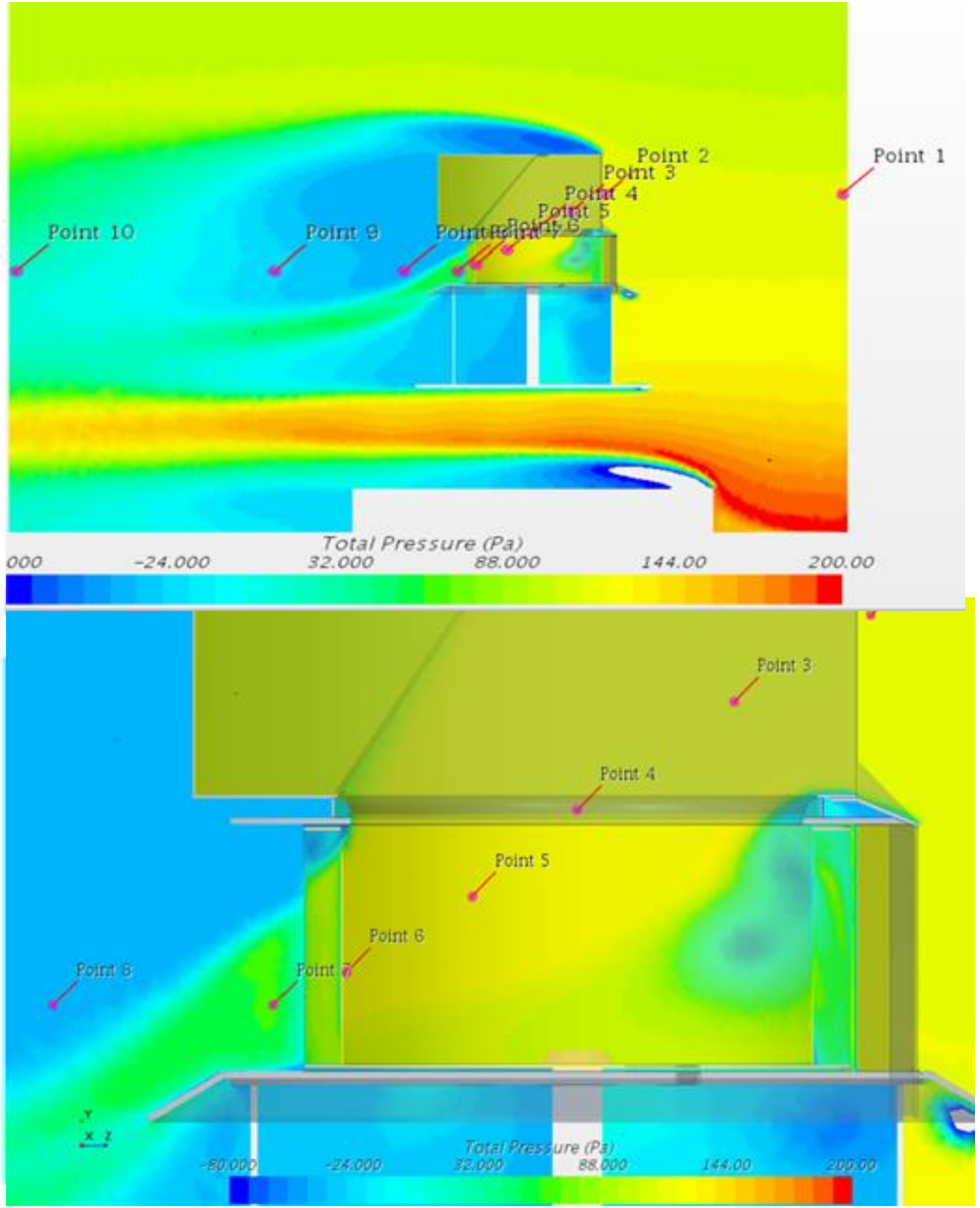
Rotating Case 2c Results – Total Pressures @ 3.5 rps

Pressures at specified points along the WINDGRABBER centerline



DP = 56 Pa
across air blades
pt. 6 & 7

DP = 91.4 Pa
across envelope
pt. 1 & 10



Latest Rimrock, AZ Prototype Field Test Unit

WINDGRABBER® Wind Energy Power Enhancer Systems & Technology

Original Lomanco 14" Roof Top Turbine Ventilator Wind Turbine Rotor Assembly

Original 18.25" OD x 6 11/16" High New York Blower Wind Turbine Rotor Assembly

Original 20.5" OD x 8" High Central Blower Wind Turbine Rotor Assembly with ~17% Camber

Original K – 2 MFC, LLC 20.5" OD x 8.0" High Wind Turbine Rotor Assembly with 6% Camber

Final K – 2 MFC, LLC 20.5" OD x 6.25" High Wind Turbine Rotor Assembly with 9% Camber

Rimrock Prototype Test Unit Results ~ 28 MPH Wind Conditions

Item Description	**Lomanco Wind Turbine Driven Ventilator**	**Lomanco Wind Turbine Driven Ventilator**	**NYB Company Std. Air Foil Bladed Acustafoil Type Blower Wheel**	**Central Blower Co. Specially Designed Forwardly Curved Air Foil Air Bladed Blower Wheel @ 16% Camber**	**K – 2 Mfr. Co. Specially Designed Backwardly Curved Air Foil Air Bladed Rotor @ 6% Camber**	**K – 2 Mfr. Co. Specially Designed Backwardly Curved Air Foil Air Bladed Rotor @ 9% Camber**
No. of Air Blades	**21**	**21**	**10**	**48**	**48**	**48**
Inlet Air Scoop to Flow Tube Area Ratio	**12:1**	**2:1**	**1.55:1**	**1.55:1**	**1.55/1**	**1.55:1**
Inter-Air Blade Open Flow Area – sq. ft.	**1.0**	**1.0**	**0.75**	**1.25**	**2.25**	**1.75**
DC Voltage Output - vdc	**6.7**	**4.75**	**6.6**	**7.1**	**6.8**	**7.6**
Mtr-Gen Elec Power Output in Watts @ 28 MPH Wind Speed	**6.23 watts**	**3.13 watts**	**6 watts**	**7 watts**	**6.5 watts**	**8 watts**
Turbine Mech Power Output in Watts @ 28 MPH Wind Speed	**~22 watts Mech**	**~11 watts Mech**	**~21 watts Mech** **~35 watts @ 50 MPH**	**~24.6 watts Mech**	**~22.8 watts Mech**	**~28 watts Mech**

Motor - Generator DC Power Calculated from P = E^2 / R @ 28.5% Electrical + Timing Belt Efficiency.

Czero Prototype Test Unit Math Modeled Power Output to the Rimrock, AZ Prototype Test Unit Comparison

Czero Air blade torque sum based calculations = 65 watts #

[Effective Wind's Air Power to Air Blades]

Rimrock Prototype Test Unit Electrical Output = 8 Watts *

* [Calc'd From P = E^2 / R From The 300 Watt Motor - Gen. vdc Output]

	Czero	Rimrock		
Aerodynamic Efficiency =	92%	43.2%	54%	(Approximated to Balance Comparison)
[Combined Aero-Mech Efficiencies = 82.8%]				
Mechanical Efficiency =	90%		80%	(2 HD Support Bearings + 12 LB. Rotor)
Speed Increasing System Efficiency =	95%		95%	(60 / 10 Timing Belt Speed Increasing Ratio)
Motor-Generator Electrical Efficiency =	95%		30%	(300 Watt DC Motor Used as DC Gen.)
Remaining Electrical Sys. Efficiency =	95%		Included above	
Total Wind Turbine System Efficiency =	70%		12.3%	

65 Watts x 70% = 45.5 Watts Elec From Motor-Generator.

8 Watts Elec / 12.3% = **65** Watts Effective Wind's Air Power to Air Blades

Czero math modeled wind turbine rotor assembly with a 20.5 inch OD x 8.5 inch ID high rotor wheel with 48 air foil air blades with a 9% camber and an inter-air blade air velocity of ~ 23.6 fps at 28 MPH wind speed and a rotor rotational design speed of 3.5 rps.

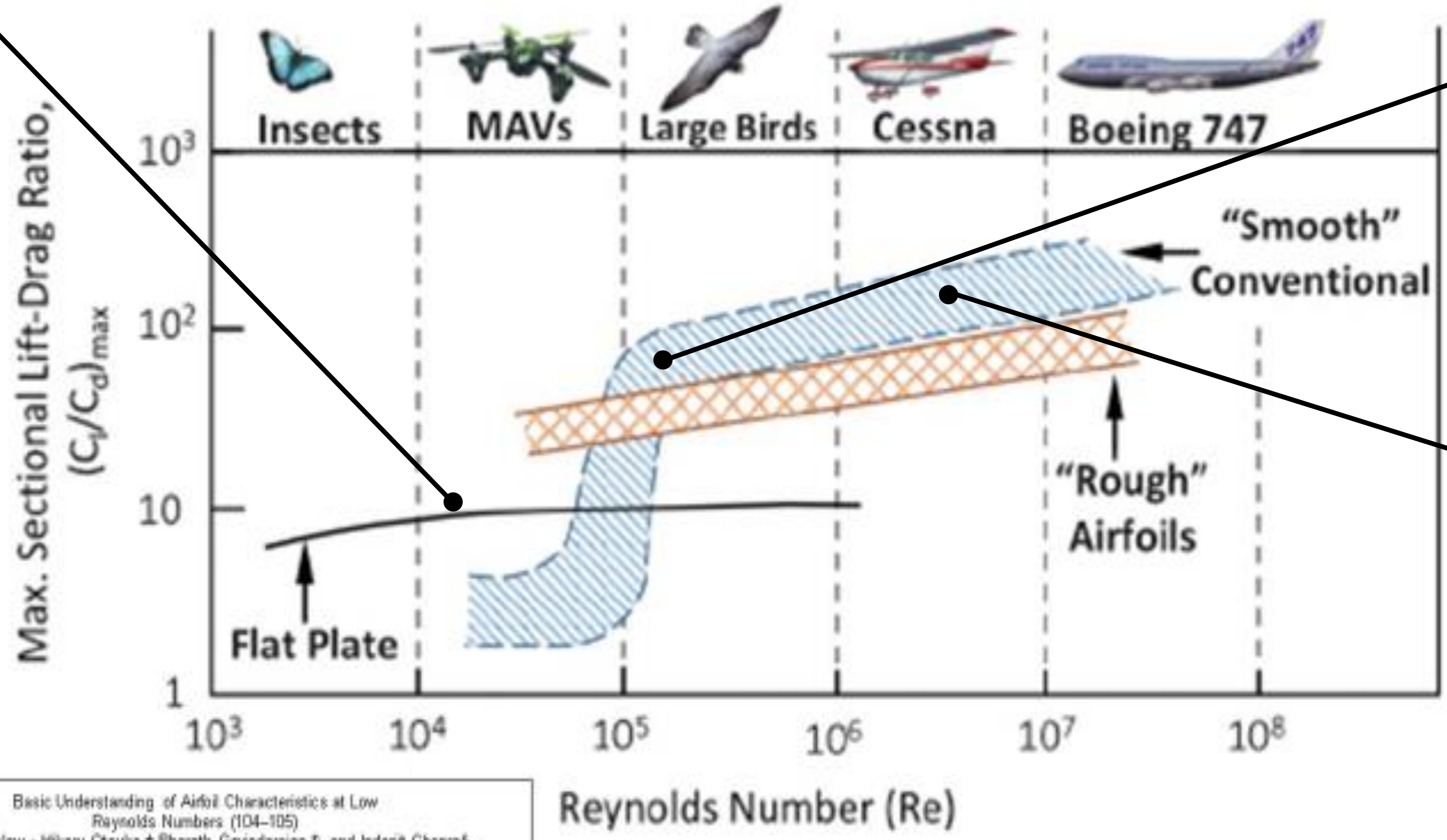
T = 2 x Pi x N x T = 65 watts = The Total power transferred from the wind to the air blades, or, the Total Usable Torque generated by the wind turbine assembly at a tangent to the air foil air blades.

* Note: P = E^2 / R = watts of DC Power Output: from Page 18, Industrial Electricity; Third Edition; by Hester Dawes.

Rimrock, AZ Prototype Test Unit – Air Foil Air Bladed wind turbine rotor assembly with a 20.5 inch OD x 6.25 inch Inside Clear Height rotor wheel with 48 air foil air blades with a 9% camber and an inter-air blade air velocity of ~ 32.13 fps at 28 MPH wind speed and a rotor rotational speed approximated at 3.5 rps.

Overcoming the Reynolds Number Effect on an Air Foil Air Bladed Radial Outflow Wind Turbine

Rimrock, AZ Prototype Test Unit



Next Generation WINDGRABBER® Prototype Test Unit

Full Scale Future WINDGRABBER® Commercialized Unit

Basic Understanding of Airfoil Characteristics at Low
Reynolds Numbers (104–105)
Justin Winslow,∗ Hikaru Otsuka,† Bharath Govindarajan,‡ and Inderjit Chopra§
University of Maryland, College Park, Maryland 20742
DOI: 10.2514/1.C034415

Determination of the Reynolds Number Effect on an Air Foil Air Bladed Radial Outflow Wind Turbine

At a 0.035 Mach Number

WINDGRABBER® Size Rating **48 Air Foil Bladed Rotor Assembly**	**Reynolds No.** **Inter-air foil air blades**	**WINDGRABBER®** **Enclosure Air Resistance & Shock Losses**
• 50 watts	2.8×10^4	$2.0 - 3.6 \times 10^5$
• 100 watts	4.0×10^4	$3.0 - 5.0 \times 10^5$
• 1,000 watts	1.2×10^5	$0.9 - 1.5 \times 10^6$
• 67 kWe	1.0×10^6	$0.7 - 1.3 \times 10^6$
• 100 kWe	1.2×10^6	$0.9 - 1.5 \times 10^7$
• 200 kWe	1.7×10^6	$1.3 - 2.2 \times 10^7$

Rimrock Prototype Test Unit Conclusions

- **WINDGRABBER® Demonstrated Ideas & Concepts Work!**
- **WINDGRABBER® USPTO Patents Proved Valid!**
- **Rimrock Pilot Unit Too Small To Conduct Valid and Potential Future Low Rotor RPM Air Foil type Air Blade R&D Work.**
- **WINDGRABBER® Single and Multi-Phased Wind Systems Both have Future Application.**
- **Pure Air Foil Type Air Blades Do Not Perform Well at Very Low Mach and/or Reynolds Numbers. Jury Still Out on Large Building Applications.**
- **The WINDGRABBER® Passively Actuated Inlet Air Scoop Works as Predicted with Either Single or Dual Flow Types of Multi-Phased Wind WINDGRABBER® Enclosure Systems.**
- **WINDGRABBER® Air Foil Air Bladed Rotors are Quiet!**
- **Future R&D Work Should Focus on the Development of BCK Consulting, LLC, USPTO Patented Advanced H – Rotor Savonius & Darrieus type WINDGRABBER® Wind Turbine Systems for Full Integration with the WINDGRABBER® Enclosure Technology.**
- **A WINDGRABBER® Enclosure & Wind Turbine System is Still Desired to Meet Future Demands for Small & Intermediately Sized Wind Power Systems For Use in Urban & Suburban Areas where Solar Power Alternatives Are Not Viable or Desired.**

• WINDGRABBER® Future Recommendations

- **Assemble A WINDGRABBER® R&D Application Team to Conduct Product Improvement & Cost Engineering Studies to Obtain Future Applied Research & Development Type Grant Funding for Full Commercialization and Application of the WINDGRABBER® Technology for Future Homes, Small Offices and Large Buildings.**
- **Assemble A WINDGRABBER® R&D Test Team to Propose a Next Phase Prototype Test & Demonstration Program In a 3 to 5 kWe Size Range for Next Phase R & D Grant Funding To Conduct a Practicable WINDGRABBER® Enclosure and Wind Turbine System R&D Collaborative Program.**
- **Team to Propose an Advanced Radial Outflow / Cross Flow Type of Wind Turbine System of Either a Pure Squirrel Cage - Air Foil or a Hybrid H - Rotor Savonius Combination Air Foil Lift – Drag Flow Type Design with WINDGRABBER® Wind Energy Power Enhancements.**

BCK Consulting, LLC Future Plans & Objectives

❖WINDGRABBER® USPTO Patented Technology

❖WINDGRABBER® USPTO Trademark

❖WINDGRABBER® Rimrock Prototype Systems & Equipment

- Continue On as Before & Provide Consulting Services to Others
- Team Up With Others to Submit a NSF or USDOE - SBIR or STTR type Program Proposal for 100% R&D Grant Funding
- License Out Technology to Others
- Sell Technology & Prototype Field Test Unit Systems & Equipment
- Auction Off WINDGRABBER® to Highest Bidder or Bidders

ASME® 2019 IMECE
International Mechanical Engineering
Congress & Exposition®

End Of Formal Presentation

Thank you!

Questions?

IMECE 2019-13039

Mr. Brett C. Krippene, PE, ASME Life Fellow, Owner / President,
BCK Consulting, LLC, brettkrippene@att.net, +1-928-592-9483

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International Mechanical Engineering
Congress & Exposition®

Thank you!

More Questions?

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Thank you!

Any More Questions?

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Thank you!

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WINDGRABBER® *Wind Energy Power Enhancer Systems & Technology*

Latest Rimrock, AZ Prototype Field Test Unit Set Up

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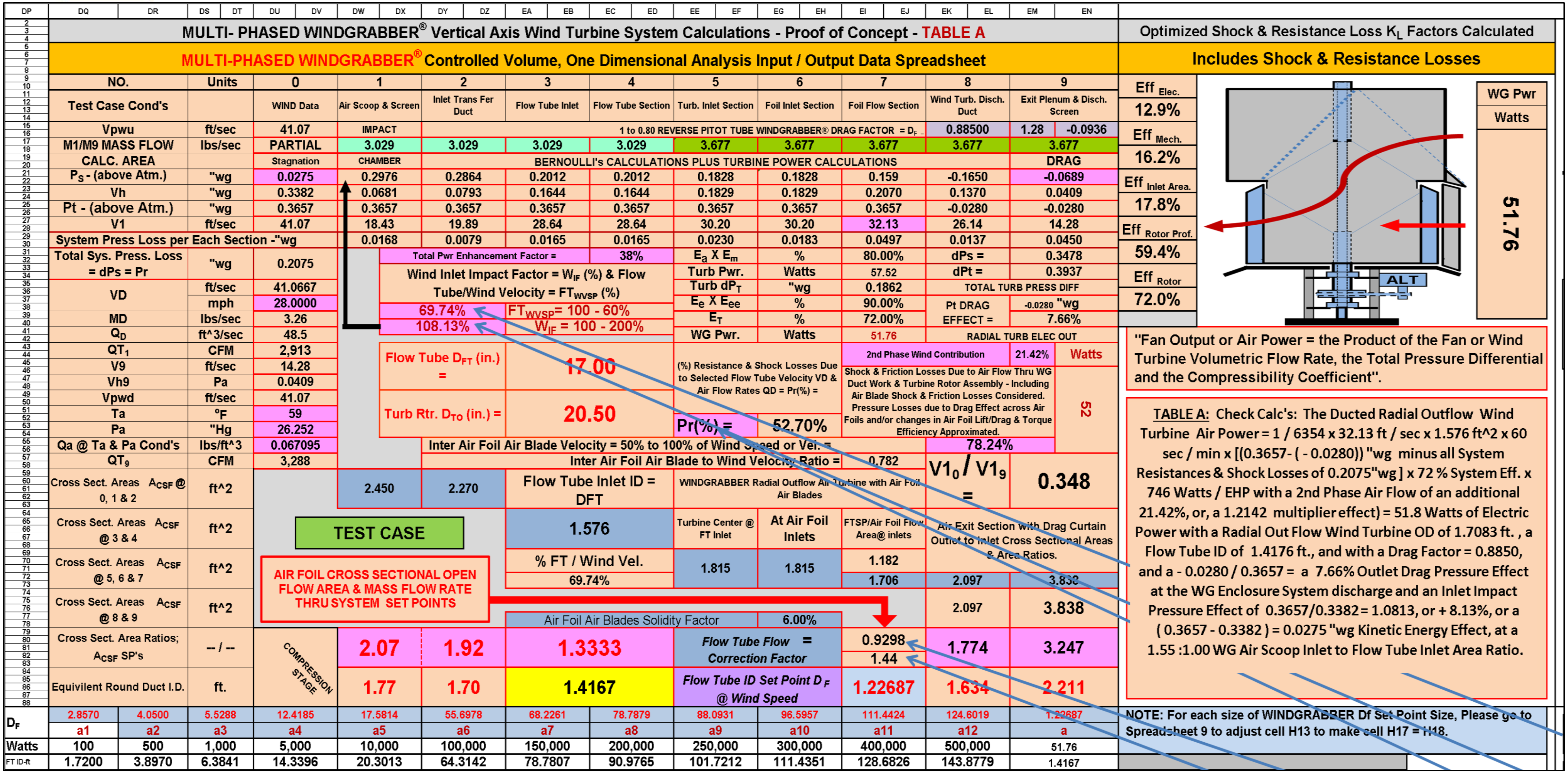

MULTI- PHASED WINDGRABBER® Vertical Axis Wind Turbine System Calculations - Proof of Concept - TABLE A

MULTI-PHASED WINDGRABBER® Controlled Volume, One Dimensional Analysis Input / Output Data Spreadsheet

NO.	Units	0	1	2	3	4	5	6	7	8	9
Test Case Cond's		WIND Data	Air Scoop & Screen	Inlet Trans Fer Duct	Flow Tube Inlet	Flow Tube Section	Turb. Inlet Section	Foil Inlet Section	Foil Flow Section	Wind Turb. Disch. Duct	Exit Plenum & Disch. Screen
Vpwu	ft/sec	41.07	IMPACT	1 to 0.80 REVERSE PITOT TUBE WINDGRABBER® DRAG FACTOR = D_F =						0.88500	1.28 -0.0936
M1/M9 MASS FLOW	lbs/sec	PARTIAL	3.029	3.029	3.029	3.029	3.677	3.677	3.677	3.677	3.677
CALC. AREA		Stagnation	CHAMBER	BERNOULLI's CALCULATIONS PLUS TURBINE POWER CALCULATIONS							DRAG
P_S - (above Atm.)	"wg	0.0275	0.2976	0.2864	0.2012	0.2012	0.1828	0.1828	0.159	-0.1650	-0.0689
Vh	"wg	0.3382	0.0681	0.0793	0.1644	0.1644	0.1829	0.1829	0.2070	0.1370	0.0409
Pt - (above Atm.)	"wg	0.3657	0.3657	0.3657	0.3657	0.3657	0.3657	0.3657	0.3657	-0.0280	-0.0280
V1	ft/sec	41.07	18.43	19.89	28.64	28.64	30.20	30.20	32.13	26.14	14.28
System Press Loss per Each Section -"wg			0.0168	0.0079	0.0165	0.0165	0.0230	0.0183	0.0497	0.0137	0.0450

Total Sys. Press. Loss = dPs = Pr	"wg	0.2075
VD	ft/sec	41.0667
	mph	28.0000
MD	lbs/sec	3.26
Q_D	ft^3/sec	48.5
QT_1	CFM	2,913
V9	ft/sec	14.28
Vh9	Pa	0.0409
Vpwd	ft/sec	41.07
Ta	°F	59
Pa	"Hg	26.252
Qa @ Ta & Pa Cond's	lbs/ft^3	0.067095
QT_9	CFM	3,288

Total Pwr Enhancement Factor = 38%

Wind Inlet Impact Factor = W_{IF} (%) & Flow Tube/Wind Velocity = FT_{WVSP} (%)

69.74% FT_{WVSP}= 100 - 60%

108.13% W_{IF} = 100 - 200%

E_a X E_m	%	80.00%	dPs = 0.3478
Turb Pwr.	Watts	57.52	dPt = 0.3937
Turb dP_T	"wg	0.1862	TOTAL TURB PRESS DIFF
E_e X E_{ee}	%	90.00%	Pt DRAG EFFECT = -0.0280 "wg
E_T	%	72.00%	7.66%
WG Pwr.	Watts	51.76	RADIAL TURB ELEC OUT

Flow Tube D_{FT} (in.) = 17.00

Turb Rtr. D_{TO} (in.) = 20.50

(%) Resistance & Shock Losses Due to Selected Flow Tube Velocity VD & Air Flow Rates QD = Pr(%) =

Pr(%) = 52.70%

2nd Phase Wind Contribution 21.42% Watts 52

Shock & Friction Losses Due to Air Flow Thru WG Duct Work & Turbine Rotor Assembly - Including Air Blade Shock & Friction Losses Considered. Pressure Losses due to Drag Effect across Air Foils and/or changes in Air Foil Lift/Drag & Torque Efficiency Approximated. 78.24%

Inter Air Foil Air Blade Velocity = 50% to 100% of Wind Speed or Vel. =

Inter Air Foil Air Blade to Wind Velocity Ratio = 0.782

$V1_0 / V1_9$ = 0.348

Cross Sect. Areas A_{CSF} @ 0, 1 & 2	ft^2		2.450	2.270	Flow Tube Inlet ID = DFT		WINDGRABBER Radial Outflow Air Turbine with Air Foil Air Blades			
Cross Sect. Areas A_{CSF} @ 3 & 4	ft^2	TEST CASE			1.576	Turbine Center @ FT Inlet	At Air Foil Inlets	FTSP/Air Foil Flow Area@ inlets	Air Exit Section with Drag Curtain Outlet to Inlet Cross Sectional Areas & Area Ratios.	
Cross Sect. Areas A_{CSF} @ 5, 6 & 7	ft^2				% FT / Wind Vel. 69.74%	1.815	1.815	1.182 1.706	2.097	3.838
Cross Sect. Areas A_{CSF} @ 8 & 9	ft^2	AIR FOIL CROSS SECTIONAL OPEN FLOW AREA & MASS FLOW RATE THRU SYSTEM SET POINTS			Air Foil Air Blades Solidity Factor	6.00%			2.097	3.838
Cross Sect. Area Ratios; A_{CSF} SP's	-- / --	COMPRESSION STAGE	2.07	1.92	1.3333	Flow Tube Flow = Correction Factor		0.9298 1.44	1.774	3.247
Equivilent Round Duct I.D.	ft.		1.77	1.70	1.4167	Flow Tube ID Set Point D_F @ Wind Speed		1.22687	1.634	2.211

D_F	2.8570	4.0500	5.5288	12.4185	17.5814	55.6978	68.2261	78.7879	88.0931	96.5957	111.4424	124.6019	1.22687
	a1	a2	a3	a4	a5	a6	a7	a8	a9	a10	a11	a12	a
Watts	100	500	1,000	5,000	10,000	100,000	150,000	200,000	250,000	300,000	400,000	500,000	51.76
FT ID-ft	1.7200	3.8970	6.3841	14.3396	20.3013	64.3142	78.7807	90.9765	101.7212	111.4351	128.6826	143.8779	1.4167

Optimized Shock & Resistance Loss K_L Factors Calculated

Includes Shock & Resistance Losses

Eff $_{Elec.}$	12.9%
Eff $_{Mech.}$	16.2%
Eff $_{Inlet\ Area.}$	17.8%
Eff $_{Rotor\ Prof.}$	59.4%
Eff $_{Rotor}$	72.0%

WG Pwr Watts 51.76

"Fan Output or Air Power = the Product of the Fan or Wind Turbine Volumetric Flow Rate, the Total Pressure Differential and the Compressibility Coefficient".

TABLE A: Check Calc's: The Ducted Radial Outflow Wind Turbine Air Power = 1 / 6354 x 32.13 ft / sec x 1.576 ft^2 x 60 sec / min x [(0.3657- (- 0.0280)) "wg minus all System Resistances & Shock Losses of 0.2075"wg] x 72 % System Eff. x 746 Watts / EHP with a 2nd Phase Air Flow of an additional 21.42%, or, a 1.2142 multiplier effect) = 51.8 Watts of Electric Power with a Radial Out Flow Wind Turbine OD of 1.7083 ft. , a Flow Tube ID of 1.4176 ft., and with a Drag Factor = 0.8850, and a - 0.0280 / 0.3657 = a 7.66% Outlet Drag Pressure Effect at the WG Enclosure System discharge and an Inlet Impact Pressure Effect of 0.3657/0.3382 = 1.0813, or + 8.13%, or a (0.3657 - 0.3382) = 0.0275 "wg Kinetic Energy Effect, at a 1.55 :1.00 WG Air Scoop Inlet to Flow Tube Inlet Area Ratio.

NOTE: For each size of WINDGRABBER Df Set Point Size, Please go to Spreadsheet 9 to adjust cell H13 to make cell H17 = H18.

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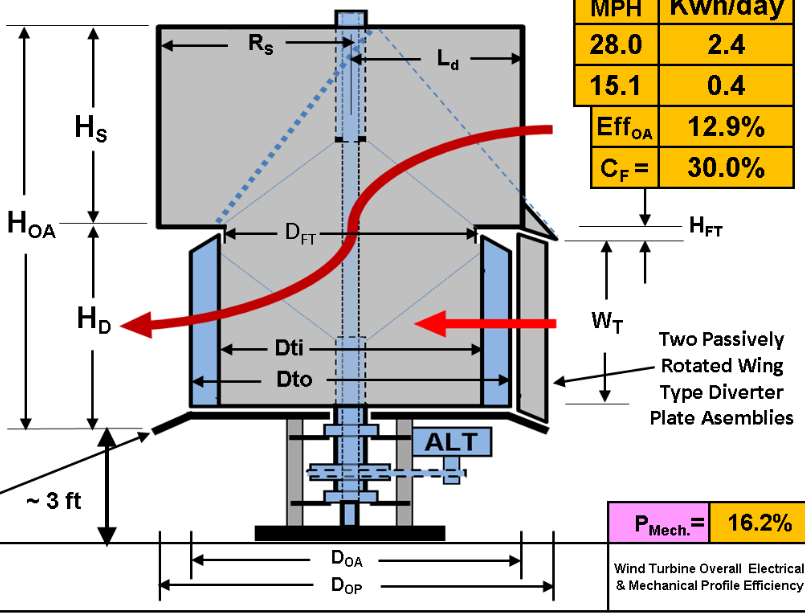
English Units

Primary Dimensions for Multi Phased WINDGRABBER for Preliminary Design Purposes @ 28.0 MPH 52 Watts

MULTIPHASED WIND FLOW

kWe	
0.05	
MPH	Kwh/day
28.0	2.4
15.1	0.4
Eff_{OA}	12.9%
C_F =	30.0%

Centrally Supported and Passively Rotated Inlet Air Scoop at 2 : 1 Air Scoop Inlet to Flow Tube Inlet Area Ratio. Can Be Replaced with a 1 : 1 or up to a 6 : 1 Inlet Area Ratio in the Field



Lower Diverter Plate Support Plate #

$P_{Mech.}$= 16.2%

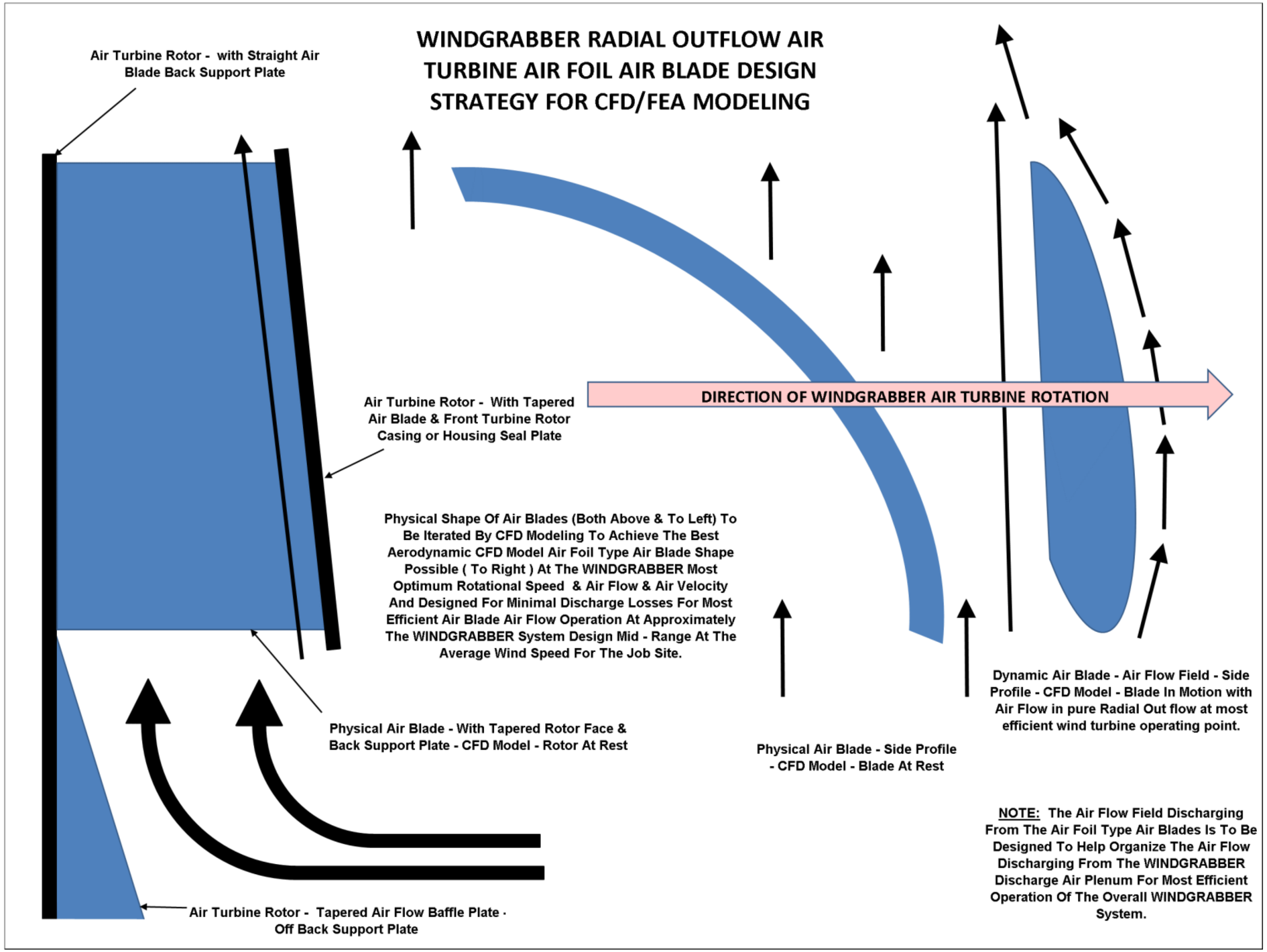
Wind Turbine Overall Electrical & Mechanical Profile Efficiency

DIM.	Sizing Factor	Component Size (ft. / in.)		Overall Size (ft. / in.)		Des. Area & Vol (ft^2 & ft^3)	Des. Area & Vol (ft^2 & ft^3)	
D_{FT}	1.00	1.42	17.0			3.14 X D_{FT}^2/ 4	1.58	
H_S	0.86	1.218	14.6	Air Scoop to Flow Tube Duct Area Ratio				1.55
~ R_S	0.71	1.006	12.1	2.03		Air Scoop Inlet Flow Area	2	2
~ L_d	0.50	0.875	10.50	% - Turb. Inlet Throat to Flow Tube Velocity				1.12
H_{FT}	0.029	0.042	0.500			D_{TO} x W_T x 3.1416 x 270 / 360	2.10	
H_D	$W_T + H_{FT} + BC_L$ =	0.745	8.94			Turbine Air Blade Throat Inlet Area	2	1.15 RATIO
H_{OA}				1.96	23.56	D_{OP} x W_T x 3.1416 x 270 / 360	2.10	
D_{OA}	1.2351	1.75		1.75	21.00			
D_{OP}	1.5440	2.19		2.19	26.25	H_{OA} x D_{OP} Profile	4.08	
D_{TO}	1.2060	1.71		1.71	20.50			
D_{TI}	1.0438	1.48		1.48	17.74	WINDGRABBER Exit Section / Turb Throat Inlet Area Ratio		1.16
W_{TI}	0.38235	6.50		6.25	6.50			
W_{TO}	Rotor ID to OD Divergeing Angle =	Degrees	180.00	6.25	6.50	Inner Rotor Height Inner vs Outer Circle	Outer Rotor Height Inner vs Outer Circle	

Reynolds Number Calculations at Air Foil Air Blade Throat Circle					
	1.0917	0.090977	2.8100E+04	or	28,100
	Air Blade Flow Area Throat Width - in-ft		Renolds Number at Air Foil Throats		29,467

Note: The difference between the DOP and the DOA Dimensions as shown above allows for sufficient space for any required structural support members and surrounding screened-in enclosures to be installed arround the inlet section's passively actuated air impact type air scoop and the exit section's wind concentrator - drag curtain adjustable baffle & divert-er plates.

DARCY Friction Factor - Straight Pipes
0.02582



WINDGRABBER RADIAL OUTFLOW AIR TURBINE AIR FOIL AIR BLADE DESIGN STRATEGY FOR CFD/FEA MODELING

Air Turbine Rotor - with Straight Air Blade Back Support Plate

Air Turbine Rotor - With Tapered Air Blade & Front Turbine Rotor Casing or Housing Seal Plate

DIRECTION OF WINDGRABBER AIR TURBINE ROTATION

Physical Shape Of Air Blades (Both Above & To Left) To Be Iterated By CFD Modeling To Achieve The Best Aerodynamic CFD Model Air Foil Type Air Blade Shape Possible (To Right) At The WINDGRABBER Most Optimum Rotational Speed & Air Flow & Air Velocity And Designed For Minimal Discharge Losses For Most Efficient Air Blade Air Flow Operation At Approximately The WINDGRABBER System Design Mid - Range At The Average Wind Speed For The Job Site.

Dynamic Air Blade - Air Flow Field - Side Profile - CFD Model - Blade In Motion with Air Flow in pure Radial Out flow at most efficient wind turbine operating point.

Physical Air Blade - With Tapered Rotor Face & Back Support Plate - CFD Model - Rotor At Rest

Physical Air Blade - Side Profile - CFD Model - Blade At Rest

NOTE: The Air Flow Field Discharging From The Air Foil Type Air Blades Is To Be Designed To Help Organize The Air Flow Discharging From The WINDGRABBER Discharge Air Plenum For Most Efficient Operation Of The Overall WINDGRABBER System.

Air Turbine Rotor - Tapered Air Flow Baffle Plate - Off Back Support Plate

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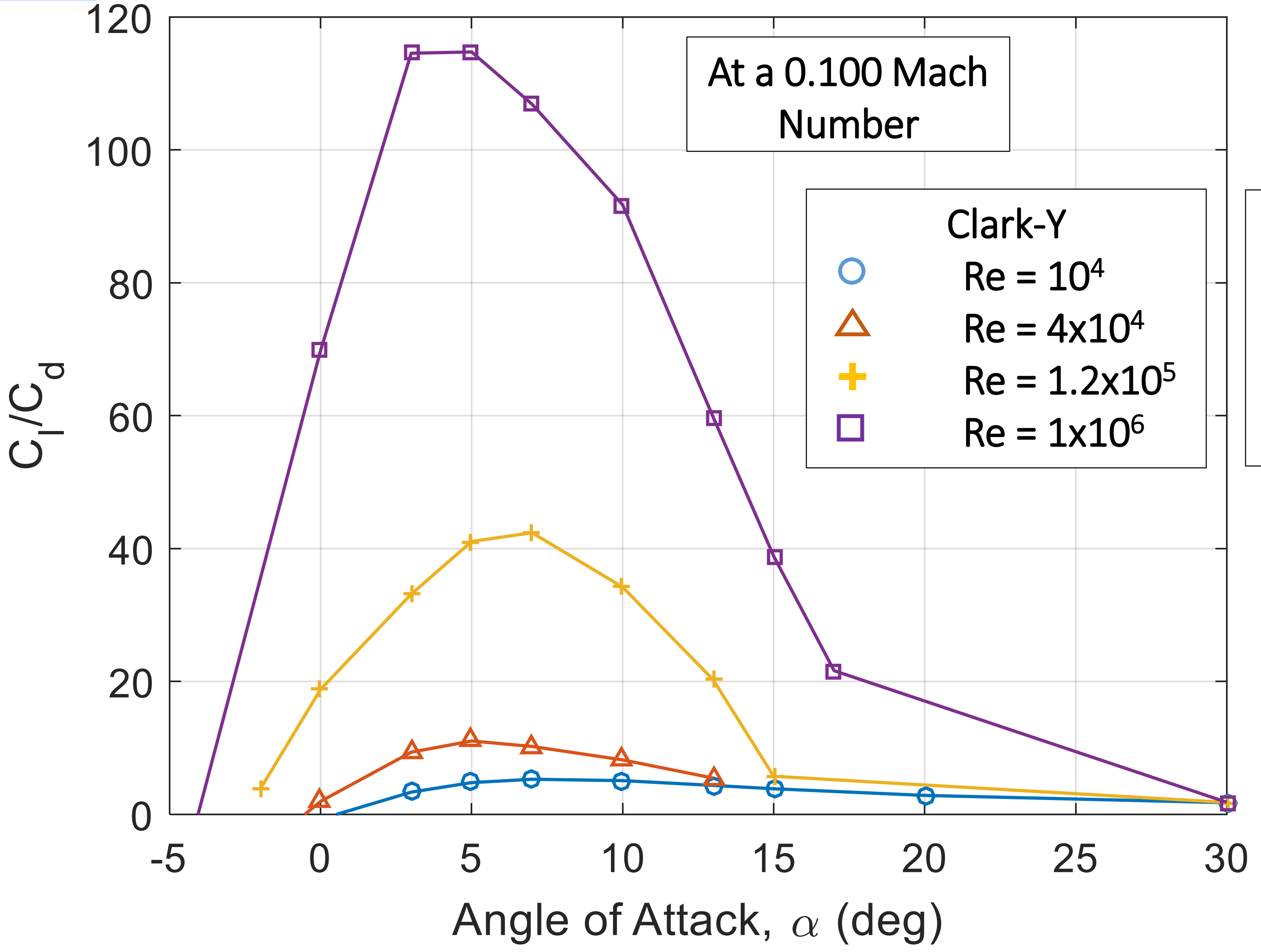

6% Cambered Plate
50 watts WG
100 watts WG
1,000 watts WG
67 kWe WG

Basic Understanding of Airfoil Characteristics at Low Reynolds Numbers (104–105)
Justin Winslow,∗ Hikaru Otsuka,† Bharath Govindarajan,‡ and Inderjit Chopra§
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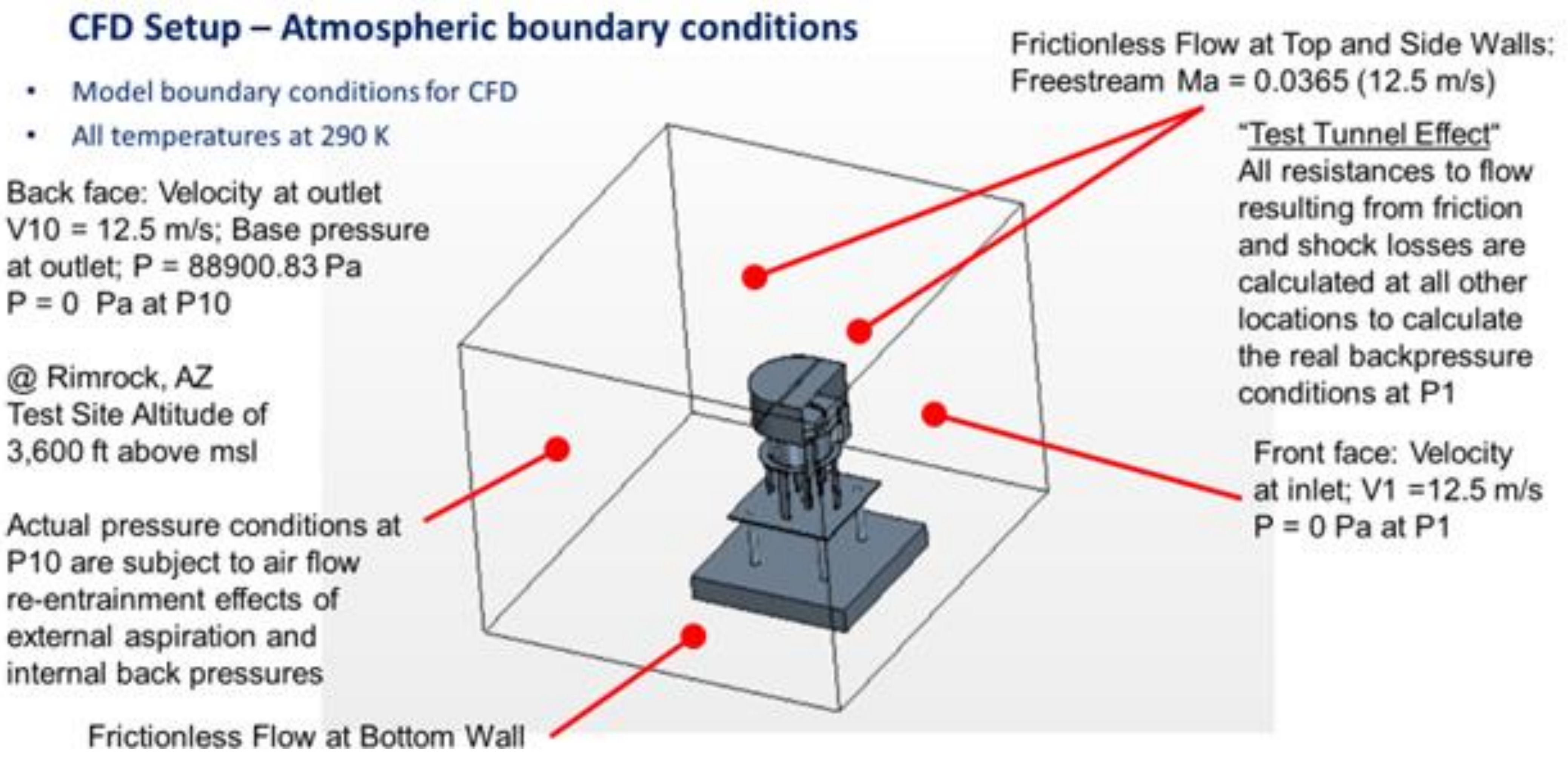


CFD Setup – Atmospheric boundary conditions

- Model boundary conditions for CFD
- All temperatures at 290 K

Back face: Velocity at outlet
V10 = 12.5 m/s; Base pressure
at outlet; P = 88900.83 Pa
P = 0 Pa at P10

@ Rimrock, AZ
Test Site Altitude of
3,600 ft above msl

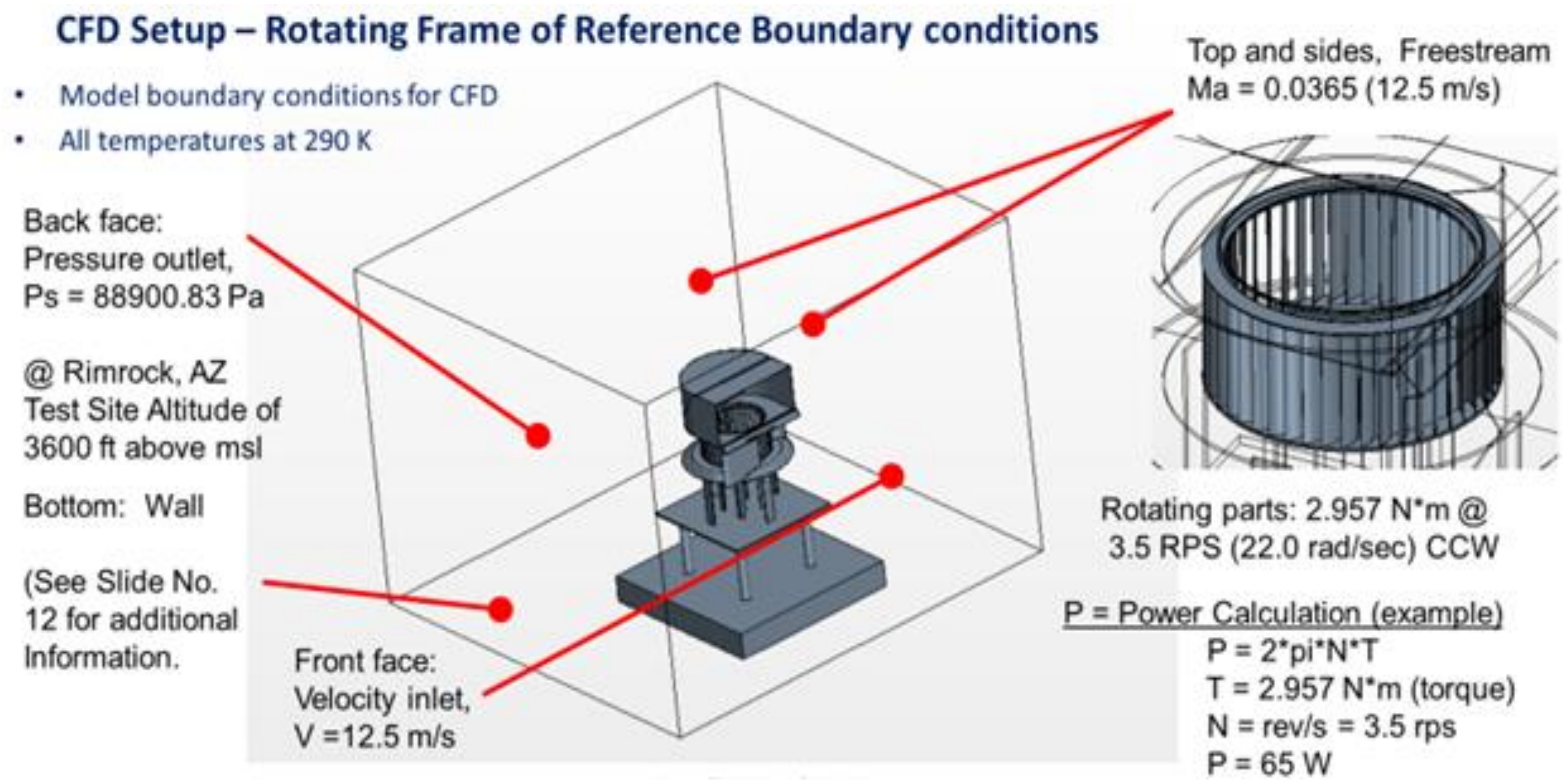
Actual pressure conditions at
P10 are subject to air flow
re-entrainment effects of
external aspiration and
internal back pressures

Frictionless Flow at Bottom Wall

Frictionless Flow at Top and Side Walls:
Freestream Ma = 0.0365 (12.5 m/s)

"Test Tunnel Effect"
All resistances to flow
resulting from friction
and shock losses are
calculated at all other
locations to calculate
the real backpressure
conditions at P1

Front face: Velocity
at inlet; V1 =12.5 m/s
P = 0 Pa at P1



CFD Setup – Rotating Frame of Reference Boundary conditions

- Model boundary conditions for CFD
- All temperatures at 290 K

Back face:
Pressure outlet,
Ps = 88900.83 Pa

@ Rimrock, AZ
Test Site Altitude of
3600 ft above msl

Bottom: Wall

(See Slide No. 12 for additional Information.

Front face:
Velocity inlet,
V =12.5 m/s

Top and sides, Freestream
Ma = 0.0365 (12.5 m/s)

Rotating parts: 2.957 N*m @ 3.5 RPS (22.0 rad/sec) CCW

P = Power Calculation (example)
P = 2*pi*N*T
T = 2.957 N*m (torque)
N = rev/s = 3.5 rps
P = 65 W

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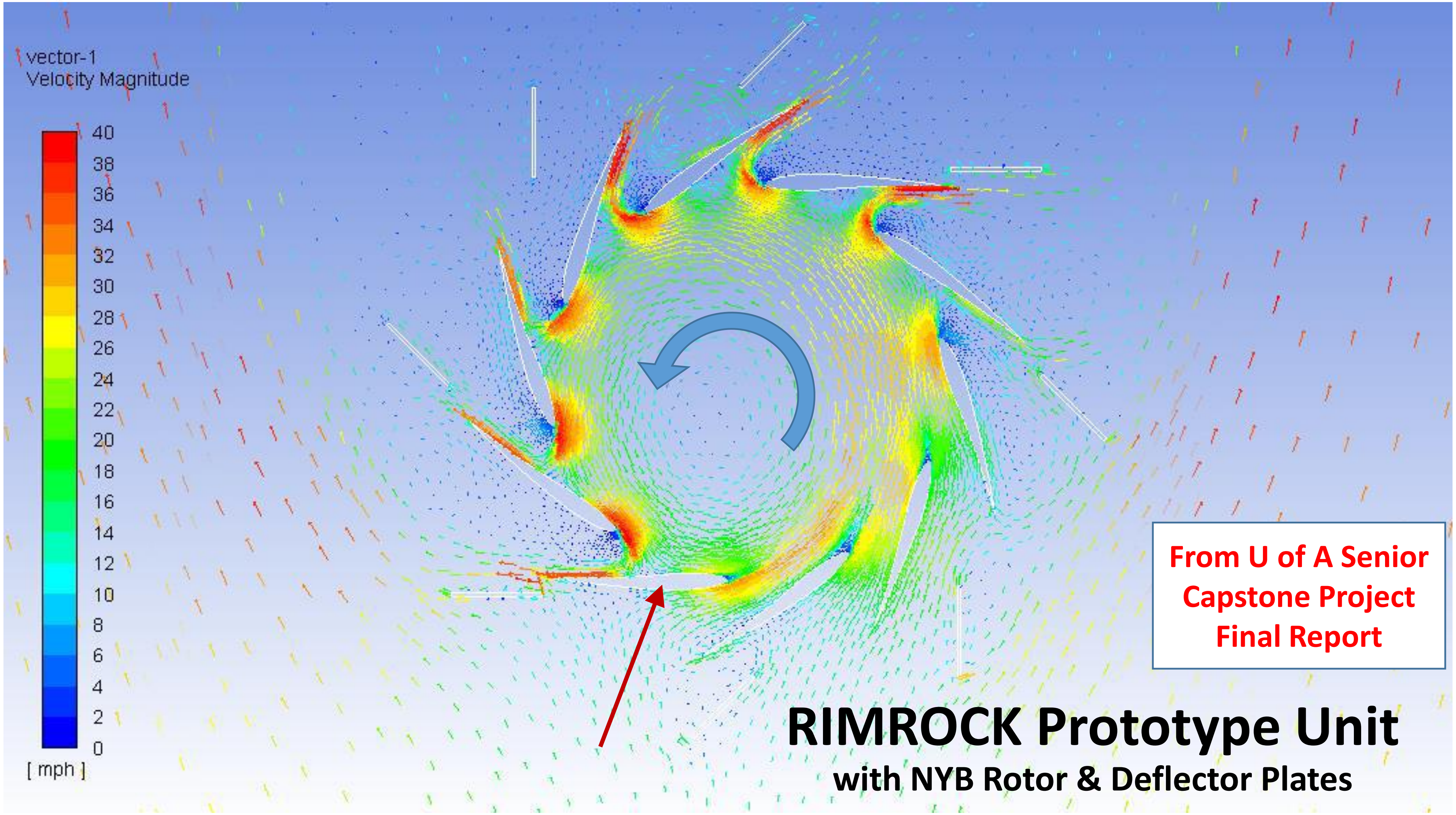

From U of A Senior Capstone Project Final Report

RIMROCK Prototype Unit

with NYB Rotor & Deflector Plates

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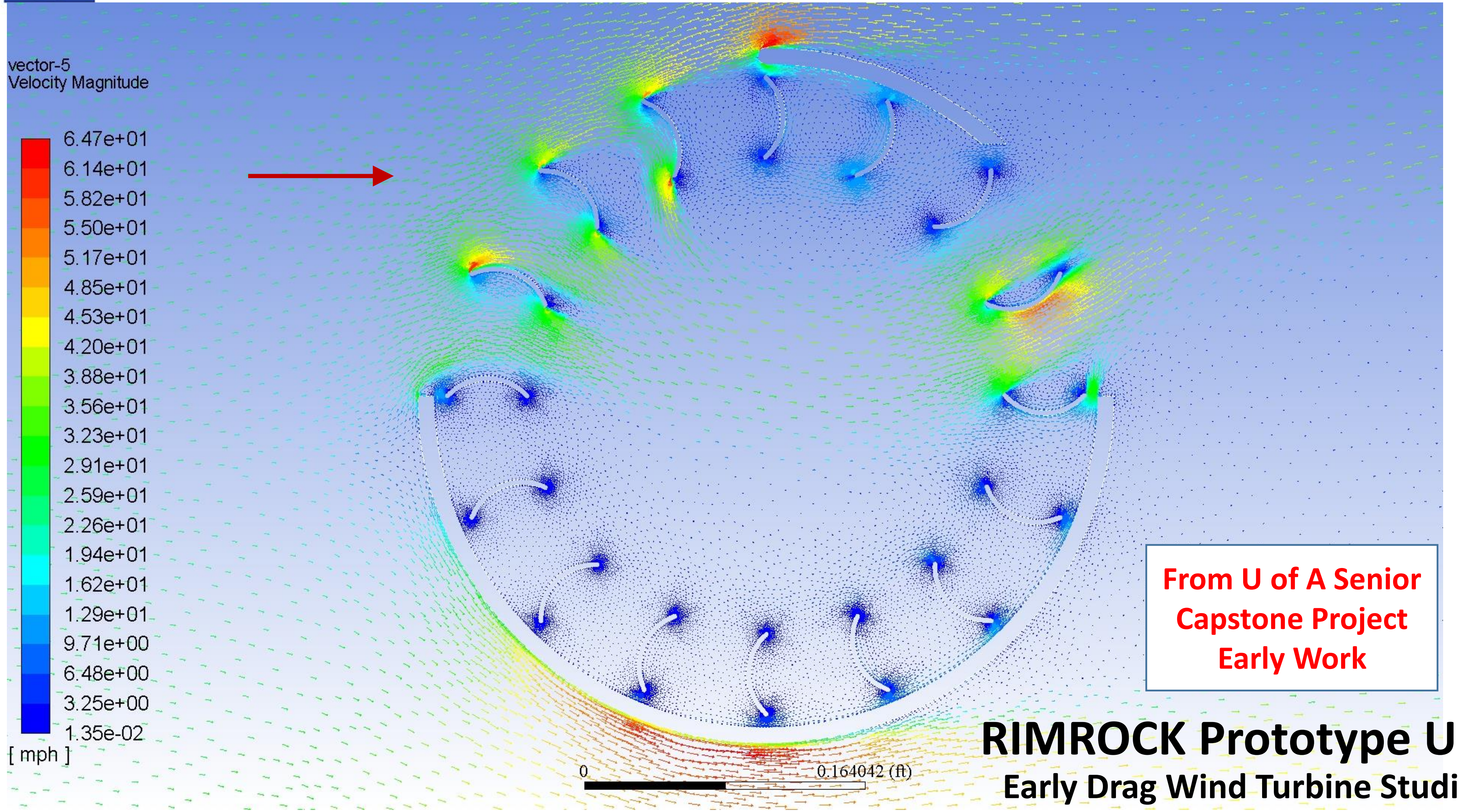
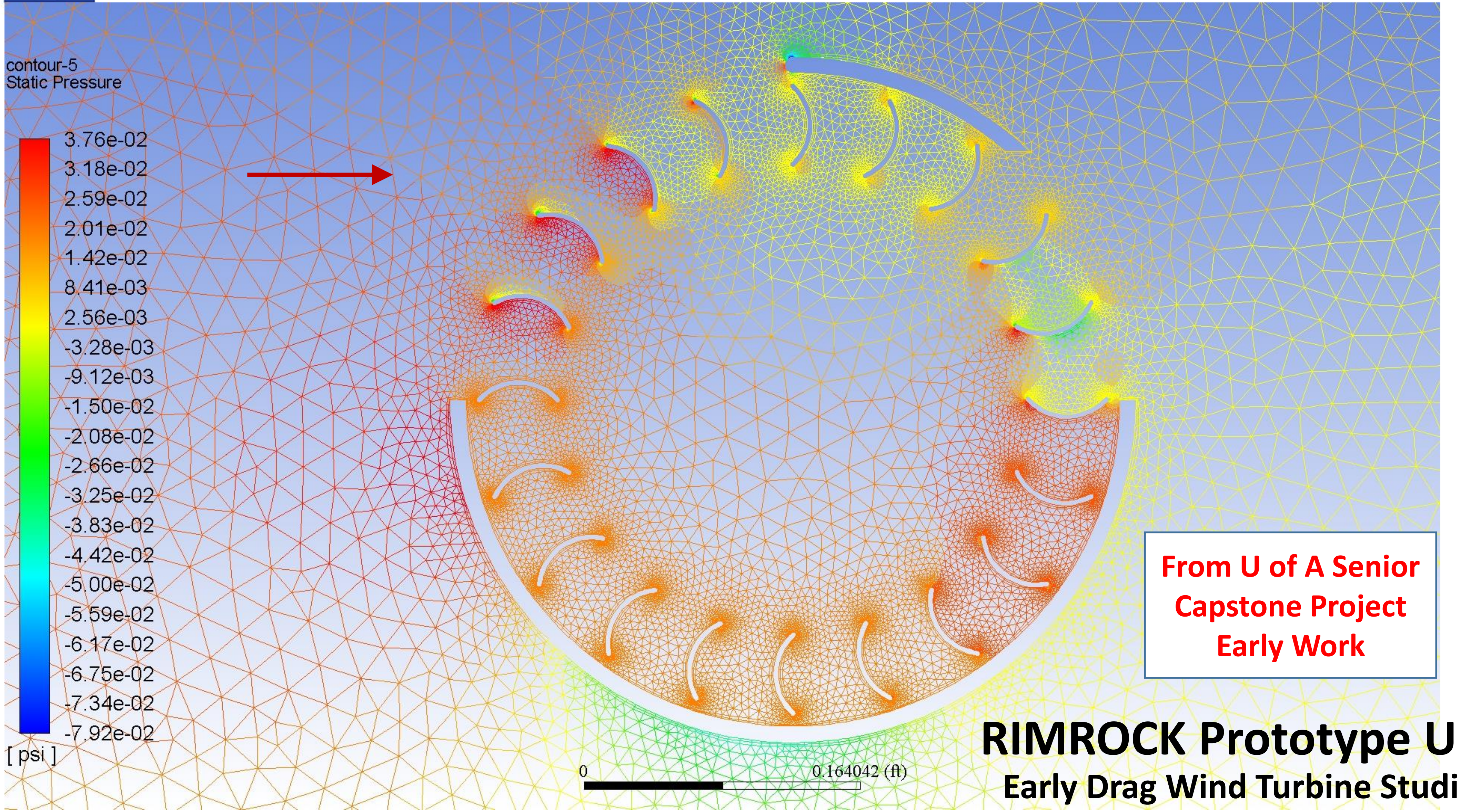


From U of A Senior Capstone Project Early Work

RIMROCK Prototype Unit

Early Drag Wind Turbine Studies

WINDGRABBER® Wind Energy Power Enhancer Systems & Technology



From U of A Senior Capstone Project Early Work

RIMROCK Prototype Unit

Early Drag Wind Turbine Studies

WINDGRABBER® *Wind Energy Power Enhancer Systems & Technology*

Original Lomanco 14" Roof Top Turbine Ventilator Wind Turbine Rotor Assembly

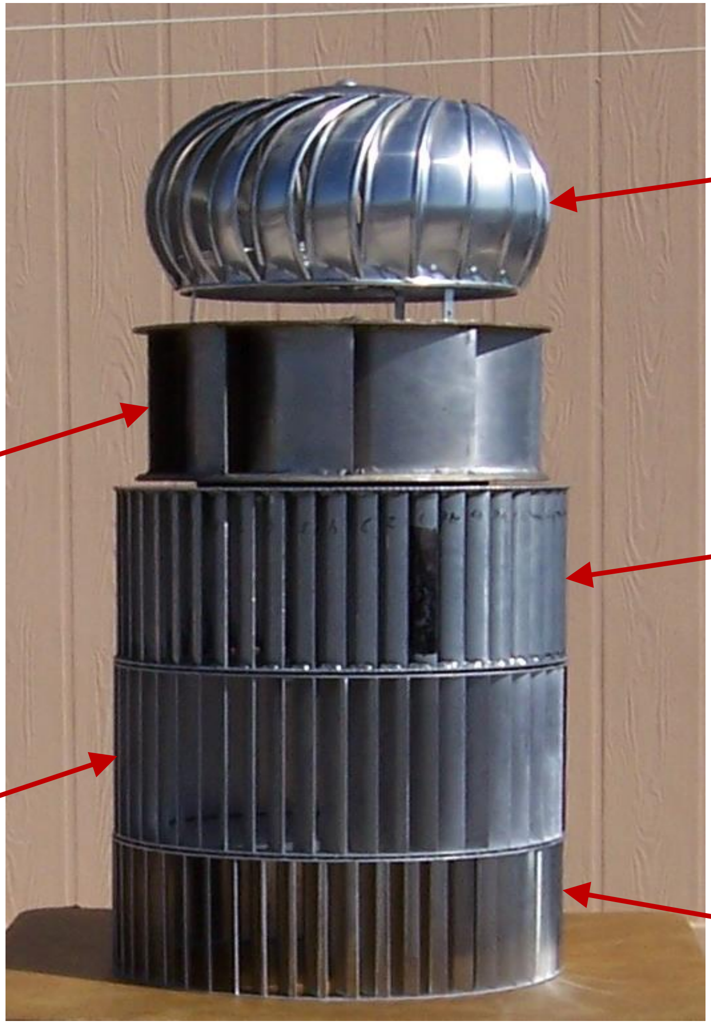
Original 18.25" OD x 6 11/16" High New York Blower Wind Turbine Rotor Assembly

Original 20.5" OD x 8" High Central Blower Wind Turbine Rotor Assembly with ~17% Camber

Original K – 2 MFC, LLC 20.5" OD x 8.0" High Wind Turbine Rotor Assembly with 6% Camber

Final K – 2 MFC, LLC 20.5" OD x 6.25" High Wind Turbine Rotor Assembly with 9% Camber

WINDGRABBER® Wind Energy Power Enhancer Systems & Technology



Original Lomanco 14" Roof Top Turbine Ventilator Wind Turbine Rotor Assembly

Original 18.25" OD x 6 11/16" High New York Blower Wind Turbine Rotor Assembly

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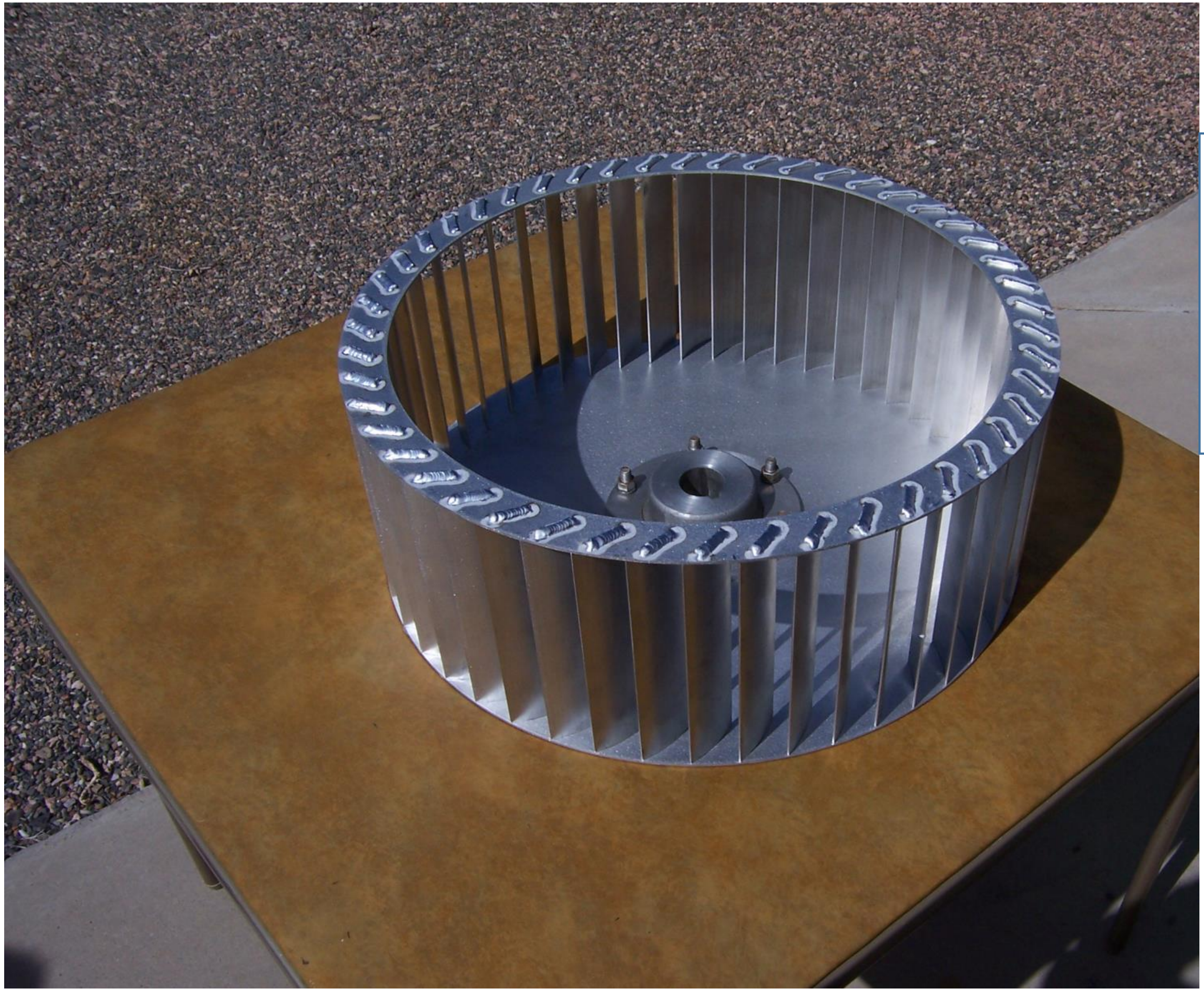
WINDGRABBER® *Wind Energy Power Enhancer Systems & Technology*

Original 18.25” OD x 6 11/16” High New York Blower Wind Turbine Rotor Assembly

WINDGRABBER® *Wind Energy Power Enhancer Systems & Technology*

Original 20.5” OD x 8” High Central Blower Wind Turbine Rotor Assembly with ~17% Camber

WINDGRABBER® Wind Energy Power Enhancer Systems & Technology

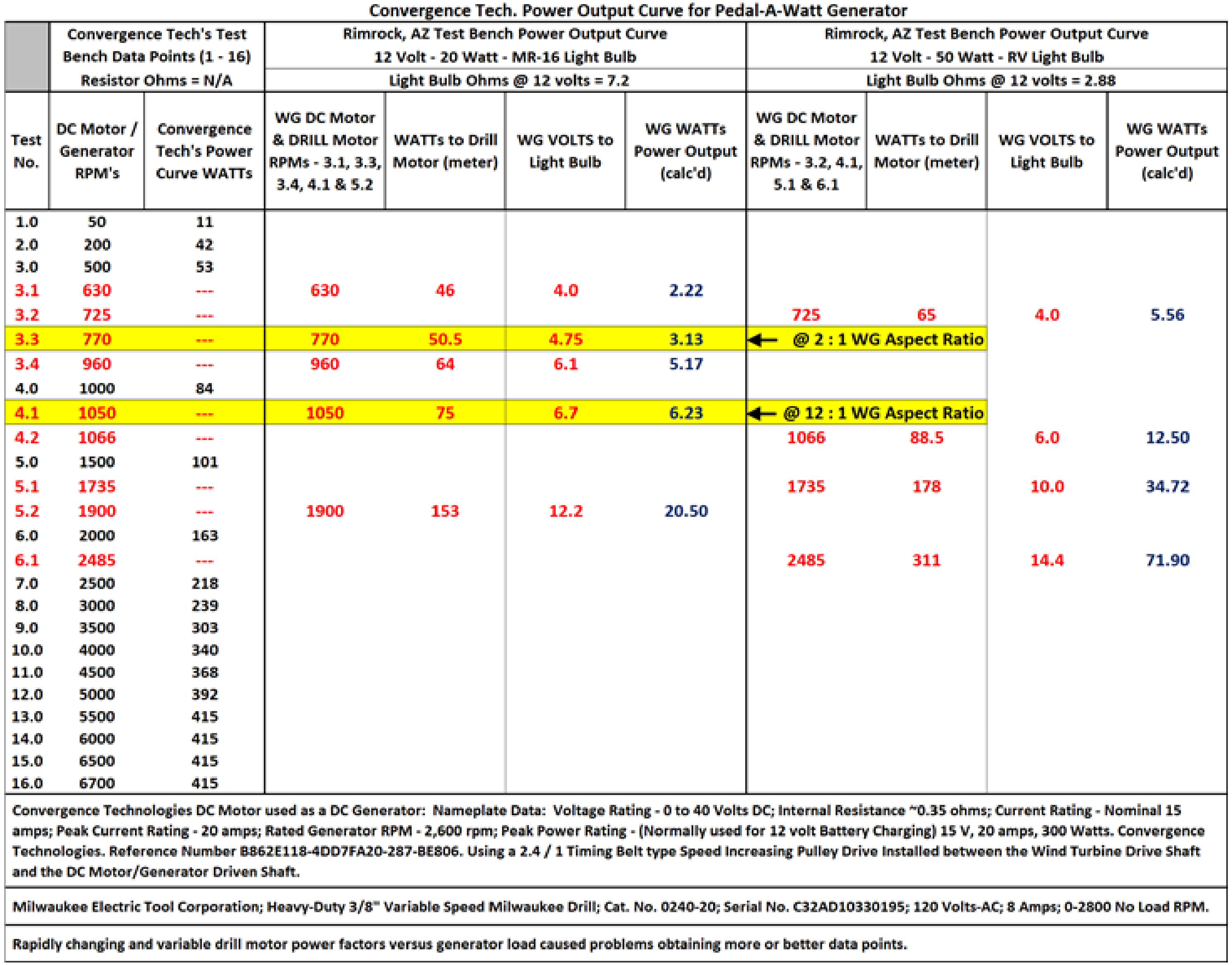


Original K – 2 Manufacturing, LLC 20.5“ OD x 8” High Wind Turbine Rotor Assembly with 6% Camber

WINDGRABBER® *Wind Energy Power Enhancer Systems & Technology*

**Final K – 2
Manufacturing, LLC
20.5“ OD x 6.25” High
Wind Turbine Rotor
Assembly with 9%
Camber**

WINDGRABBER® Wind Energy Power Enhancer Systems & Technology



Convergence Tech. Power Output Curve for Pedal-A-Watt Generator

Convergence Tech's Test Bench Data Points (1 - 16) Resistor Ohms = N/A			Rimrock, AZ Test Bench Power Output Curve 12 Volt - 20 Watt - MR-16 Light Bulb Light Bulb Ohms @ 12 volts = 7.2				Rimrock, AZ Test Bench Power Output Curve 12 Volt - 50 Watt - RV Light Bulb Light Bulb Ohms @ 12 volts = 2.88			
Test No.	DC Motor / Generator RPM's	Convergence Tech's Power Curve WATTs	WG DC Motor & DRILL Motor RPMs - 3.1, 3.3, 3.4, 4.1 & 5.2	WATTs to Drill Motor (meter)	WG VOLTS to Light Bulb	WG WATTs Power Output (calc'd)	WG DC Motor & DRILL Motor RPMs - 3.2, 4.1, 5.1 & 6.1	WATTs to Drill Motor (meter)	WG VOLTS to Light Bulb	WG WATTs Power Output (calc'd)
1.0	50	11								
2.0	200	42								
3.0	500	53								
3.1	630	---	630	46	4.0	2.22				
3.2	725	---					725	65	4.0	5.56
3.3	770	---	770	50.5	4.75	3.13	← @ 2 : 1 WG Aspect Ratio			
3.4	960	---	960	64	6.1	5.17				
4.0	1000	84								
4.1	1050	---	1050	75	6.7	6.23	← @ 12 : 1 WG Aspect Ratio			
4.2	1066	---					1066	88.5	6.0	12.50
5.0	1500	101								
5.1	1735	---					1735	178	10.0	34.72
5.2	1900	---	1900	153	12.2	20.50				
6.0	2000	163								
6.1	2485	---					2485	311	14.4	71.90
7.0	2500	218								
8.0	3000	239								
9.0	3500	303								
10.0	4000	340								
11.0	4500	368								
12.0	5000	392								
13.0	5500	415								
14.0	6000	415								
15.0	6500	415								
16.0	6700	415								

Convergence Technologies DC Motor used as a DC Generator: Nameplate Data: Voltage Rating - 0 to 40 Volts DC; Internal Resistance ~0.35 ohms; Current Rating - Nominal 15 amps; Peak Current Rating - 20 amps; Rated Generator RPM - 2,600 rpm; Peak Power Rating - (Normally used for 12 volt Battery Charging) 15 V, 20 amps, 300 Watts. Convergence Technologies. Reference Number B862E118-4DD7FA20-287-BE806. Using a 2.4 / 1 Timing Belt type Speed Increasing Pulley Drive Installed between the Wind Turbine Drive Shaft and the DC Motor/Generator Driven Shaft.

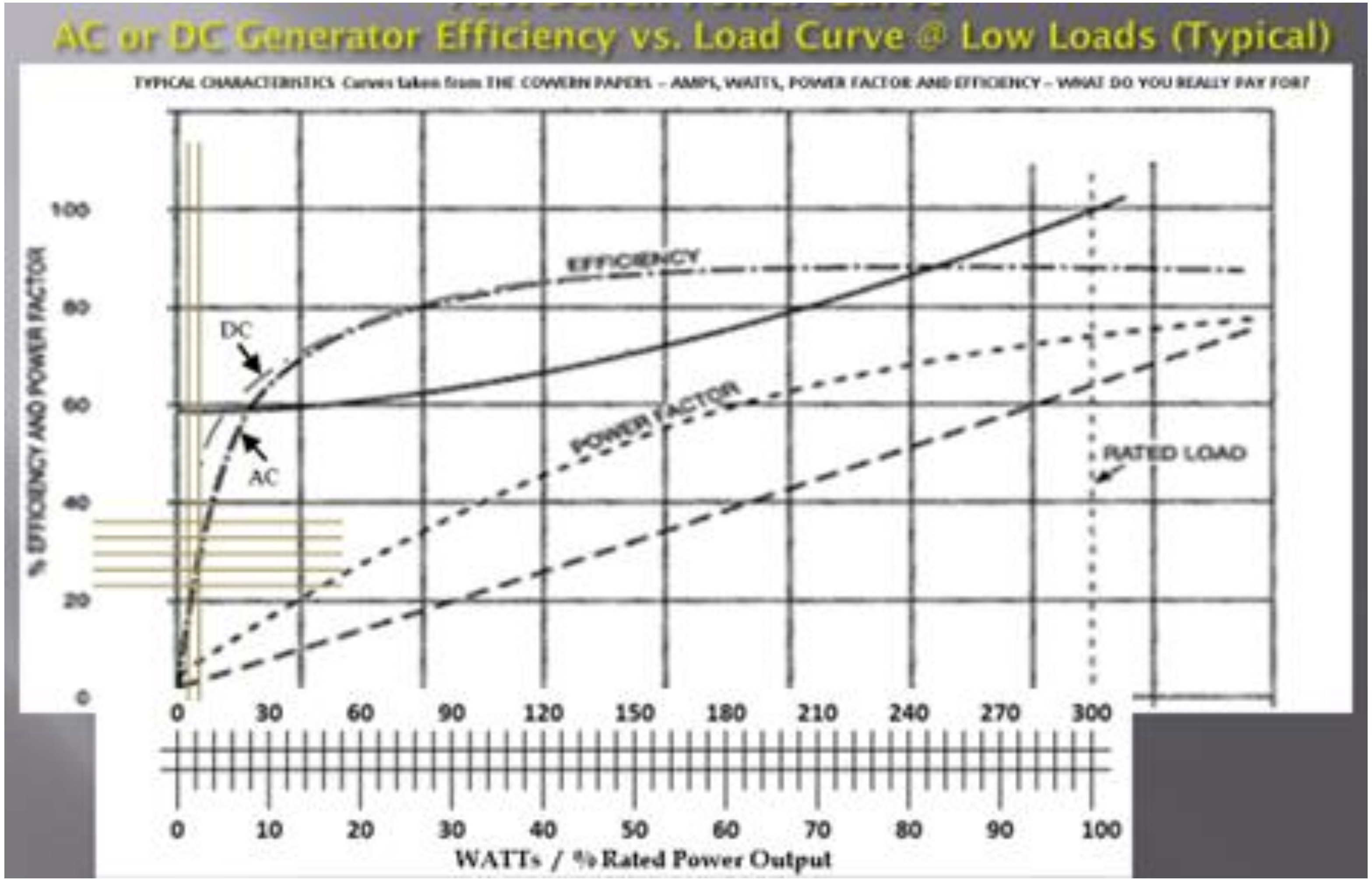
Milwaukee Electric Tool Corporation; Heavy-Duty 3/8" Variable Speed Milwaukee Drill; Cat. No. 0240-20; Serial No. C32AD10330195; 120 Volts-AC; 8 Amps; 0-2800 No Load RPM.

Rapidly changing and variable drill motor power factors versus generator load caused problems obtaining more or better data points.

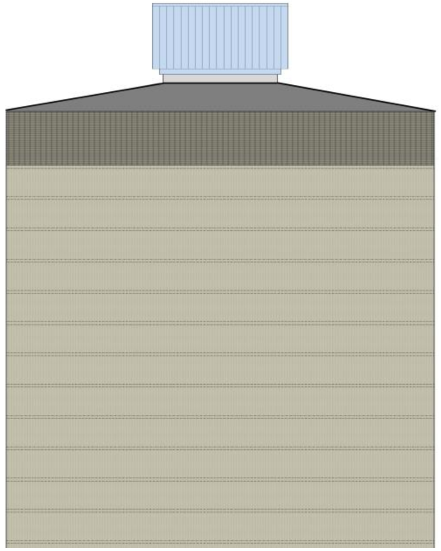
WINDGRABBER® at Rimrock, AZ Test Bench Power Curve Data

NO.	Rimrock WINDGRABBER™ Conceptual Pilot Plant Demonstration Unit Power Output Approximations under Variable Wind Conditions	Units	Input/Output	Test No. 1 12 / 1 Aspect Ratio	Test No. 2 12 / 1 Aspect Ratio	Test No. 3 2 / 1 Aspect Ratio
0	Light Bulb Information	'- /- '	'- /- '	MR - 16	A - 19	MR - 16
1	Milwaukee Variable Speed Drill / Generator - Shaft RPM's	RPM	Data Input	1050	970	770
6	Milwaukee Drill Motor Electric Power Input	Watts	Watt Meter	75	74	50.5
8	Milwaukee Drill Motor Input to Output Electrical/Mechanical Efficiency	%	Approximated	28%	28%	25%
9	Convergence Tech. DC Motor/Generator Electric Efficiency	%	Approximated	30%	30%	25%
12	Convergence Tech. DC Motor/Generator Electric Voltage Output when Driven from the WINDGABBER Pilot Plant Wind Turbine	Volts	Data Input	6.70	6.00	4.75
13	Convergence Tech. DC Motor/Generator Electric Power Output when Driven from the WINDGABBER Pilot Plant Wind Turbine	Watts	Calc'd	6.23	6.25	3.13
14	Convergence Tech. DC Motor/Generator Electric Efficiency	%	Approximated	30.00%	30.00%	25.00%
15	WINDGRABBER Speed Increaser Mechanical Efficiency	%	Approximated	96.00%	96.00%	96.00%
16	WINDGRABBER Wind Turbine Mechanical Power Output	Watts	Approximated	21.6	21.7	13.1
20	Light Bulb Rated Ohms	Ohms	Data Input	7.20	5.76	7.20
21	Average Test Wind Speed	MPH	Data Input	28	28	28
22	Average Test Wind Temperature	°F	Data Input	70	70	70
23	Average Test Wind Barometric Pressure	" Hg	Data Input	26.32	26.32	26.32

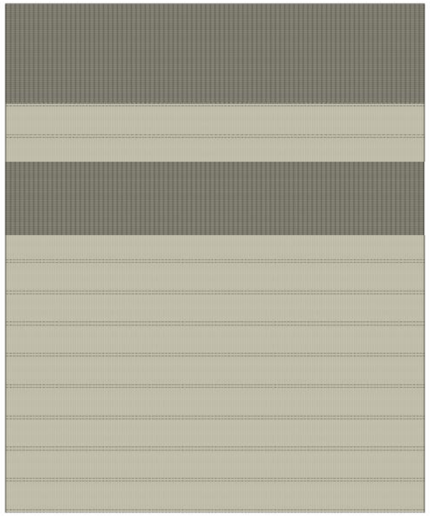
WINDGRABBER® at Rimrock, AZ Test Bench Power Curve Data



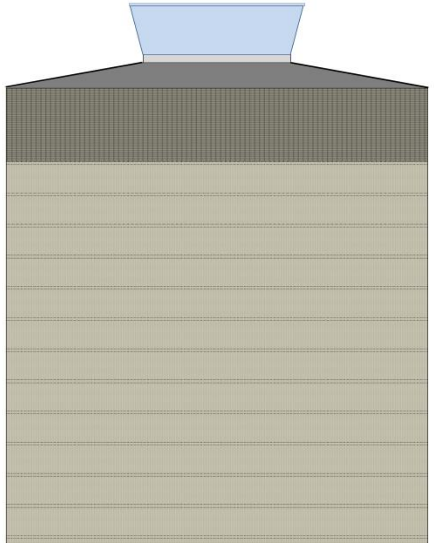
WINDGRABBER® For Buildings – The Primary Objective



LARGE BUILDING OMNIDIRECTIONAL SEMI-ROOFTOP WINDGRABBER®
500 kWe RADIAL FLOW TURBINE

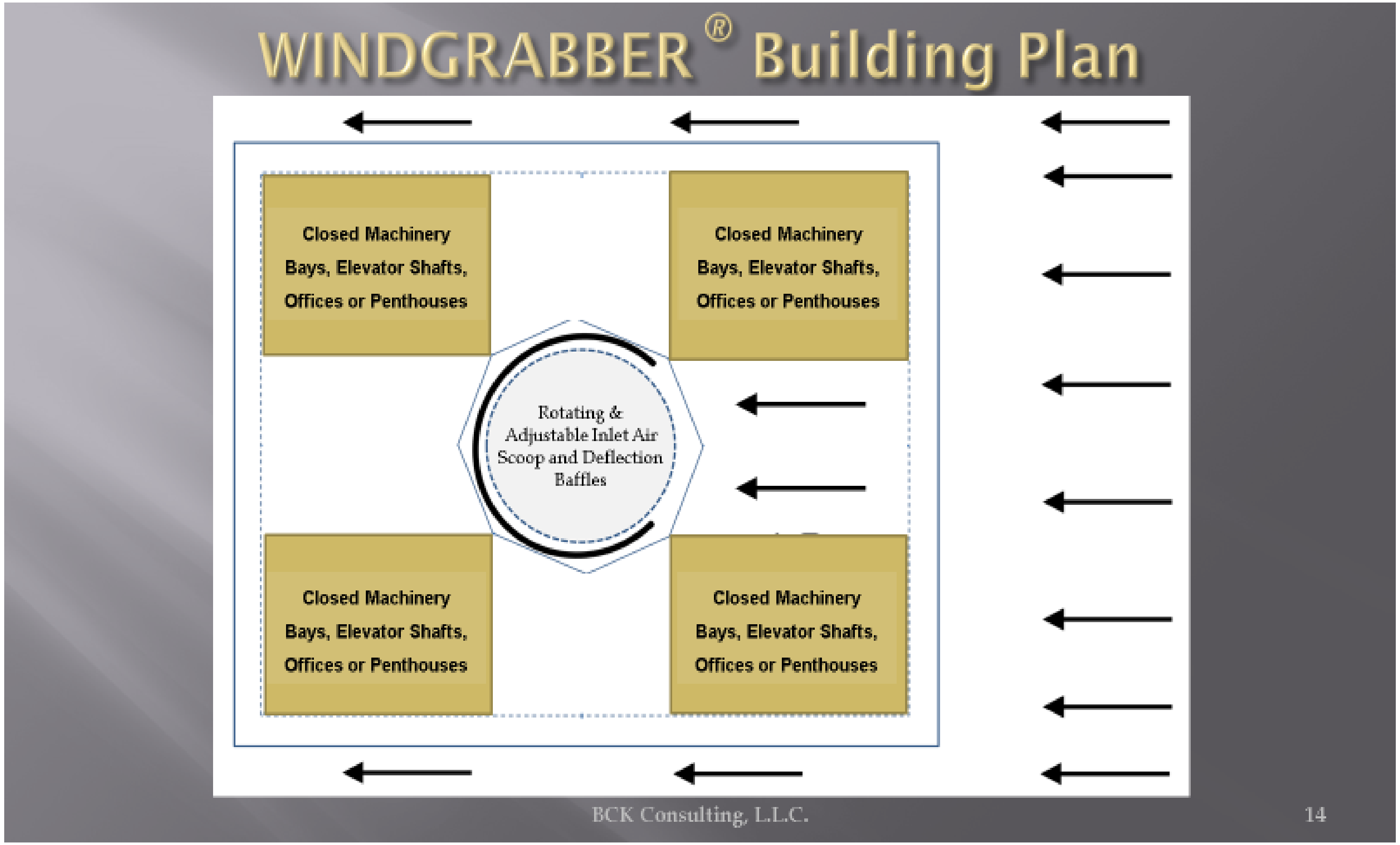


LARGE BUILDING OMNIDIRECTIONAL CROSS BUILDING WINDGRABBER®
500 kWe RADIAL FLOW TURBINE



LARGE BUILDING OMNIDIRECTIONAL SEMI-ROOFTOP WINDGRABBER®
420 kWe AXIAL FLOW TURBINE

WINDGRABBER® For Medium to Large Building Upper Stories



WINDGRABBER® Building Plan

BCK Consulting, L.L.C.

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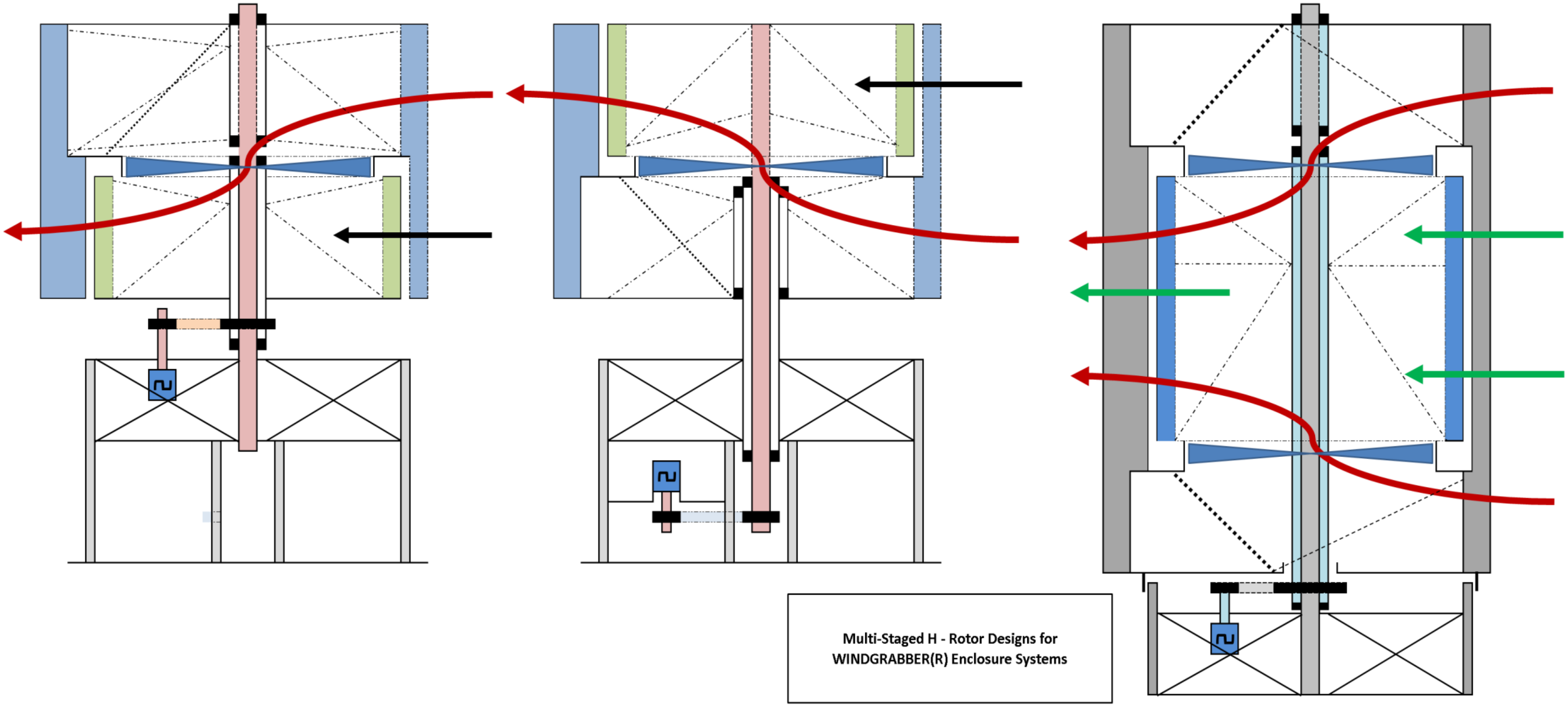
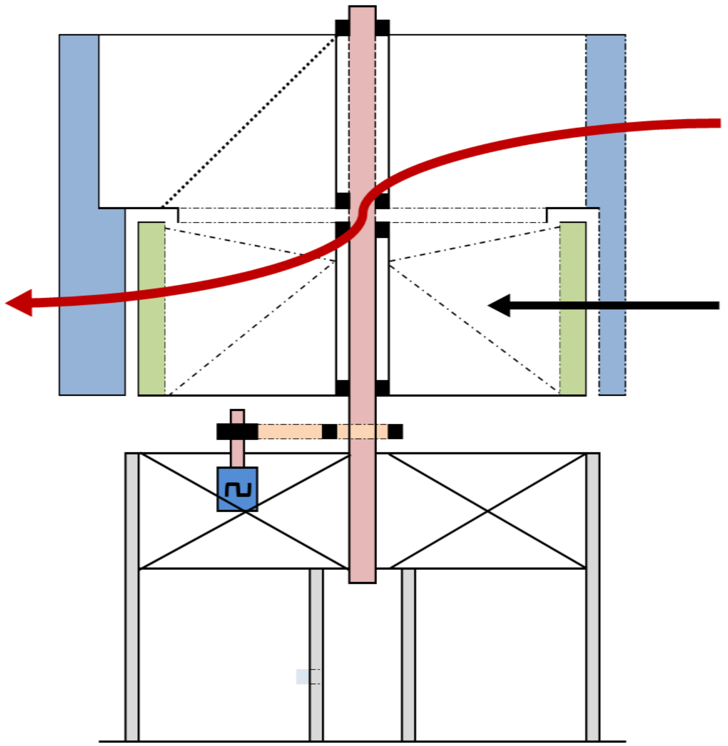
Next Generation WINDGRABBER® Enclosure & Wind Turbine Systems

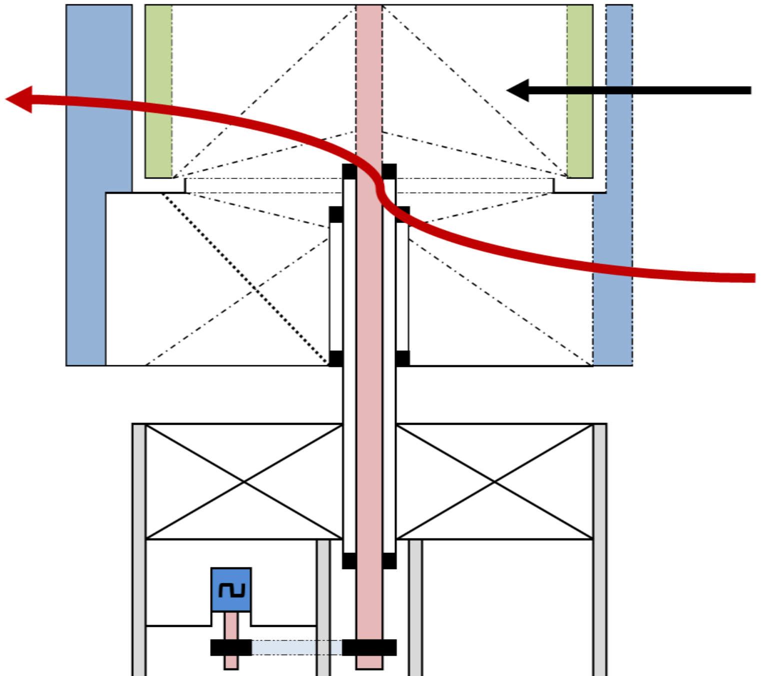


Multi-Staged H - Rotor Designs for WINDGRABBER(R) Enclosure Systems

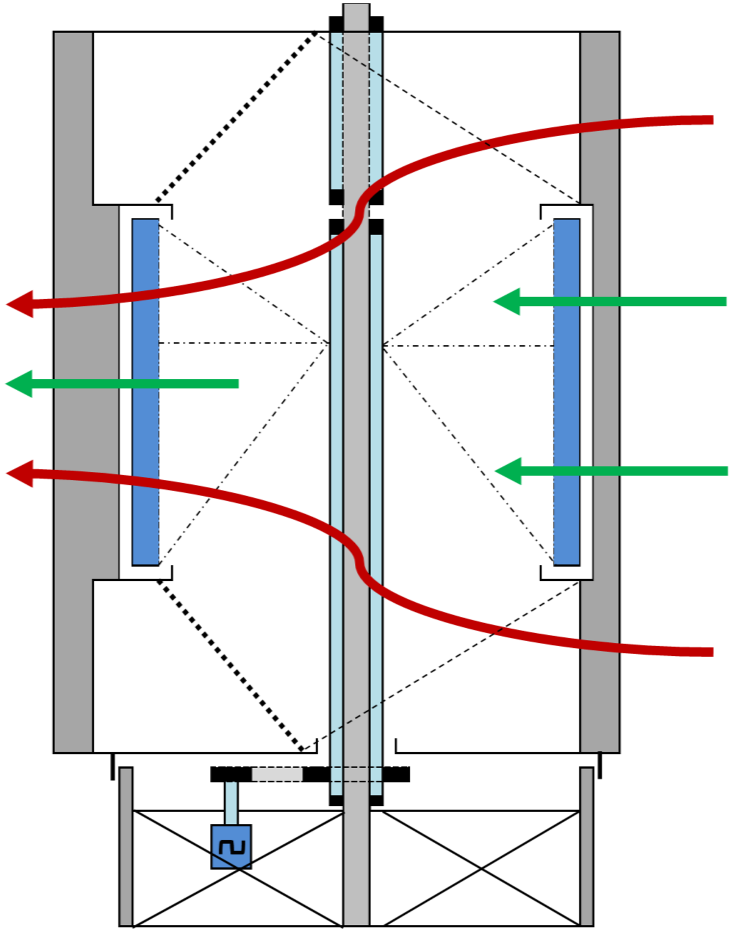
Next Generation WINDGRABBER® Enclosure & Wind Turbine Systems



Single Inlet Down flow
Multi-Phased Open
WINDGRABBER®



Single Inlet Up flow
Multi-Phased Open
WINDGRABBER®

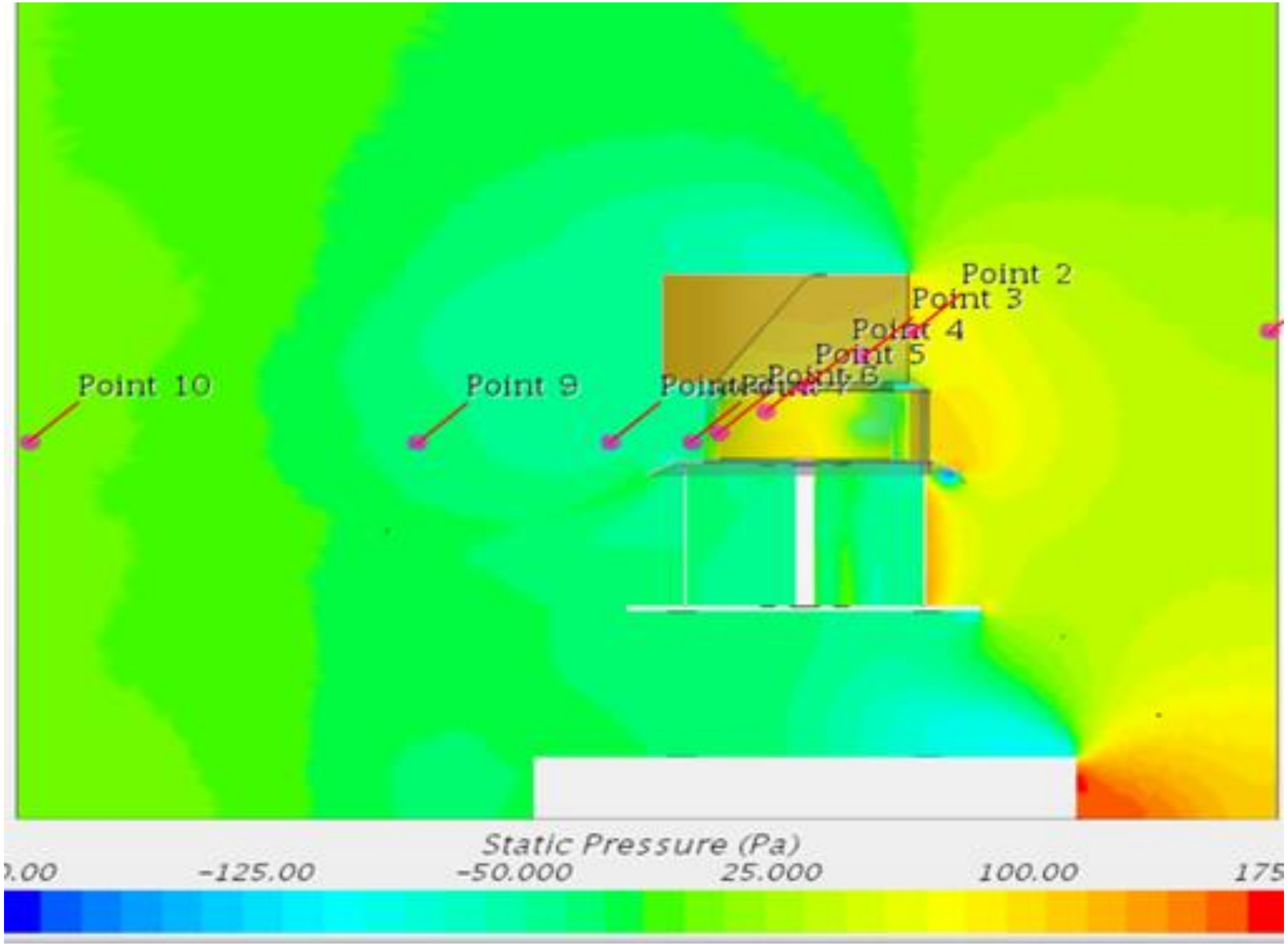


Dual Inlet Multi-Phased
Open WINDGRABBER®

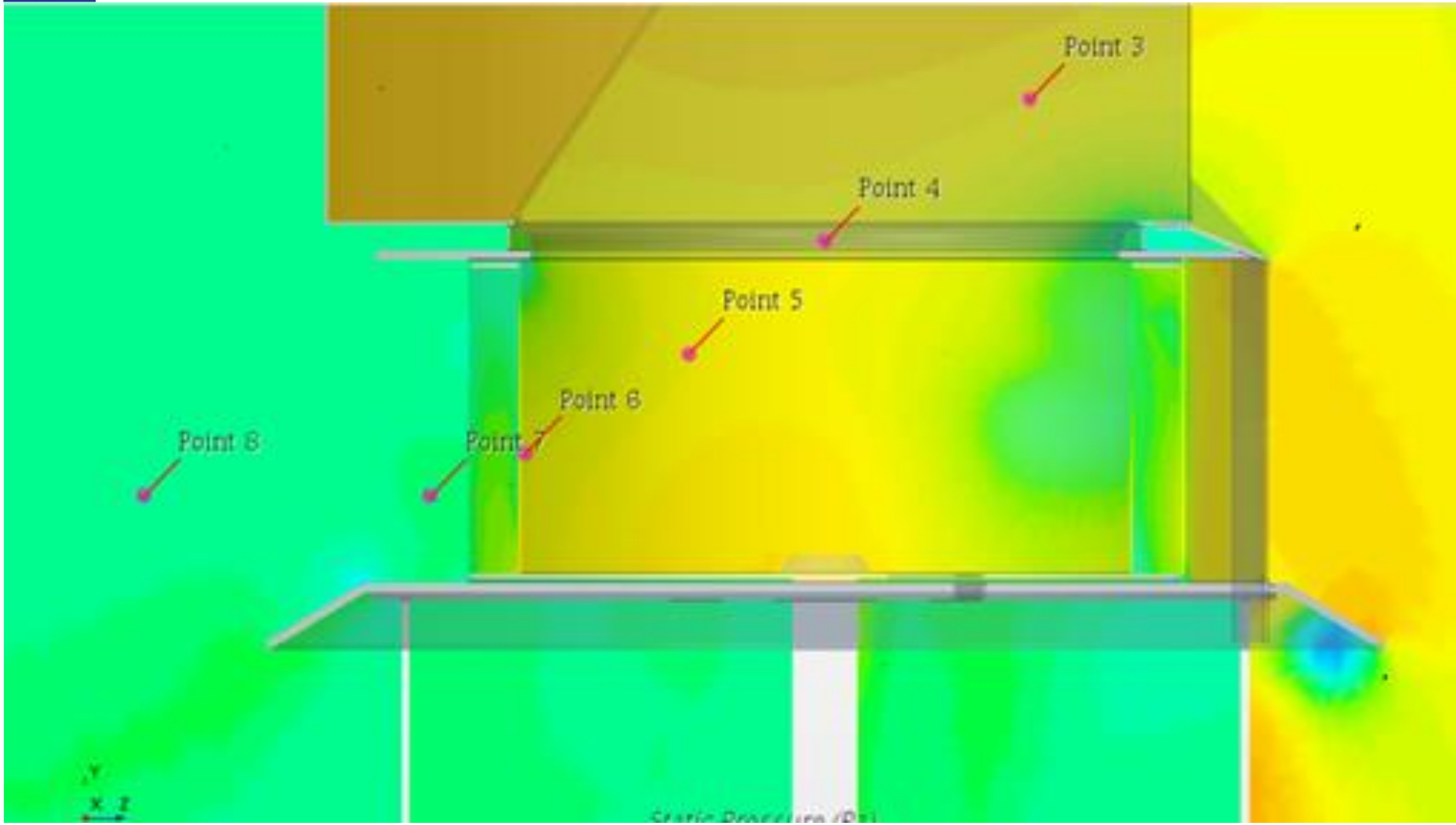
Czero Conclusions and Next Steps

- Curved thin flat plate case with a shorter turbine wheel height showed the best static turbine wheel torque.
  - Smaller turbine height increased both static pressure at the turbine inlet and velocity through turbine blades.
  - Curved thin flat plates showed increased lift compared to other two geometries examined.
  - Mass flow through system was highest for NACA geometry and lowest for the initial geometry (~15% lower).
- The predicted torque on the turbine decreased when turbine wheel rotation was modeled. Torque decreased further as the rotation speed of the wheel was increased. Turbine power was highest at 3.5 RPS, 1% higher than at 3 RPS and decreased by 8% as speed was increased to 4.77 RPS.
- The mass flow relatively constant with rotation speed but flow spilt favors primary flow path with increased rotation speed.
- The RFR method used to estimate the effects of the rotating turbine blades on system performance has limitations for this geometry and flow. It does not accurately simulate the actual transient flow patterns around the blades and thus cannot reliably predict the details of the rotation on blade performance.
- A transient CFD analysis with a rotating/moving mesh should be performed to better understand the effects of the angle of attack and Reynolds number on the turbine wheel/blade performance for both the prototype and full scale geometry.
- The next step will be to build and field test a new wind turbine rotor assembly at the Rimrock, AZ home test site.

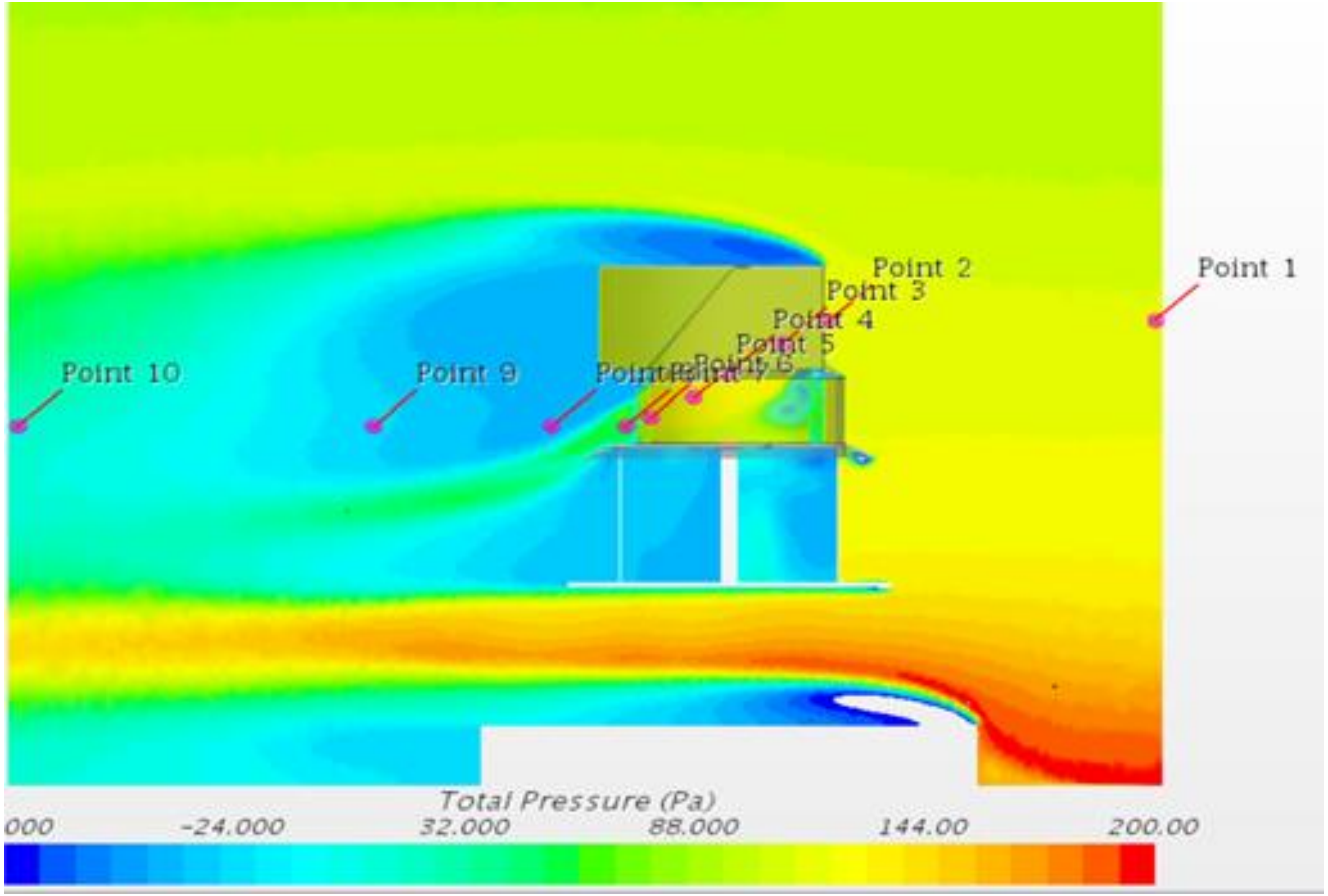
WINDGRABBER® Wind Energy Power Enhancer Systems & Technology



WINDGRABBER® *Wind Energy Power Enhancer Systems & Technology*



WINDGRABBER® *Wind Energy Power Enhancer Systems & Technology*



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