An Abstract of the Thesis of

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in the Department of Industrial Technology

TITLE: Windmill Documentary

This thesis documents the ideation of a new wind-powered device and the process of constructing a model to present the concept. Prior art that aided in the conception of the new design is reviewed and used to question the novelty of the device. It is concluded that the device is not novel and exists as prior art. This thesis helps illustrate some of the decisions made in the field of model-making in regards to model scale and material selection by contrasting different choices with each other.

Introduction

The consumption of wind-energy is rising. From 1999 to 2000, U.S. consumption of wind energy rose 124%. From 2000 to 2001, 2001 to 2002, and from 2002 to 2003, wind energy consumption rose by 119%, 154%, and 103% respectively (U.S. Department of Energy, 2004). Because of this growing need for energy, the author in 2001 bore the idea of a new type of wind-powered device. The work begun in 2001 was continued in 2005, resulting in a working prototype. The goal of this thesis is to discover if there is any prior art of such a device, and also to document the ideation and prototyping of the device.

I. Ideation

Supporting Art

In the spring of 2001 the author was exposed to vertical-axis windmills for the first time. These types of windmills rotate on an axis that is not parallel to the wind, but perpendicular; thus the axis is also seen as perpendicular to the surface of the earth. A benefit of this orientation is that the windmill would never have to turn to face the wind. In effect, the windmill would always be ready for the wind no matter where it came from. This "always-on" effect is important because conventional horizontal-axis windmills must be specifically engineered to take the gyroscopic stresses of turning into the wind. That is to say that horizontal-axes wind turbines must give up efficiency in order to sustain the stress loads of turning to face a change in the wind. Could a vertical-axis windmill achieve greater efficiency due to the elimination of that stress-relieving material? An internet search turned up many different types of vertical-axis windmills which were studied for their operation. Following are two devices which would later most influence the creation of a new device.

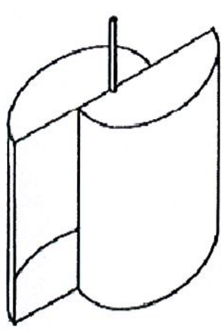
[1]

Figure 1 shows the Savonius turbine (or rotor). This turbine works by providing less resistance to the wind on one side than on the other. This creates an imbalance of force around the center axis, causing the device to turn. After noting this concept, the author was impressed with the idea that the greater the imbalance of force, the more efficient the device would be at producing power from the wind.

[1] Retrieved from Wikipedia, *Savonius wind turbine,* under GNU Free Documentation License.

Figure 1

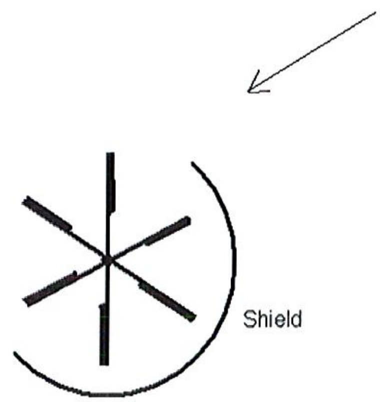

Figure 2

The first windmills on record were developed by the Persians around a thousand years ago (Manwell, J. F., McGowan, J. G., Rogers, A. L. 2002). Like the Savonius turbine, these windmills were drag-based and relied on less resistance on one side of the axis than the other to produce rotation. The Persians achieved this imbalance of force by building a shield of sorts around part of the rotating device, allowing the full brunt of the wind to access wind-catching panels on one side of the device at a given moment. See figure 2 for bird's eye (top) view. It should be noted that this shield is stationary unless manually moved by a force other than the wind. This is of particular interest because should the wind direction change, the windmill will produce less power, or even cease to operate as the shield would no longer be optimally placed. Could a windmill with a combination of the extreme imbalance of this Persian "plate" windmill, and the flexibility of wind direction of the Savonius rotor, be devised? Could this new device leave behind the negative attribute from the Persian windmill of no-to-little flexibility in regards to wind change? Could it also leave behind that smaller imbalance which allows the Savonius to work, in favor of a larger imbalance such as that of the Persian windmill? These are the questions asked in search for a better device. A few weeks of thought on the matter would yield a device.

Embodiment

The thinking of and the dawning of a new idea is such an abstract process that it cannot be easily put into words. Weeks would go by with different concepts and ways of doing things (windmill speaking) before a tangible idea would strike. And then there it was. A concept of panels on a vertically rotating device much like the Persian windmill, but hinged on the outer edge. The panels would be prevented from passing an imaginary plane between the outer post and the center axis. In this way no shield would be required. Panels would catch the wind on one side of the device, be pushed against that imaginary plane, and there they would provide maximum resistance to the wind. Simultaneously on the other side of the device, the panels would swing on their hinges, cutting straight into the wind providing a *minimum* of resistance. See figure 3 for a perspective view of the device and figure 4 for a top view.

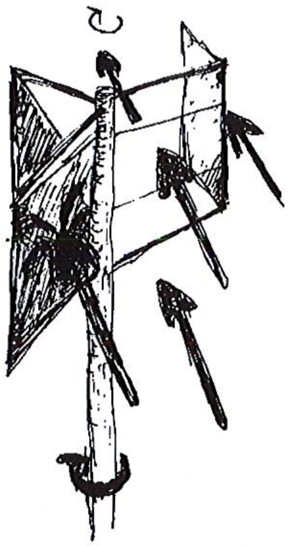

Figure 3

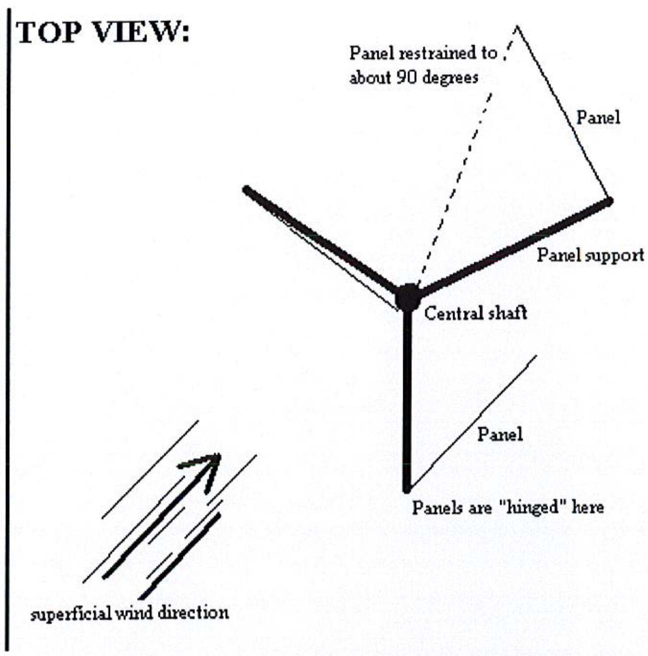

Figure 4

Operation of the device is achieved through airflow sufficient enough to move a panel on its secondary axis until it is restrained to the plane between the secondary axis and the main shaft whereupon further rotation of the panel is not permitted. Because of the orientation of the axis, and because of a unidirectional airflow, only a fraction of the device's panels will be in position resting against the main axis at any moment with their broadest side(s) facing the direction of airflow. Moreover, because of the orientation of the axis and because of a unidirectional airflow, panels not being restrained to the main axis will be free to take the path of least resistance and will therefore cut into the flow of the air current. The effect of this ongoing process is an imbalance of resistance in the device resulting in rotation.

Before the concept was lost it was quickly sketched on paper, and then, because the idea did not require many resources to be produced in its most basic form, a model was made. Two metal clothes-hangers were quickly bent into the shape of a main shaft and three secondary shafts. Paper was cut to form panels and then taped into place. The unit was placed in front of a fan and buzzed in action. The concept worked! But had it already been invented?

Novelty

In accordance with the United States Patent and Trademark Office, novelty and non-obviousness are the conditions which must be met in order for an invention to receive a patent[2] (2005). Furthermore, "an invention cannot be patented if: '(a) the invention was known or used by others in this country, or patented or described in a printed publication in this or a foreign country, before the invention thereof by the applicant for patent,' or '(b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country more than one year prior to the application for patent in the United States…'".

In the search for prior art which would void the novelty or "non-obviousness" of this new device, there are predominately two realms which offer the extensiveness and ease of search necessary for the private individual to undertake such a task. These realms are books and literature on the area of study (windmills, in this case), and online patent searching of the United States Patent and Trademark Office. In this particular case, books on wind devices were first searched, and it was here that the search ended. In *Wind Machines,* the author, Eldridge, mentions and includes two sketches of *panemones (1980)..* (See figure 5 and 6.) Of these machines, the device in figure 5 should immediately draw attention due to its similarities to the author's own panel windmill as explained in a preceding passage. The windmill Eldridge displays possesses the same center shaft about which panels are hinged to secondary shafts and are governed by the wind, coming to rest on a plane between the main shaft and the secondary shafts to create maximum resistance, and then cutting into the wind on their return, minimizing resistance. Because of the sameness of these devices, the author's device cannot be considered novel, and without novelty, a patent cannot be granted. In fact, because the device is not novel,

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[2] A patent is "a right, granted by the government, to a person or legal entity…which gives its holder the right to exclude others from making, using or selling the invention 'claimed' in the patent deed for 20 years from the date of filing" (Hitchcock, 2000).

it is likely that there is little use in pursuing it as a power-generating device because, had it been more efficient, others would have by now pursued that end. Other potential uses for the device will briefly be discussed in the summary of the thesis.

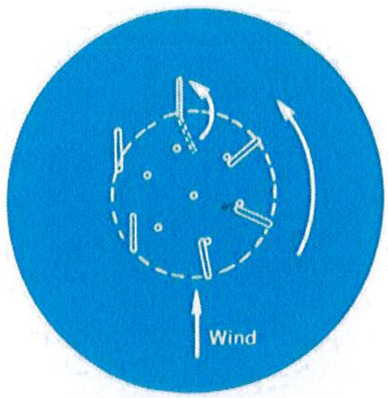


Figure 5

Figure 6

II. Model Planning

In industry, it is most common and most profitable to build a product, or even a model of a product, after research has established the product's novelty. That is because, should the product be novel, it may be patented and then enjoyed exclusively by the inventing company. Should the product not be novel, but has been patented, the researching company may have saved itself from a lawsuit by preventing its intrusion unto another entity's patent.

The author's "invention" has been shown to exist as prior art; yet this was not known until after the building of a model. It is acknowledged and noted that this is not an optimum order of operations as far as product development goes. However, in the name of academic research the planning and construction of the model shall be included in this document. In these next two sections the author asks the reader to please excuse the hypothetical guesses that are evident and are a result of work completed prior to the planning and construction of the model.

Finite Element Method

Although the theory of operation behind the device seems entirely plausible, there are only two ways to discover how well the device would work. One method is through mathematical formulas involving the different wind resistances, material properties, and mechanical and thermal forces called the *finite element method.* This technique does not have to be undertaken though hundreds of hours of calculations on paper, rather, its implementation through the use of computer software, referred to as *finite element analysis,* will allow most if not all of these calculations to be completed in a matter of seconds. All that is needed is the proper entry and manipulation of the data, though it must be noted that this takes a great deal of knowledge in itself.

Models

The second method for discovering how the device performs is to build a prototype or model. The decision to build a model of a product or device can be propagated by any number of factors. Models are built to test hypotheses, to further understanding of a product, as well as for display. Thus, models may be categorized as *working models*, *display models*, and a *combination* of working and display.

Working models are not necessarily finished to look identical to the final product or the designer's idea. Instead, working models serve some kind of function. A working model of a car, for instance, might show off a new suspension system. The car may not be painted, and it may not even have body panels or an interior. The car would look unfinished, but would have a *working* suspension system. Working models do not have to have moving parts however. Models of earrings, dresser pulls, and electronics chassis are often made to test the usability of a product and may therefore be considered working models.

Display models are made with aesthetics in mind. Architectural models are made predominantly for display. Also a form of display modeling, are models of products that have not yet come to market. These models are often made in order to take pictures for the advertising which will be needed upon the product's release.

There are times when models are made with the purpose of fulfilling a *combination* of both looks and function. These are often product ideas which are modeled in such a way that they may be used to judge customer satisfaction of the proposed product in both function and aesthetics. An example of this type of model could be an action figure made to look and work as the final product.

Decisions: Cost/Benefit Trade-off

To test the theory of the wind-powered device, a decision must be made between the two alternatives listed above, proceeding with either a finite element analysis or the construction of a prototype model. Because finite element analysis software is prohibitively expensive for the author to purchase, and because it is not otherwise available, it is eliminated as a possibility for testing the device. Its mother of sorts, the laborious *finite element method*, is beyond both the author's mathematical capacity and time constraints, leaving a physical model as the only realistic option to test the theory of the device.

Relying on a display model alone would not show the device to work or not to work; therefore, a working or combination model must be constructed. Because the theory behind the device is simple, time spent on making the model attractive (for display) will generate more interest in the model than if it were a purely working model. Based on these assumptions, a combination model seems to generate the most benefit at the least cost, and so it is the combination model that will be built to test and show the device.

Scale

The primary purpose of this model is to test the concept of the device; yet remain attractive. Both of these functions may be met at a wide range of sizes, yet there is an optimum size for aesthetics and cost. A model ten feet tall couldn't easily be seen and mentally dissected, nor can it be easily transported or shown in presentations. Therefore the model shall be limited to a size which will allow these activities. The model shall be no taller than three feet, and no wider than two feet.

The cost of the model increases dramatically as its size is reduced below nine inches in height. This is because it is assumed that below this point, special jigs must be used to join the different pieces that make the device. Moreover, at smaller scales greater caution must be exercised to avoid errors. I.e., a scratch on an item two feet square might be unnoticeable, yet a scratch on an item two inches square becomes a major feature and an eyesore of that item. This is because the scratch can be seen as a ratio to the planned product. Using this illustration it is easy to see that an error-to-planned-product ratio of 1:50,000 might be negligible, whereas an error-to-planned-product ratio of 1:5 would be obscene.

The model size chosen was 18 inches in height for the main shaft. This size was chosen because the author interpreted it as an optimum trade-off in cost, mobility, and aesthetics.

Component Material Properties

The size and type of model have been chosen, limiting the types of materials suitable for its construction. To aid in material selection, the windmill is broken down into its main components. (See figure 7 and figure 8.)

[3]

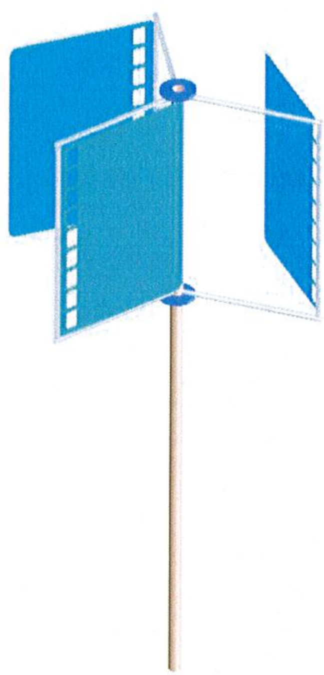


Figure 7

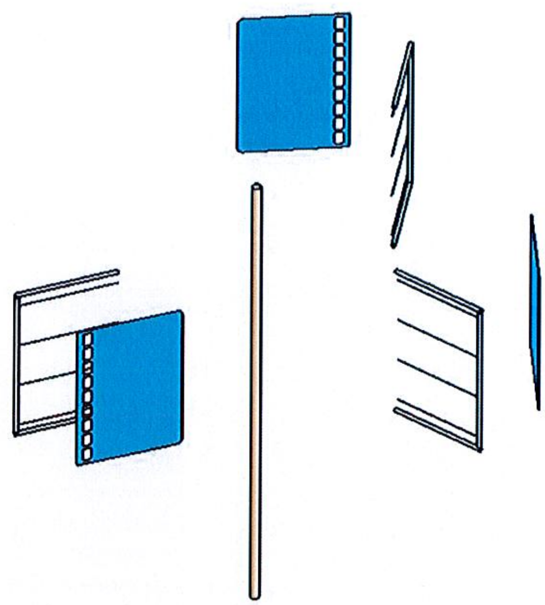


Figure 8

[3] SolidWorks, a 3D Computer Aided Drawing (CAD) program, was used to create part drawings.

Main Shaft

The main shaft (figure 9) serves as a support for the panel cage, lifting it into the "cleaner" and stronger air currents above the ground. It also transfers the torque generated by the panels to a unit located on the ground to accomplish work (such as powering a generator). Even in the working model, the main shaft's duties will remain the same, though its height (in reaching "cleaner' and stronger air currents") has no bearing except in portraying aesthetics and realistic proportions. The model will also not be connected to a generator but will be allowed to rotate freely. Because this model is made to function without transmitting torque, plastic or metal tube or rod would be an ideal material. Both have excellent finishes and finishing capabilities, and both run true (are straight). It is decided than an aluminum arrow tube, which is of ideal diameter, strength, and weight, will be used as the main shaft.

Figure 9

Cage Assembly

The wing armature or "cage assembly" directly supports the wing and limits movement of the wing to an imaginary plane created by the outermost member of the cage and the main shaft. In figure 10 it is seen that the wing's movement is limited by small cables drawn between the main shaft and the outer member of the wing armature (secondary axis or shaft). If a wing were attached to the secondary axis, hinged, and then rotated, it could move 360 degrees but not continuously. I.e., if it were to start rotation with its free edge resting upon the main shaft, it could come around nearly 360 degrees until the limiting cables would stop it. This limiting effect is paramount to the operation of the device as explained previously under *Embodiment* (page 4). It should be noted that the cage is attached to the main shaft in such a fashion as to be completely immovable in relation to the main shaft.

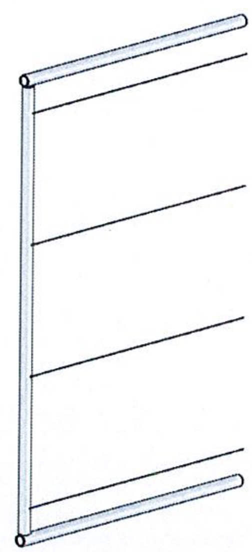


Figure 10

Aluminum tubing, readily available at a local hardware store, will provide an ideal finish, sufficient strength, and low cost. Therefore the cage assembly's main supports shall be made of this tubing. The "limiting cables" could be made of smaller tubing, but this, in comparison with a fine nylon filament (thread), is much heavier. Aesthetically, the thread is much more attractive, and because it will likely be strong enough to absorb the force exerted by the wing, it shall be used.

Wing

The panel or "wing" provides resistance to the wind and transfers this force to the cage assembly. As such, the wing is allowed an axis of rotation or flexibility so that the plane which is made by the wing may change its angle relative to the imaginary plane which lies between the secondary axes and the main shaft. This "axis of rotation" may be achieved by a hinge which links it to the secondary axis, or through the use of a living hinge, as pictured in figure 11.

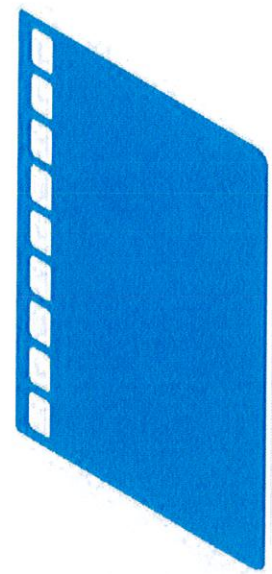


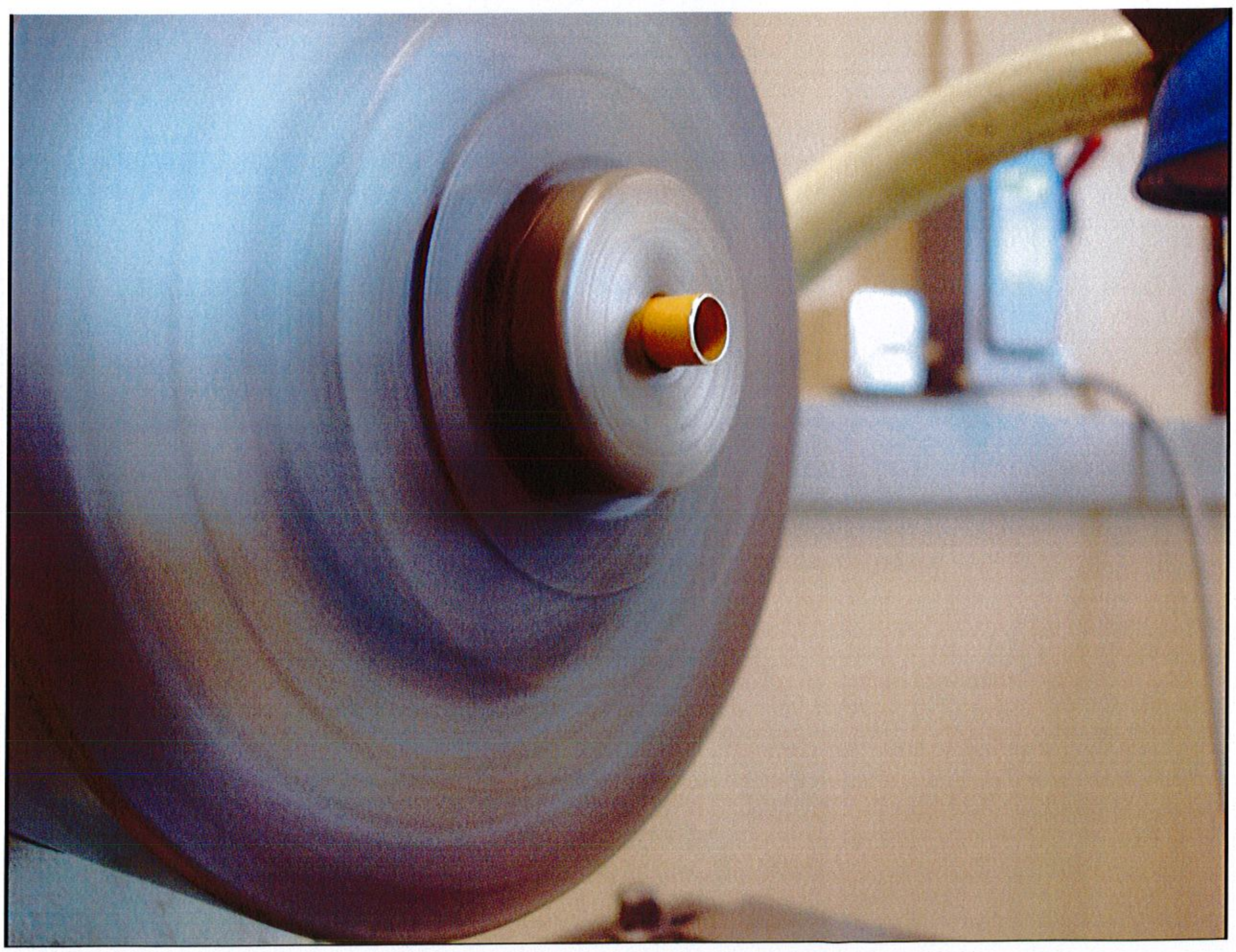
Figure 11

III. Construction of the Model

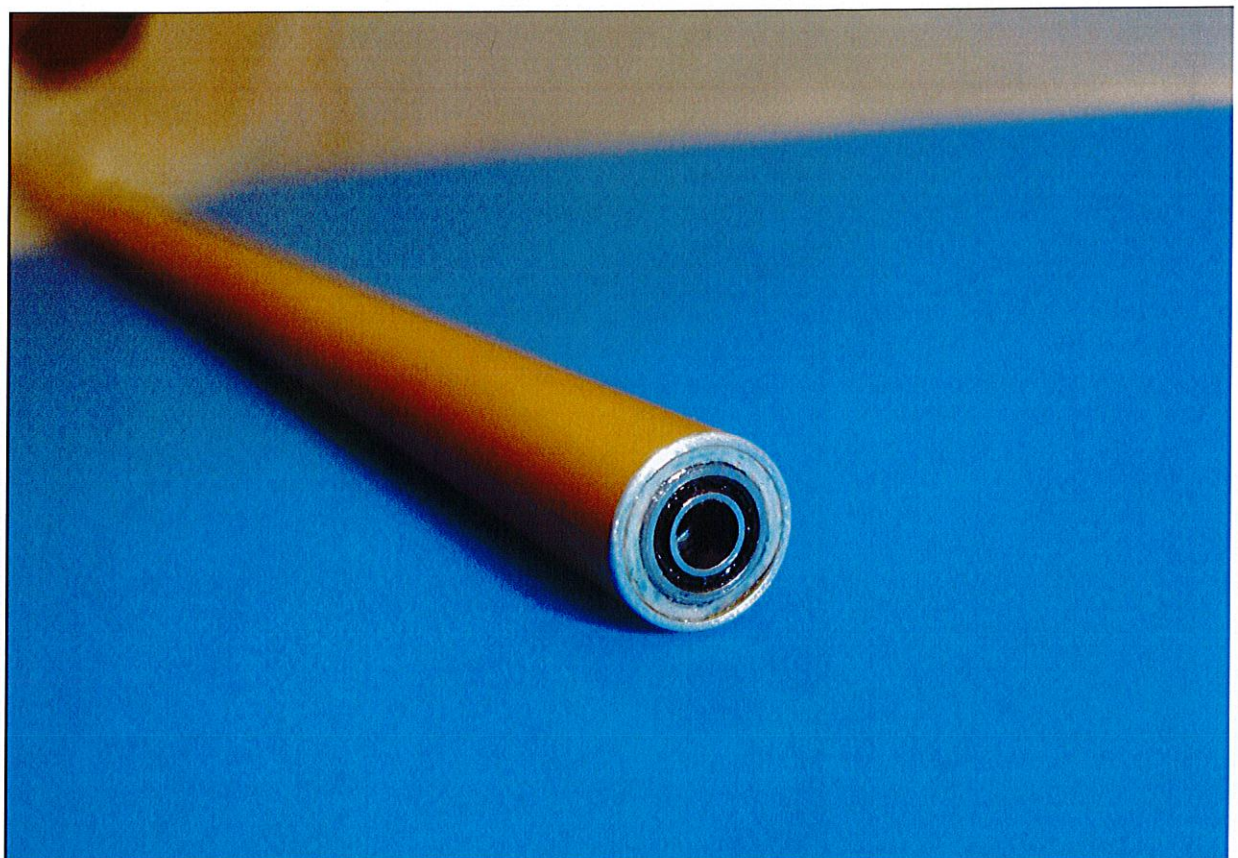
The device was broken down into 22 parts for fabrication prior to the joining together to form the whole. These were identified as:

1 main shaft
2 shaft inserts
3 cage assemblies
9 panel restraints
3 panels
2 minor axles
1 support system
1 base

The main shaft was cut to length and de-burred on a lathe.

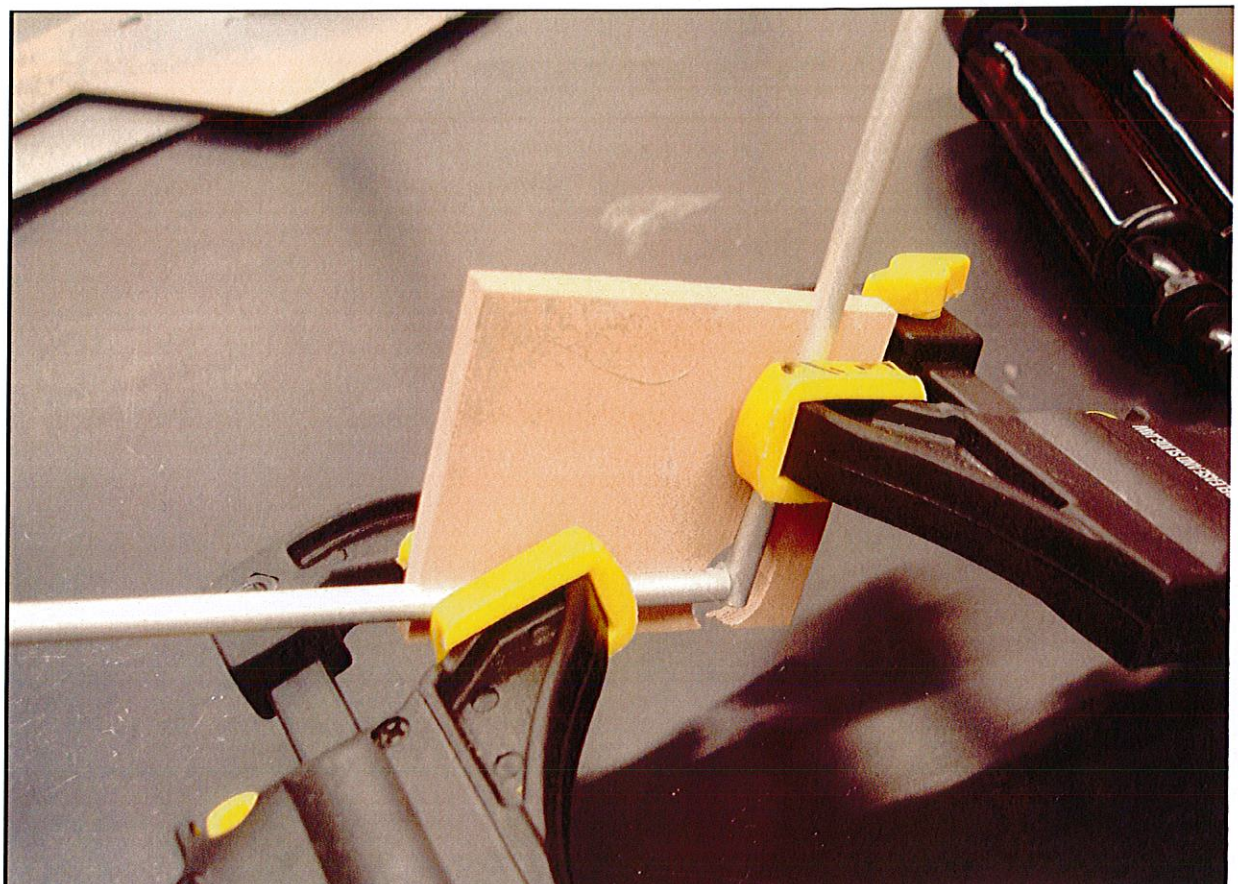


Two bearing assemblies were created by wrapping paper around bearings until the difference between the smaller, outside diameter of the bearings met the larger, inside diameter of the main shaft. The paper was then saturated with Superglue. This quickly created a composite material with high compression strengths. The assemblies were then inserted and glued inside the two ends of the main shaft.



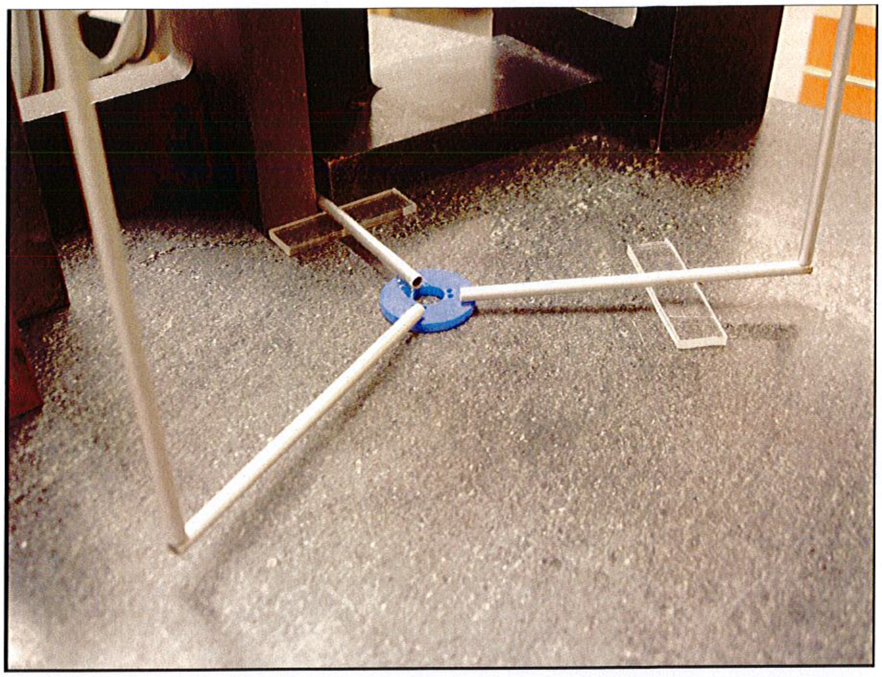
Main shaft with bearing and bearing assembly visible.

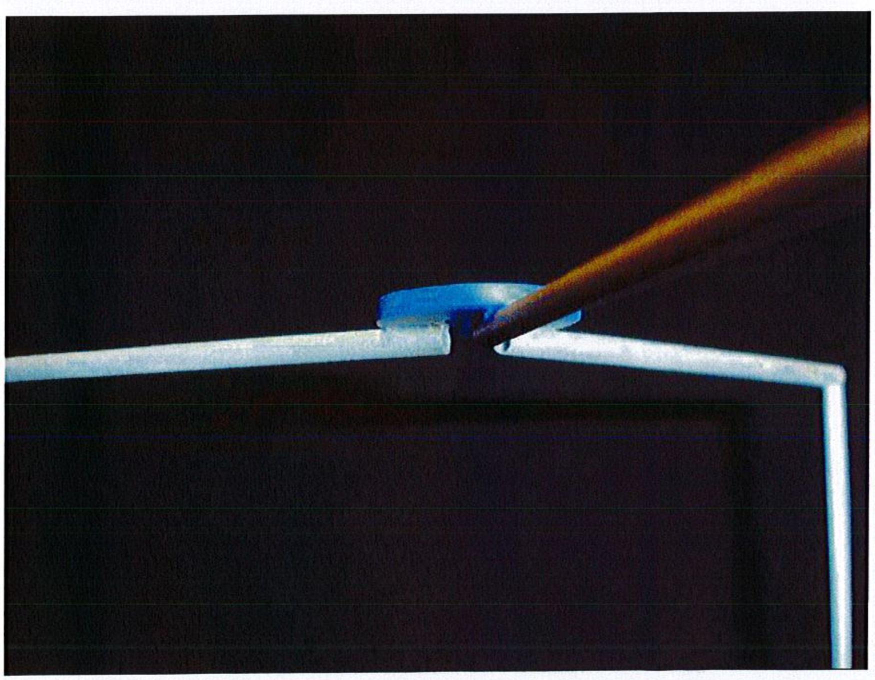
The three cage assemblies were each made of three pieces of 1/8th aluminum tubing which, after being cut to dimensions, were connected to each other through the use of a hi-strength epoxy from Devcon. Fixtures were created to aide in the alignment of the pieces. This was necessary because the pieces needed to be joined at right angles to each other while keeping the same imaginary plane running through the tubes' centers.



Fixtures aided in the construction of the cage assemblies.

The three cage assemblies were fixed at each end to a central piece of acrylic plastic so their secondary shaft components would be parallel to the main shaft. The acrylic would later be fitted upon the main shaft.





Panels for the device were first presumed to be made from textured polyethylene plastic shim stock; use of this material, it was thought, would result in durable and aesthetically pleasing panels. Due to the material's rejection of most forms of adhesion however, as well as its overall weight, a lighter and adhesive-friendly material was chosen: vellum paper. An advantage of the paper was that it could act as a live hinge, bending under little force. The design for the panel was drawn in AutoCAD (figure C6) and then sent to a laser plotter which easily and accurately cut the shape in the vellum. Testing of the hinge would be necessary because the amount of force required to flex the hinge would vary depending upon the amount of material left to act as the hinge. A simple model was constructed for testing (figure C7).

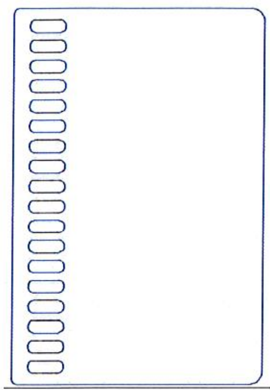


Figure C6

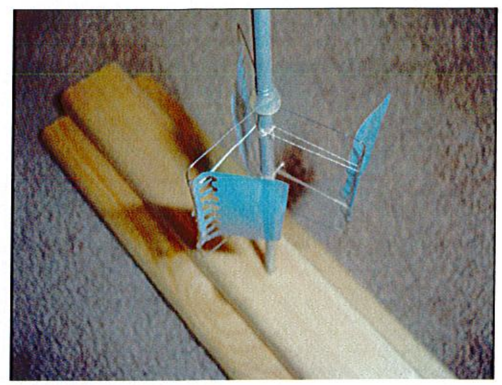


Figure C7

Testing showed the hinge to be too resistant to the force exerted by the available fans. The amount of acting material in the hinge was reduced by severing segments of the hinge. This was done until an acceptable "hinge resistance" was achieved. The material remaining on the hinge was measured and then applied in modifying the CAD drawing of the hinge. The resulting final hinge is shown in figure C8.

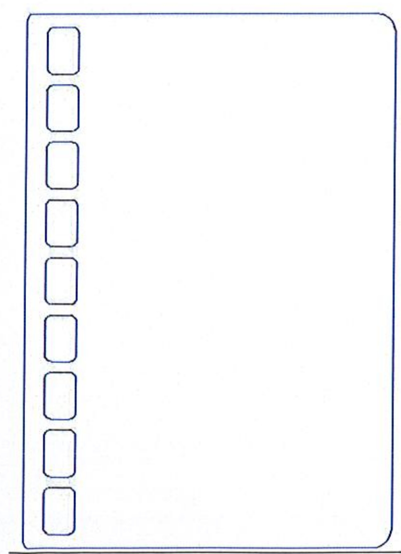
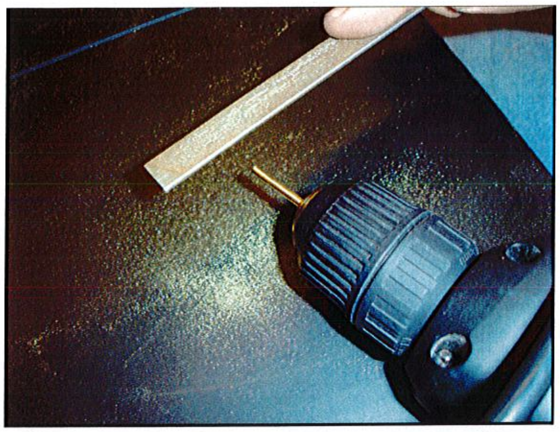
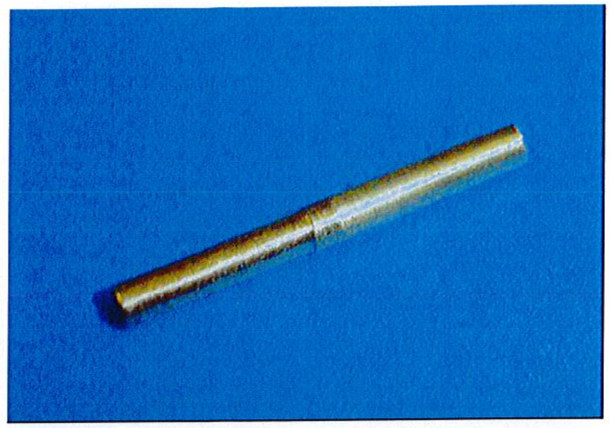


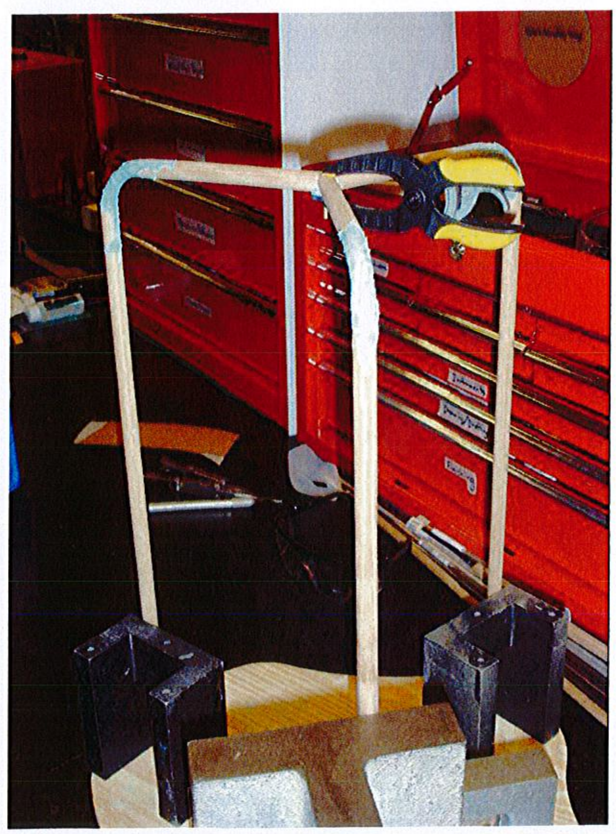
Figure C8

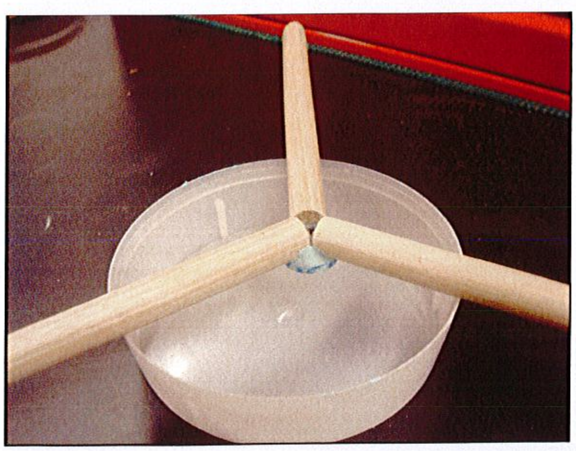
The two minor axles were to be inserted into the bearing assemblies on each end, but to have a lip or an enlargement of diameter to prevent full insertion into the bearing assembly. The axle at the top of the model would support the main shaft from horizontal movement, while the axle at the bottom of the assembly would prevent both horizontal as well as vertical movement. Brass tubing was cut to length and then chucked up in a drill which would serve as a make-shift lathe. A file was used as the cutting tool.



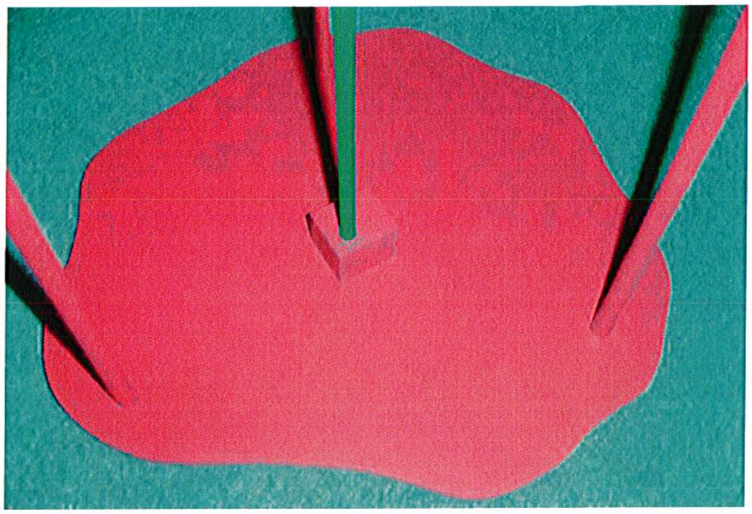


The support system was created from ½ inch oak dowel, cut, joined and filleted, and then joined at a central hub of acrylic plastic. A polyester resin filler, "bondo", was used to create fillets.

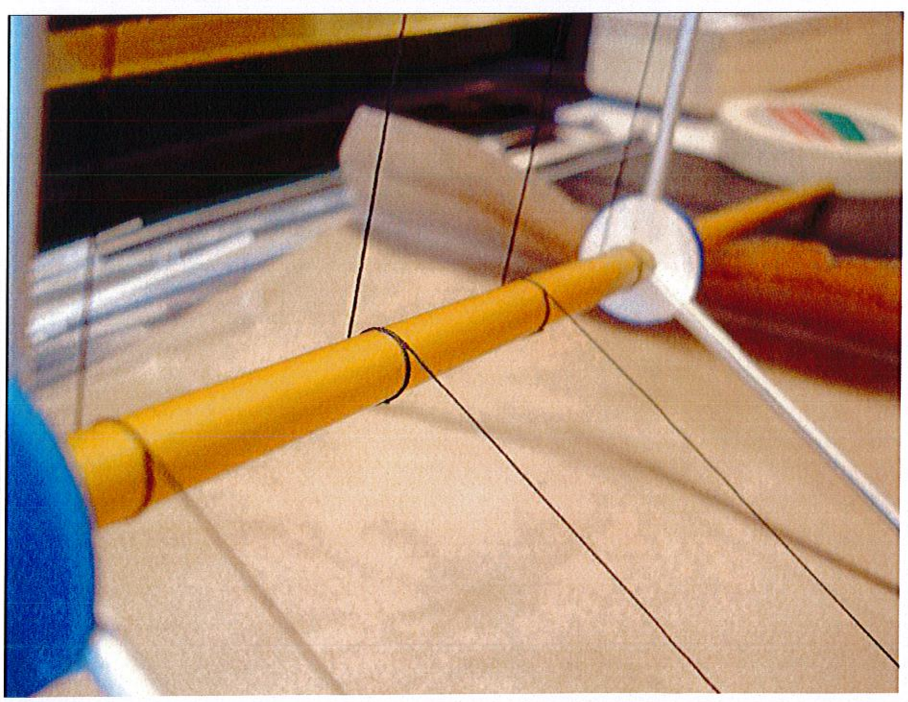




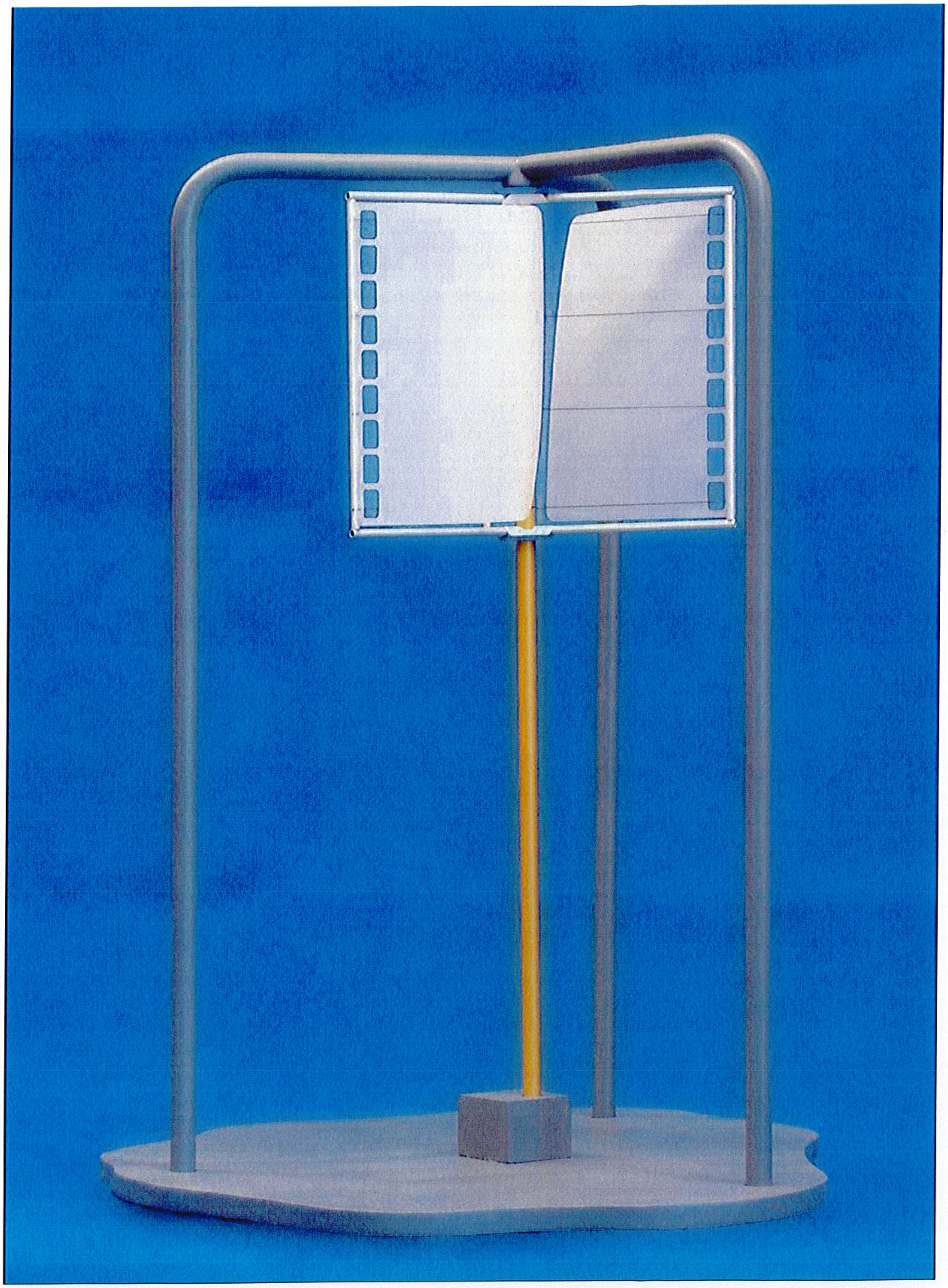
The base was cut free-hand from ½ inch plywood using a scroll saw. An "organic" shape was chosen to emphasize the strong connection the windmill has with renewable and environmentally friendly energy sources. The base along with the support system was painted gray so that the windmill itself, and not these secondary features, becomes the focus of the viewer.

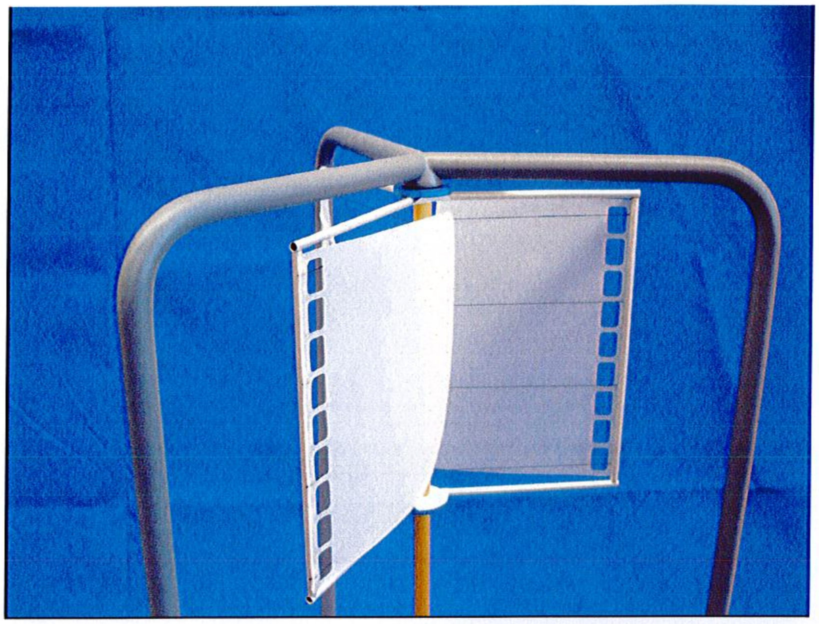


Black nylon thread (below) was utilized for the nine panel restraints. It is strong, light, and absorbs shock easily. Superglue allowed it to be attached with a "clean" look.

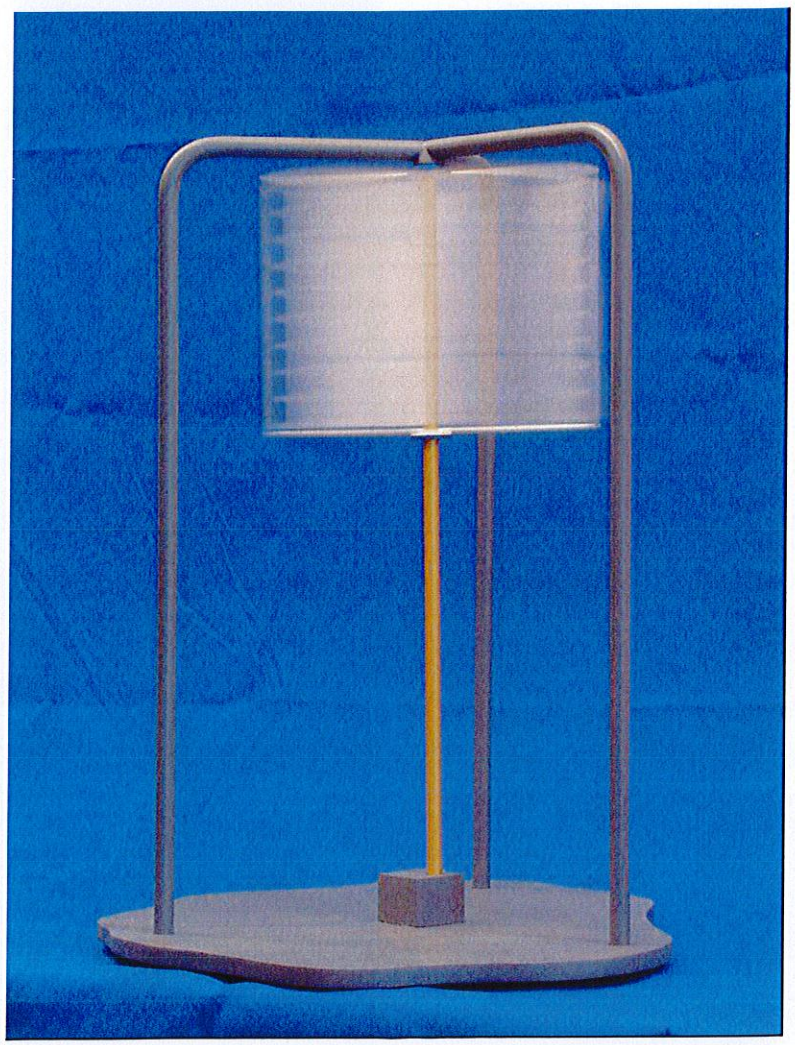


With the attachment of the wing panels, the model was complete.





The windmill whirs in action (at right) after a shot of compressed air is directed at it.



IV. Conclusion

If any conclusions are to be drawn from this thesis, they are that a little bit of research can save a lot of resources. In the project which this thesis documents, had the undertaker been a company, the construction of a useless model might have cost thousands of dollars. That is not to say that research is costless, but typically less costly than brashly rushing ahead with a project.

The discovery that a device is not novel does not mean that profit may not be gained from it. This windmill, for example, may serve as a form of eye-catching advertising with slogans or information painted across its panels. It could also be sold as lawn ornaments should there be enough interest in it.

The art of model design and model making carries with it many decisions in reference to materials and tools used. This thesis illustrates a bit of this decision-making process in reference to the model of the windmill.

Further Research

The wind-powered device in this project has been shown not to be novel; however, no research indicating its actual efficiency was encountered in this project. Additional research might show the efficiency of this device. It might be especially interesting to compare an *efficiency-to-manufacturing-cost ratio* of this windmill to conventional horizontal-axis windmills in widespread use today.

The device exists as prior art, yet it may have been in existence long enough for all ownership of the idea to be extinct. In this situation the device may be freely manufactured, though not enjoyed exclusively. If this is the case, market research for developing the device for use in advertising or as a lawn ornament may prove profitable.

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