[redacted]

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-82/53+545-1		

4. Title and Subtitle Installation of a SWECS at the Wichita Falls District Office	5. Report Date November, 1982 6. Performing Organization Code
7. Author(s) Kenneth D. Hankins and Frank S. Craig	8. Performing Organization Report No. 545-1
9. Performing Organization Name and Address Texas State Department of Highways and Public Transportation P.O. Box 5051 Austin, TX. 78763	10. Work Unit No. 11. Contract or Grant No. DTFH 71-81-52-TX-04
12. Sponsoring Agency Name and Address Federal Highway Administration Demonstration Projects Division 1000 North Glebe Road Arlington, VA. 22201	13. Type of Report and Period Covered Interim - Installation November, 1982 14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This report describes the site selection, initial cost and installation of a Small Wind Energy Conversion System. A description of the first few months of operation are also included. A 25 kwh system was selected and installed at Wichita Falls on the grounds of the District Office.

17. Key Words	18. Distribution Statement
Solar Energy Small Wind Energy Conversion Systems Wind Velocity Wind Direction	No restrictions. Report available from National Technical Information Service, Springfield, Va. 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	20	

Form DOT F 1700.7 (8-69)

Installation of a SWECS at the Wichita Falls

District Office

by

Kenneth D. Hankins

and

Frank S. Craig

Research Report 545-1

Research Study 1-3D-81-545

Asphalt Tank With Solar Heating

Conducted by

Transportation Planning Division
Research Section
State Department of Highways
and Public Transportation

In Cooperation With the

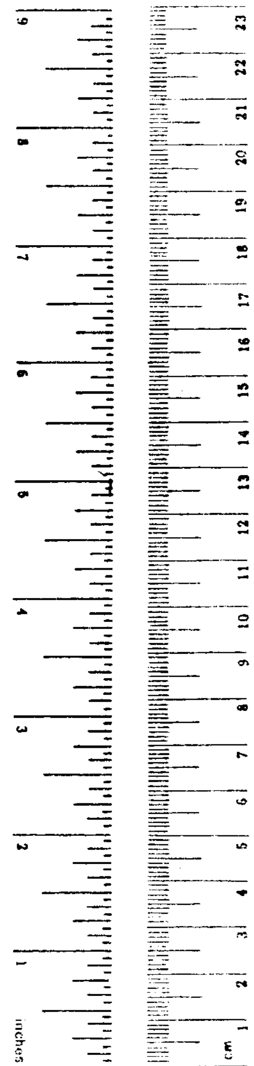
U. S. Department of Transportation
Federal Highway Administration
Demonstration Projects Division

November, 1982

METRIC CONVERSION FACTORS

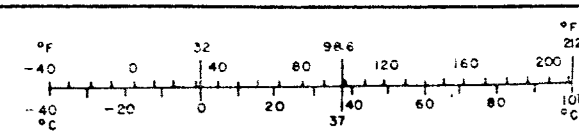
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the views or policies of the Federal Highway Administration. This report does not constitute a standard, specification or regulation.

The United States Government and the State Department of Highways and Public Transportation do not endorse products or manufacturers. Trade or manufacturer's names appear herein solely because they are considered essential to the object of this report.

The research reported herein was conducted under the supervision of Mr. John F. Nixon, Engineer of Research, and the general supervision of Mr. Phillip L. Wilson, State Planning Engineer, Transportation.

Acknowledgement is given to:

Mr. Brad Hubbard, Mr. B. D. Cannaday and Mr. Randy Beck for the technical support received during this study. A special thanks is given to Mr. C. L. Gross and Mr. James Wyatt who set up the microprocessor equipment and developed the program which monitors the data system.

Mr. Edward Kristaponis and Mr. King Gee with the Federal Highway Administration for the administrative and technical information and support offered during the initiation and duration of this study.

The personnel from the Wichita Falls District (District 3). These personnel not only assisted in the site selection, equipment selection and installation of the equipment, but prepared the grounds, constructed the foundation, laid conduit and cabling, and installed the monitoring instruments. The District is under the general supervision of Mr. Jimmy L. Stacks, District Engineer. Supervision of the work was performed by Mr. Frank S. Craig and Mr. Frank L. Ragland. Special thanks are given to Mr. Robert Fenoglio and Mr. Jerry Harris who performed much of the work mentioned above and who monitored the daily operation.

Texas Electric Service Company, particularly Mr. Jack A. Harris, Marketing Research and Training Manager and Mr. R. D. Vickers, Customer Representative, for the suggestions, information and aid received in the installation and operation of the SWECS unit.

TABLE OF CONTENTS

List of Figures

Implementation Statement

The implementation of this report is inherent in that a Small Wind Energy Conversion System (SWECS) is to be installed. This project will demonstrate the capabilities of a SWECS. The project is open to the public and a display area showing actual operation, and past and present power production has been made available. Continuous print-outs of wind velocity, wind direction, power consumed by the facility and power produced are on display. Small written articles and advertisements have been forwarded and used by several newspapers. Therefore, it is believed the implementation of this project will be that of providing knowledge to interested parties concerning future use of such systems.

Summary

This report describes the site selection, equipment cost and installation methods of a Small Wind Energy Conversion System (SWECS). After considerable study, discussions with knowledgeable people, and observations of working systems a 25 kw unit was selected for installation and demonstration. The unit was installed at the maintenance and storage area at the Wichita Falls District Office. The initial cost of the equipment was approximately $25,000 including the equipment, installation and some future inspection and minor modifications. Only a few manufacturers of this size unit were found, but the manufacturer with the lowest cost, meeting the requirements proposed, was Jay Carter Enterprises, Inc. at Burkburnett, Texas. The unit was installed May 12, 1982, and put on lines at 3:40 p.m. The unit has performed satisfactorily since that time.

Recommendations

The performance of the system will be monitored for a one-year interval. No long-term recommendations should be made until several months of study.

INSTALLATION OF A SWECS AT THE WICHITA FALLS DISTRICT OFFICE

I. Background

At the initiation of this project the United States had just experienced a period of critical shortage of fossil fuels at the retail market level. Even though more stable supplies are presently available, attempts are being made to study alternate or so called renewable energy sources for present and future use. This project was initiated to demonstrate one form of such an energy source - the power gleaned from the wind.

After considerable study, it was decided to select a SWECS in the 25 kw range. It was reasoned that this size unit would be the size most used by the more isolated Departmental field offices and a size most economically priced for small businesses or small rural groups of say three to four dwellings to a unit.

Several visits were made to sites having operating equipment and discussions were held with people knowledgeable in the SWECS field. These visits produced excellent information. For example, Dr. R. N. Clark working with the U.S. Department of Agriculture and in cooperation with DOE was developing information on SWECS. A visit with Dr. Clark at Bushland, Texas proved very beneficial. The DOE study at Bushland involved several vertical axis "egg beater" type units along with a down wind horizontal axis unit which was used to provide power for agricultural purposes. Also a visit with Dr. Vaughn Nelson and the personnel at the Alternative Energy Institute, West Texas State University in Canyon, Texas was helpful not only in providing information on SWECS units but also in providing wind velocity and direction information.

II. Object

The object of this report is to provide information concerning the site selection, equipment costs and installation methods used in setting up a SWECS.

III. Site Selection

The basic criteria in the site selection was that the site be on Departmental grounds. Also, the site should be in a position to receive the best available wind velocity with consideration of the dominate wind direction if possible. The site should be such that noise and other distractions to the surrounding houses or public be non-existant, however, the unit should be highly visible to the public in order that inquiry and demonstration could occur. Considerable monitoring of the unit was planned, therefore, the unit should be sited at a location within easy access by monitoring personnel. After considerable planning and discussion, a request was made to the FHWA and permission received to locate the unit at the maintenance and storage yard at the Wichita Falls District Office. It had originally been planned to set up wind and weather monitoring equipment at two or more locations where departmental offices were located. Wind data would have been collected for approximately one year while the SWECS was being fabricated. The site having the best wind velocity information would be selected for installation. However, as it developed the SWECS was available prior to receiving the weather monitoring equipment. It was necessary to accept the SWECS or experience a lengthy delay. The procedure of studying the wind information prior to site selection is recommended for future use.

The storage yard at the Wichita Falls District Office is several hundred yards back of the warehouse. The warehouse in turn is several hundred feet back of the main office portion of the complex. The main office faces a highway which is a major city street in Wichita Falls. The storage yard is at or near the crest of a long rolling hill, therefore, the SWECS is highly visible to the public passing on the street and the unit is in an excellent position to receive the winds from every direction without excessive turbulence. The nearest housing is approximately 1000 yards from the SWECS.

Studies were made of the effects of noise to the surroundings by obtaining readings with a meter measuring decibels. This testing was obtained prior to site selection by visiting sites having a SWECS unit similar to that being purchased. Values were obtained at one location on more than one occasion. Readings were obtained in four directions at various intervals beginning at the SWECS tower and moving out until the meter did not change (obtained a common or background noise level). In no case was the reading greater than 71 dBA with a 60-foot tower. A background noise level of 48 to 52 dBA was achieved about 150 to 200 feet from the tower. Therefore, a difference of 15 to 20 dBA can be attributed to the SWECS, however, little effect of noise was noted at a distance of 150 feet from the tower.

IV. The SWECS Unit

After considerable study, which included reports from the DOE studies at Rocky Flats, Colorado, it was decided to select a horizontal axis, downwind, SWECS. It developed that only a small number of manufacturers (3 companies in 1980) produce a SWECS unit in the 25 kw size range. Therefore, requests for price information and operational details were forwarded and received from manufacturers which had 25 kw SWECS units available. The manufacturer with the lowest cost meeting the requirements proposed was Jay Carter Enterprises, Inc. at Burkburnett, Texas. Specifications for the unit may be found in Appendix A.

V. Equipment Costs

Jay Carter Enterprises bid $25,000 for the SWECS unit complete with 80 foot tower and installation. It was necessary for the Department to construct the foundation and provide the conduit and cabling from the meter near the office complex to the SWECS. The Department also provided the services of an electrician to connect the system to the service company system. Therefore, the following are approximate costs associated with the installation of the system:

1.	Carter Wind Generator Model 25 with 80-foot tower	$25,000
2.	System components and delivery costs	1,410
3.	Conduit and Cabling	550
4.	Electric Work	200
5.	Foundations (Material, Equipment and Labor)	750
	Total	$27,910

VI. The Electric Utility Company

During the initial planning, Texas Electric Service Company (TESCO), which supplies power to the Wichita Falls area, was contacted. From the initial contact a high degree of interest and aid has been received. The company supplied watt meters and pulse generators (purchased) for monitoring energy outputs. TESCO also offered to share digital type data from a pulse generator attached to a watt meter used to monitor the generator output.

At the time of initial contact, TESCO was observing several other units and the "buy back" price was about $ .02 per kWh.

VII. Installation Methods

The SWECS was delivered and installed on May 12, 1982. The installation was performed by a well-trained crew using well endowed and specialized equipment. The unit was delivered on a trailer especially equipped with mountings to contain the components while in transport. The trailer was towed by a medium size truck also well equipped (see Figure 1).

Prior to installation departmental personnel had constructed the foundation for the unit as directed by Jay Carter Enterprises, Inc. The foundation consisted of six small concrete pads. The top of the pads was finished close to ground level and was relatively deep in the ground. Figure 2 shows one of the pads and the installation of hardware by the contractor.

One of the pads was in the center or surrounded by four other pads which were at the North, South, East and West positions and at a distance from the center pad. The center pad contained the mounting for the tower (See Figure 3) and the other four pads were used as tie downs or "dead man" for cable bracing. The sixth pad contained a brace to hold the generator off the gound when it is in a lowered position for installation or maintenance. The 80-foot tower was delivered in two pieces and is actually larger at the top than at the bottom. Figure 4 shows the contractor connecting the two parts of the tower which is accomplished using a hydraulic piston attached to a preprepared clevis on each part. One end of the tube tower fits into the other end with a close tolerance in end areas. The lower end of the tower is fitted to the support on the center pad and the tower, with generator, is placed on the brace mentioned on the sixth pad above.

The cable braces are attached and some tension is exerted on the "side" cables. Provision has been made to level the generator by actually observing a level mounted on the generator. The generator is raised into position and two levels mounted in a transverse manner on the generator are observed using a telescope. Adjustments are made to the cable lengths to level the genera-

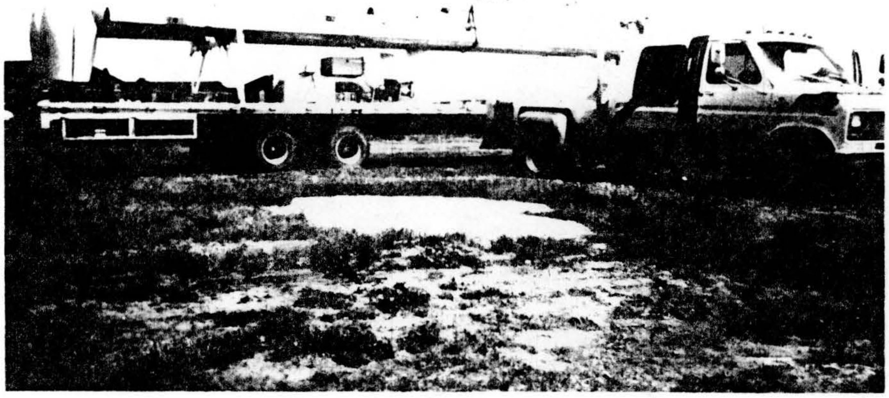


Figure 1 - SWECS Transport

Figure 2 - SWECS Foundation

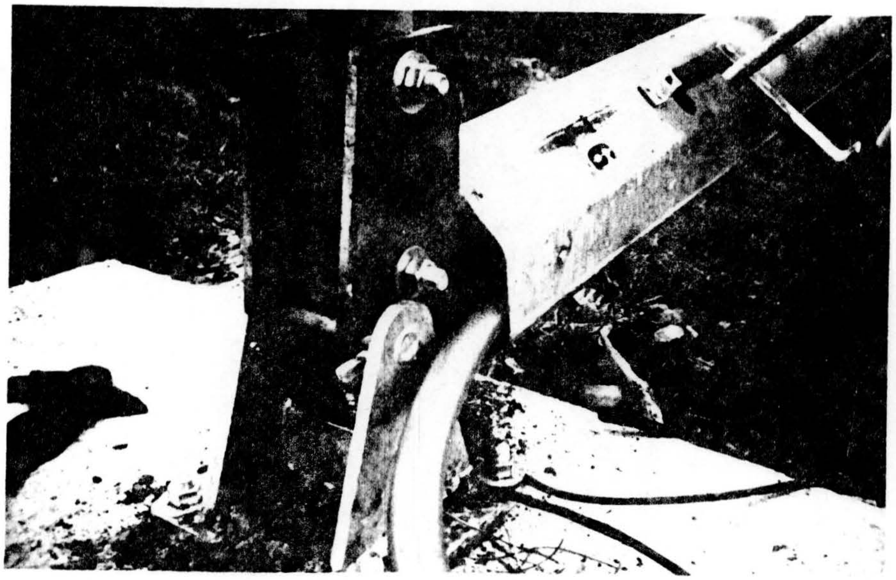


Figure 3 - Tower Mounting

Figure 4 - Connection of Tower Lengths

5

tor. After leveling, the generator is lowered for further work. Figure 5 shows a view of the generator with the top cover removed to mount the transverse levels. Figure 6 shows the contractor observing the levels so the cabling can be adjusted to level the generator horizontally. When complete the side cables remain in position and the "front" cable has received a set length. The rear cable and a gin-pole arrangement allow the generator and tower to be raised and lowered using a pulley system. The truck was used to pull the tower and generator up and also to lower the unit. This operation is shown in Figure 7.

The blades are installed and adjusted as shown in Figures 8 and 9. When complete the tower is again raised with the gin-pole, pulley-cable and truck as shown in Figure 10. Some instrumentation is provided by Jay Carter Enterprises and is mounted near the generator as shown in Figure 11. After the electric cabling is attached and checked out, the system is initiated. The unit was put on line at 3:40 p.m.

VIII. SWECS Operation

At present the SWECS unit has operated with no down time except for short time periods to perform the suggested maintenance. Wind velocities were low during the summer months and relatively small amounts of power were delivered, however, wind velocities appear greater during the fall months.

A microprocessor system was installed to monitor the performance of the SWECS unit and to collect weather information. The system obtains weather information from a digital weather monitor and energy information from the pulse generators on the watt meters described previously. The data was processed, stored on a cassette, and hourly reports printed for display as part of the demonstration of the system. Later, three reports were prepared from

Figure 5

SWECS with Cover Removed

Figure 6

Leveling the Generator

Figure 7 - Raising the Unit

Figure 8 - Blade Installation

Figure 9 - Blade Adjustment

Figure 10

Completed Unit

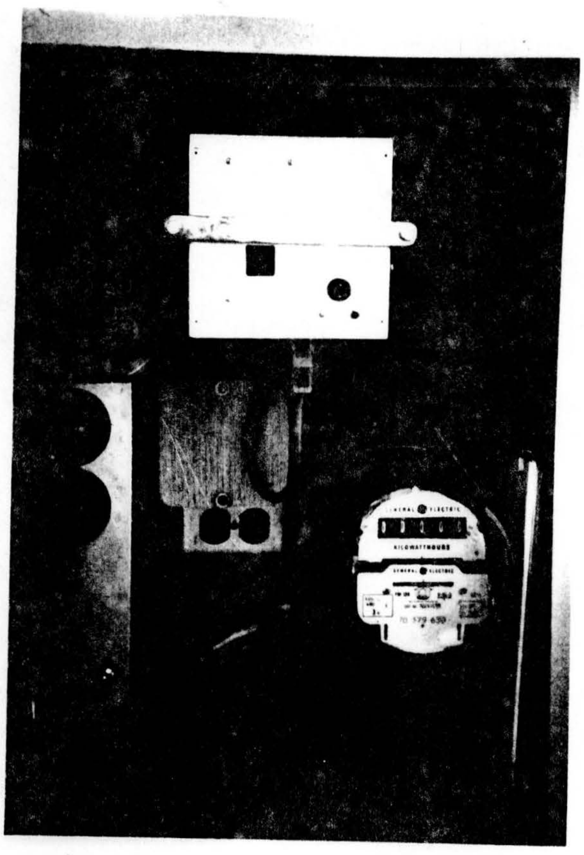


Figure 11

Instrumentation

data stored on the cassette. One of these reports was a daily plot of the hourly averages or summaries. An example of this plot is shown in Figure 12. Note, two days are shown with hourly time intervals on the vertical axis and two different scales on the horizontal axis. Four plots are used showing energy output by the generator, total energy consumed by the district office complex, (Note the scale value should be multiplied by ten) average wind velocity and the cubed average wind velocity. The average wind velocity is the arithmetic average of velocities obtained at one-second intervals. The cubed average wind velocity was calculated by obtaining one-second wind velocities, cubing the one-second velocities, and summing the cubes for a one-hour interval. The one-hour sum of the cubes was divided by the number of one-second observations and the cube root of this value found. This cube root value is the cubed average wind velocity for the hour in question.

An example of the second report is found in Figure 13. This report is a monthly summary composed of daily values. The daily values were obtained from the hourly data similar to that explained in the plot of Figure 12. In addition, the average daily temperature is shown along with the Theoretical Wind Power generator efficiency and (dominant) wind directions. The Theoretical Wind Power is a calculated value based on the measured wind velocity cubed, air density, the swept area of the blades of the generator and a "pile-up factor" of 59.2 percent. The Efficiency of the Generator is the quotient of the power produced by the SWECS divided by the Theoretical Wind Power. It should be noted that a watt meter for the SWECS output malfunctioned and was removed on October 1 through 5, 21 and 22, and 27 through 28, 1982. Also the microprocessor was down for several hours on October 6, 1982, which affected the value shown for Power Used by Facility.

PLOT OF POWER & WIND SPEED VS TIME
CARTER-25 WICHITA FALLS, TEXAS
OCTOBER 1982

* = WIND SPEED MEASURED AT 80 FT   # = WIND SPEED CUBE FUNCTION
\+ = POWER GENERATED BY CARTER-25   X = (POWER USED BY FACILITY)X10 IN KWH

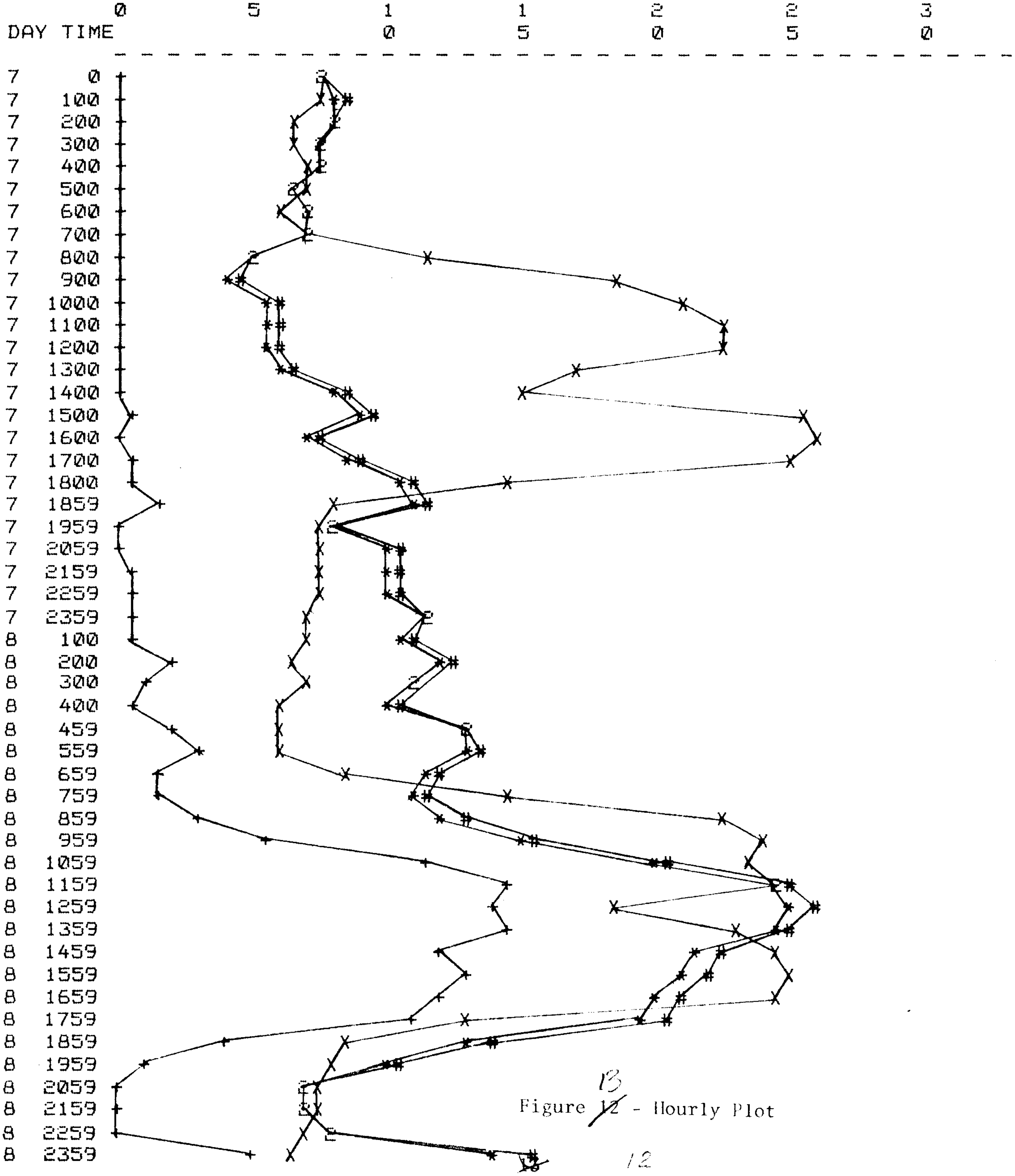


Figure ~~12~~ 13 - Hourly Plot

SWECS CARTER-25 WICHITA FALLS
MONTHLY SUMMARY
OCTOBER 1982

DAY	WIND DIR	AVG WIND VEL (MPH)	AVG WIND CUBE (MPH)	SWECS POWER PRODUCED (KWH)	POWER USED BY FACILITY (KWH)	THEORETICAL WIND POWER (KWH)	EFF. OF GENERATOR (%)	AVG TEMP
1	SE	14.9	15.3	0.0	2615.9	149.8	0.0	79
2	ESE	10.4	11.3	0.0	1251.1	106.9	0.0	76
3	N	4.0	4.3	0.0	1207.9	7.9	0.0	74
4	ESE	7.3	7.7	0.0	3235.3	49.6	0.0	77
5	SE	12.1	12.5	0.0	2666.9	98.5	0.0	77
6	N	11.1	11.6	10.7	564.0	23.9	44.7	78
7	E	7.7	8.1	4.7	3193.2	37.6	12.5	77
8	S	14.8	15.3	131.9	3279.8	302.9	43.5	77
9	WNW	9.9	10.4	51.2	1293.8	97.4	52.6	76
10	WNW	8.4	8.8	21.6	1151.6	53.3	40.5	75
11	N	6.6	7.1	1.7	1460.5	22.0	7.7	74
12	NNE	6.4	6.8	4.2	1938.9	22.6	18.6	66
13	SW	6.4	6.7	4.9	1913.2	22.8	21.5	63
14	SSW	6.4	6.8	4.5	2077.3	25.1	17.9	64
15	WNW	7.1	7.6	11.6	2323.0	38.4	30.2	67
16	N	7.2	7.6	3.7	1155.1	30.2	12.3	67
17	ESE	11.5	11.8	51.8	1232.1	112.7	46.0	68
18	ESE	13.6	13.9	99.7	2744.7	180.5	55.2	72
19	NNW	16.6	17.3	182.9	2405.8	379.1	48.2	68
20	NNW	6.4	6.7	4.9	1393.1	23.0	21.3	52
21	E	3.7	4.1	0.0	1484.2	5.0	0.0	54
22	NE	3.0	3.4	0.0	2314.2	3.6	0.0	59
23	ESE	6.7	7.0	1.1	1224.1	28.5	3.9	58
24	ESE	7.5	7.8	1.8	1162.4	34.7	5.2	58
25	ESE	9.6	9.8	14.5	2273.7	60.7	23.9	57
26	ESE	14.8	15.1	14.9	2244.8	231.4	6.4	60
27	SE	16.8	17.2	0.0	2353.9	351.8	0.0	67
28	WNW	11.4	12.0	0.0	2651.0	165.6	0.0	65
29	SSE	8.6	8.9	23.7	2523.6	55.7	42.5	60
30	ESE	12.3	12.7	88.9	1360.6	141.4	62.9	65
31	SSE	14.0	14.4	128.6	1548.0	193.8	66.4	73

Figure ~~13~~ 14 - Monthly Summary

An example of the third report is shown in Figure 14. The third type of report contains wind information and allows the observer to study the wind velocity and directions in tandem. Note the wind directions are listed vertically and observed in rows. For example, during the month of October 18, 3 percent of measurements were from the East-South-East. The columns are wind velocities in MPH. For example, the third column is the information for an 8 to 12 MPH wind. About 8.4% of the time this velocity was observed from the ESE and 28.4% of the observed measurements in October were in the 8 to 12 MPH group.

Future work will be directed toward continued performance study of the SWECS. Data similar to that described above will be collected and analyzed and a report prepared of this work.

SWECS CARTER-25 WICHITA FALLS
WIND DIRECTION/VELOCITY SUMMARY
OCTOBER 1982

WIND DIR	<--PERCENT OF THE TOTAL-BASED ON ONE HOUR PREDOMINANT DIRECTION--> 0-4	4-8	8-12	12-16	16-20	20-24	24-28	28-32	32+	TOTAL
N	0.3	4.2	2.0	0.6	0.1	0.1	0.0	0.0	0.0	7.3
NNE	1.1	3.2	0.8	0.0	0.0	0.0	0.0	0.0	0.0	5.2
NE	2.4	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5
ENE	0.3	0.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0	1.0
E	1.0	1.7	3.2	0.4	0.1	0.0	0.0	0.0	0.0	6.5
ESE	1.1	2.4	8.4	5.8	0.4	0.1	0.0	0.0	0.0	18.3
SE	0.1	1.4	4.8	4.6	1.8	0.4	0.0	0.0	0.0	13.2
SSE	0.4	1.5	3.0	3.4	2.7	1.1	0.0	0.0	0.0	12.1
S	1.5	1.0	1.0	1.0	1.0	0.6	0.4	0.0	0.0	6.5
SSW	1.4	1.7	0.6	0.8	0.1	0.1	0.0	0.0	0.0	4.8
SW	1.0	1.7	0.1	0.1	0.0	0.0	0.0	0.0	0.0	3.0
WSW	0.1	0.4	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.7
W	0.7	1.4	1.0	0.3	0.1	0.0	0.0	0.0	0.0	3.5
WNW	0.3	2.7	2.1	1.7	0.1	0.0	0.0	0.0	0.0	6.9
NW	0.3	1.4	0.1	0.0	0.1	0.0	0.1	0.0	0.0	2.1
NNW	0.3	1.4	1.0	0.3	0.1	0.4	0.0	0.0	0.0	3.5
TOTAL	12.4	29.7	28.4	19.1	6.9	3.0	0.6	0.0	0.0	100.0

****TOTAL NUMBER OF HOURS ANALYZED = 711

15

Figure 14 - Monthly Wind Summary

Appendix A

Specifications For A Wind Generator

and

Mounting Tower

SPECIFICATIONS FOR A

WIND GENERATOR

AND

MOUNTING TOWER

General

The wind generator shall be so designed and fabricated to have low maintenance, good reliability, long life, pleasing esthetics, and high efficiency. The unit shall contain an induction type generator producing 3-phase, 440 volt, 60 cycle AC current. The unit shall be a horizontal, down-wind system which naturally weather vanes. The blades shall be fabricated to stall in a high wind condition to protect the generator from overloading. An overspeed control shall cause the blades to pitch up and stall. The blade design shall contain a self-start feature.

The blades shall be formed basically of fiberglass and shall be very strong but highly flexible. In a non-rotating condition, in winds of 125 mph, the blades will "unload" by bending to an angle of 45 degrees without damage.

Output

The generator shall be capable of producing 25 kw in a 26 mph wind. The maximum output will be 30kw in approximately a 30 to 40 mph wind and the minimum output will occur at a 7 1/2 mph wind. The system shall be capable of being "tied in" with parallel operation in an electric utility company line with appropriate safety and operational features, meeting the attached "Guidelines for the Parallel Operation of a Customer-Owned Small Wind Energy Conversion System (SWECS) at the Utility Company Service Voltage Level." (Obtained from Texas Electric Service Company.)

Blades

The rotor diameter shall be 32 foot. The blade chord shall be 13 inches at the tip and 42 inches at the root. The blade shall be fabricated primarily from fiberglass and PVC foam. The spar shall be composed of a continuous filament wound unidirectional glass structure with a 25 to 1 safety factor.

Tower

The tower shall be 80 feet high and fabricated from galvanized pipe. It shall be a single pole structure supported with four guy wires. The tower shall contain a single gin pole arrangement which will permit the tower (and generator) to be raised or lowered by one or two persons by rotating the tower about the base from a vertical to horizontal position (or vice versa). This tower and generator arrangement shall permit maintenance functions to be accomplished at ground level.

Yaw Control

The yaw control shall be a free yaw system but with dampening. The yaw control shall be a passive system and shall not contain a yaw servo system or other devices for monitoring and evaluating wind direction before controlling the yaw with the servo system.

Overload Control

The overload control shall also be a passive system in which the blades automatically stall in high winds to prevent generator overload. However, the system shall still be capable of generating electricity in winds of 100 mph. Servo system and monitoring equipment which change blade pitch to control rpm or kw output shall not be used.

Overspeed Control

The overspeed control shall be accomplished through the design characteristics of the spar and blade which will cause the blade to pitch up and stall in an overspeed condition to limit maximum rpm. If the overspeed was due to the utility break or malfunction, causing generator turn off, then the generator will automatically reset and come back on when power is restored to the line.

Braking

The system shall contain a mechanical or disc brake capable of stopping the rotor in 125 mph winds under extremely high rotational velocities by manual control from ground level.

Out of Balance Control

Should the blade(s) or rotor become out of balance to a dangerous level, the system shall be equipped with mechanical brake which shall be activated. This brake shall be capable of stopping the rotor in any wind under any rotational velocity.

Gear Box

The gear box shall be fabricated for long life and to resist the effects of weather. The gear box shall be of Tenzaloy aluminum alloy with cast in place steel inserts for bearing supports. The gears shall be hardened to insure long life.

REFERENCES

1. Clark, R.N., and Schneider, A.D., "Irrigation Pumping with Wind Energy", ASAE, Vol. 23, No. 4, pp. 850-853, 1980.

2. Nelson, Vaughn and McGaughey, David, "Consumer's Guide for Wind Energy in Texas", Alternative Energy Institute, West Texas State University.

3. "Is the Wind a Pratical Source of Energy for You?", Special publication - DOE Rocky Flats Wind Systems Program, September, 1980.

4. Park, Jack and Schwind, Dick, "Wind Power for Farms Homes and Small Industry, Report No. RFP-2841/1270/78/4, September, 1978.

5. Proceedings - National Conference American Wind Energy Association, Summary 1980, Pittsburgh, Pennsylvania, Hosted by ALCOA, June, 1980.