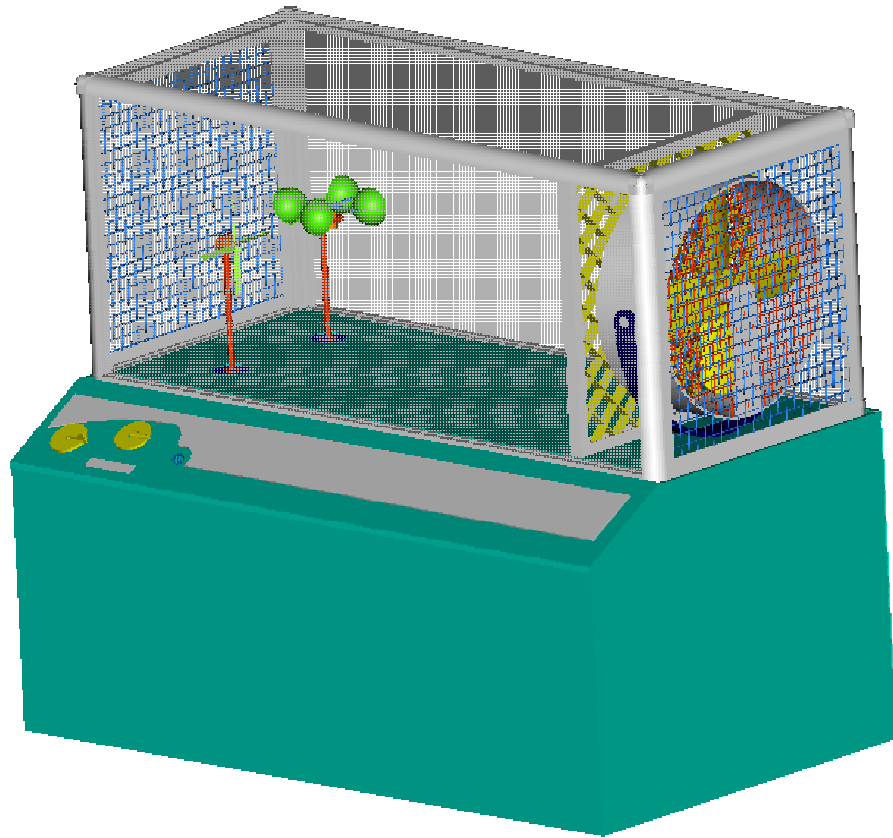


# **“Wind Power”**

## Wind Energy Demonstration



## Operations Manual

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# Operations Manual

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## **1.0 Introduction**

The “Wind Power” museum exhibit has been designed and tested by Wind Energy Systems Incorporated and has been deemed fully operational. With children as the target audience, this wind energy demonstration has been designed to comply with the safety constraints deemed important by the Mary Brogan Museum of Arts and Science. However, certain safety warnings must be included to ensure safe operation.

## **2.0 Warnings**

Any device with electrical or moving components can create a hazard to anyone that comes into direct contact with the unit. With children being the target audience, several warnings need to be followed during the operation of the “Wind Power” exhibit to ensure safety for all museum visitors.

### **2.1 Electrical**

The museum exhibit is an electrically driven device with numerous electrical components. Although all electric circuits and components are located securely in the base of the exhibit, certain precautions should be followed. Moisture has drastic effects on electrical equipment; therefore the exhibit should be located in a dry, climate-controlled environment. Drinks and other liquids should never come in contact with the exhibit, due to the chance of electric shock or damage to the unit. If the exhibit comes into contact with a liquid or moisture, the exhibit should be immediately unplugged, cleaned and dried. If the liquid has penetrated the exhibit, the unit should be kept unplugged and non-operational until an internal cleaning can be performed or the liquid has a chance to evaporate. Once this has been completed, the exhibit can be safely restarted.

## **2.2 Moving Parts**

The exhibit is fully enclosed with plastic panels, laminated wood and mesh screens. The openings in the mesh screen are relatively small, but are necessary to allow airflow to enter and exit the exhibit. Nothing should be inserted through the wire mesh screens to ensure the safety of museum visitors and prevent damage to the exhibit. The wind-generating fan is located just inside the wire mesh screen on the left side of the exhibit. The fan, its electrical components and moving parts are also protected with an aluminum wire screen. However, the penetration of a small enough object, such as a pencil, could enter and obstruct the moving parts of the fan. This could cause damage to the fan assembly or injure a museum guest or employee. Therefore, probing or inserting an object into the exhibit through the wire mesh screens should be avoided at all costs.

## **3.0 Installation and Setup**

The museum exhibit should be transferred into its new environment using a palette jack or some other lifting and transporting device to ensure the unit stays level during transportation. Once the exhibit is placed in the museum, the unit should be leveled using the adjustable feet located in the four corners of the frame. If the exhibit is not leveled before initial operation, there is a possibility of incorrect operation of the device and all of its components.

The exhibit is an electrical device that uses power from a standard electrical wall socket. The entire exhibit is wired into one electrical cord to simplify the installation process. If the wall outlet to be used is located away from the exhibit, the electrical cord should be hidden or secured to prevent a museum visitor from tripping or falling over a loose cord. Once the exhibit is installed and connected to a power outlet, it will be in full working condition.

## **4.0 Operating Instructions**

Once the “Wind Power” exhibit is positioned and connected to its power source, the experience can begin. The unit will be on standby until a museum visitor initiates the system by pressing the start button. This start button is wired to the fan and a timed kill switch designed to cut power to the exhibit. After a set time interval, the kill switch will reset the exhibit back into a standby state. Once the start button is pressed, the exhibit will come alive. The wind-generating fan will start, producing an airflow that passes through an aluminum honeycomb screen. The honeycomb regulates the generated wind into an even laminar flow, allowing each wind turbine to receive an equal portion of the airflow. This is necessary since the comparison of the horizontal axis and vertical axis turbines is sought. Once the laminar airflow reaches the wind turbines, they will begin to rotate on their respective shafts. These rotating shafts run small DC motors in reverse providing a current and a voltage. The power produced by each turbine is the product of the current and voltage multiplied together. This operation is calculated in a hidden electrical circuit, and is displayed using the two light towers. The airflow then exits the right side of the exhibit, giving the museum visitors the opportunity to feel the strength of the generated wind.

## **5.0 Interaction Points**

The main goal of this design was to create an interactive demonstration. The first interaction a guest will come across is the variable wind speed. The fan operates at three settings, low medium and high. The velocity of the generated wind is measured and displayed on the control panel by the mini-vane anemometer. The anemometer also displays the airflow’s temperature. As the fan setting is increased, the airflow velocity increases, producing higher power outputs for each wind turbine. As the power outputs increase, more lights in the light

towers will ignite displaying this increase. The second interaction a guest will have with the exhibit is the angle at which the airflow strikes the wind turbines. This angle at which the wind turbines sit in the airflow can be changed from thirty degrees to negative thirty degrees from a starting point perpendicular to the airflow. Both wind turbines rotate using the same timing belt pulley system and control dial. Since grooved timing belts were used, both wind turbines will rotate and remain at the same angle. This interaction point compares the two different styles of wind turbines. The angle of attack should not affect the vertical axis turbine; therefore, the power display should remain constant at each velocity setting. On the other hand, the horizontal axis wind turbine's efficiency will diminish as the angle of attack is varied from zero or the perpendicular starting position. This efficiency loss will be displayed on the respective light tower by lights cutting off one by one as the angle of attack is increased.

## **6.0 Routine Maintenance**

Basic cleaning instructions for the exhibit can be applied to keep the exhibit in proper working order. The Plexiglas panels can only be cleaned with mild soap and water. Note that the Plexiglas panels will be damaged if a chemical surface cleaner is used. To keep the inside of the exhibit in good working condition, the right-hand side wire mesh can be removed by unscrewing the nuts and bolts holding the wire mesh in place. Dust and other foreign particles can be removed with a soft cloth, taking care not to damage the delicate components inside the exhibit. Dust should also be removed from the electronics and pulley system in the bottom portion of the exhibit. The back wooden panel can be removed by removing the nuts and bolts. Check on each component in the exhibit approximately once every two to three months to ensure that each piece is in proper working condition. Abiding by these guidelines will help to keep the exhibit in proper working conditions for the time duration of the display.

## **7.0 Future Complications (Should they arise)**

The “Wind Power” exhibit has been designed with durability in mind, since the unit will be displayed over the next few years. However, there is always a chance of faulty parts or component wear and damage due to the long duration of use. In this case replacement parts can be ordered from the correct vendor stated in the component list, which follows. In the component list all parts, part numbers, vendors, prices and ordering information are listed. Failure of the exhibit or any of its components is not expected, but if the worst happens, the components can easily be replaced.

The members of Wind Energy Systems Incorporated stands behind this design, and hope the Mary Brogan Museum utilizes the unit to help educate the public, both young and old, on wind energy.

## **8.0 Component List**

This component list has been divided into component sections. Each section lists what parts were used, part numbers, quantity used, description, unit price, and vendor. Ordering information for each vendor is located in section 9.0, the vendor list.

### **8.1 8020 Aluminum Framework**

The exhibit frame was made from modular aluminum pieces produced by 8020. The aluminum framework will not bend under the loads of the exhibit, and should outlast the duration at which the exhibit will be displayed. However, with cleaning and maintenance of the exhibit, the connecting screws and t-nuts may strip if not properly removed and aligned during reassembly. In this case, replacement machined screws and t-nuts can be ordered from 8020. The part numbers and unit price of all frame accessories are located below in Table 8.1.

Table 8.1: Component list for the exhibit framework

<i>Exhibit Frame</i>						
<i>Part Number</i>	<i>Quantity</i>	<i>Length (in)</i>	<i>Description</i>	<i>Cost Per Item</i>	<i>Total</i>	<i>Vendor</i>
1515	5	63	T-slotted extrusion	\$31.50	\$157.50	8020
1515	2	60	T-slotted extrusion	\$30.00	\$60.00	8020
1515	1	48	T-slotted extrusion	\$24.00	\$24.00	8020
1515	3	36	T-slotted extrusion	\$18.00	\$54.00	8020
1515	2	28.5	T-slotted extrusion	\$14.25	\$28.50	8020
1515	2	27	T-slotted extrusion	\$13.50	\$27.00	8020
1515	10	27.84	T-slotted extrusion	\$12.00	\$120.00	8020
1515	2	20.938	T-slotted extrusion	\$10.47	\$20.94	8020
1515	2	10.375	T-slotted extrusion	\$5.19	\$10.38	8020
2474	2	6.250 SQ ft	Black PVC Coated Wire Mesh	\$18.44	\$36.88	8020
2609	3	13.750 SQ ft	Clear Polycarbonate	\$98.31	\$294.93	8020
7010	29	N/A	Parts Cut to Length	\$1.85	\$53.65	8020
7025	4	N/A	Tap Extrusion Ends	\$2.25	\$9.00	8020
7095	2	N/A	Shearing Expanded Metal	\$9.75	\$19.50	8020
7155	3	N/A	Cut Polycarbonate Panels	\$16.50	\$49.50	8020
2190	4	N/A	Deluxe Leveling Foot	\$12.25	\$49.00	8020
4301	42	N/A	Hole Inside Corner Bracket	\$4.05	\$170.10	8020
4388	6	N/A	90° Degree Pivot Nub	\$4.55	\$27.30	8020
4396	12	N/A	Straight Arm	\$5.25	\$63.00	8020
3320	168	N/A	Economy T-Nut	\$0.57	\$95.76	8020
3278	125	N/A	5/16-18 Economy T-Nut	\$0.25	\$31.25	8020
3330	8	N/A	Flanged BHSCS	\$0.34	\$2.72	8020
91355A087	3	1"	5/16-18 Alloy Steel Cap Screw (25pk)	\$10.92	\$32.76	Mcmaster
91355A093	3	5/8"	5/16"-18 Alloy Steel Cap Screw (25pk)	\$9.91	\$29.73	Mcmaster

## 8.2 Flow Management

The flow management components consist of the Qmark LDC20 fan, a honeycomb sheet, and aluminum angle for mounting the honeycomb. The fan has been modified from its original



purchase condition voiding the warranty. If the fan fails or is damaged a replacement fan can be ordered from heatersplus.com. The honeycomb and the aluminum angle have been selected to outlast the exhibits display lifespan, and should never need replacing. All parts used for the flow management component of the exhibit can be found in Table 8.2.

Table 8.2: Component List for the flow management devices

<i>Flow Management</i>						
<i>Part Number</i>	<i>Quantity</i>	<i>Length (in)</i>	<i>Description</i>	<i>Cost Per Item</i>	<i>Total</i>	<i>Vendor</i>
9635K73	1	24	Honeycomb	\$44.55	\$44.55	Mcmaster
88805K47	1	96	Aluminum Angle	\$9.87	\$9.87	Mcmaster
LDC20	1	20	Fan	\$215.25	\$215.25	Heaters Plus

### 8.3 Electronics

The electronics were ordered from numerous companies. If a part fails during exhibit use, replacements can be ordered from the respective vendor. All of the electrical components are listed in Table 8.3 below.

Table 8.3: Summary of Electrical Components

<i>Electronics</i>						
<i>Part Number</i>	<i>Quantity</i>	<i>Length (in)</i>	<i>Description</i>	<i>Cost Per Item</i>	<i>Total</i>	<i>Vendor</i>
8654T7	2	17.5	Light Tower	\$142.06	\$284.12	Mcmaster
6X154	1	N/A	Time Delay Relay	\$54.00	\$54.00	Grainger
407117	1	N/A	Anemometer	\$459.00	\$459.00	Cole Parmer
156221	1	N/A	A/C Adapter	\$25.00	\$25.00	Cole Palmer
918-0005	2	4.5	Analog Meters	\$77.90	\$155.80	Allied
288-1241	15	N/A	Voltage Comparators	\$0.78	\$11.70	Allied
288-1242	15	N/A	Voltage Comparators	\$0.35	\$5.25	Allied
5X852	1	N/A	Connection Base	\$7.14	\$7.14	Grainger
288-1514	5	N/A	Op-Amps	\$4.41	\$22.05	Allied
879-0099	2	N/A	A/C Adapter	\$52.12	\$104.24	Allied

### 8.3.1 Light Tower Replacement Parts

The light towers house five incandescent light bulbs. These light bulbs are rated for 7000 hours of life. When any of the light bulbs fail due to fatigue, their replacements can be ordered from McMaster. The light bulbs are interchangeable, therefore can be ordered in excess for backup bulbs. McMaster also provides replacement lenses in case of damage. When ordering replacement lenses, the color needs to be identified. The part numbers for these maintenance replacements can be found below in Table 8.4.

Table 8.4: Light tower maintenance components

<b>Light Tower Replacement Accessories</b>						
<b>Part Number</b>	<b>Quantity</b>	<b>Length (in)</b>	<b>Description</b>	<b>Cost Per Item</b>	<b>Total</b>	<b>Vendor</b>
8654T8	1	N/A	Replacement Bulbs	\$2.20	\$2.20	Mcmaster
8654T9	1	N/A	Replacement Lens	\$4.93	\$4.93	Mcmaster

### 8.3.2 Anemometer Warranty

The Extech 407117 Heavy Duty Mini Vane CFM Thermo Anemometer is a very expensive piece of equipment. The control panel has been designed to protect this unit from harsh effects that may cause damage. However, Extech offers a warranty for this model. The manufacturer's warranty reads:

Extech Instruments Corporation warrants this instrument to be free of defects in parts and workmanship for three years from the date of shipment (a six month limited warranty applies on sensors and cables). If it should become necessary to return the instrument for service during or beyond the warranty period, contact the Customer Service Department at (781) 890-7440 for

authorization. A Return Authorization (RA) number must be issued before any product is returned to Extech. The sender is responsible for shipping charges, freight, insurance and proper packaging to prevent damage in transit.

This warranty does not apply to defects resulting from action of the user such as misuse, improper wiring, operation outside of specification, improper maintenance or repair, or unauthorized modification. Extech specifically disclaims any implied warranties or merchantability or fitness for a specific purpose and will not be liable for any direct, indirect, incidental or consequential damages. Extech's total liability is limited to repair or replacement of the product. The warranty set forth above is inclusive and no other warranty, whether written or oral, is expressed or implied.

The anemometer was shipped on 2/18/2005, which gives the warranty until the same date in 2008.

#### **8.4 Pulley System**

The pulley system utilizes six timing belts and pulleys. The pulleys are constructed of a polycarbonate material with an aluminum insert, while the belts are neoprene with fiberglass acting as the tension member. Both the pulleys and timing belts were designed for a maximum duration at high angular velocities, therefore, have a minimal chance of failure in the low torque application of the exhibit. The components used to fabricate the angle of attack pulley system are listed in Table 8.5.

Table 8.5: Component list for the pulley system

<i>Pulley System</i>						
<i>Part Number</i>	<i>Quantity</i>	<i>Length (in)</i>	<i>Description</i>	<i>Cost Per Item</i>	<i>Total</i>	<i>Vendor</i>
A6Z3-24DF03708	2	N/A	Timing Pulley with 0.250" bore	\$4.93	\$9.86	SDP/SI
A6Z3-24DF03712	4	N/A	Timing Pulley with 0.375" bore	\$4.93	\$19.72	SDP/SI
A6R3-146037	1	29.20"	Horizontal Timing Belt	\$8.83	\$8.83	SDP/SI
A6R3-169037	1	29.20"	Angled Timing Belt	\$7.58	\$7.58	SDP/SI
89215K421	1	36	Supporting cross bar	\$17.10	\$17.10	Mcmaster
6389K625	2	3/8"	Nylon Bearings (5pk)	\$1.49	\$2.98	Mcmaster

## 8.5 Wind Turbines

The wind turbines were fabricated using machined aluminum parts and components found at a Hobby Town USA in Tallahassee, Florida. The list of all the purchased and donated wind turbine components is below in Table 8.6.

Table 8.6: Wind turbine components

<i>Wind Turbines</i>						
<i>Part Number</i>	<i>Quantity</i>	<i>Length (in)</i>	<i>Description</i>	<i>Cost Per Item</i>	<i>Total</i>	<i>Vendor</i>
N/A	2	N/A	DC motors	\$4.50	\$9.00	Hobby Town
N/A	2 (1 extra)	N/A	Plastic cup propeller	Donated	\$0.00	Inspeed Hobby Town
N/A	1	N/A	11" wooden propeller	\$4.00	\$4.00	
86985K33	1	72	Aluminum Rod for Turbine Shafts	\$13.01	\$13.01	Mcmaster

## 9.0 Vendor List

The vendor list below in Table 8.7, displays the website, phone and fax numbers, and street address for each vendor used for the exhibit.

Table 8.7: Complete Vendor List

<i>Vendor List</i>				
<b>Vendor name</b>	<b>Website</b>	<b>Phone</b>	<b>Fax</b>	<b>Address</b>
8020	<a href="http://8020.net">http://8020.net</a>	(260) 248-8030	(260) 248-8029	1701 South 400 East Columbia City, IN 46725
Mcmaster	<a href="http://www.mcmaster.com">http://www.mcmaster.com</a>	(404) 346-7000	(404) 349-9091	PO Box 740100 Atlanta, GA 30374
Grainger	<a href="http://www.grainger.com">http://www.grainger.com</a>	(850) 575-4137	(850) 575-1764	3924 West Pensacola St. Tallahassee, FL 32304
Cole Parmer	<a href="http://coleparmer.com">http://coleparmer.com</a>	1 (800) 323-4340	(847) 247-2929	625 East Bunker Court Vernon Hills, IL 60061
Allied	<a href="http://www.alliedelec.com">http://www.alliedelec.com</a>	1 (800) 433-5700	N/A	7410 Pebble Drive Fort Worth, TX 76118
SDP/SI	<a href="http://sdp-si.com">http://sdp-si.com</a>	(516) 328-3300	(516) 326-8827	PO Box 5416 New Hyde Park, NY 11042
Heaters Plus	<a href="http://heatersplus.com">http://heatersplus.com</a>	(616) 784-1121	(616) 784-7775	5880 Alpine Ave NW Comstock Park, MI 49321
Hobby Town	<a href="http://www.hobbytown.com">http://www.hobbytown.com</a>	(850) 671-2030	N/A	3111 Mahan Dr. Suite 13 Tallahassee, FL 32308
Inspeed	<a href="http://inspeed.com">http://inspeed.com</a>	(978) 397-6813	N/A	10 Hudson Road Sudbury MA 01776