



Marine Corrosivity Effort

December, 2013

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Original Objectives

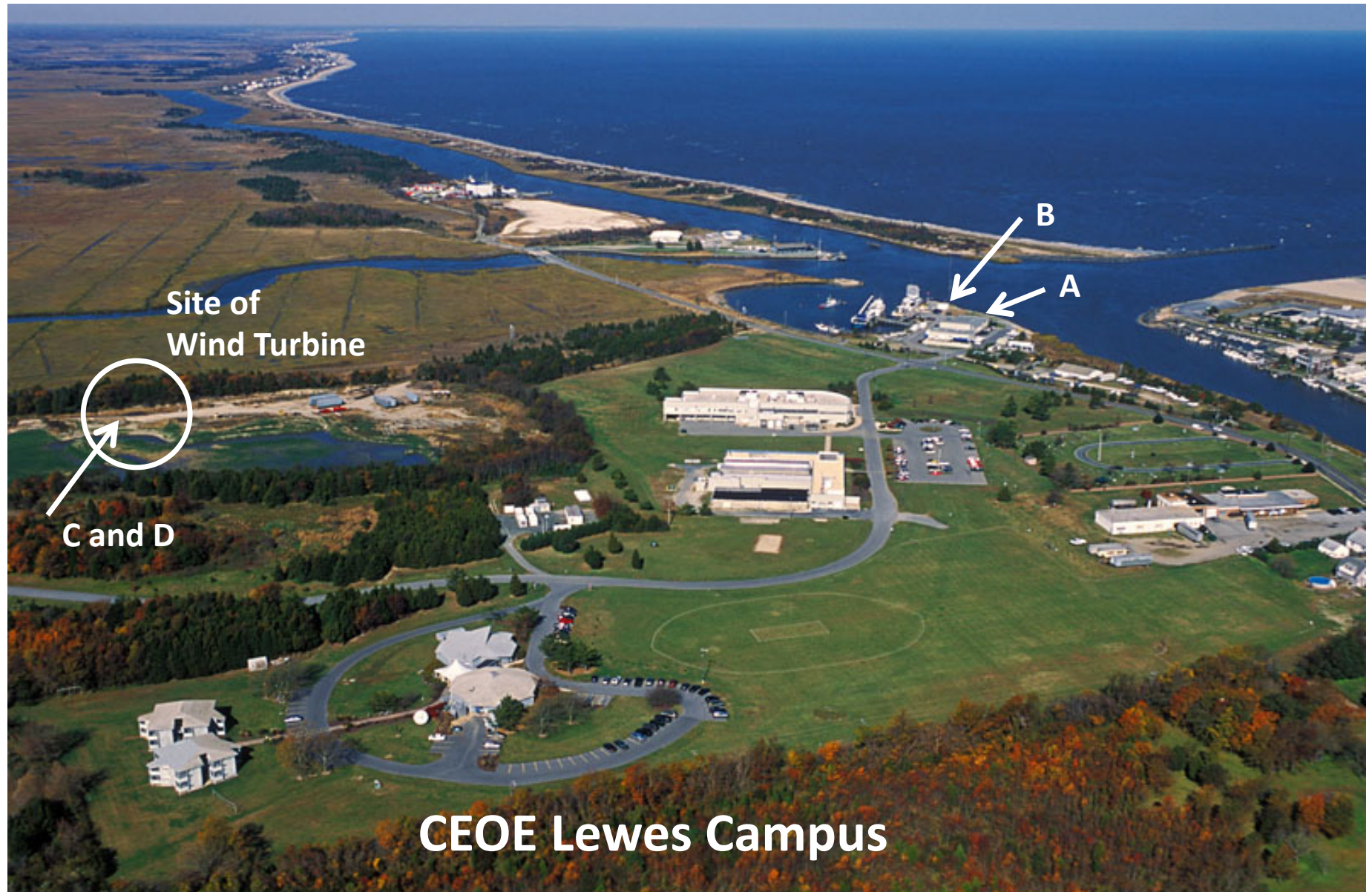
Calibrate the corrosivity of the Lewes, DE wind turbine site with the intention of being able to predict the corrosivity of future sites.

Monitor the real time corrosion of critical wind turbine systems as one component of a condition based maintenance program

Original Project Goals:

- a. Deploy corrosivity test surfaces at a range of heights and distances from the water in the vicinity of the Lewes turbine site.
- b. Analyze the corrosivity values as measured above to determine the corrosivity of the atmosphere at the Lewes turbine site as a function of distance from, and height above the water over a 2-Yr period.
- c. Evaluate the corrosivity of the present turbine site in comparison to that at other sites along the US Atlantic coastline using plain carbon steel test surfaces.
- d. Develop a strategy for condition-based maintenance using electronic sensors for detecting corrosion of real turbine components. (Not possible due to safety issues)

Placement of Corrosivity Samples

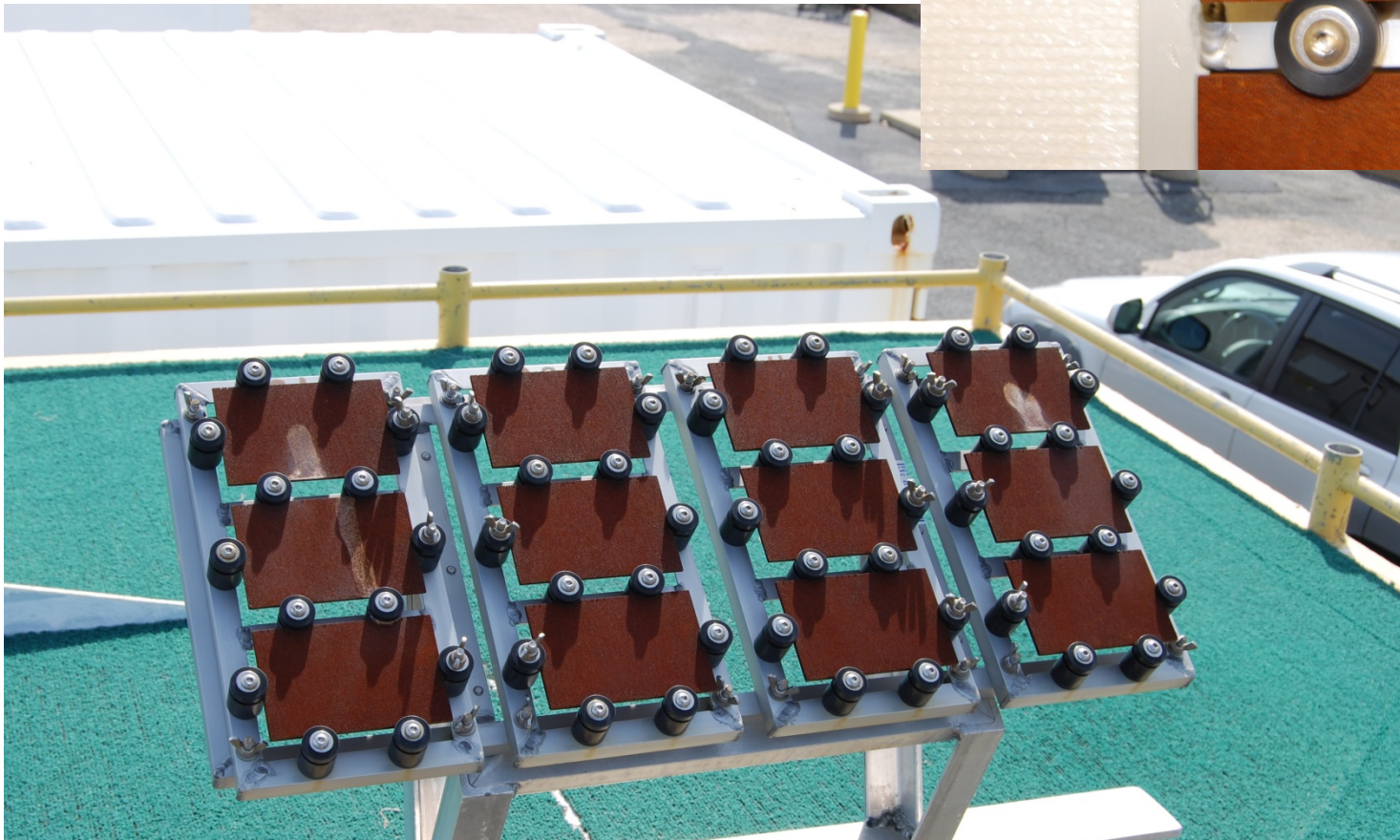
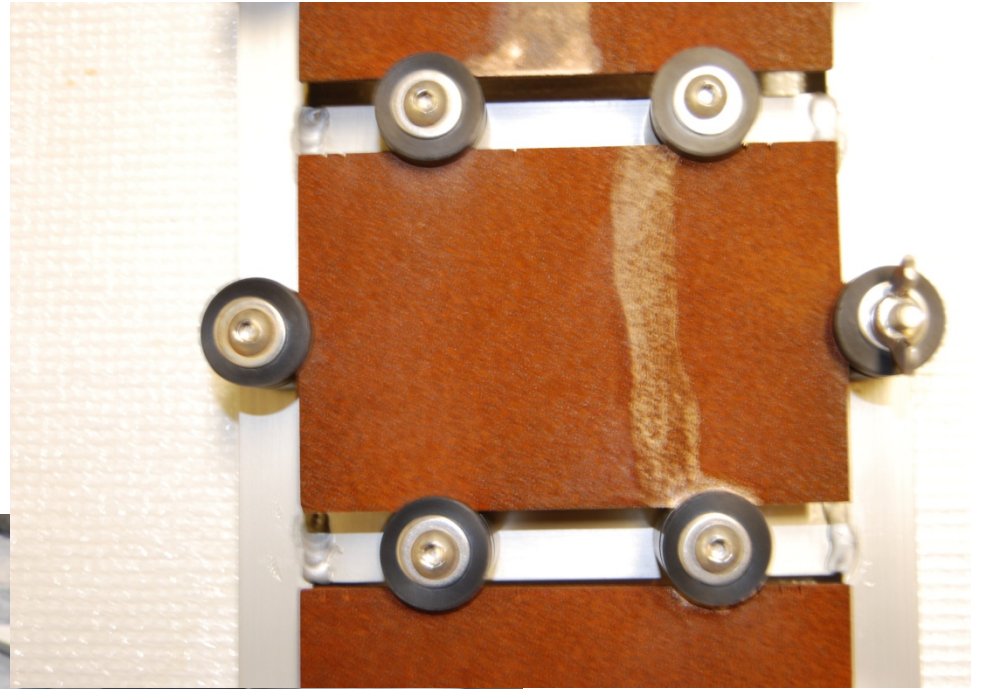


Testing

Location B
10 ft back 8 ft high
(Close and Low)



Location B (MOB Low)

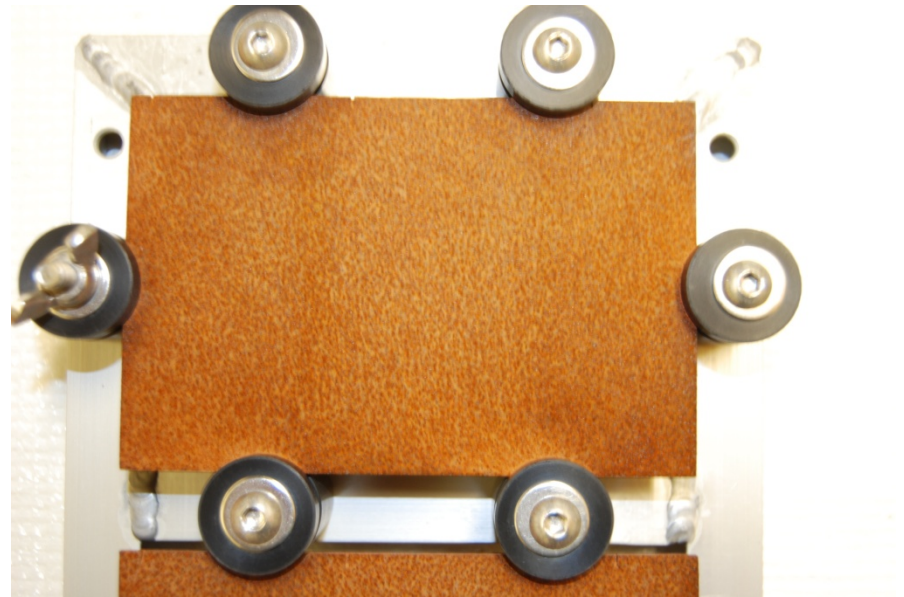


**Testing
Location A
(MOB High)
(100 ft back 30 ft high)**



Location A

(MOB High)



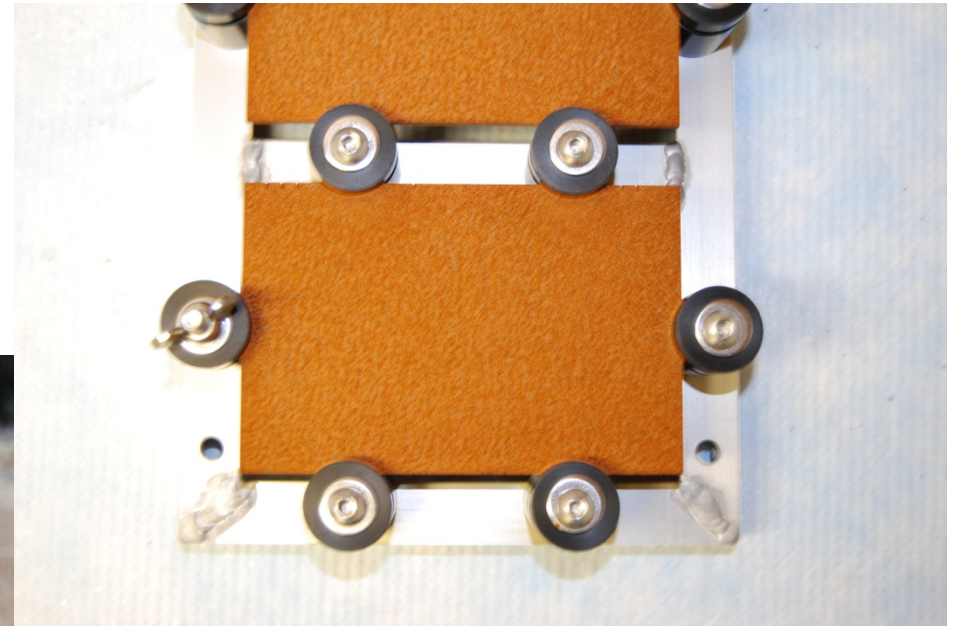
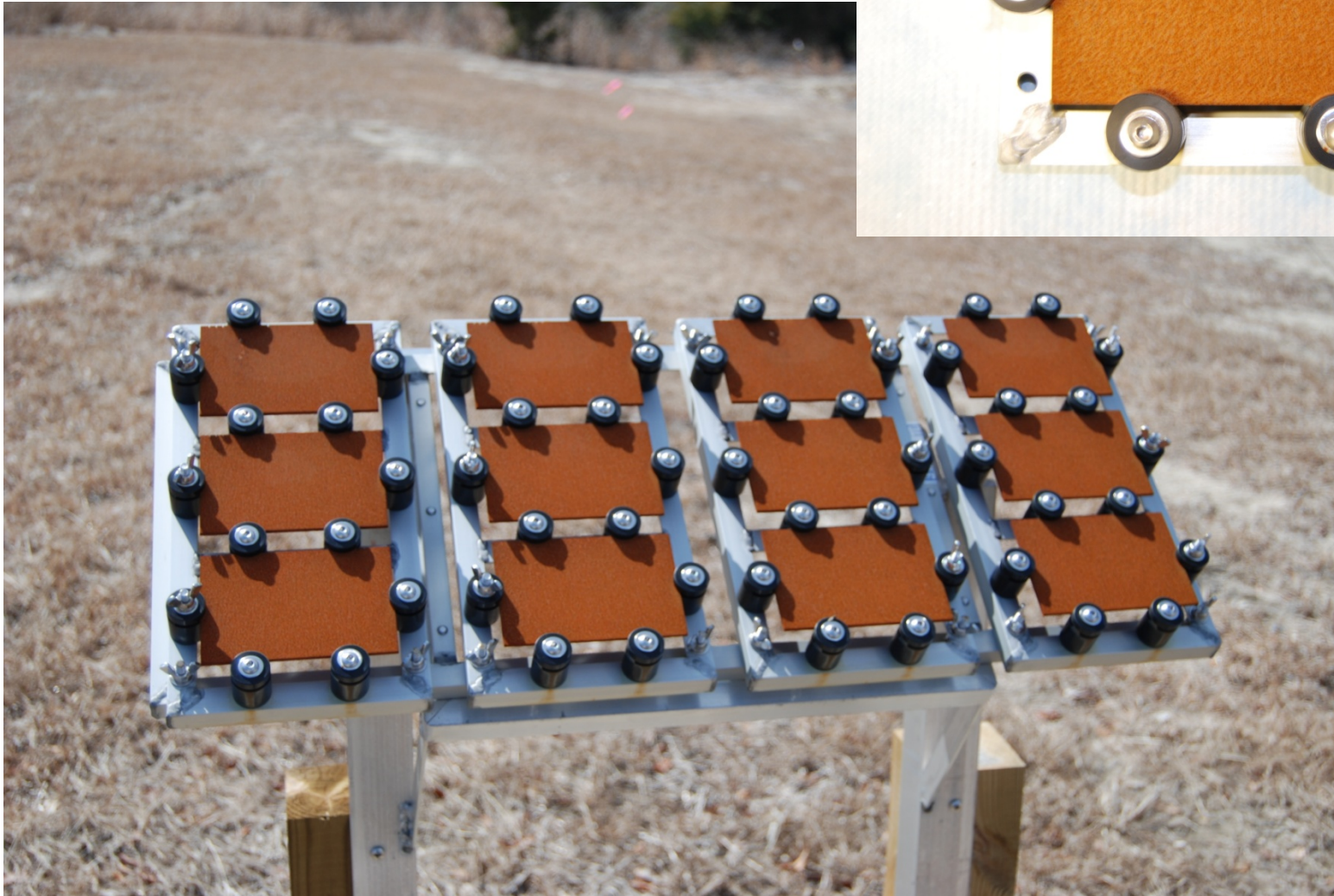
Testing



Location C
(At Turbine base)

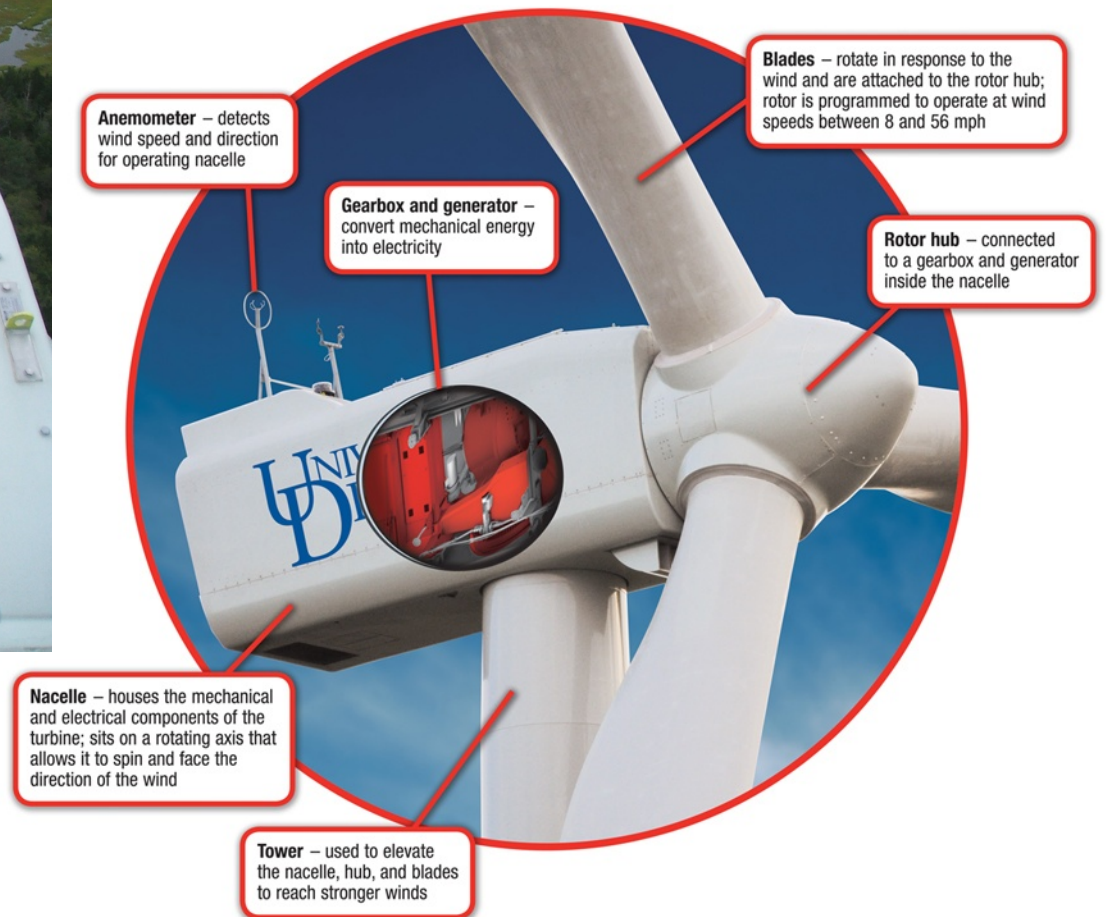
Location C

(At Turbine Base)

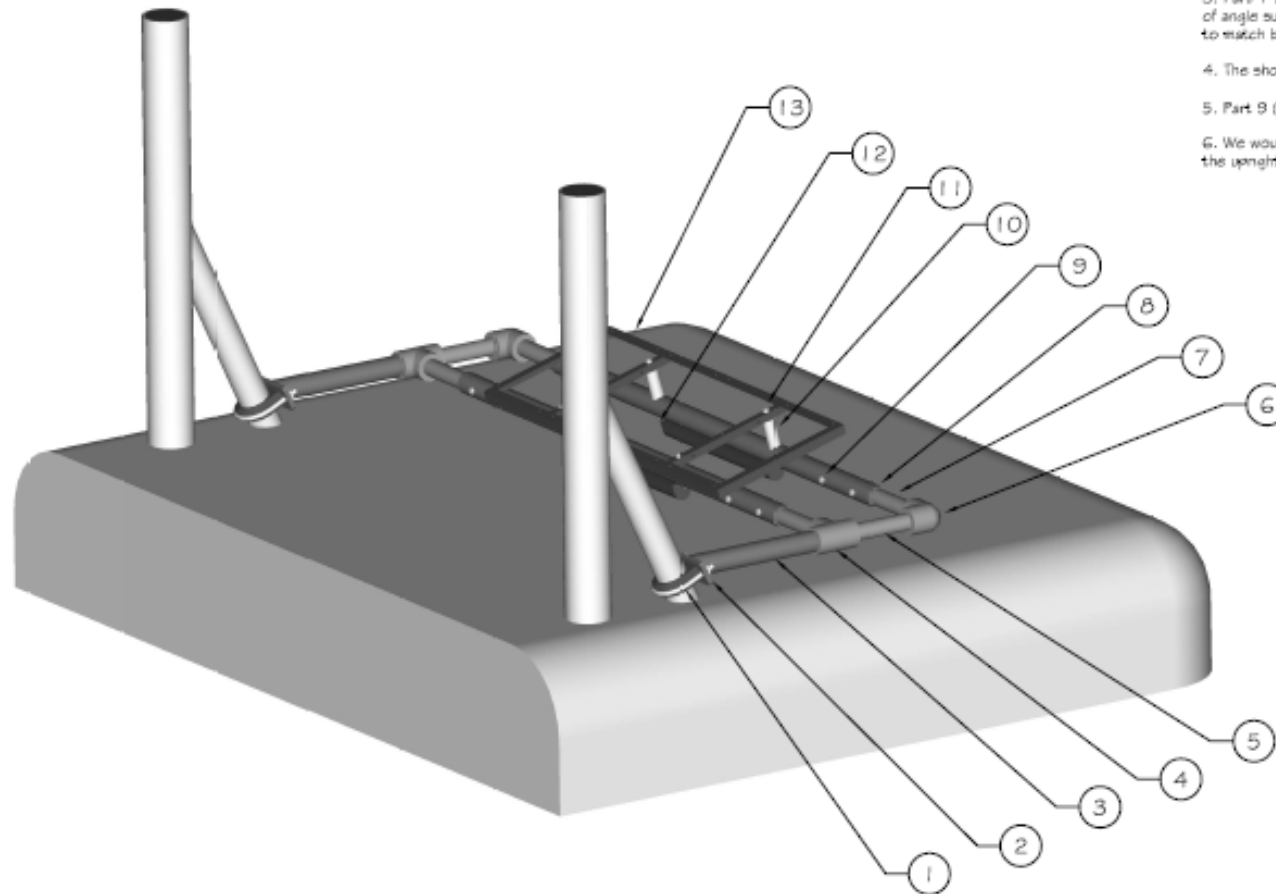




Location D (On Top of Nacelle)



Holder for Samples on top of Nacelle



1. Part 2 and 3 to be welded together.

2. All parts anodized for corrosion protection prior to installation.

3. Part 1 to be purchased from McMaster Carr, Part 1 to be purchased once pipe size of angle support on top of Nacelle is provided, Part 3 Mounting Flange to be machined to match bolt pattern of part 1.

4. The shown assembly should accommodate uprights between 47°-75°.

5. Part 9 (1/4-20 x 2.5) Bolts to be drill in place, at time of installation.

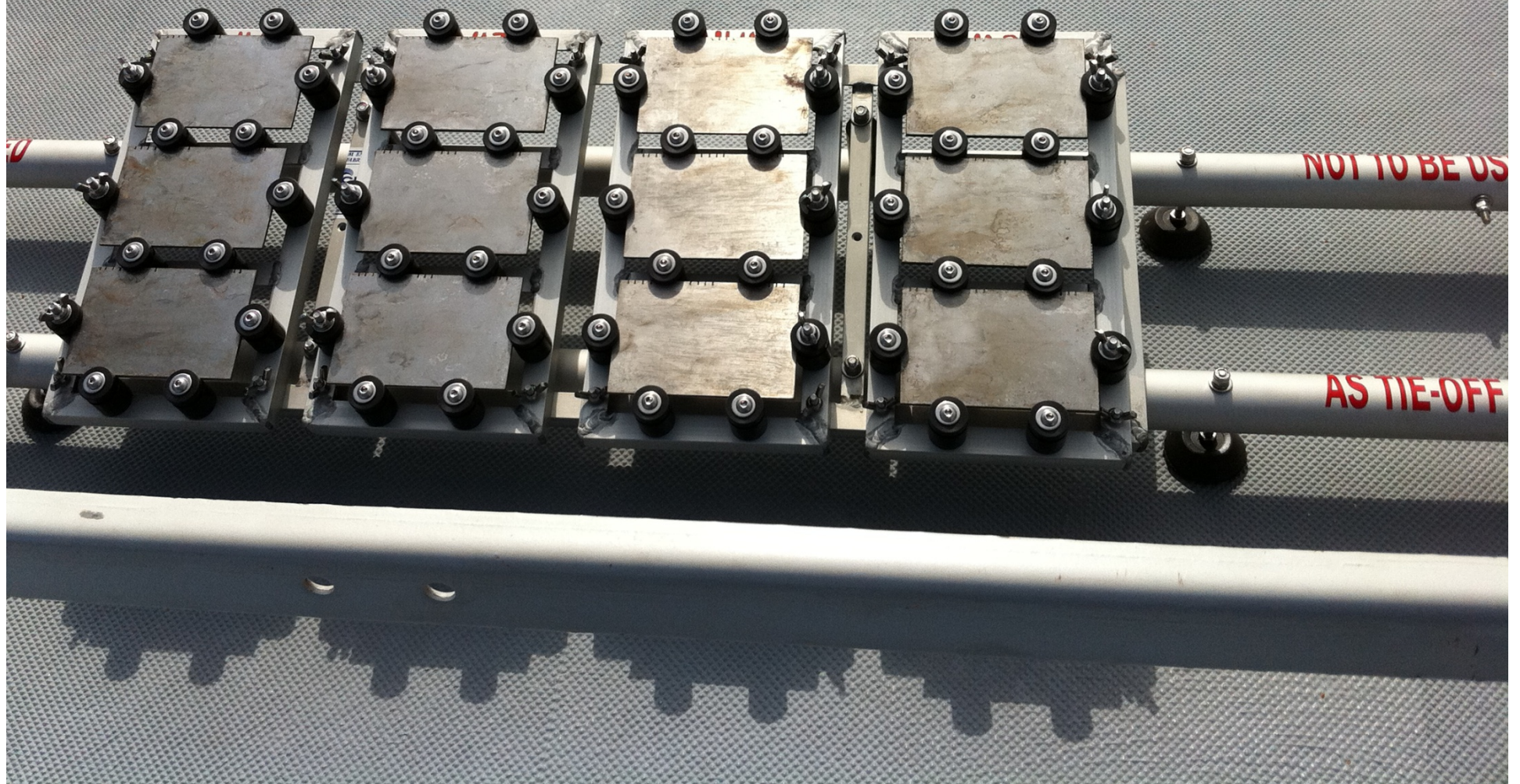
6. We would also recommend a wire rope tether to attach Sample Mounting Frame to the uprights as a fail safe.

| | | |
|--------|------|---|
| 13 | 1 | Castings Al. Sample Mounting Frame |
| 12 | 2 | Rubber Bumpers 1.5" x 1.4", Bolted to body. |
| 11 | 4 | 1/4"-20 Bolt, Washer, Double Nut |
| 10 | 2 | Ø1" Support, Angle Upright Support |
| 9 | 8 | 1/4-20 x 2.5" Thin Bolts |
| 8 | 2 | 1 - 1/4" Sch. 40 Aluminum Pipe, Approx. 42" LG. |
| 7 | 4 | 1" Sch. 40 Aluminum Pipe, Approx. 18" LG. |
| 6 | 2 | 1" Aluminum Female 90° Elbow |
| 5 | 2 | 1" Sch. 40 Aluminum Pipe, Approx. 5" LG. |
| 4 | 2 | 1" Aluminum Female T |
| 3 | 2 | 1 - 1/4" Sch. 40 Aluminum Pipe, Apron, 12" LG. |
| 2 | 2 | 3/8" Tk. Mounting Flange |
| 1 | 2 | Vibration Damping Clamping U-Bolt |
| Number | Qty: | Description |

NOTES:
1. BREAK ALL SHARP EDGES.

| | | |
|--|-----------------------|---------------------|
| CHPT, Incorporated | | |
| Nacelle Corrosion Mounting Frame | | |
| University of Delaware - Newark Campus | | |
| DATE: 12/21/10 | DESIGNED: [Signature] | REVIEW: [Signature] |
| PROJECT: [Signature] | APPROVED: [Signature] | 5151 B |

**Corrosivity Samples at Location “D” atop the Nacelle
(Sept 2nd, 2011)**



Thanks to: Avinash Taware, Gamesa
Jonathan Harp, CHPT
Bob Johns, Wood Group
Rodney McGee, CEOE
Deanna Sewell, CEOE



Sample Cleaning and Weighing Procedure

- **Immerse in Conc HCl solution containing the Buffers:**
 - **Sb_2O_3 (Antimony Trioxide)**
 - **SnCl_2 (Stannous Chloride)**
- **For 30 to 45 min at 25 deg C**
- **Rinse copiously in DI Water**
- **Dry with Ethanol**
- **Weigh to nearest 0.001 gm**

Cleaned Sample



Summary of Weight Loss Data Over 24 Mo

| Exposure Time | | 6 Months | 12 Months | 18 Months | 24 Months |
|-----------------------------|----------|-------------|-------------|-------------|-------------|
| Location | Sample # | Wt Loss (%) | Wt Loss (%) | Wt Loss (%) | Wt Loss (%) |
| MOB Low (B) | 1 | 1.119 | 1.69 | 2.59 | 3.84 |
| (10 ft back 8 ft high) | 2 | 1.108 | 1.67 | 2.38 | 3.98 |
| | 3 | 1.146 | 1.70 | 2.75 | 4.33 |
| | | | | | |
| MOB High (A) | 1 | 0.886 | 1.62 | 2.31 | 3.01 |
| (100 ft back 30 ft high) | 2 | 0.855 | 1.46 | 2.19 | 2.86 |
| | 3 | 0.869 | 1.62 | 2.19 | 2.90 |
| | | | | | |
| Turbine Base (C) | 1 | 0.620 | 1.41 | 1.96 | 1.96 |
| (1150 ft back, 3ft high) | 2 | 0.625 | 1.39 | 1.87 | 2.09 |
| | 3 | 0.645 | 1.43 | 1.97 | 2.16 |
| | | | | | |
| Turbine Top (D) | 1 | 0.82 | 1.50 | 1.76 | 1.99 |
| (1150 ft back, 100 ft high) | 2 | 0.83 | 1.46 | 1.78 | 2.03 |
| | 3 | 0.86 | 1.45 | 1.81 | 2.07 |

Summary of Avg. Weight Loss Data Over 24 Mo

| | 6 Months | | 12 Months | | 18 Months | | 24 Months | |
|------------------|----------|------|-----------|------|-----------|------|-----------|------|
| | (gm) | (%) | (gm) | (%) | (gm) | (%) | (gm) | (%) |
| MOB Low (B) | 2.74 | 1.12 | 4.11 | 1.68 | 6.26 | 2.57 | 9.86 | 4.05 |
| | | | | | | | | |
| MOB High (A) | 2.11 | 0.81 | 3.79 | 1.57 | 5.44 | 2.23 | 7.05 | 2.92 |
| | | | | | | | | |
| Turbine Base (C) | 1.53 | 0.63 | 3.41 | 1.41 | 4.74 | 1.94 | 5.04 | 2.07 |
| | | | | | | | | |
| Turbine Top (D) | 2.04 | 0.84 | 3.57 | 1.47 | 4.32 | 1.78 | 4.95 | 2.03 |
| | | | | | | | | |

Conclusions:

1. Something on top of the Nacelle (perhaps turbulence from the blades) interferes with corrosion product film formation during the first year of exposure.
2. After the first year of exposure, the effect disappears.

Dexter, Corrosivity: Progress as of 12/2013

| | |
|---------------------|--|
| June – Aug, 2010 | Construct Corrosivity Samples & Holders |
| Sept, 2010 | Deploy 1 st 3 Corrosivity Sample Groups |
| March, 2011 | Remove and Analyze 6 Mo Samples |
| March, 2011 | Design Holder for Nacelle Samples |
| June, 2011 | Approval to put Samples on Nacelle |
| Summer, 2011 | Gathering Atmospheric Corrosion Data (still on-going) |
| Summer, 2011 | Build Sample Holder for Nacelle |
| End of Aug, 2011 | Mount Samples atop Nacelle at Loc D |
| End of Aug, 2011 | Remove 12 Mo Samples from Locations A, B & C |
| Early Sept, 2011 | Analyze 12 Mo Samples at A, B & C |
| Fall, 2011 | Design Electronic Corrosion Monitors |
| 1/12 – 3/12 | Deploy Electronic Corrosion Monitors |
| March, 2012 | Remove and Analyze 18 Mo Samples + 6 Mo at Site D |
| Sept, 2012 | Remove and Analyze 2Yr Samples + 12 Mo at Site D |
| March, 2013 | Remove and Analyze 18 Mo Samples from Nacelle Site D |
| Sept, 2013 | Remove and Analyze 2 Yr Samples from Nacelle Site D |
| Dec, 2013 | Compare to other sites along US East Coast |
| Dec, 2013 | Finish Analysis and Write Final Report |

Not Possible

A photograph of a wind turbine at night. The turbine is a three-bladed model with a tall tower, silhouetted against a dark sky. A bright, jagged lightning bolt strikes the sky above the turbine, creating a large, glowing purple and white cloud of light. The foreground is dark, showing the silhouette of a field and some distant lights.

Lightning Over The Lewes Wind Turbine