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Analytical Prediction and Experimental Verification of Blade Loads Experienced by Two, Three-Bladed, Fixed Pitch, Horizontal Axis Wind Turbines

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ANALYTICAL PREDICTION AND EXPERIMENTAL VERIFICATION OF BLADE LOADS EXPERIENCED BY TWO, THREE-BLADED, FIXED PITCH, HORIZONTAL AXIS WIND TURBINES.

by
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This Thesis submitted by Scott M. Klingenstein in partial fulfillment of the requirements for the degree of Master of Science from the University of North Dakota, is hereby approved by the Faculty Advisory Committee under whom the work has been done.

(Chairman)

This Thesis meets the standards for appearance and conforms to the style and format requirements of the Graduate School of the University of North Dakota, and is hereby approved.

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ABSTRACT

Wind turbine blade structural designers need measured blade structural load data to project blade life. These data are necessary to validate analytical prediction models and to optimize advanced blade structural designs. The objective of this work is to furnish designers current blade load data and to compare the analytical blade load predictions to the measured loads.

This analysis is based on ninety hours of wind turbine loads data collected in 1990, on the SERI 7.9 m and Aerostar 7.5 m blades. The blades were installed on identical turbines, located adjacent to each other. The data were collected covering a wide range of atmospheric conditions. The data were characterized based on several meteorological parameters that are well correlated with loads, including atmospheric stability, turbulence level, and mean wind speed.

As part of this effort, measured blade flapwise and edgewise bending moments were compared to FLAP: an analytical computer prediction model, developed at the Solar Energy Research Institute. Four mean wind speed data sets: 12, 17, 22, and 27 mph, were used in the load comparisons. The methodology included experimental determination of two important, but often difficult to model, input parameters: blade mass and stiffness distributions.

From the ninety hours of test data, 409 valid 10-minute

NOMENCLATURE

A	Cross sectional area (m^2)
B	Number of blades
c	Blade chord width (m)
E	Modulus of elasticity (psi)
HAWT's	Horizontal Axis Wind Turbines
I	Moment of inertia (in^4)
KB	Kilo-bytes
MB	Mega-bytes
n	number of revolutions per second
PCM	Pulse-code-modulated
P_{TOT}	The total power available in a wind stream (W)
P_{MAX}	The theoretical maximum power that can be extracted from a wind stream (Betz Limit)
R	Radius of swept area (m)
ρ	Air density (kg/m^3)
S	Solidity ratio
SERI	Solar Energy Research Institute
TSR	Tip Speed Ratio
VAWT's	Vertical Axis Wind Turbines
V_i	Incoming wind velocity (m/s)
WEC's	Wind Energy Conversion systems

FLAP INPUT VARIABLE DESCRIPTION

ALENTH	Distance from yaw axis to hub center (ft).
ALPHA0	Angle from the zero-lift line to the airfoil section chord line (degrees).
BETA0	Blade precone angle (degree).

BLSHNK	Length of the blade shank measured from the blade root to the start of the airfoil section (ft).
BLTIP	Blade length measured form the blade root to the blade tip (ft); rotor radius is HUBRAD + BLTIP.
CHI	Rotor tilt angle (degrees).
CSBMAC	Airfoil pitching moment coefficient (dimensionless).
DRGFRM	Drag coefficient form constant.
HUBHT	Hub height (ft).
HUBRAD	Radius of rotor hub (ft).
KSHADW	Tower shadow; "number of oscillations" within tower shadow zone.
NBLADS	Number of rotor blades.
NPANEL	Number of blade property values to be read in from the input data file; maximum = 11.
OMEGA	Rotor speed (constant, rpm).
PHIAMP	Amplitude of periodic yaw motion (degrees).
PHIOMG	Maximum yaw rate (deg/s).
PHI0	Rotor yaw mean angle (degrees).
PSIZER	Half-angle width of tower shadow region (degrees).
SHERXP	Wind-shear power exponent.
THETAP	Orientation of the principal bending axis at station of primary interest (degrees).
THETAT	Built-in blade twist angle between section chord line at station of "primary interest" to section chord line at blade tip (positive towards feather; degrees).
TSUBP	Tower shadow sinusoidal component (usually set to $\Delta V/2V_h$; dimensionless.
TSUB0	Tower shadow offset component (usually set to $\Delta V/2V_h$; dimensionless).

VHUB Hub-height mean wind speed (ft/s).

XLEFT Radial positions of blade distributed property data (unevenly spaced; ft).

WEIGHT Blade sections weight per unit length (input as lb_f/ft).

AEIARE Flapwise bending stiffness, input at each station (lb_f-$ft^2 x 10^6$).

AIEMAS Second mass moment of inertia of the blade cross section in edgewise direction (generally set to zero).

AIFMAS Second mass moment of inertia of the blade cross section in flapwise direction (generally set to zero).

AOFFST Distance from elastic axis to mass axis (center of gravity) of a blade cross section (positive if mass center forward of elastic axis, toward leading edge; ft).

ACHORD Blade chord length; distance between blade's leading and trailing edges (ft).

ATWIST The blade built-in twist angle as a function of blade span; angle from section chord line at each station to section chord line at tip (degrees).

ACLALF Lift curve slope (dimensionless).

ACLMAX Maximum or stall value of lift coefficient (dimensionless).

ACDZER Drag coefficient (dimensionless).

AESBAC Distance from elastic axis to aerodynamic center (positive if aero center forward, toward leading edge of elastic axis; ft).

CHAPTER I

INTRODUCTION

In the United States, our standard of living is attributable, in part, to the availability of "cheap" energy supplies. Since the fossil fuel crisis of the early 70's, energy prices have escalated and our dependence on other countries for energy stocks continues to increase. The Persian Gulf crisis of the 90's shows just how vulnerable our energy supplies are. The proposed 1991 National Energy Strategy continues to stress increased oil exploration and a revival of the nuclear power industry, while giving minimal attention to renewables.

Fortunately, there are a few individuals and organizations actively developing renewable energy sources. One of the most promising renewable technologies is wind power. Wind energy is an energy source which is relatively environmentally benign, renewable and abundant, and reasonably accessible in many parts of the country. The cost of power generated by the wind has steadily dropped in the past two decades, making it economically competative with more convention sources. Revitalizing the wind industry, also benefits the country by providing jobs in this country, keeping our energy dollars at home.

Wind turbines installed in California in the late 70's and early 80's were characterized by inappropriate designs and materials, and poor manufacturing quality control.

This was due in part to tax credits which placed the emphasis on initial costs rather than power production and longevity. Today the tax credits are gone, and only those seriously concerned with developing wind technology remain in the business.

Wind power is not power without its' own inherent problems. Wind power is not accessible on demand. Operators of wind turbines continue to experience equipment problems such as blade and yaw drive failures, and excessive drive-train wear. However, these are engineering problems which are solvable given adequate resources.

Wind turbine blades account for approximately one fifth of the capital costs of a wind energy conversion system. Wind turbine blades have been designed using airfoils originally designed for use on aircraft. New aerodynamically designed blades have improved the efficiency of wind turbines. Blades also need structural improvements to prevent blade component and fatigue failures, and to reduce blade weight and costs. Understanding blade loads will provide blade designers a basis from which improvements can be made.

Wind Energy Conversion Basics

Wind is a form of solar energy, in that winds are caused by an uneven heating of the earth's surface by the sun. Wind energy is the kinetic energy in a stream of moving air molecules that exert pressure on anything placed in their way. The total available power in a wind stream is (1):

$$P_{TOT}=\frac{1}{2}\rho A V_i^3 \qquad [1]$$

The maximum power that can be extracted from a wind stream is (1):

$$P_{MAX}=\frac{8}{27}\rho A V_i^3 \qquad [2]$$

The maximum theoretical efficiency, often referred as the power coefficient or the Betz limit is (1):

$$\eta_{MAX}=\frac{P_{MAX}}{P_{TOT}}=\frac{16}{27}=0.5926 \qquad [3]$$

The efficiencies of wind turbines are often compared to the Betz limit as in Figure 1 (2).

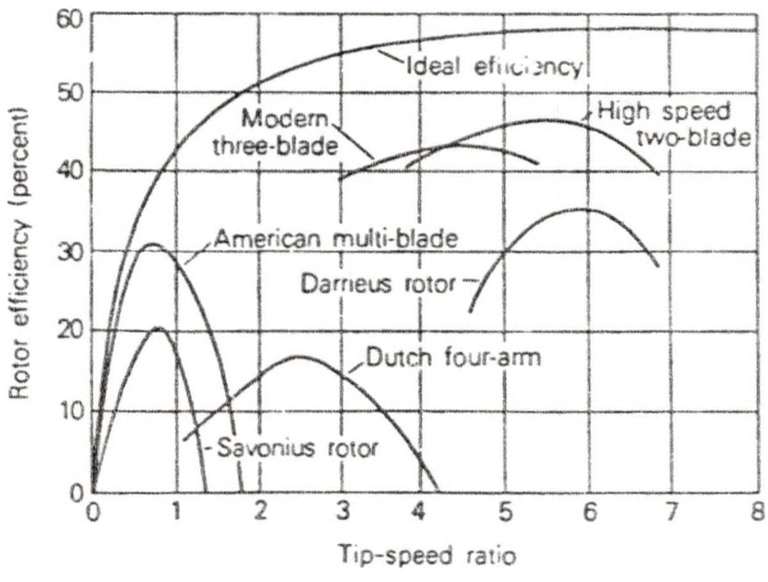


Figure 1. Typical performance curves for various types of wind turbines.

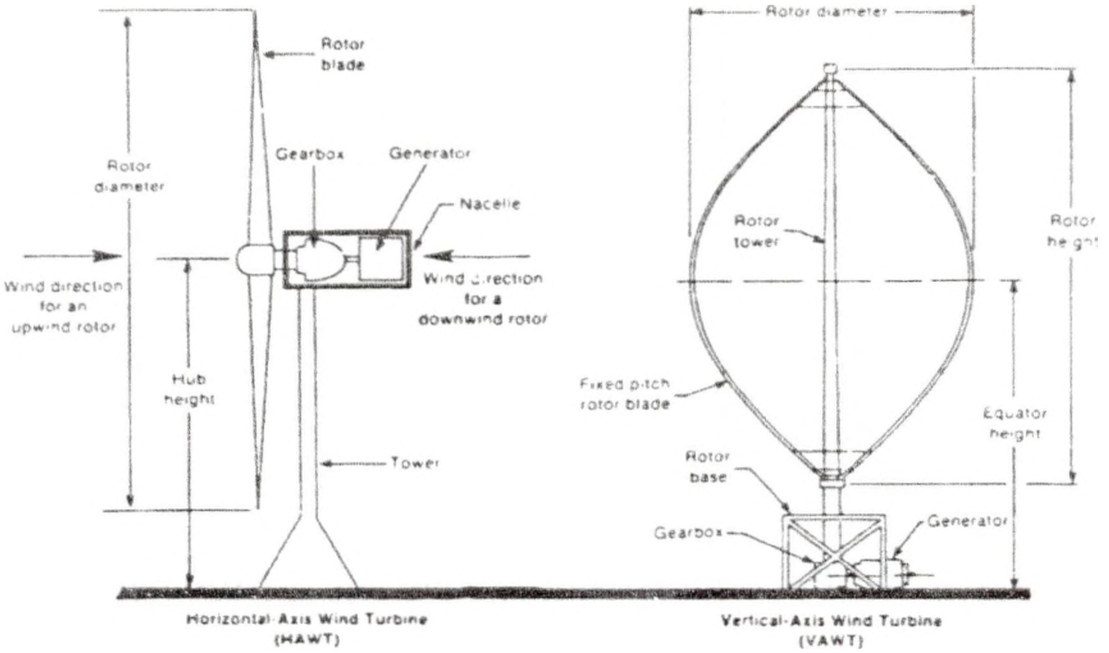


Figure 2. Basic wind turbine configurations.

The kinetic energy in the wind can be converted, using Wind Energy Conversion Systems (WECS), into electric power or mechanical energy. Two types of wind turbines have evolved; one utilizes drag forces, while the other is the lift type that uses aerodynamic lift. From these two types of wind turbines, many designs have been tried, however these are primarily adaptations of the two basic lift type designs (See Figure 2)(3): Horizontal Axis Wind Turbines (HAWT's), in which the rotating axis is horizontal, and Vertical Axis Wind Turbines (VAWT's), in which the axis is vertical.

HAWT's lift type designs include single, double, three-bladed, or multibladed, upwind or downwind, teetering or rigid hub machines. VAWT's utilize two basic configurations: the Savonius drag type or Darrieus lift type (See Figure 3).

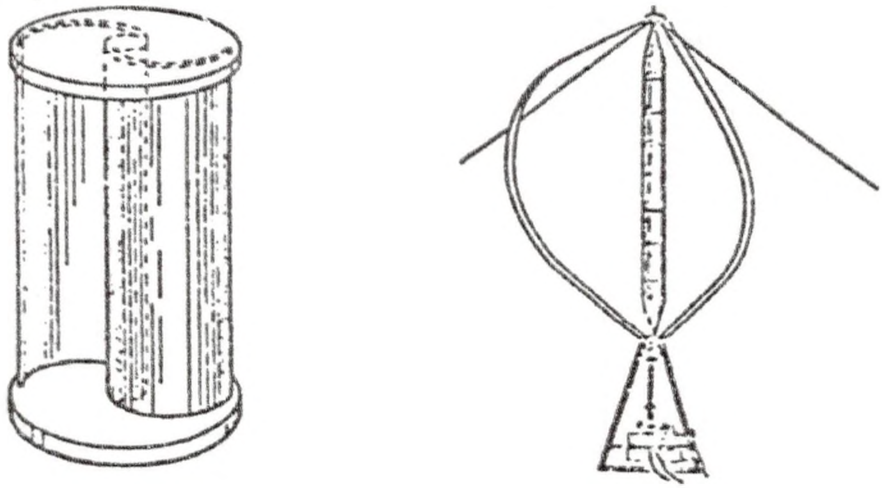


Figure 3. Savonius and Darrieus rotors.

Horizontal Axis Wind Turbines (HAWT's)

HAWT's are used extensively for commercial electric power generation. HAWT's utilize various airfoils and the aerodynamic lifting forces pull the blade in the thrust direction, turning the rotor. Drag forces, which are smaller in magnitude than the lifting forces work against this thrust (See Figure 4)(4).

Aerodynamic lift is produced at right angles to the relative wind that the airfoil sees. The relative wind is the vector sum of the blade motion and the wind velocity at a given position on the rotor disk. If the angle of attack is optimized along the entire blade, the thrust developed

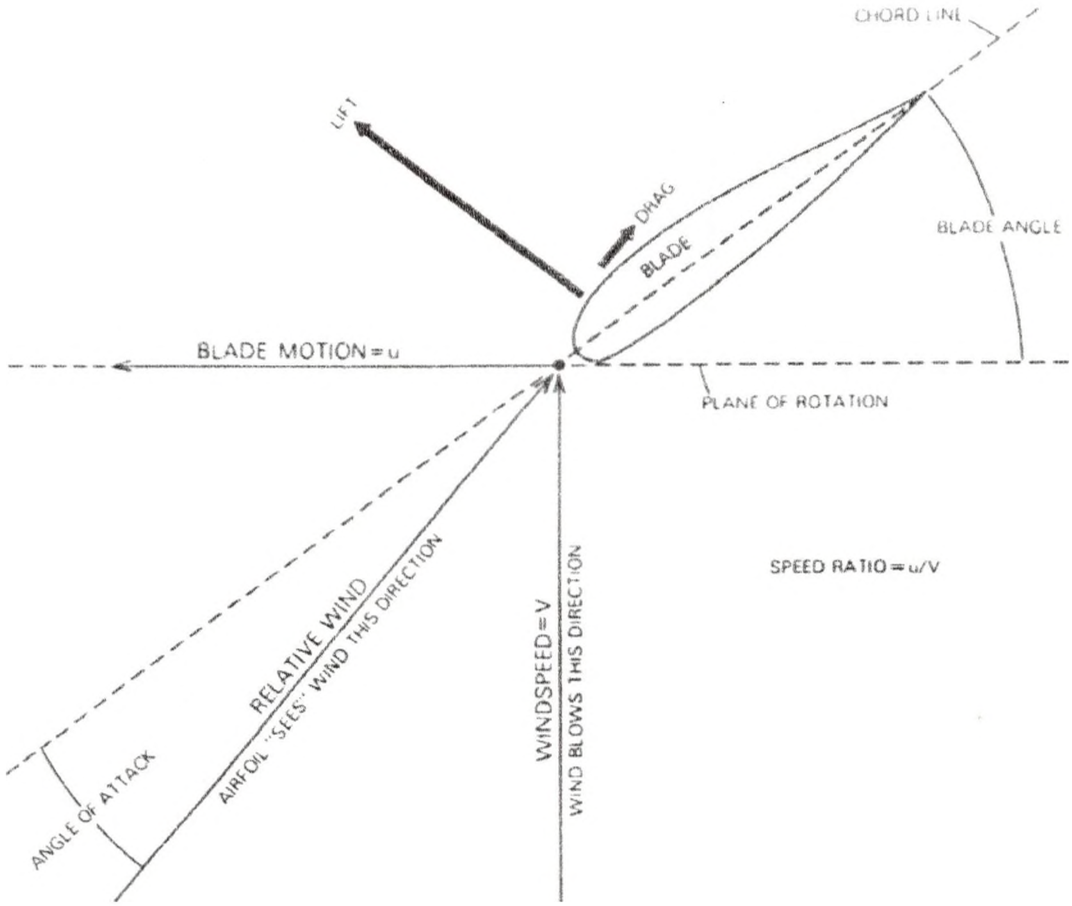


Figure 4. Vector diagram of the airflow at a point on the blade.

will reach a maximum. The thrust in turn generates the shaft torque that spins the generator.

For electric power generation, a low solidity and high tip speed ratio (TSR), are desirable, whereas a high solidity, and a low tip speed ratio produces more starting torque, which is required for water pumping. For optimum power extraction, as the rotational speed increases, the solidity ratio must decrease.

Solidity is the ratio of blade area to swept area (5).

$$S = \frac{BRc}{\pi R^2} \qquad [4]$$

The TSR is the ratio of the blade tip speed to the freestream windspeed and is used to compare different rotors instead of the rotor rpm (5).

$$TSR = \frac{2\pi nR}{V_i} \qquad [5]$$

Optimum blade design requires that the power output be maximized at each position along the blade and drag losses minimized (5). SERI has developed a set of thin-airfoils that were incorporated into a 7.9 m blade that was geometrically optimized for a 65 kW wind turbine (6) (See Figure 5). The SERI blades were designed as "replacement blades", to replace the Aerostar 7.5 m. The Aerostar blades are based on the NACA 44XX series airfoils, originally developed for aircraft.

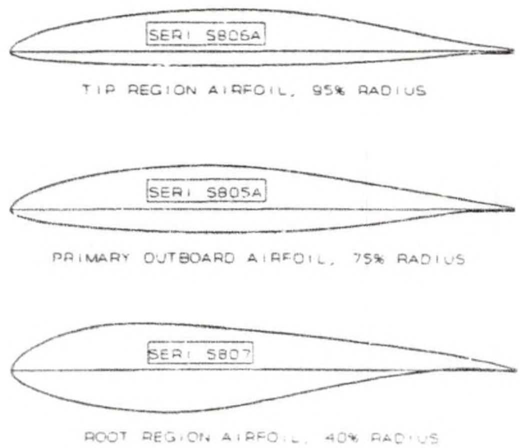


Figure 5. SERI thin-airfoil family.

Both the SERI and Aerostar blades stall-regulate the turbine. At wind speeds above the design wind speed of 30 mph, portions of the blade go into stall, losing lift, and in turn decreasing shaft torque. This stall regulation protects the generators and transmission from excessive loads.

Blade Testing

During the 1989 wind season, SERI and SeaWest Energy Group, conducted performance testing of the new 7.9 m SERI and the old 7.5 m Aerostar blades. The blades were mounted on two identical turbines, located side-by-side at Altech III Wind Farm, near Palm Springs, California. In the 1990 wind season the two wind turbines were extensively instrumented and atmospheric testing was completed. Measurements taken included blade loads, shaft torque, tower bending, power output, and numerous meteorological parameters.

The testing was conducted during the months of July and August. Spring and Fall are normally the windy season at the wind farm, and no high wind speed cases were recorded.

Objective

From the copious amount of field test data, this analysis will concentrate on:

1. Differentiating the data sets.
2. Reducing the data.
3. Comparing blade loads between the SERI and Aerostar blades.
4. Comparing predicted loads to measured blade loads.
5. Drawing conclusions and making recommendations for improvements in FLAP.

CHAPTER II

EXPERIMENTAL APPARATUS

The Solar Energy Research Institute (SERI), in cooperation with Seawest Energy Group, has completed atmospheric testing of the SERI 7.9 m and the Aerostar 7.5 m wind turbine blades, during the 1989-90 wind seasons (6,7). The purpose of the testing was to experimentally verify the predicted performance and operating loads of the two turbines under actual operating conditions.

The tests were performed on two "identical", (See Table 1) Micon 65/13 horizontal-axis wind turbines, installed side-by-side at the SeaWest Wind Farm, near Palm Springs, California.

Turbine No.	Component	Vendor Name	Model No./ Type	Serial No.	Rating	Additional Data
37-21 37-22	Turbine	Micon	65/13	10507 10497	65 kW	
37-21 37-22	Blades	Alternegy	7.5 m	Blade 1: 733-259-I Blade 2: 733-260-II Blade 3: 733-261-III Blade 1: 85-727-223 Blade 2: 85-727-224 Blade 3: 85-727-225	n/a	Blade hub material is cast steel
37-21 37-22	Main Bearings	FAG	SW 230	n/a	n/a	
37-21 37-22	Main Gearbox	Flender	SZNK 1275	421-505-010-1-13 421-505-010-1-3	75 kW	Ratio = 25.8; n1 = 1200; n2 = 46.5 Brake disk is welded construction
37-21 37-22	Generator 1	BBC	QUX160L6AG	GS = 5946182R14 GS = 5946182R10	13 kW	V = 480; ph = 3; A = 22; pf = 0.81 rpm = 1235; Hz = 60; I.Cl = F
37-21 37-22	Generator 2	BBC	QMX280M6AG	GS = 5946181R16 GS = 5946181R01	65 kW	V = 480; ph = 3; A = 96; pf = 0.82 rpm = 1222; Hz = 60; I.Cl = F
37-21 37-22	Yaw Drive Gearbox	Bonfiglioli	MVF62/130RQ	86211996 88297233	0.75 hp	i = 900
37-21 37-22	Mainframe	Micon	n/a	130	n/a	
37-21 37-22	Tower	Micon	n/a	n/a V13C-65	n/a	

Table 1. Test wind turbine component nameplate information, Micon 65/13.

The turbines are orientated in a row perpendicular to the prevailing West-North-West wind (See Figure 6). The two turbines used in the test, 37-21 and 31-22, for the SERI and Aerostar respectively, were selected based on their past performance. The turbines were characterized as being lower energy producers and subject to higher fatigue damage than similar turbines at the site.

The Micon 65/13 is an upwind, three-bladed, fixed pitch, rigid hub machine with an active yaw drive. A 13 kW generator is used during low wind speed operation and a 65 kW generator for medium and high wind speed operation. Cut-in wind speed for the turbine is 9 mph (≈4 m/s). Above 30 mph (≈ 13 m/s), maximum power output is regulated by the rotor blade's stall characteristics. Over speed is controlled with centrifugally activated tip brakes at approximately 65 rpm and 58 rpm for the SERI and Aerostar blades, respectively.

With the 7.5 m Aerostar blades, the rotor diameter is 16.0 m, and with the 7.9 SERI blades, the rotor diameter is 17.0 m. This is a 13 percent increase in swept area. The Aerostar blades are based on 50 year old airfoil geometries, NACA 44XX, originally developed for aircraft use. The SERI blade utilizes airfoils from the thin-airfoil family; S806A, S805A, and S807, developed by Tangler and Somers (8) in 1985. The SERI blade was geometrically optimized by Jackson (9) for 65 kW commercial wind turbines. Differences in the planforms of the two blades are shown in Figure 7, and other

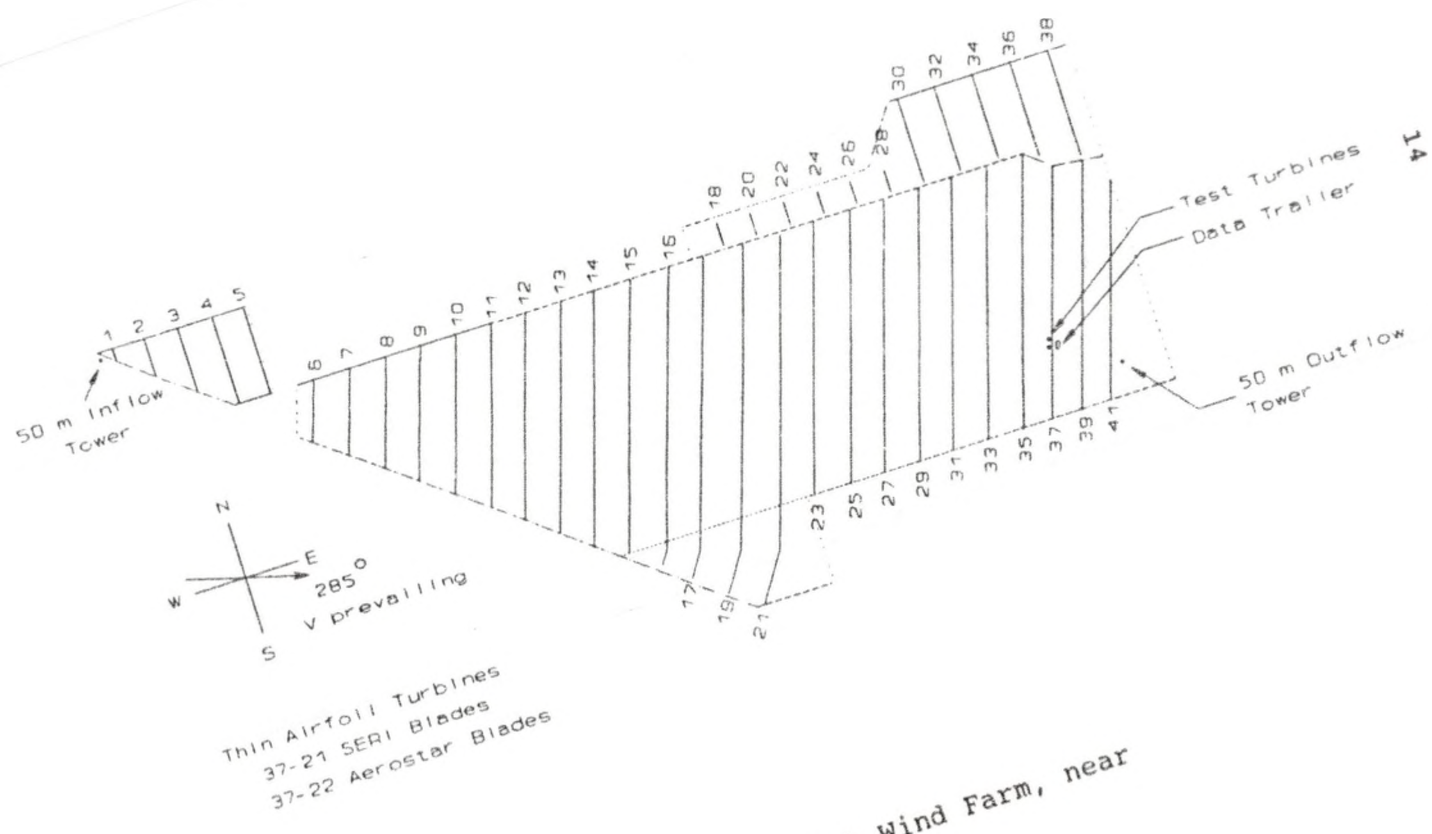


Figure 6. Wind turbine test site: SeaWest Wind Farm, near Palm Springs, California.

differences in the blades are listed in Table 2.

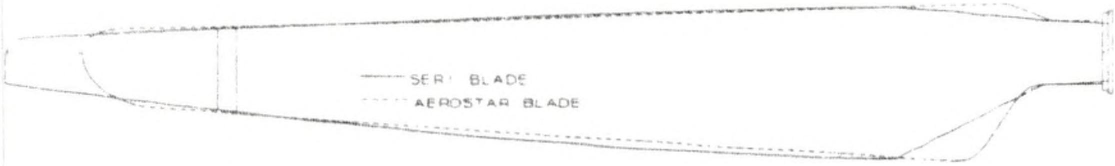
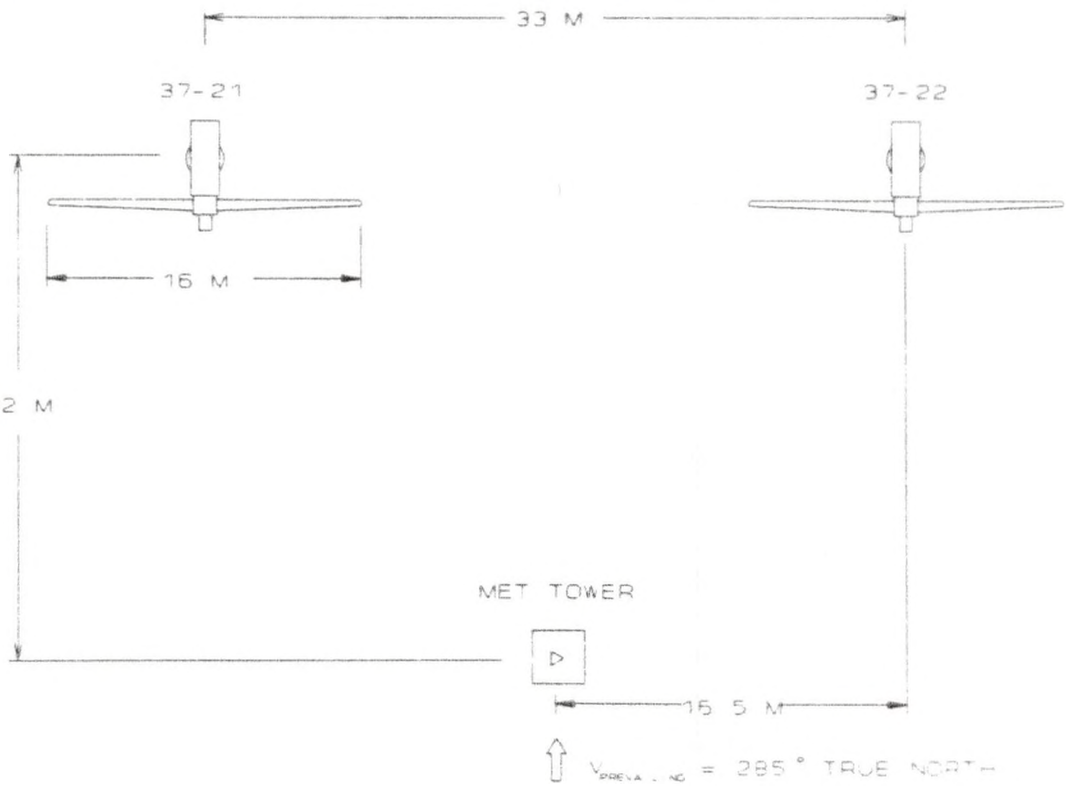


Figure 7. SERI and Aerostar planforms.

Item Description	SERI Blade	Aerostar Blade
No. of Blades	3	
Blade Airfoil Type (Root to Tip)	S808,S807,S805A,S806A	NACA 4415-24
Blade Center of Gravity Distance:		
From Blade Root Flange	1.86 m (6.1 ft)	2.7 m (8.9 ft)
From Rotor Hub Centerline	2.46 m (8.1 ft)	3.3 m (10.9 ft)
Blade Chord at Root (maximum)	1118 mm (44.0 in)	1160 mm (45.7 in)
Blade Chord at Tip	330 mm (13.0 in)	500 mm (19.7 in)
Blade Construction Material	Fiberglass Reinforced Polyester	
Blade Flange Thickness	35 mm (1.38 in)	72 mm (2.8 in)
Blade Length	7.96 m (26.1 ft)	7.4 m (24.3 ft)
Blade Mass	286 kg (19.6 slugs)	363-385 kg (24.8-26.4 slugs)
Blade Modal Characteristics:		
1 st Flapwise Frequency	3.16 hz	4.05 Hz
1 st Edgewise Frequency	7.20 Hz	5.80 Hz
Blade Root Type	Steel Root Flange	Hutter FRP Root Flange
Blade Tip Speed (@ 65 kW rating)	43 m/s (96 mph)	40 m/s (90 mph)
Blade Tip Speed (@ 13 kW rating)	26 m/s (58 mph)	24 m/s (54 mph)
Blade Twist Angle	30 deg (nonlinear)	8.4 deg (linear)
Blade Weight	28023 N (530 lbf)	3559-3781 N (800-850 lbf)
Rotor Cone Angle	4 deg downwind	
Rotor Diameter	17.1 m (56.2 ft)	16.0 m (52.5 ft)
Rotor Direction of Rotation	Clockwise (looking downwind)	
Rotor Hub Height	23.0 m (75 ft)	
Rotor Hub Radius (Micon 65)	0.6 m (1.97 ft)	
Rotor Hub Type	Steel, Cast	
Rotor Orientation	Upwind of Tower	
Rotor Overspeed Control	Centrifugally - activated Tip Brakes	
Rotor Overspeed Control: Activation	65 rpm (135% rated speed)	58 rpm (120% rated speed)
Rotor Overspeed Control: Reactivation		29 rpm (60% rated speed)
Rotor Pitch Type	Fixed	
Rotor Speed (nominal), Gen 1 = 13 kW	29 rpm	
Rotor Speed (nominal), Gen 2 = 65 kW	48 rpm	
Rotor Swept Area	227 m2 (2445 ft2)	201 m2 (2165 ft2)
Rotor Tilt Angle	4 deg above horizontal	

Table 2. Test wind turbine blade information.

Measurements recorded included meteorological measurements, turbine performance, blade loads, and tower loads. The meteorological tower was located 32 meters upwind of the turbines and centered between the two turbines (See Figure 8). Parameters measured from each turbine were flapwise and edgewise bending of the three blades, rotor shaft torque and speed, blade and nacelle azimuth position, yaw drive torque, tower torque and bending loads, electrical system power, and energy output (See Figure 9). Meteorological measurements included wind speed, wind direction, temperature, and pressure (See Figure 10).



[illegible] 8. Test wind [illegible] meteorolo[illegible]al tower layout.

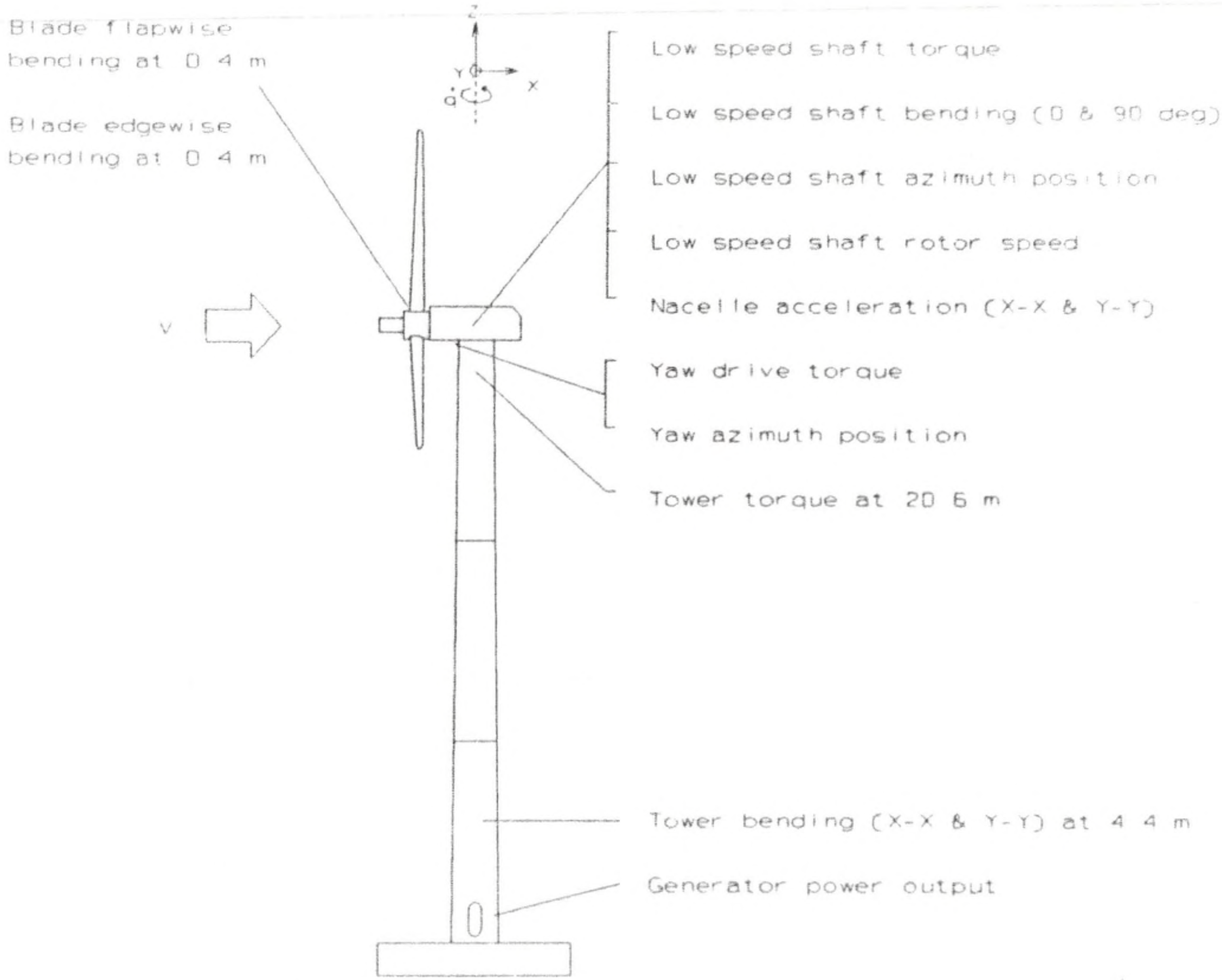


Figure 9. Measured wind turbine instrumentation locations.

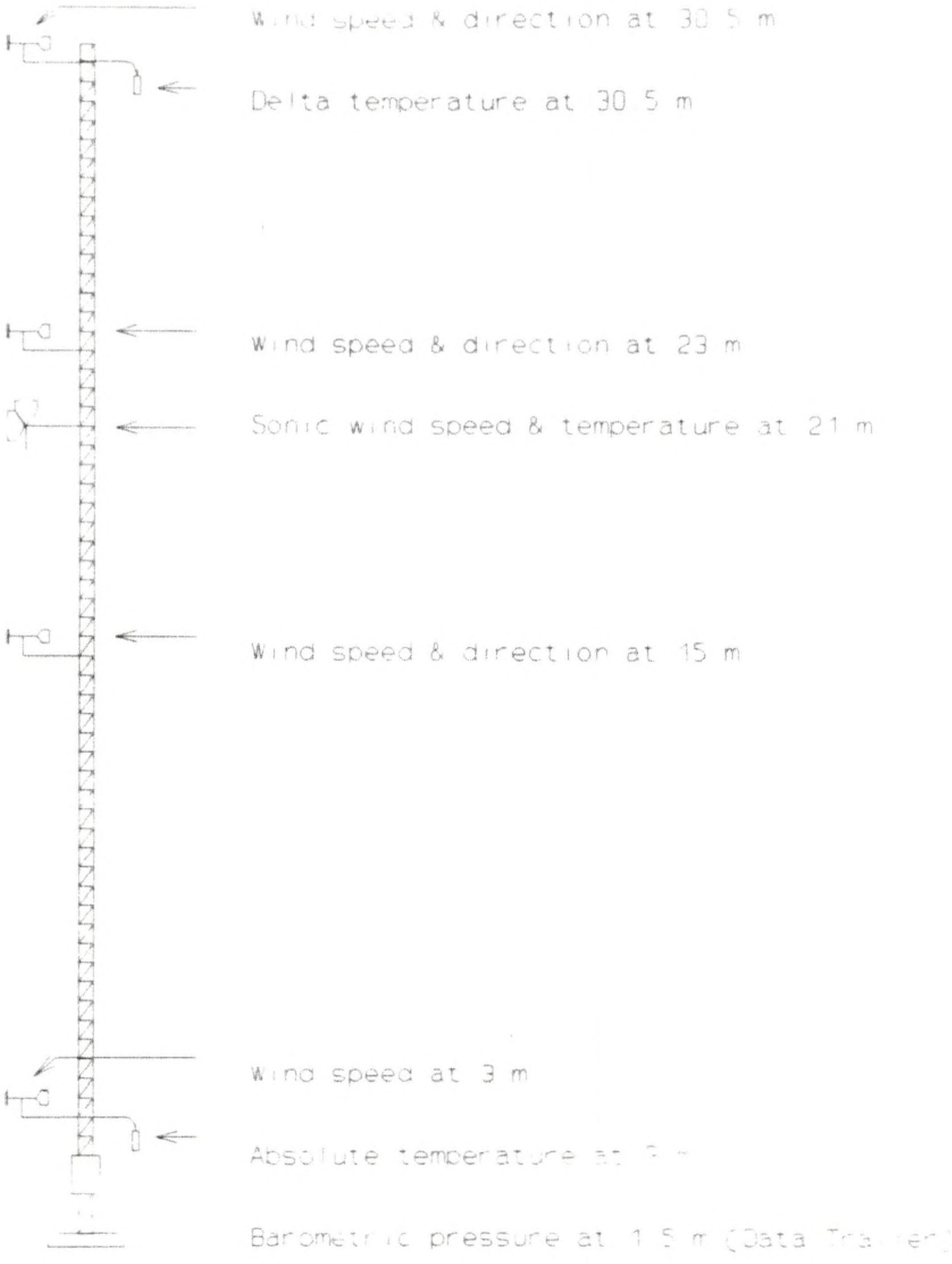


Figure 10. Measured meteorological tower instrumentation locations.

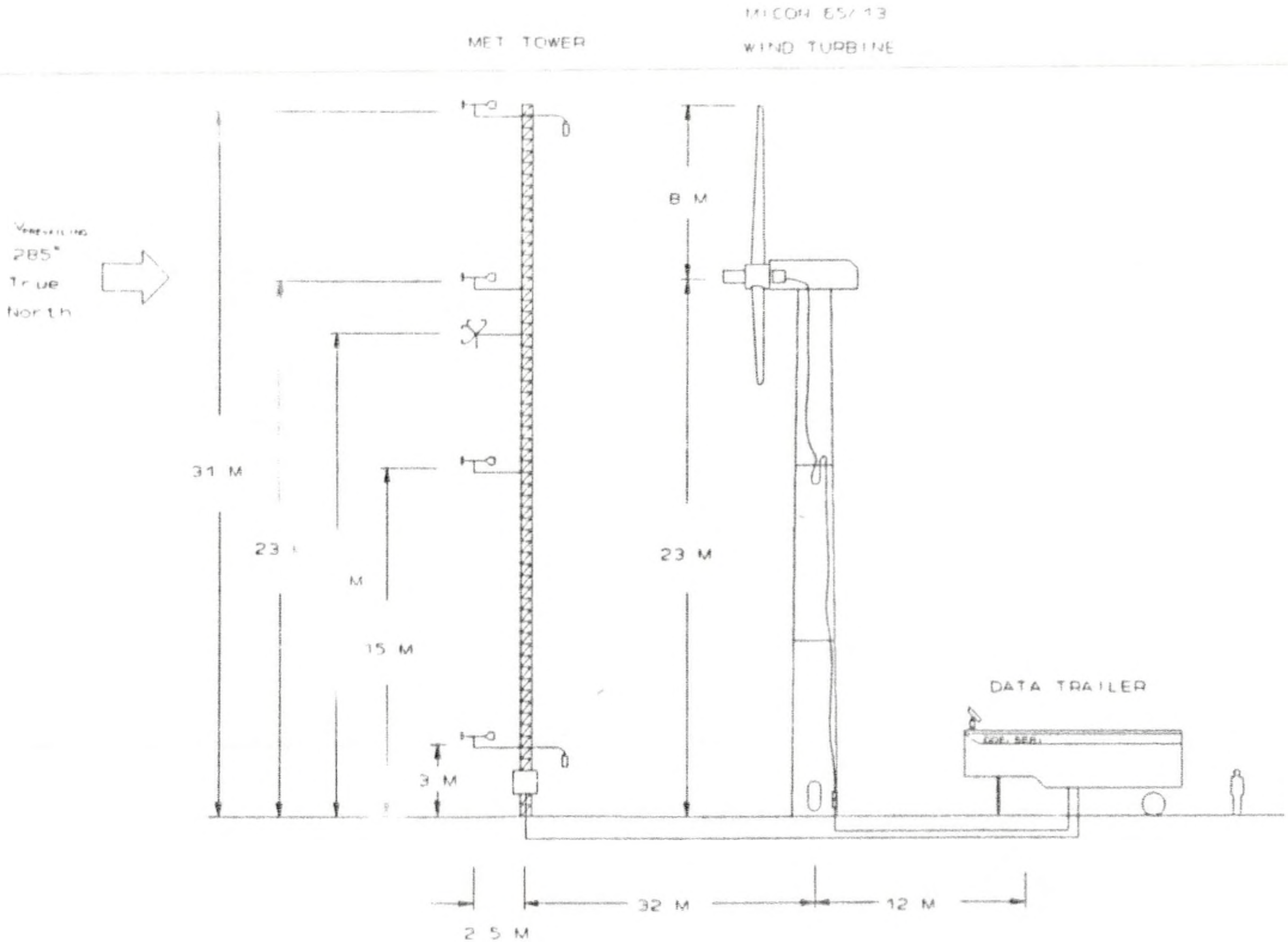


Figure 11. Test wind turbine and meteorological tower elevation.

Blade flapwise and edgewise bending, low speed shaft torque and bending, yaw drive torque, and tower torque and bending, were measured with full-bridge strain gages. Nacelle acceleration was measured with an accelerometer and yaw position with a rotary potentiometer. The low speed shaft was fitted with an optical shaft encoder to determine blade position and rotor rpm. (See Appendix A).

Wind speed and direction were measured at 30.5, 23, 15, and 3 meters with propvane anemometers and at 21 meters with a sonic anemometer. Absolute atmospheric temperature was measured at 3 meters and a delta temperature was measured at 30.5 meters with a temperature sensor. Barometric pressure was measured at 1.5 meters in the data trailer with a pressure sensor, at an elevation of approximately 800 feet above sea level.

Data signals on the rotating system were transferred through slip rings on the tower, and fed into the data trailer. All of the incoming signals were pulse-code-modulated (PCM), except the optical signals (low speed shaft azimuth and rpm), prior to recording on a 16-track Honeywell tape recorder. The signals were then fed into a Dell 386-25 computer equipped with a Keithley 500 data acquisition board. Labtech Notebook software was used to digitize the analog data into 32 Hz, binary form, and was then recorded on an optical disk drive.

Experimental Test Procedures

During the 1989 wind season, instrumentation was installed and calibrated. Testing focused on comparing power output from the two turbines, to establish power curves (7).

During the 1990 wind season, power curves were established based on 100 hours of data for both clean and dirty conditions (6). Dirty conditions were simulated using double-sided adhesive tape, with randomly scattered grit, on the upper and lower surfaces of the leading edge. This simulates the bug build up that occurs under normal operating conditions.

From July 24 through August 1, 535 10-minute data sets, of load and performance data were collected. Additionally, 2-minute data sets were collected during startup, shutdown, and for calibration sets. Eleven calibration sets were taken over the eight day period. Data was collected when SERI personnel were on site and the wind was blowing.

Calibration

Four different calibration procedures were used to establish the gains and offsets (10):

1. Blade pulls and tower pulls (once per wind season).
2. Azimuth rotation (once per month).
3. Slow rotation of rotor and nacelle (approximately once per day).
4. Low-cal, high-cal, operational-cal sequence (approximately once per day).

Blade and tower pulls were used to set the strain gauge gains for flapwise and edgewise blade bending, tower bending, and tower torque. For blade pulls, a sling was placed around the blade inboard of the tip-cut line and a come-along connected between a load cell and a cable attached to the tower. Applying a known load with the come-along, the responses of the strain gauges were recorded. The tower pulls were done in a like manner. The bending moments and torques calulated from the strain gauge measurements were then compared to engineering calculations for validation.

Azimuth rotation was used to establish baseline strain gauge offsets for flapwise and edgewise bending. Strain gauge voltages were recorded at 30° azimuth increments, averaged, and a baseline offset determined. A low wind speed condition is required for this test. On July 29th, this test was performed and set the baseline for the July-August test period.

Slow rotations (rpm < 17) were used to check for drift in gains of gravity sensitive signals such as edgewise and shaft bending. The signals were plotted versus time for an integral number of revolutions. Segments were selected from each data set where the rotor speed is stable, and the means determined. These means were then used as the offset. It was found that the edgewise bending moment varied strongly with temperature, and an additional regression was done on this signal versus temperature.

Low-cals were used to set offsets; the electronic zero of the signal. Low-cals were done on propvane wind speed, wind direction, and temperature signals, and to adjust the baseline strain gauge offsets for azimuth rotations. High-cals, the response of the signal to a known input, were used to watch for general gain and measurement problems. Operational-cals were used to set offsets for the nacelle, tower, and yaw drive signals, while the rotor was free to rotate, but the turbine was off line. The rotor was perpendicular to the wind for determining accelerations, torques, and Y-bending moments, and parallel to the wind for X-bending moments.

The optical shaft encoder was arbitrarily aligned, with blade one at 0° (blade straight up). The encoder pulses at 512 and 1 pulse per revolution measuring rotor azimuth and rpm. Nacelle accelerometers, meteorological presets, and gains and offsets, were determined by SERI's Calibration Lab staff. The pressure and temperature transducers, and sonic anemometers were calibrated by the manufacturers.

CHAPTER III

MEASURED DATA ANALYSIS

Technological advances in data acquisition systems permits the experimenter to collect copious amounts of raw data. Based on the purpose of the experiment, the analyst must process the data and draw conclusions. The analyst must make a decision as to how much data is required to validate his findings. Processing all the data may yield a high (98%) confidence level, however by selecting a sample of the data, a slightly lower (95%) confidence level might be obtained and the results just as credible.

In the wind industry, 10-minute data sets have become an accepted standard record length on which to make comparisons between turbines, components, etc. Ten minute data sets provide a record length which is considered to be statistically stationary (11). There is however, some debate as to how many data sets are required to characterize the loads experienced by a wind turbine.

Raw Data

This analysis has been based on a series of 10-minute records collected from July 24 through August 1, 1990. These data were collected in such a manner as to include a wide range of turbulence inflow conditions. A total of 535 data records were available for analysis. They consisted of 54 parameters sampled 32 times a second. Brian Smith, a SERI Test Engineer, and Tim Olsen, a consultant for SeaWest, converted the data into engineering units using WINDATS (12), a Fortran program developed at SERI.

During the data collection period, eleven sets of scaling factors, and offsets, were determined for the 54 data channels. Each set was used for a specific data run within the data collection period. A control file for WINDATS (See Appendix B), was written for each of the calibration sets and the data was then processed to convert the raw binary data into calibrated, scaled engineering units. Six additional channels were also calculated: yaw error, low speed shaft power, and drive train efficiency for both turbines. In addition to a scaled data output file, a statistics file was generated for each 10-minute data set which included the mean, standard deviation, coefficient of variance, and minimum and maximum values for each channel (See Appendix C).

Data Analysis

Each of the scaled 10-minute data sets was written to a file requiring approximately 4.7 MB, in binary form, and when converted to ASCII format the size increases to over 17 MB. The statistics files however are only 15 KB. The analysis was done on a Compaq 386-20 with a 60 MB hard drive, and, due to the limitations of a personal computer, an efficient means to process the data needed to be devised.

The 10-minute statistics files served as a means to classify each data set. Meteorological parameters:

atmospheric stability, turbulence intensity, and or wind speed, were used to classify the data sets.

The data were first analyzed graphically to determine if there were gross errors in the files and thus provide a basis to eliminate bad files. A shareware database program, File Express and two Fortran programs written by the author (See Appendix D), were used to selectively sort the files. Quattro Pro was used to graph the results.

Atmospheric stability is measured by calculating the Richardson number, as given below. Stability is defined as the ratio of buoyant (thermal) to mechanical (shear) turbulence in an atmospheric layer (13).

$$Ri=\frac{\left(\frac{g}{\theta_{avg}}\right)\left(\frac{dt}{dz}\right)}{\left(\frac{du}{dz}\right)^2} \qquad [6]$$

Where:

$$g = 9.81\ m/s^2 \qquad [7]$$
$$\theta_{avg} = (\theta_1 + \theta_2)/2 \qquad [8]$$
$$dt = \theta_2 - \theta_1 \qquad [9]$$
$$du = u_2 - u_1 \qquad [10]$$
$$dz = z_2 - z_1 \qquad [11]$$
$$\theta_1 = (T_1 + 273.15)(1000/P_1)^{0.286} \qquad [12]$$
$$\theta_2 = (T_2 + 273.15)(1000/P_2)^{0.286} \qquad [13]$$
$$P_2 = P_1 - dz/10 \qquad [14]$$

and wind speed u (m/s), temperature T (°C), height z (m), and pressure P (mbar). Note: height z_2 is above z_1.

A Richardson's number which is positive indicates a stable atmosphere, approximately zero indicates a neutral atmosphere, and a negative indicates an unstable atmosphere (See Table 3 (12)).

Class	Richardson's Number Range	Classification
1	Ri ≤ -1.00	Very Unstable
2	-1.00 ≤ Ri ≤ -0.01	Unstable
3	-0.01 ≤ Ri ≤ 0.01	Neutral
4	1.00 ≤ Ri ≤ 0.16	Critically Stable
5	0.16 ≤ Ri ≤ 0.25	Stable
6	0.25 ≤ Ri ≤ 1.00	Very Stable
7	1.00 ≤ Ri	Extremely Stable

Table 3. Richardson's number classifications.

Unstable conditions occur when turbulence generation is dominated by thermal convection. Stable conditions occur when energy is transferred under conditions that are buoyancy damped and shear generated turbulence is prevalent. Under neutral conditions, only mechanical turbulence is present.

Turbulence intensity, the coefficient of variance of the wind speed, is often used to characterize data sets (11). Methods which were used to characterize the data sets included:

1. Turbulence intensity versus mean wind speed.
2. Turbulence intensity versus SERI power.
3. Peak/mean wind speed versus mean wind speed.
4. SERI power versus mean wind speed.
5. Peak/mean power versus SERI power

and the results are presented in Figures 12-16.

There are a few outliers in Figures 12,13,& 16, however in Figures 14 & 15, the errors are apparent. Figure 15 represents a wind turbine power curve. A power curve should reach a maximum value (65 Kw rated output) near the design

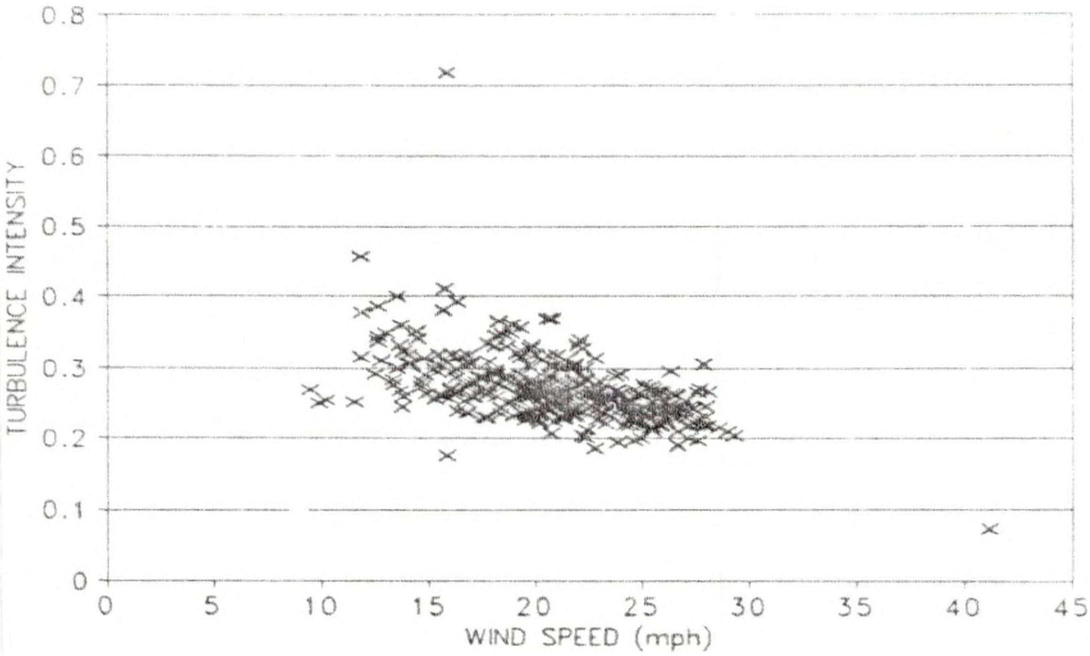


Figure 12. Turbulence intensity vs mean wind speed.

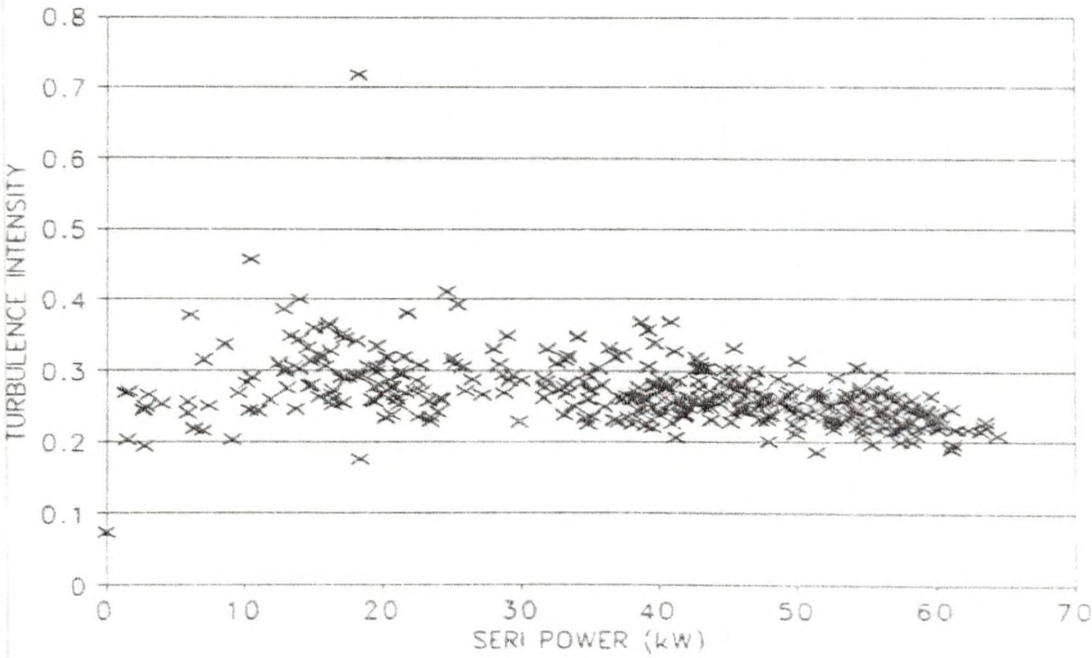


Figure 13. Turbulence intensity vs SERI power.

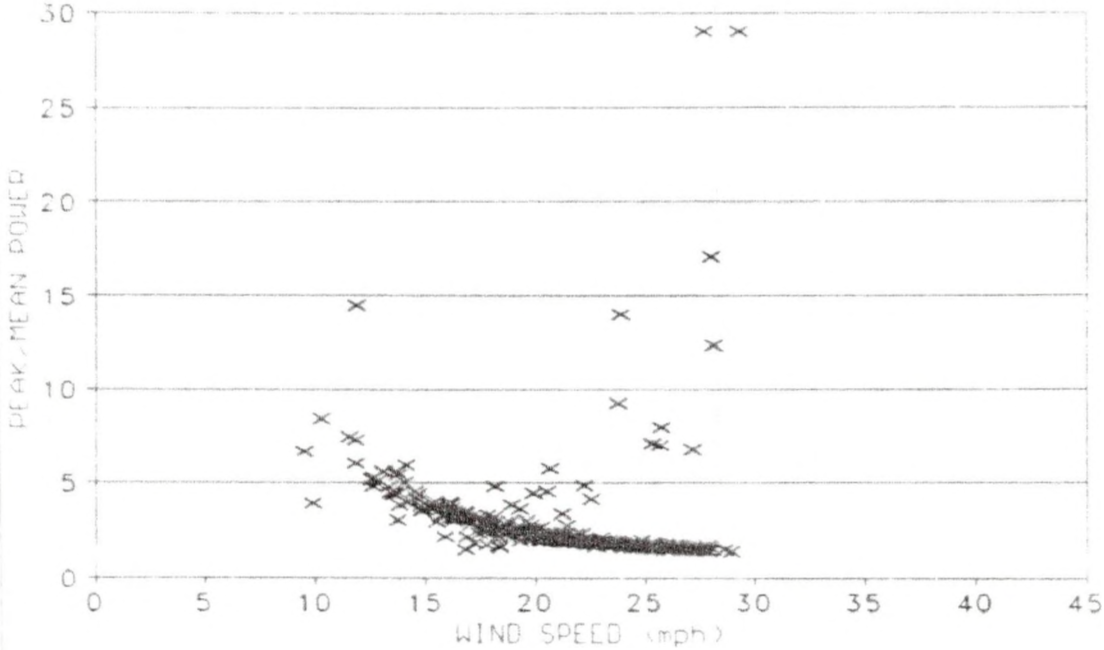


Figure 14. SERI peak/mean power vs mean wind speed.

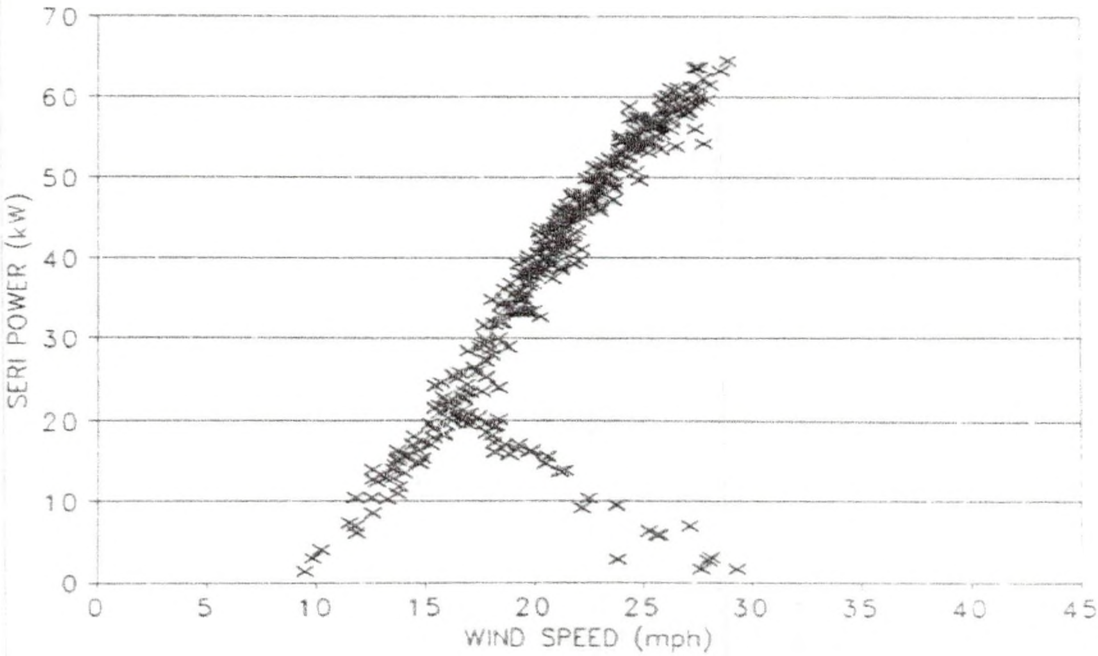


Figure 15. SERI power vs mean wind speed.

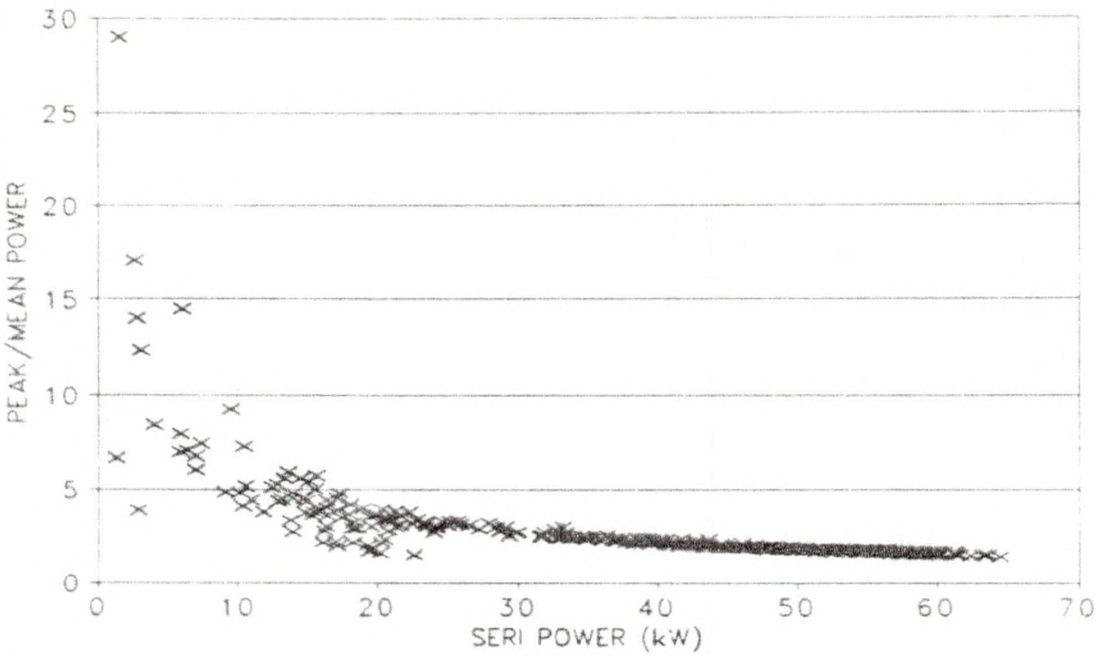


Figure 16. SERI peak/mean power vs SERI power.

wind speed (30 mph for the SERI turbine). Because these are stall regulated wind turbines, the power should level off and then slowly decrease at wind speeds above the design wind speed. There is clearly an error when the power is decreasing while the winds are increasing from 17 to 30 mph.

The suspect files were checked for ambiguities, and eliminated from the data set (See Appendix E). The errors in the data sets are probably due to computer software processing errors rather than measurement errors. The processing software likely had some difficulty determining the starting and stopping point of the initial binary files. It appears that approximately 5 percent of the files (25 or 30 files), were processed incorrectly. Additionaly, some of the records were not a complete 10-minute data set, and these were removed, leaving 409, good files.

After the suspect files were deleted, the data were again plotted. The results are shown in Figures 17-21. In Figure 17, the points at wind speeds below 15 mph, are scattered, which is to be expected at lower mean wind speeds. It also appears the data points are cohesive. In Figure 18, the data is evenly distributed about a mean turbulence of 0.25. For Figures 19, 20, & 21, the data follows a definite trend. The power curve actual looks like a power curve. However, in Figure 21 there are still outliers that are suspect.

The intent of this investigation is to compare field test measured flapwise and edgewise bending loads with predicted loads from the FLAP code. Past discrepancies in comparisons of predicted and measured loads are thought to be due to unknown inflow into the rotor (14). Turbulence fluctuations are not known, however the turbulence effects can be minimized by selecting cases with a low turbulence intensity. FLAP predictions are also not accurate for cases with high yaw errors.

Due to the large volume of information, it is not practical nor desirable, for this study to include a complete analysis on all 535, 10-minute data sets. The known parameters which adversely effect the prediction of loads were considered in selecting data sets. Four data

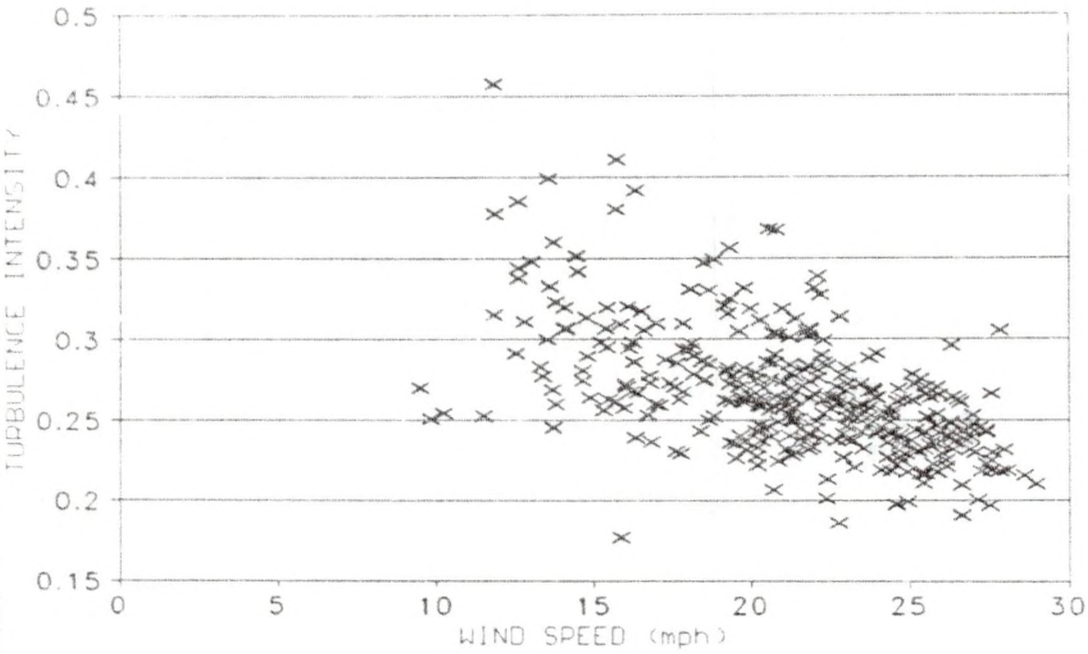


Figure 17. Turbulence intensity vs mean wind speed.

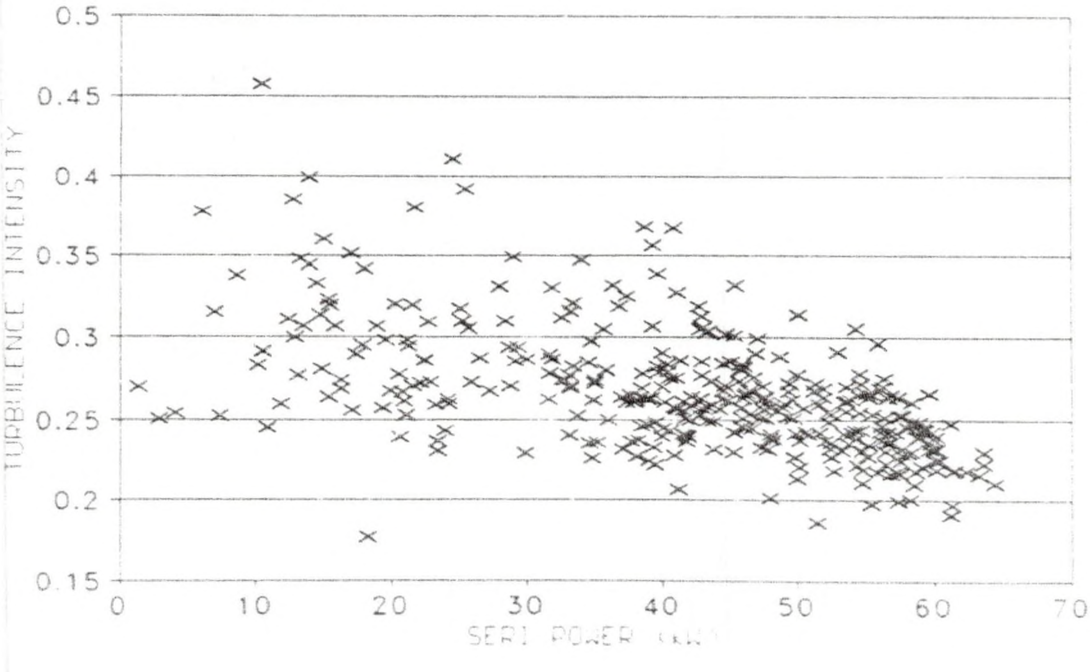


Figure 18. Turbulence intensity vs SERI power.

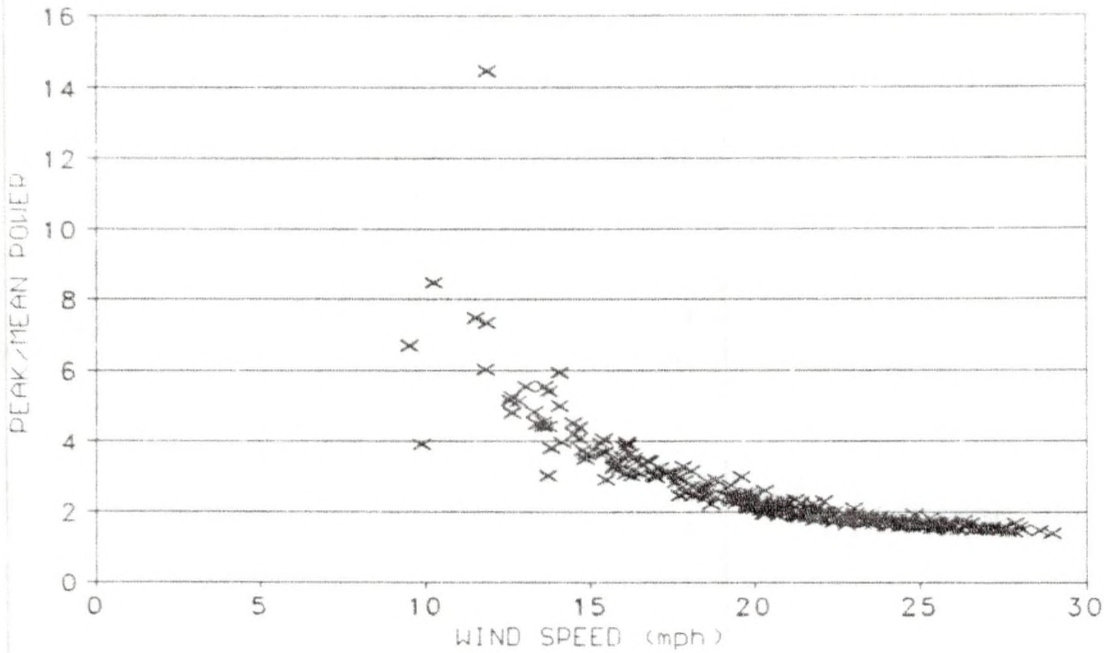


Figure 19. SERI peak/mean power vs mean wind speed.

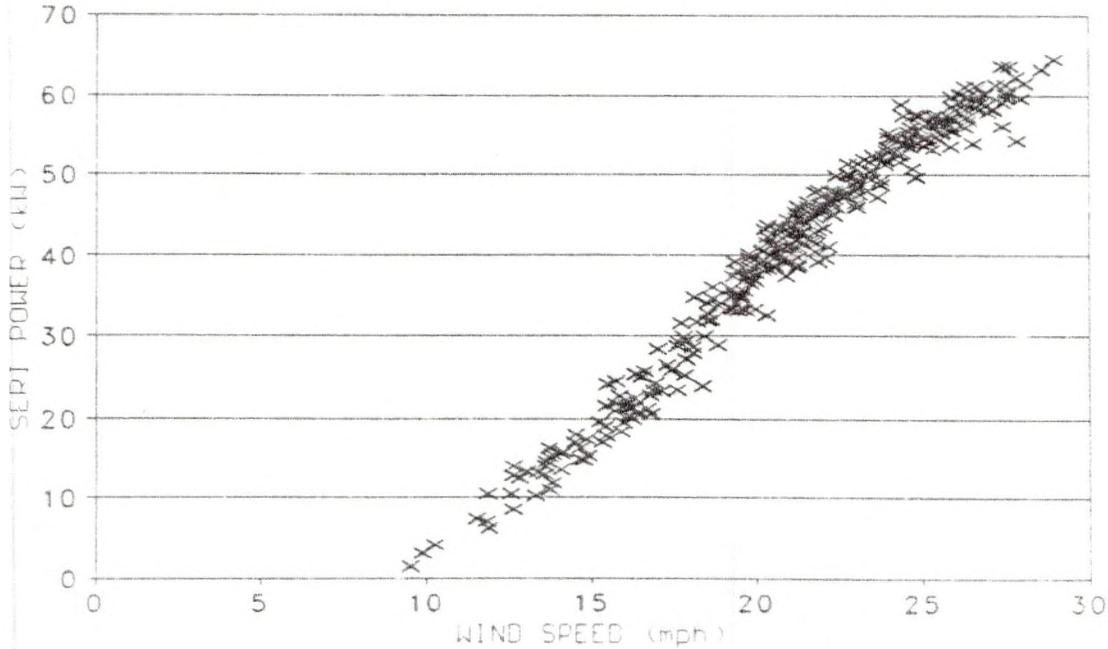


Figure 20. SERI power vs mean wind speed.

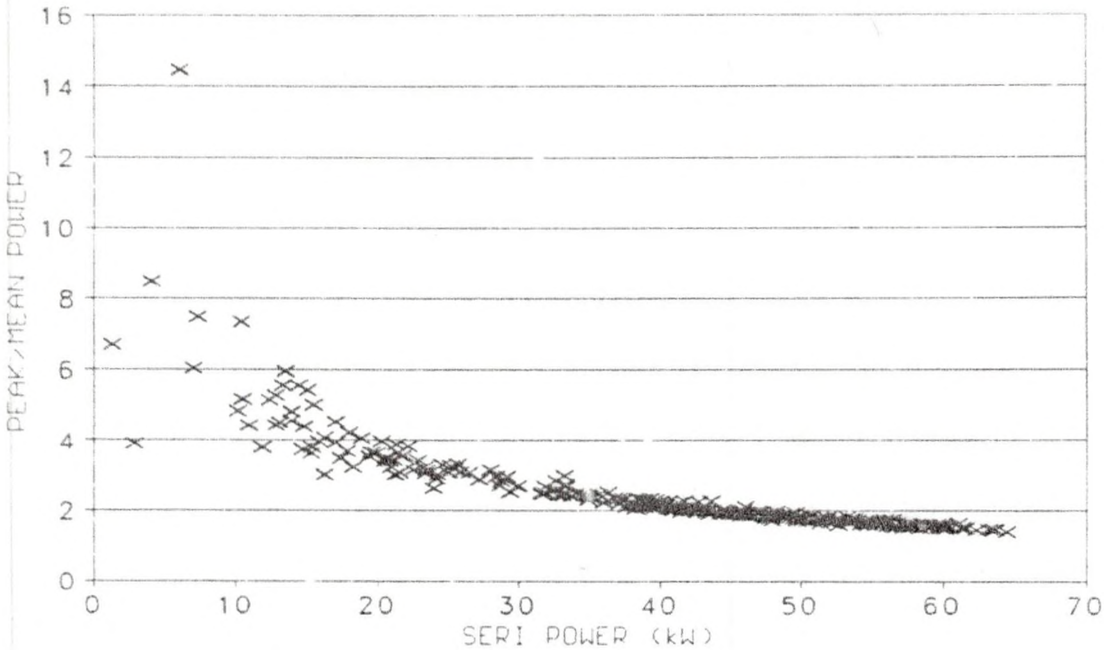


Figure 21. SERI peak/mean power vs SERI power.

sets were selected with a turbulence intensity of approximately 0.25 and relatively small yaw errors for comparison to FLAP (See Table 4). These four data sets were chosen to provide a large range of wind speeds.

FILE NAME	AVG WS (mph)	COV	YAW ERROR SERI (deg)	YAW ERROR AEROSTAR (deg)
1. L072629	26.91	0.2450	15.77	5.57
2. L072733	21.57	0.2512	5.77	6.77
3. L072822	16.71	0.2526	10.22	6.10
4. L072964	11.52	0.2523	8.34	3.32

Table 4. Files selected for comparing loads to FLAP predictions.

It has been suggested by Neil Kelley, the resident SERI Meteorologist, that stability, wind speed standard deviation, and mean wind speed, in that order of

FILE NAME	Z/L	WSσ (mph)	WS (mph)
1. L072959	-0.248	3.68	15.22
2. L07260	-1.01	4.40	21.41
3. L072976	-0.204	5.40	12.86
4. L072749	-0.046	5.49	22.48
5. L072941	0.121	3.64	14.78
6. L072923	0.057	4.06	19.24
7. L080127	5.616	5.25	11.16
8. L072741	0.014	5.47	22.57
9. L072414	0.0	5.89	23.75

Table 5. File matrix based on stability, wind speed sigma, and mean wind speed.

significance, is a better way to rank data sets. By selecting files in this manner, a more complete spectrum of loads would be established. A full spectrum of blade loading information is an invaluable asset to the turbine and blade designer. The blade designer can use the load spectrum to determine the blade's fatigue life. Validation of this hypothesis, which was not done by this analyst, would require selecting a matrix of files based on stability, wind speed standard deviation, and mean wind speed as shown in Table 5.

CHAPTER IV

ANALYTICAL MODEL

The analytical model used was FLAP (15), initially Subsequently, the code (written in Fortran 77) has been refined at SERI and modified for use on the IBM-PC family of computers. The code has been validated by comparing the predictions to wind tunnel test data on the MOD-2. This data was unique in that the inflow was known and the turbulence low.

With FLAP, the analyst is able to determine 9 quantities at 11 blade stations for the desired number of azimuth positions (see Table 6).

1. Blade section flap displacement (ft).
2. Blade section flapwise slope (ft/ft).
3. Blade section flap velocity (ft/s).
4. Blade tension (lbf).
5. Blade edgewise shear (lbf).
6. Blade flapwise shear (lbf).
7. Blade flapwise moment (lbf-ft).
8. Blade edgewise moment (lbf-ft).
9. Blade torque (lbf-ft).

Table 6. Calculated FLAP outputs.

To check blade mass and stiffness inputs, the program also calculates the blade 1st flapwise bending frequency.

FLAP is divided into 2 modules: FLAP1 and FLAP2. FLAP1 is a preprocessor of the raw blade and turbine properties for input into FLAP2, performing unit conversions and dividing the blade into 20 equally sized sections. The input into FLAP2 generally does not change from run to run, however the analyst is able to change several parameters from within FLAP2 such as wind speed and yaw error. FLAP2 performs the model run; solving the equations of motion, calculating loads, and outputting the results.

FLAP Inputs

Accurate blade and turbine data are essential as known inputs into FLAP. A complete listing and brief explanation of the input parameters for FLAP are included in the Nomenclature section. For a more thorough definition of each input variable refer to the FLAP manual (15). Currently the model is limited to 11 blade radial input points. The analyst selects the input points based on the how the blade properties vary.

Extensive turbine data is usually available from the turbine's technical data sheet. Blade data, on the other hand, is more difficult for the analyst to obtain. The blade manufacturer may or may not be able to supply all the required blade information. The analyst must either make some assumptions or determine the required inputs through measurements or calculations. This is particularly true for the blade mass and stiffness distributions (15).

The blades used in this study are a hand-laid fiberglass composite. Using a hand-laid process, the blades weight often differ ± several percent. The set of 3 blades are then matched to the weight of the heaviest blade in the set by adding lead to the root or weigh tubes. It is not uncommon to see blade weights differ 20 or 30 pounds from set to set. Part of the deviation in weight is attributable to the crews constructing the blades. More experienced crews tend to produce lighter blades, resulting in a higher glass-to-resin ratio, than an inexperienced crew. The glass-to-resin ratio also effects the modulus of elasticity, and blade stiffness. The FLAP manual provides a guide in determining most of the inputs, however, it lacks a clear explanation on how to obtain the mass and stiffness distributions. It appears that the mass and stiffness variables, WEIGHT and AEIARE respectively, are used as 'free variables'. That is, the mass and stiffness inputs are adjusted until the blades calculated first flapwise natural frequency agrees with the actual blade natural frequency.

If FLAP is to be used by the blade designer, as a design tool rather than a post processor, a methodology to analytically determine the mass and stiffness distribution must be established.

Mass Distribution

The blades mass distribution can be calculated from knowing the weight and location of the individual blade constituents. A composite fiberglass blade utilizes differing materials at various stations along the blade in both the radial and chord wise directions (See Appendix G). Calculating the mass distribution is therefore not as straight forward as would be the case for a homogenous crossection.

The blades planform defines the blades geometry at stations along the blade (See Appendix H). Stations are spaced on 6 inch centers from the blade root to tip. Blade geometry at each crossection is defined by X,Y data pairs. Due to the complex blade geometry, Equation 15 was used to determine the perimeter of each station.

$$L = \sum(\delta Y^2 + \delta X^2)^{0.5} \qquad [15]$$

Using the perimeter of two adjacent stations and the Trapezoidal Rule, the exterior area for each 6 inch wide blade increment was calculated.

The blade weight per foot (converted by FLAP to mass per foot) was determined by first dividing the blade into 2 foot sections. A smaller section width could have been chosen, i.e. 6 inches however, the addition work could not be justified based on the fore mentioned FLAP limitations. From coupon samples, the weight per square foot of each of the materials used was determined by Phoenix Industries, Crookston, Minnesota. The weight and center of gravity of 'fixed components', i.e. root metal and tip mechanism was also provided by Phoenix Industries. With the fixed and variable weights of the constituents known, it was then possible to calculate the blade weight.

A spreadsheet was setup and the blade weight was then calculated (See Appendix I). The calculated weights were 642.4 lbs and 836.4 lbs and the actual weights are 639.3 lbs and 829.5 lbs resulting in an error of 0.5% and 0.8% for the SERI and Aerostar blades respectively. Further refinement of the weight distribution was required to reduce the 13 blade sections into 11 point loads.

Two required FLAP input points are the root and tip, but the other points are left up to the analyst's discretion. The points should be selected to minimize discontinuities in properties while accurately describing the blade. Logical geometrical choices for points include the beginning and end of the root barrel, the end of the cuff (widest chord length station), and the tip. Fixed weight location should also be considered when selecting points.

Eleven points were selected and the Trapezoidal Rule was again applied to assure that the weight of each section, defined by two adjacent points, was the same as previously calculated (See Appendix J). The blade weights thus obtained were 643.6 and 837.6 pounds resulting in an error of 0.7% and 1% for SERI and Aerostar blades respectively.

An additional check of the validity of the weight distribution is provided by comparing the centers of gravity (C_g). The reported C_g for the SERI is 76 inches (from the root), and as calculated from the weight distribution is 75.61 inches. The reported C_g for the Aerostar is 89 inches and was calculated 90.15 inches. The C_g was not measured prior to installation and can not be measured until the blades are taken down.

Stiffness Distribution

Stiffness, by definition is the EI product. If the blades were of constant cross section and the materials are homogenous and isotropic, such as aluminum, the stiffness could be calculated in a straight forward manner. The modulus of elasticity (E) can be found in a handbook such as Mark's Handbook, and the moment of inertia (I), can be calculated using a formula from Roark's Formulas for Stress and Strain.

In the case of a fiberglass composite material which is not homogenous nor isotropic, tabulated data is essentially nonexistent. Additionally, the plies tend to act synergistically, thus the rules generally applied to composites such as volume or weight fractions, no longer apply. Therefore, the modulus of elasticity must be determined experimentally. Determining the moment of inertia at each crossection of the blade is also not clear cut. The crossection varies in thickness around the perimeter, and the internal structure must also be considered.

Given the complexity of the problem of determining the stiffness, perhaps taking the approach of using the stiffness as a floating variable has some merit. After appraising the problem, it seemed the problem warranted further investigation. Finite element software does calculate the stiffness distribution, and some, such as GIFTS, allows the user to extract the stiffness matrix.

The difficulty in using a finite element package is defining the model with enough detail such that the model behaves as would the physical blade. Defining the blade geometry is no problem using a CAD package such as Autocad. The real obstacle is defining material properties.

After discussing the problem with Rich Osgood, a SERI Test Engineer with expertise using finite element models, he suggested trying to model the blade first as a cantilever beam, and just see what type of results were obtained. The overall approach used was to keep the initial model simple.

Rather than use the actual blade geometry, 26 crossections were modeled as simple cylinders and rectangles (See Appendix K). Blade wall thickness was assumed to vary linearly. In the root barrel (from the root outboard 48 inches), the wall thickness was doubled in the flapwise direction to account for the unidirectional fiber, used as root bundles, tendency to migrate towards the bottom of the mold halves during manufacturing. The modulus of elasticity was assumed to be constant at $3x10^6$ psi and isotropic.

From the model, the first flapwise bending frequency was 4 Hz, the true blade frequency is 3.8 Hz. Considering the crudeness of the model, being off only 0.2 Hz, came as a pleasant surprise. However, extracting the stiffness matrix proved more difficult then originally envisioned. The stiffness matrix is not a normal output, it comes out embedded in a matrix. After several phone conversions with GIFTS technical support staff, it became clear that obtaining the stiffness matrix would require a great deal of work, and the finite element model was dropped (time was the major constraint).

Obtaining the stiffness experimentally was the only viable option left. Applying a point load outboard on the blade and measuring the deflection at points along the blade would provide enough information to plot a deflection curve. A polynomial can then be fit to the deflection curve and the stiffness calculated using Equation 16 (16).

$$EI(X) = \frac{M}{Y''} \qquad [16]$$

The SERI and Aerostar blades were tested applying the fore mentioned procedure. The SERI blade was mounted vertically and four blade pulls were made. The Aerostar blade was mounted horizontally with the trailing edge mounted up and again four blade pulls were made. Blade deflections were measured using a tape measure and transit. The moments and deflections from each of the pulls were averaged and the resulting deflection curves were plotted. Using GRAPHER, a polynomial, fifth order or higher, was fit to each of the deflection curves, and the stiffness calculated (See Appendix L).

Comparing the stiffness values for the SERI blade to those reported in the blade design report, the stiffness determined experimentally was of the correct order of magnitude. However, three feet outboard, the calculated stiffness reached a maximum value. The same trend was seen on the Aerostar blade, but the maximum stiffness occurred one foot outboard.

Theoretically, blades are designed such that the stiffness is a maximum at the hub and decreases going outboard. Therefore, the experimental stiffness values are suspect. The problem may be attributed to the lack of resolution in the measurements taken, particularly near the root. With a tape measure and transit, the precision in the measurements was ± 1/32 of an inch. Near the root, the deflections are thought to be on the order of thousandths of an inch, thus invalidating the test results.

To test this hypothesis, digital dial gauges and string potentiometers were ordered to measure the deflections. The equipment was ordered in May and should be out of the calibration lab by mid June. At the present time, it appears the test setup will not be completed and ready for deflection tests for inclusion in this work.

Wind Shear Velocity Distribution

For each 10-minute data set used in comparing FLAP loads, the wind shear exponent (m) must be calculated. Wind speed measurements were taken at 31, 23, 21, 15, and 3 meters heights in front of the turbines. The anemometer used at 21 meters was a sonic anemometer and the others were prop-vane anemometers. There is currently a debate concerning the accuracy of the prop-vane anemometers, the error appears to be as much as 2 mph, and an investigation is in progress to confirm or disprove the hypothesis. The 15 meter anemometer readings are grossly in error and will not be used. In order to retain continuity, the 21 and 15 meter height anemometer will not be used in calculating the wind shear exponent.

Wind shear is generally described using the power law in the form of Equation 17 (15). The reference height velocity $V(H_o)$ is normally hub height (23 m), H is the

$$V(H) = V(H_o)\left(\frac{H}{H_o}\right)^m \qquad [17]$$

height and V(H) the velocity at that height. A wind shear curve was fit to the remaining 3 "good" anemometer readings by minimizing the sum of the square of the residuals. The wind shear exponents for each of the four comparison cases are in Table 7 and the wind shear curves in Appendix M.

27 mph case:	$V(H) = 26.906(H/23)^{0.100}$
22 mph case:	$V(H) = 21.574(H/23)^{0.127}$
17 mph case:	$V(H) = 16.706(H/23)^{0.090}$
12 mph case:	$V(H) = 11.524(H/23)^{0.120}$

Table 7. Wind shear exponent calculations of 4 data sets.

CHAPTER V

ANALYTICAL AND EXPERIMENTAL RESULTS

Results from the field tests are introduced first as they form the nucleus of this investigation. In an attempt to validate the analytical model, the predicted and field flapwise and edgewise bending loads are presented together to facilitate drawing conclusions.

Experimental Results

The four 10-minute data sets for the SERI and Aerostar turbines were processed using WINDATS. Each channel was binned using the azimuth position and wind speed (See Appendix N for the control files used), and the azimuth results plotted (Figures 22-37). Azimuth was binned in 9° band widths, the minimum integer degree band width as calculated from Equation 18, given below. Wind speed was binned in 1 m/sec band widths.

$$azimuth\ bin\ size(deg) = rpm\left(\frac{1\mathrm{min}}{60\mathrm{sec}}\right)\left(\frac{1\mathrm{sec}}{sample\ rate(Hz)}\right)\left(\frac{360deg}{rev}\right) \qquad [18]$$

From the plots, it appears that the data for each of the three blades are consistent. The flapwise max and min loads however appear to be lagging +60°, and the edgewise lagging +30°, from where they are expected to occur.

Azimuth Shift

Flapwise loads are a function of wind speed, with the highest wind speed at the top of the rotor disk, as

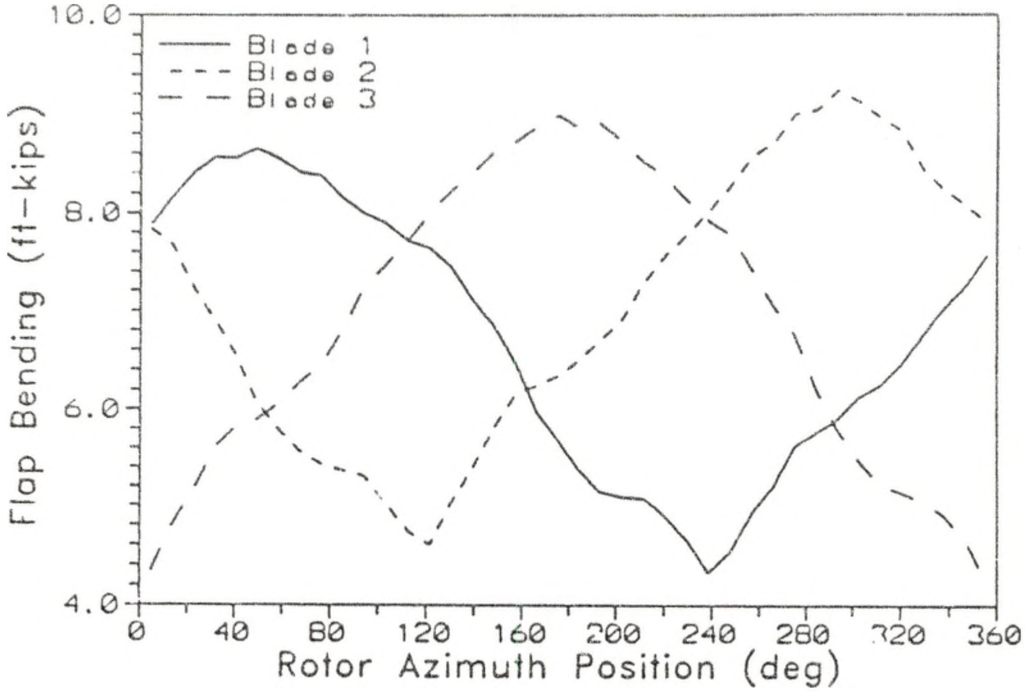


Figure 22. SERI flapwise bending: 27 mph case.

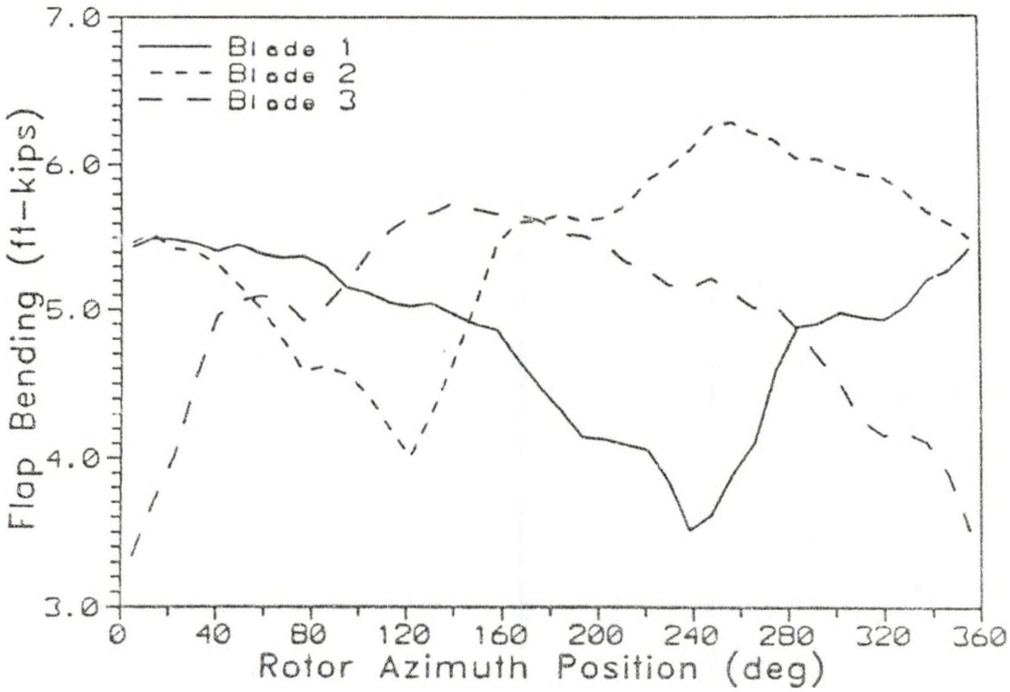


Figure 23. SERI flapwise bending: 22 mph case.

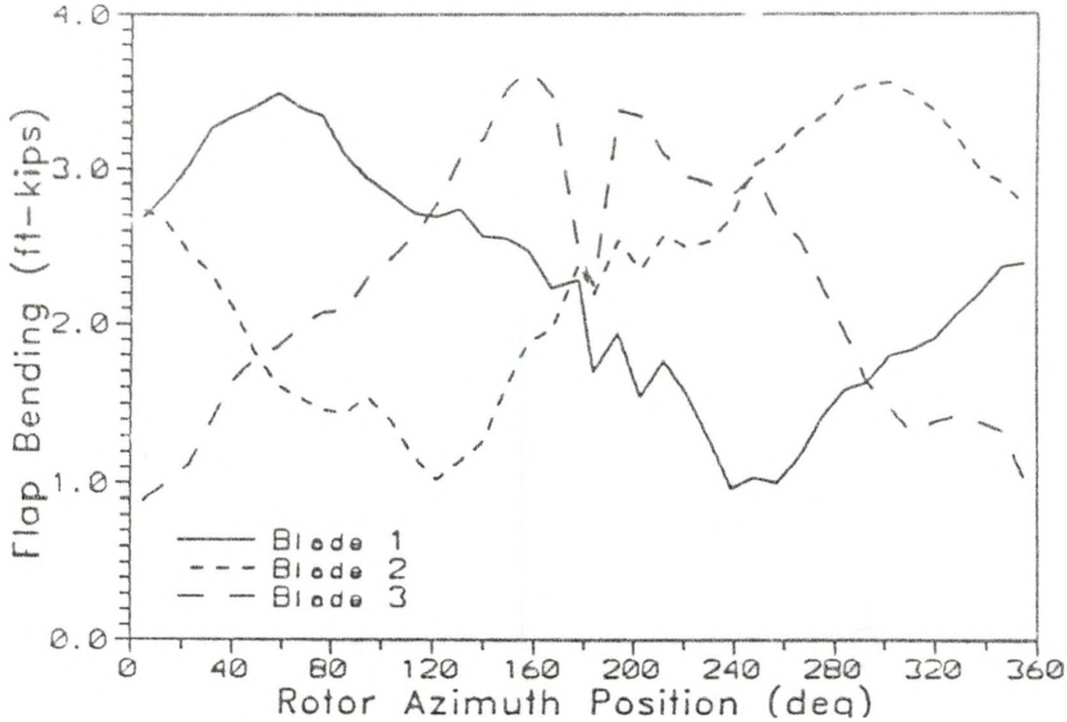


Figure 24. SERI flapwise bending: 17 mph case.

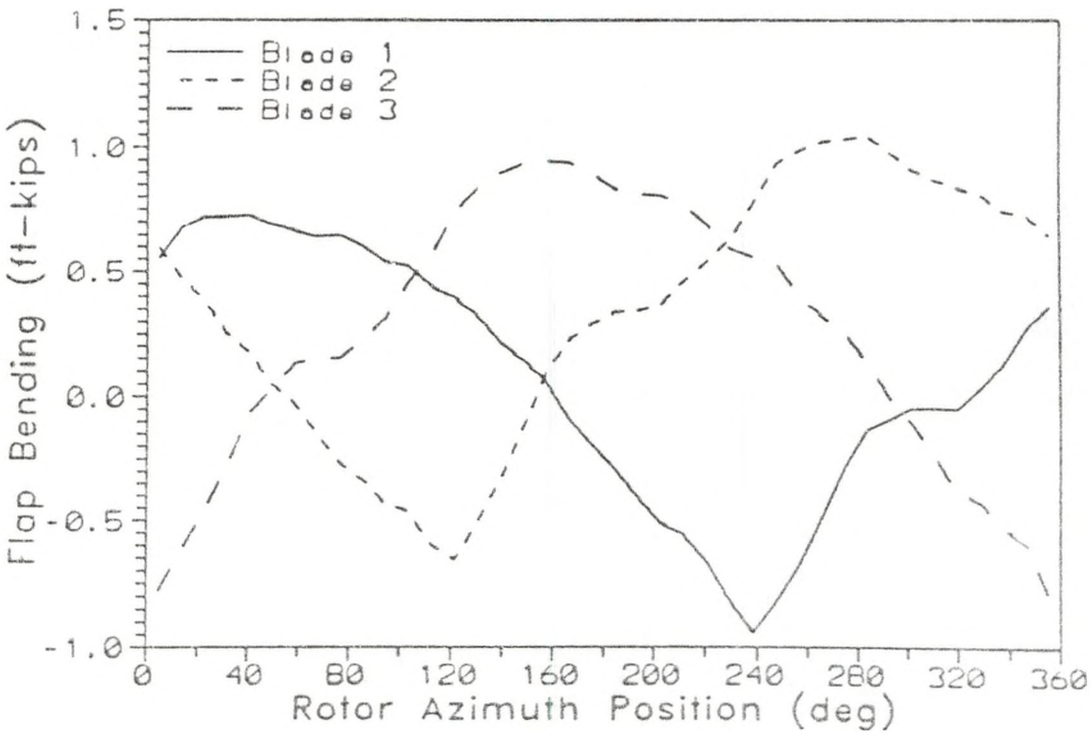


Figure 25. SERI flapwise bending: 12 mph case.

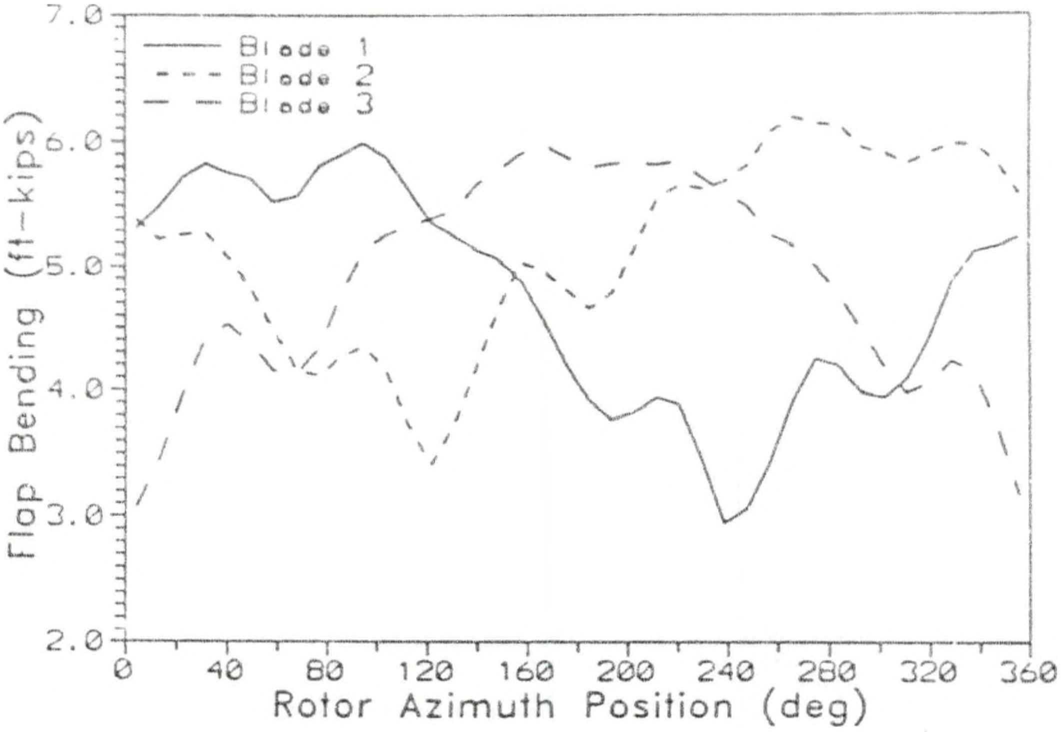


Figure 26. Aerostar flapwise bending: 27 mph case.

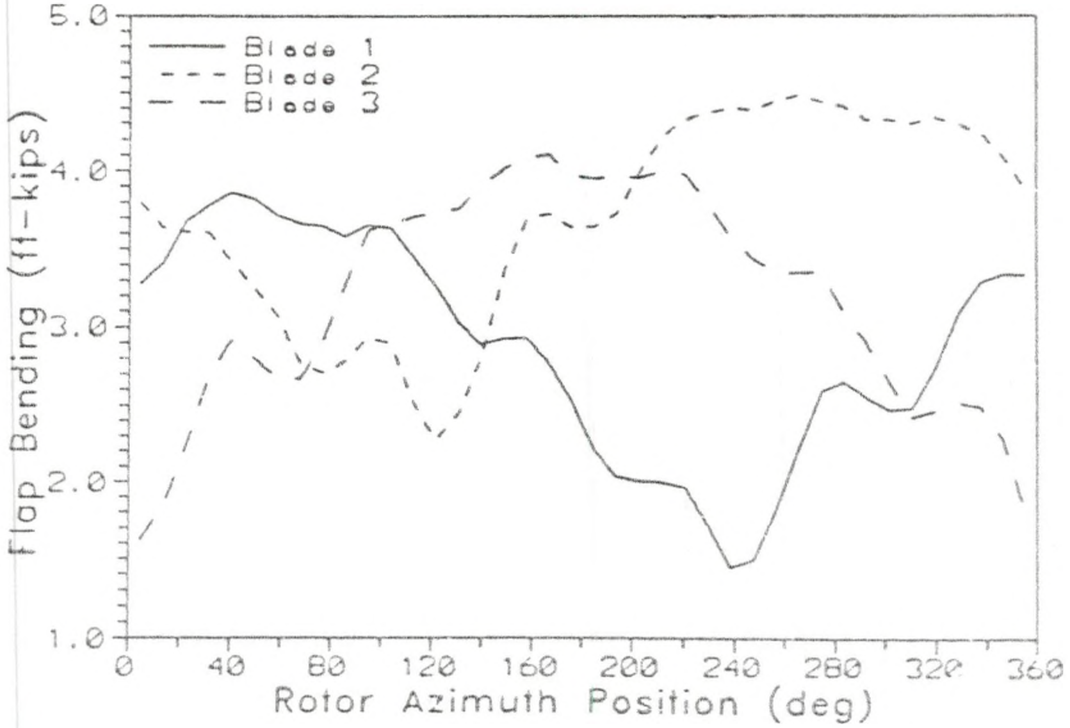


Figure 27. Aerostar flapwise bending: 22 mph case.

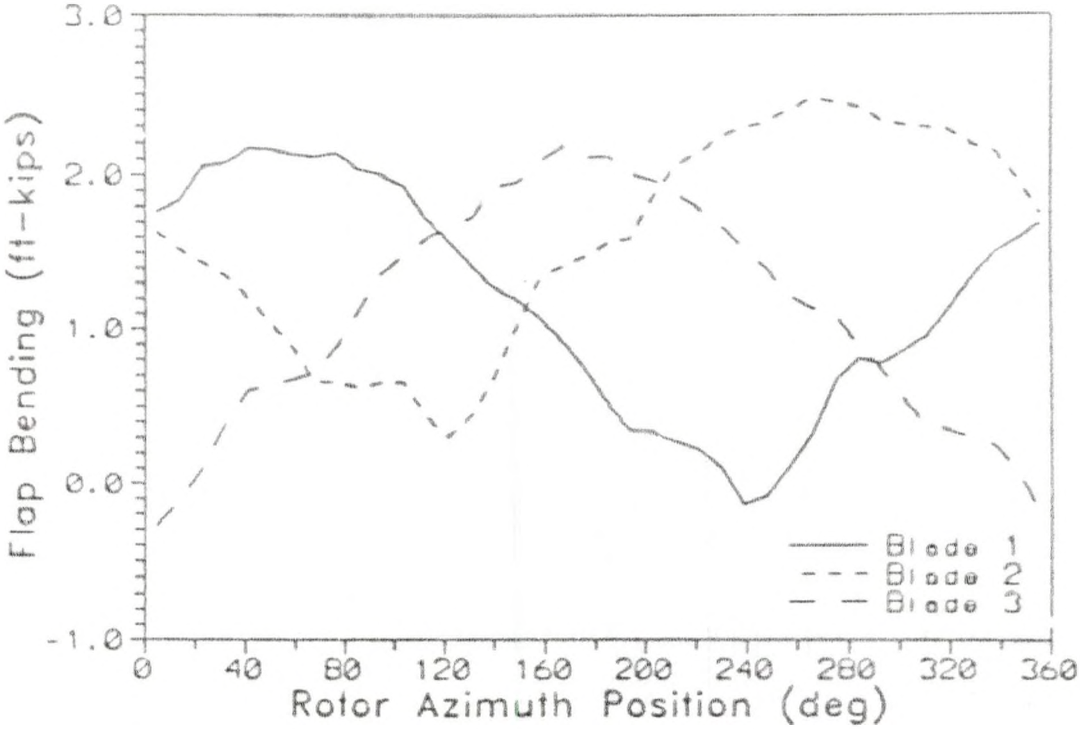


Figure 28. Aerostar flapwise bending: 17 mph case.

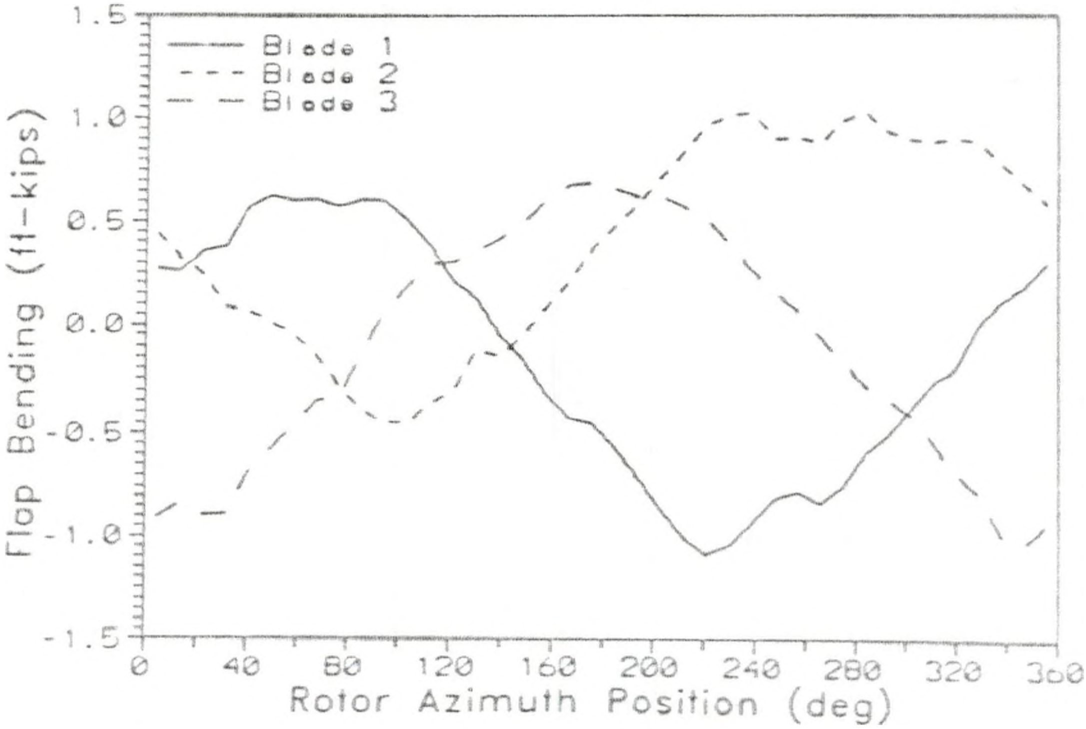


Figure 29. Aerostar flapwise bending: 12 mph case.

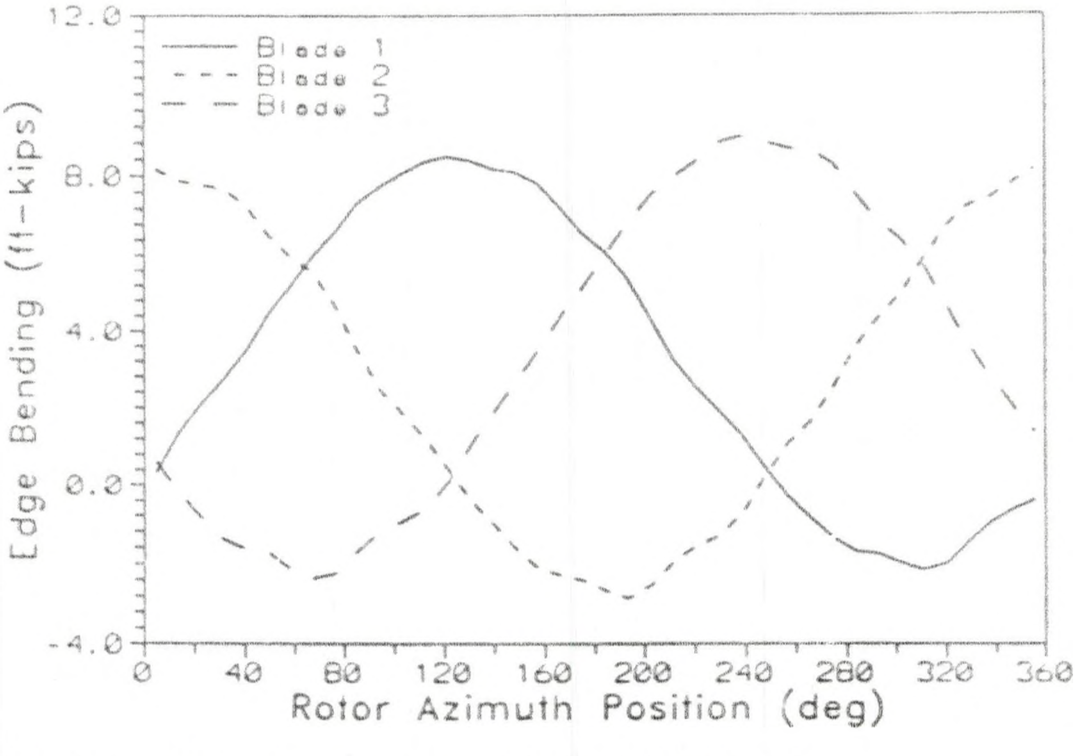


Figure 30. SERI edgewise bending: 27 mph case.

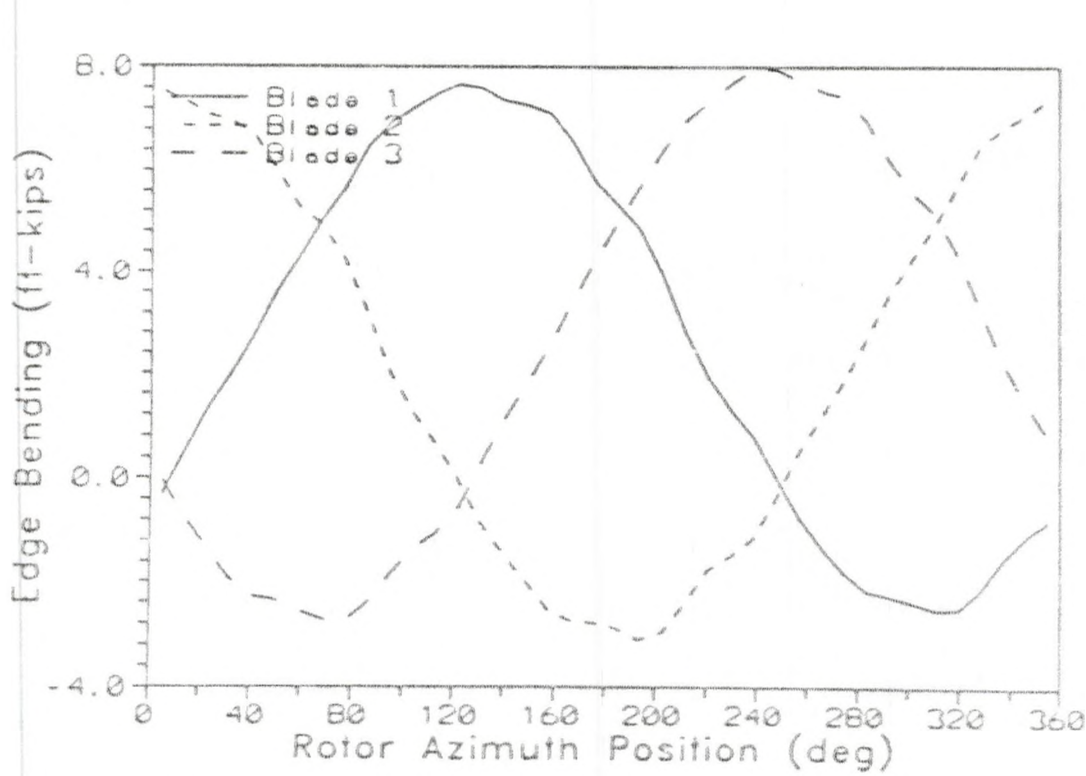


Figure 31. SERI edgewise bending: 22 mph case.

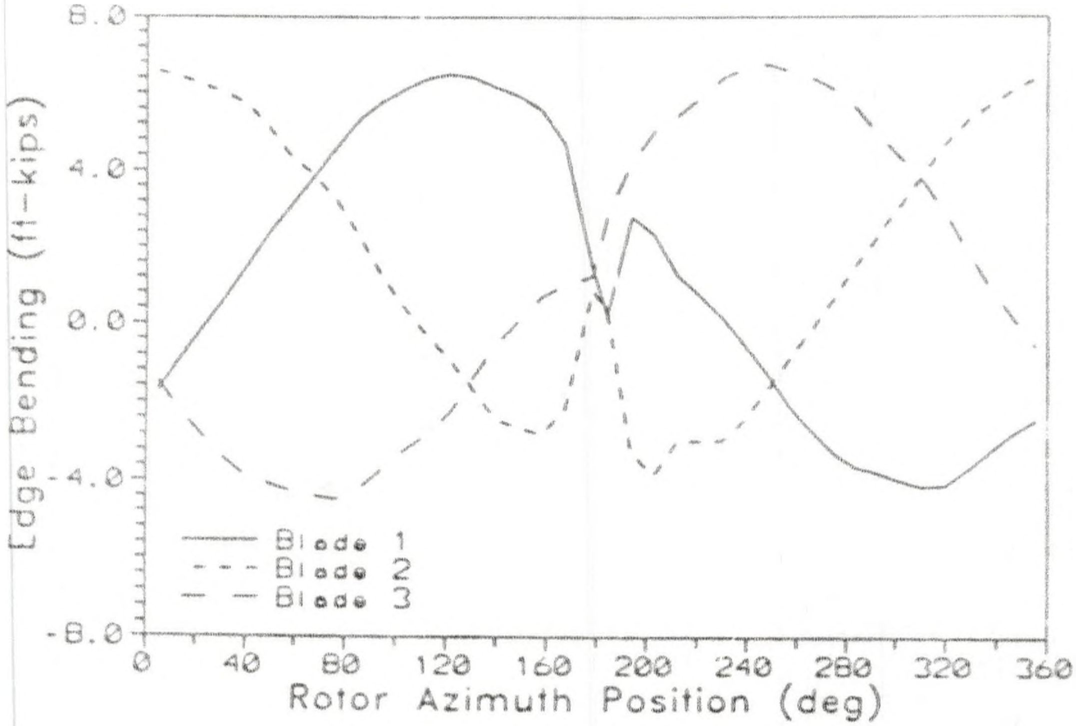


Figure 32. SERI edgewise bending: 17 mph case.

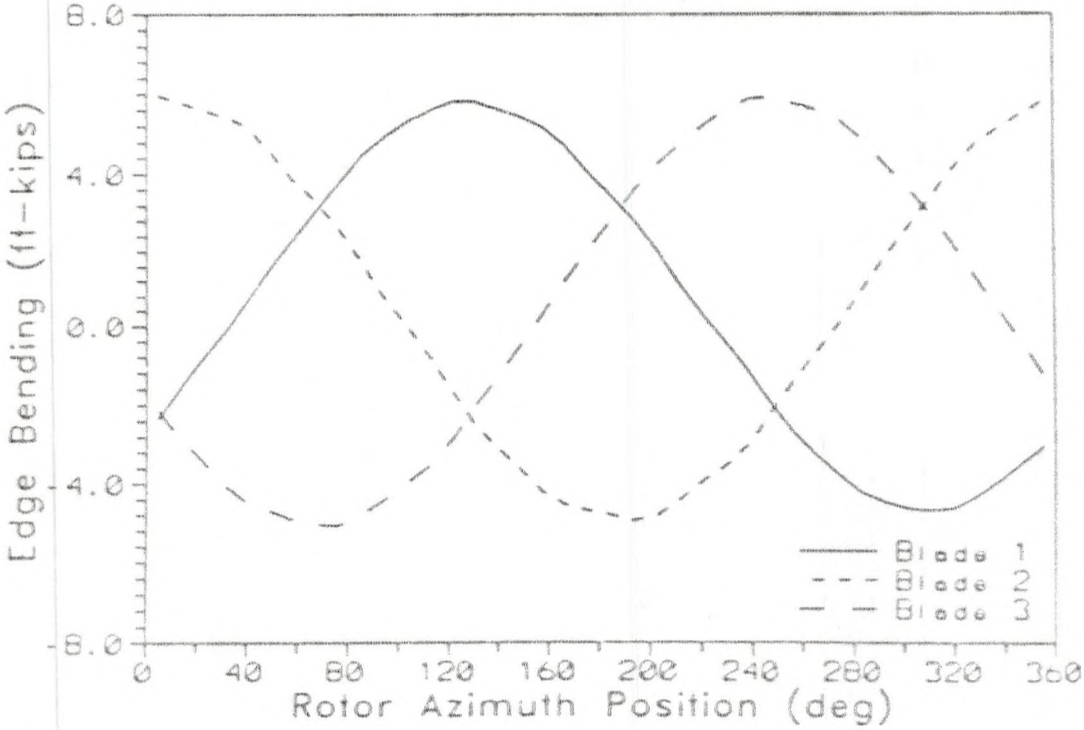


Figure 33. SERI edgewise bending: 12 mph case.

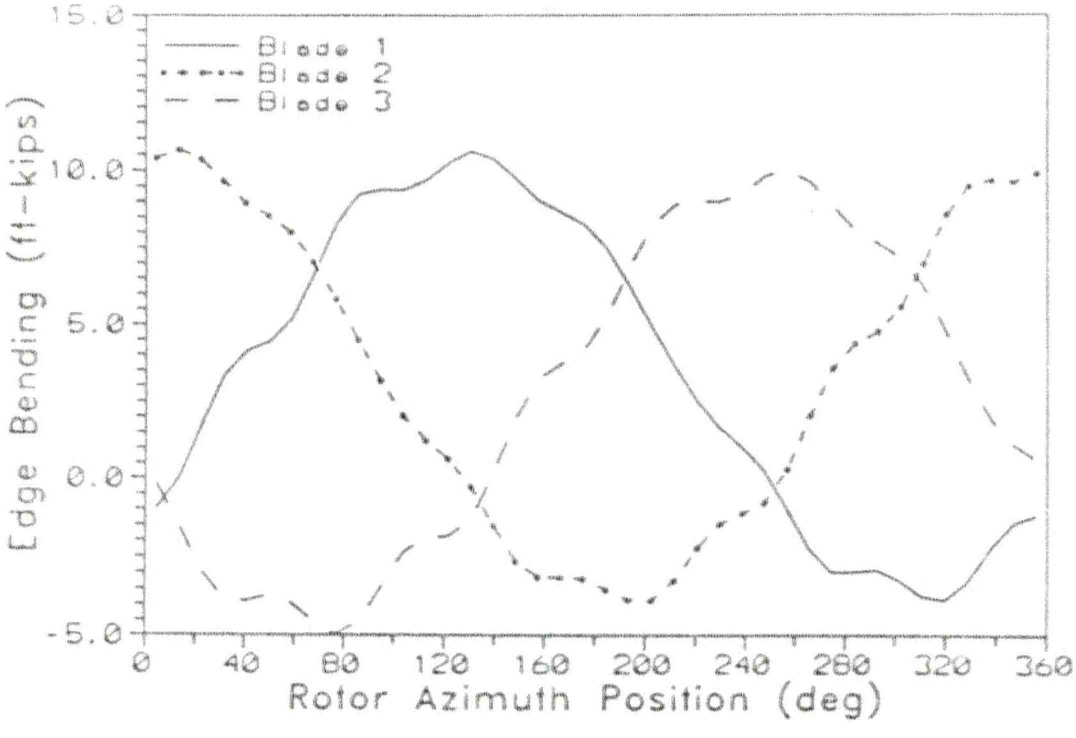


Figure 34. Aerostar edgewise bending: 27 mph case.

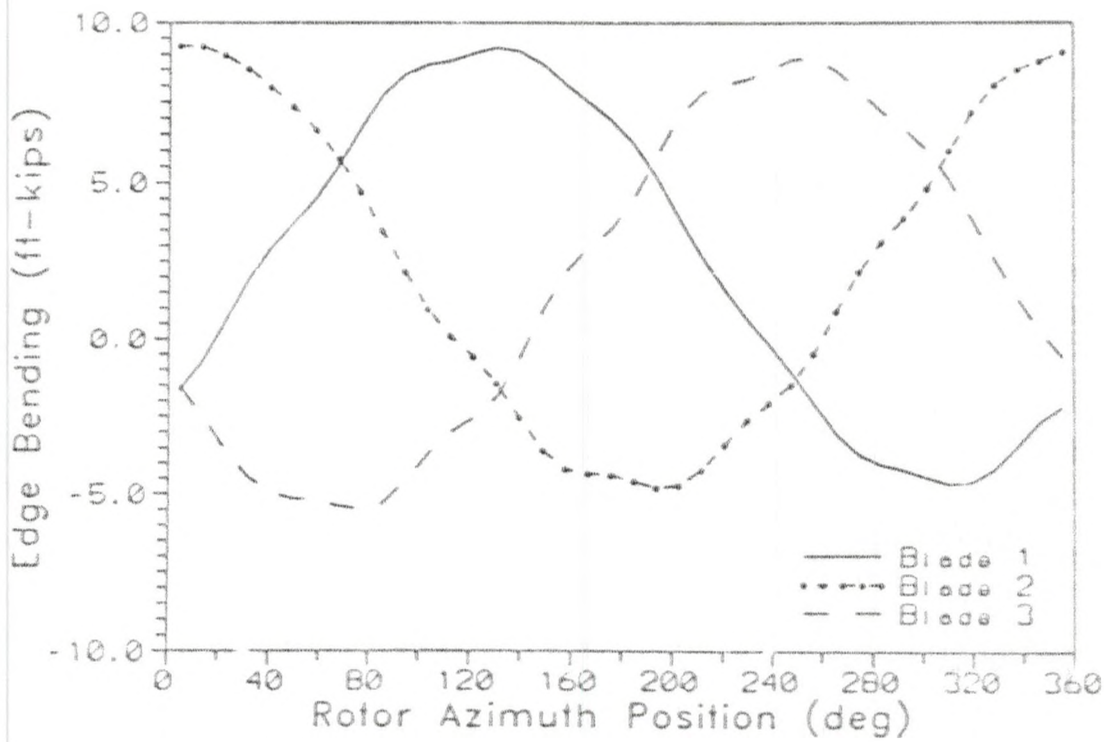


Figure 35. Aerostar edgewise bending: 22 mph case.

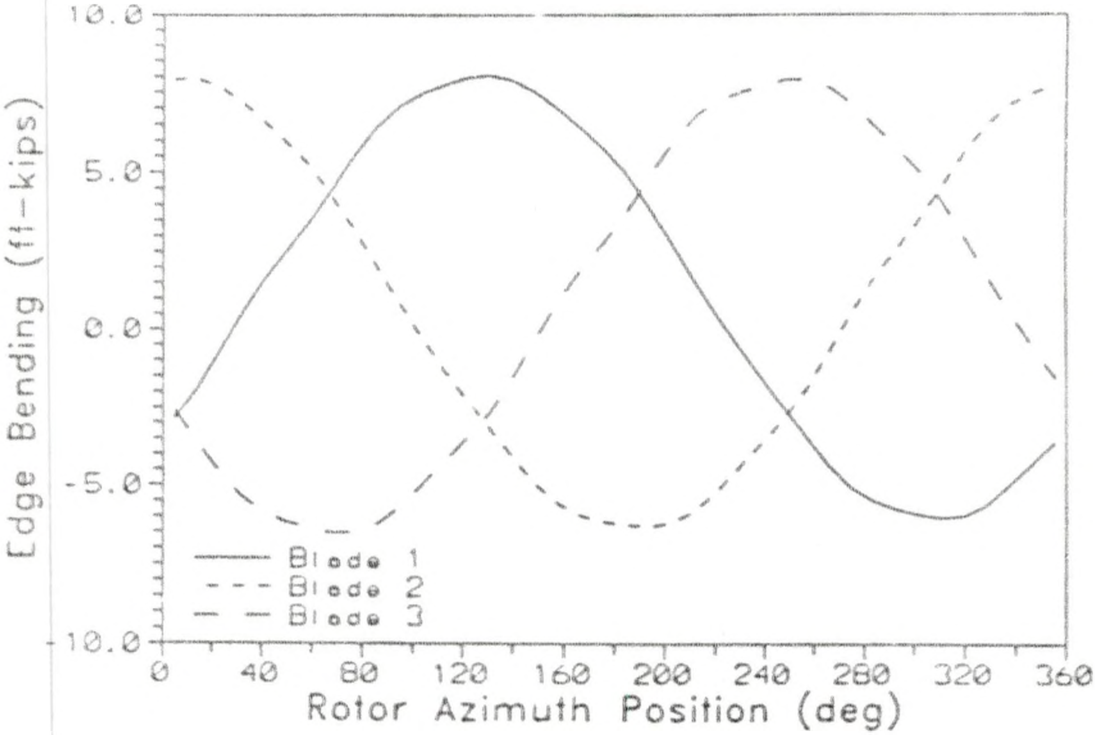


Figure 36. Aerostar edgewise bending: 17 mph case.

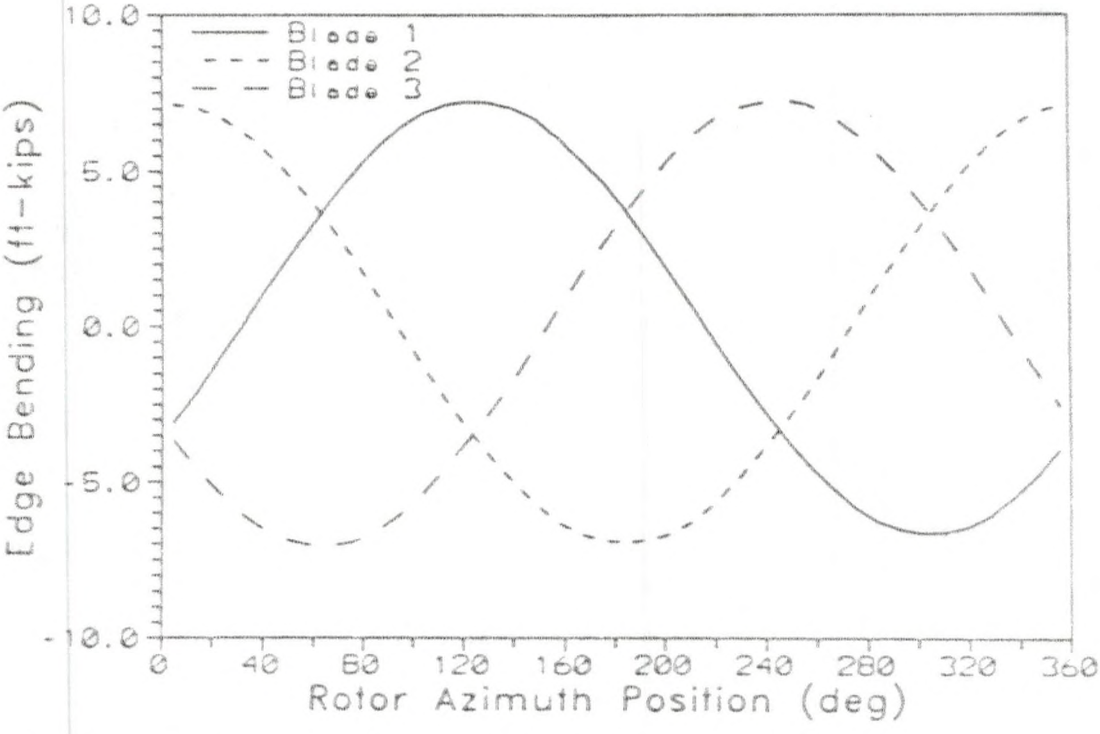
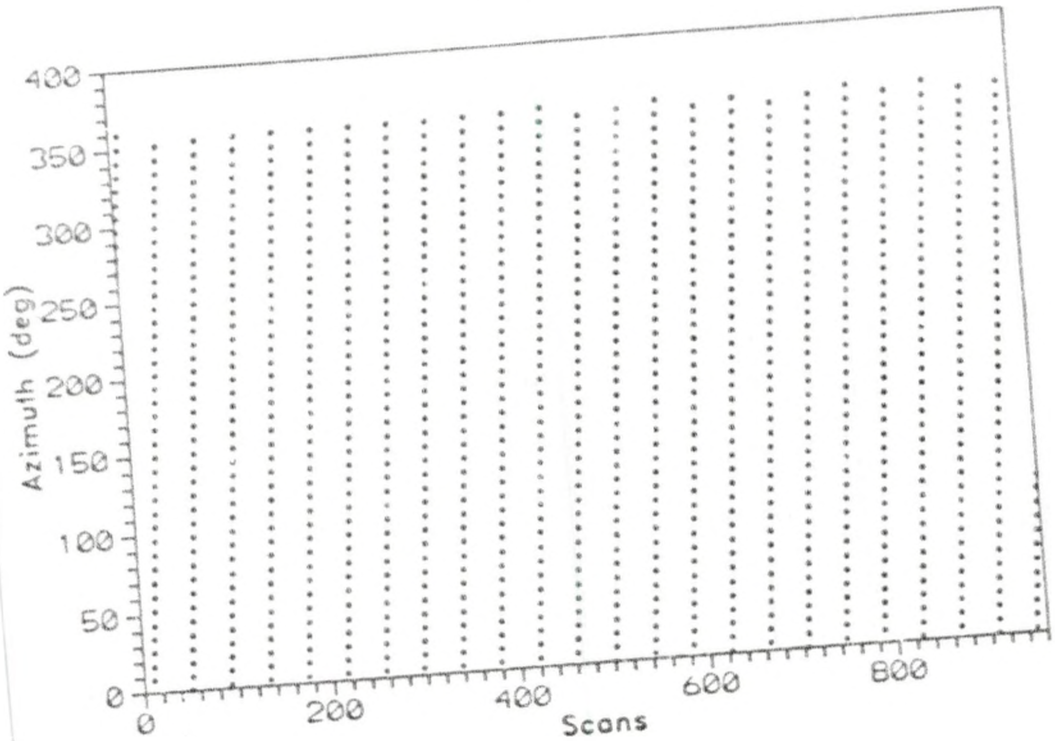


Figure 37. Aerostar edgewise bending: 12 mph case.

indicated by the wind shear. Edgewise loads are gravity induced loads, where the maximum moment arm associated with the blades C_g occurs when the blade is horizontal. Flapwise max and min loads should occur at 0° and 180° respectively. Edgewise max and min loads should occur at 90° and 270° respectively. Blade loads under ideal static conditions exhibit behavior as just described.

Once the blades begin to rotate, wind turbulence, aerodynamic forces, and centrifugal blade stiffening contribute to the loads and may appear as an azimuth shift. Other possible explanations for the azimuth shift is cross talk in the strain gauges or an error in processing the data.

Although the turbine is a "constant 48 rpm machine", the rpm fluctuates ± 2 rpm under normal operating conditions. The 9° azimuth bin size was selected based on the turbine operating at a constant 48 rpm. An error in azimuth binning might occur due to the voltage switching from +2.5V to -2.5Vs between 360° and 0°. During the transition from +2.5V to -2.5V, if a sample is recorded, it will be placed in the bin corresponding to that voltage. Figure 38 shows the azimuth signal for the first minute of the 27mph data set. Over the one minute period, one tenth of the data set, there were no points recorded during the transition period. Because no extraneous points were recorded during the first minute, the binning method used



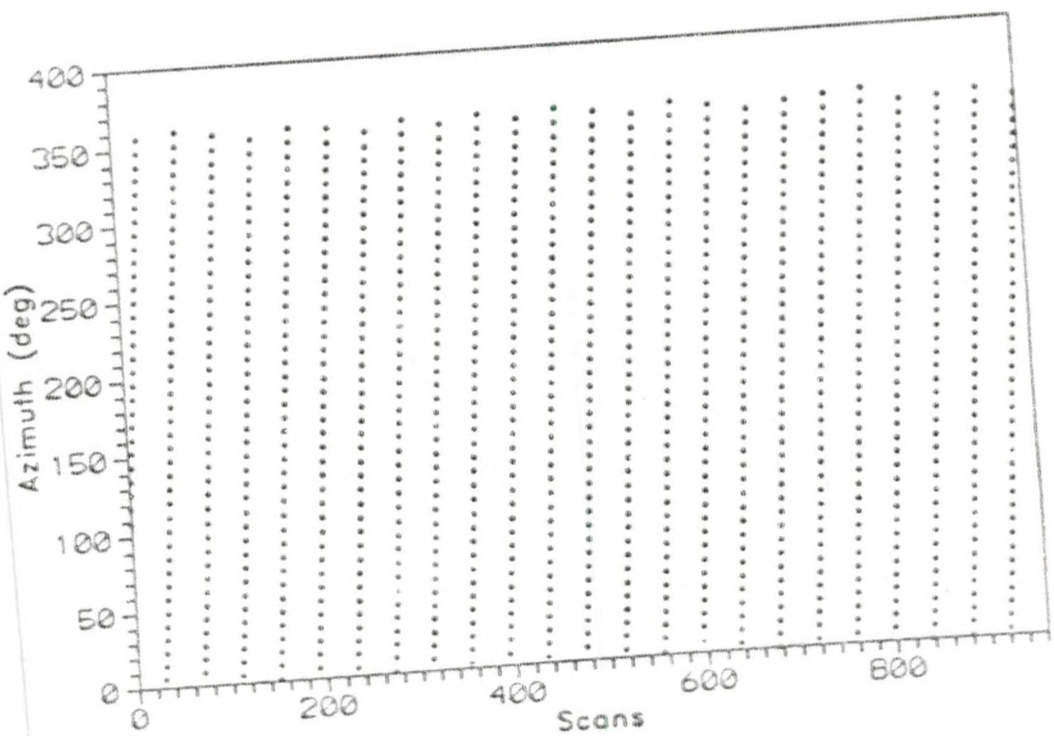


Figure 38. Blade azimuth positions recorded in sequence for two consecutive 30 second periods from the L072629 data file.

did not cause the azimuth shift.

Crosstalk becomes a problem if the strain gauges are mounted out of plane or something, such as centrifugal blade stiffening, adds to the axial strain. If the strain gauges were mounted out of plane slightly, they would respond to out of plane forces. Calibration curves of "static" blade pulls, blade 1 flap and edge bending for the SERI and Aerostar blades, show a minimal amount of cross talk (See Appendix O). Trying to adjust the data to remove the cross-talk is an exercise in futility because by adjusting one signal the other signal changes. Due to the order of magnitude difference in slopes of the crosstalk, the effects are minimal and would not shift the azimuth.

From three 2-minute calibration data sets, which includes data during start up, slow rotations, and shut down, the max and min flapwise and edgewise loads occur at the expected azimuth for the low rpm cases. It is not until the turbine starts to gain speed that the azimuth shift is seen (See Appendix P). This suggests that the azimuth shift is a real response attributable to environmental and dynamic effects. It is beyond the scope of this work to resolve the azimuth shift issue.

Flapwise and Edgewise Load Comparisons

Flapwise and edgewise bending loads of the four wind speed cases and both turbines are depicted in Figure 39. In flapwise bending, the SERI blade exhibits a more dynamic

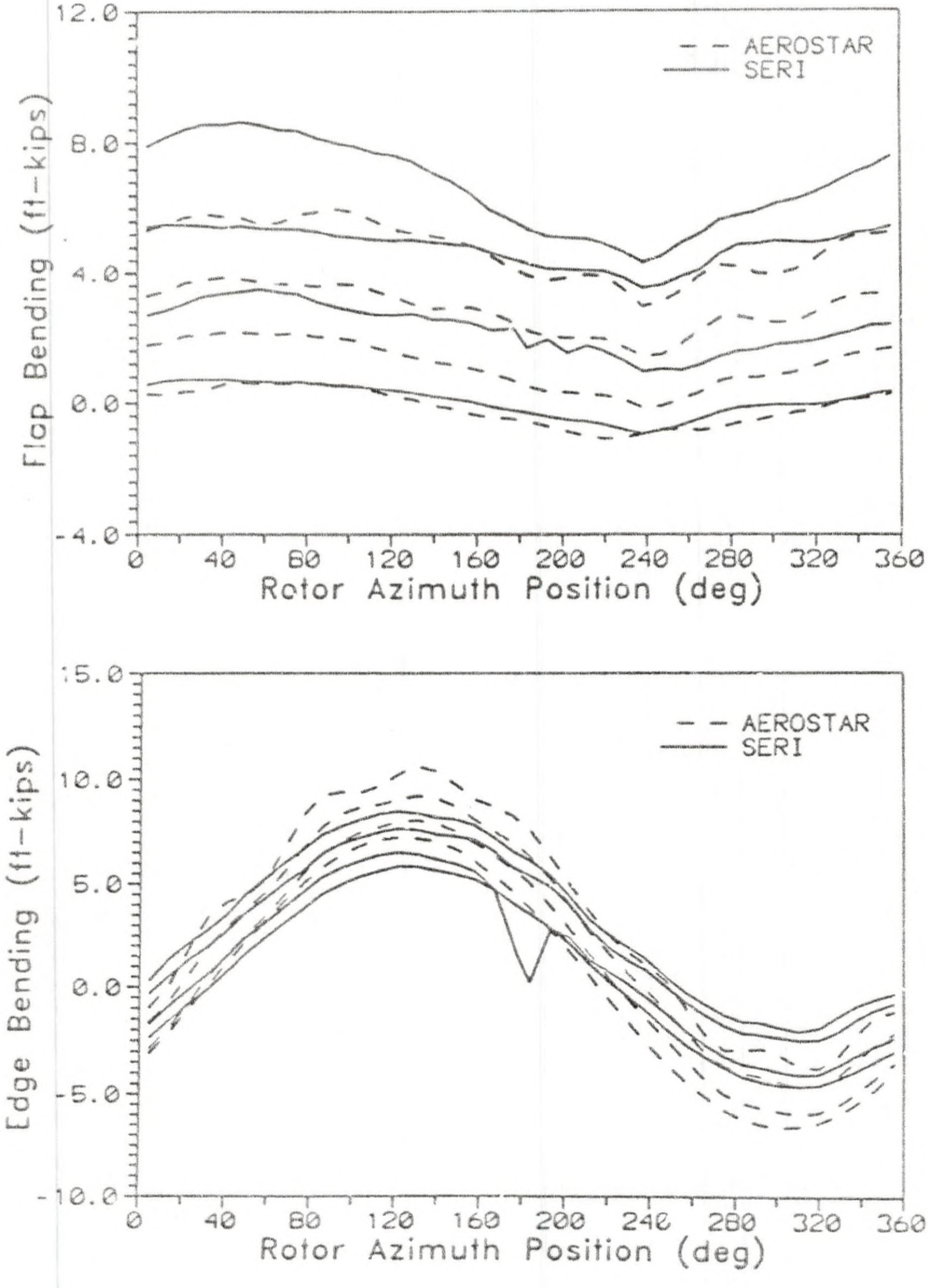


Figure 39. Flapwise and edgewise blade 1 loads for the SERI and Aerostar blades.

response to increased wind speed than does the Aerostar. In edgewise bending, the Aerostar blade has the largest response range.

It appears as if the something is happening to the signal of the 17 mph wind speed case of the SERI blade between approximately 170° and 210°. From the statistics file, there are 10673 samples in the bin centered at 177.79° and 483 in the bin centered at 183.61°, with approximately 200 samples in each of the remaining bins. This suggests an error in recording the azimuth signal. To pin point what caused the azimuth error and when it began, a time series would have to be checked. Because the remaining data in the record appears reasonable, no time series check was made. It should be noted however that an anomaly in the data is suspected, and not considered real.

Analytical Results: FLAP Code Predictions

FLAP predictions were run for the SERI and Aerostar blades for the four wind speed cases. The input for each run was held constant, except the measured yaw error (PHIO) and wind speed (VHUB), and the calculated wind shear

WS	SHERXP	VHUB	PHIO (deg)	
(mph)		(ft/sec)	SERI	Aerostar
27	.100	39.60	15.77	5.57
22	.127	32.27	5.77	6.77
17	.090	24.93	10.22	6.10
12	.120	17.60	8.34	3.32

Table 8. FLAP variable inputs.

exponent (SHERXP) were used (See Table 8).

Blade 1 mean FLAP predictions and measured flapwise and edgewise bending moments along with the percent error in the predictions are presented in Table 9. Figures 40-43 show the predicted and measured flapwise and edgewise bending for both blades.

SERI						
WS	FLAP		EDGE		% ERROR	
mph	PREDICTED	MEASURED	PREDICTED	MEASURED	FLAP	EDGE
12	-827	74	412	561	1218	27
17	1357	2275	1151	973	40	18
22	3457	4830	2222	2527	28	12
27	3949	6708	3072	3205	41	4
Aerostar						
WS	FLAP		EDGE		% ERROR	
mph	PREDICTED	MEASURED	PREDICTED	MEASURED	FLAP	EDGE
12	364	142	457	227	156	101
17	27[illegible]	1190	1273	986	134	29
22	4614	2868	2297	2265	61	1
27	4934	4751	3110	3343	4	7

Table 9. Measured and predicted flapwise and edgewise mean loads.

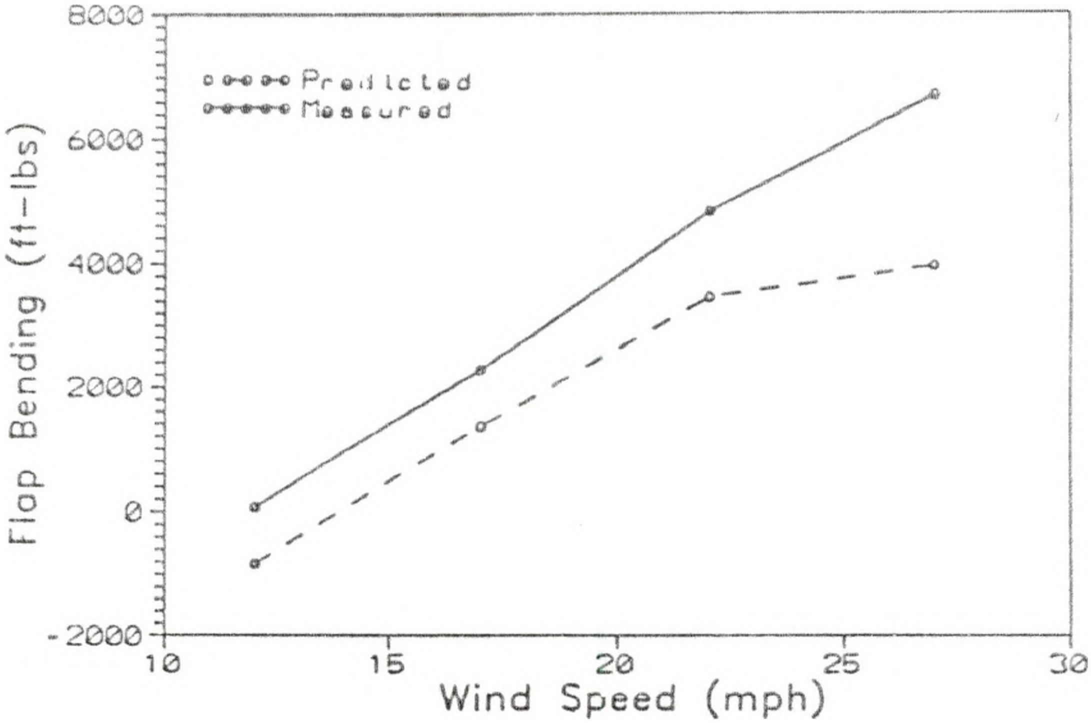


Figure 40. SERI predicted and measured flapwise bending.

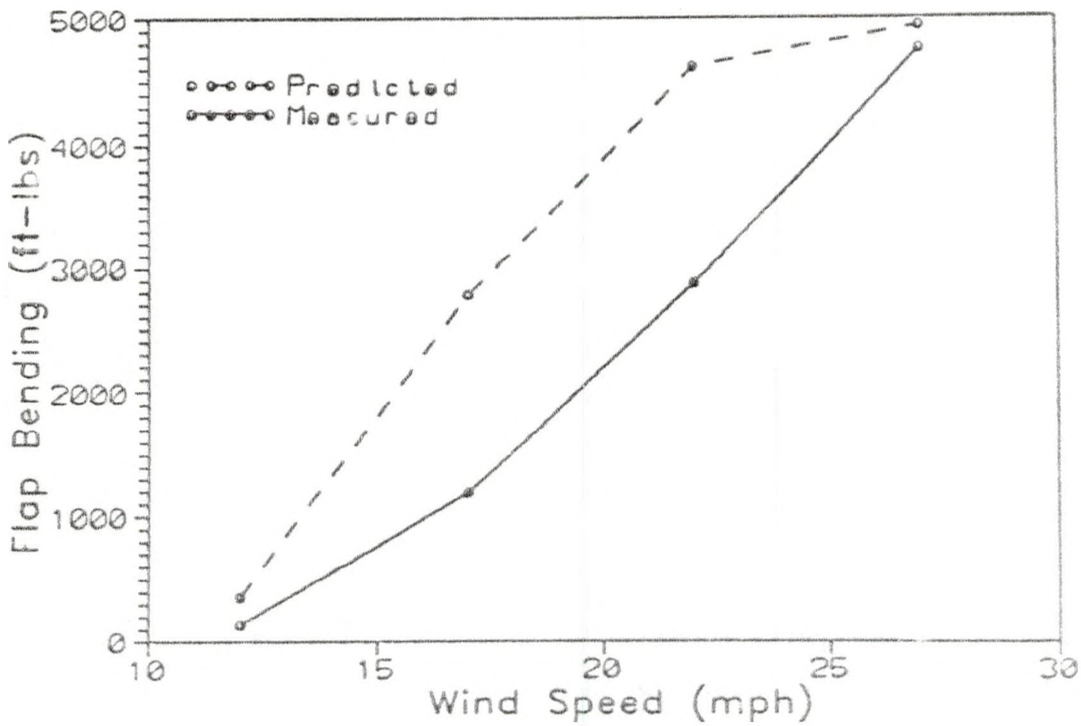


Figure 41. Aerostar predicted and measured flapwise

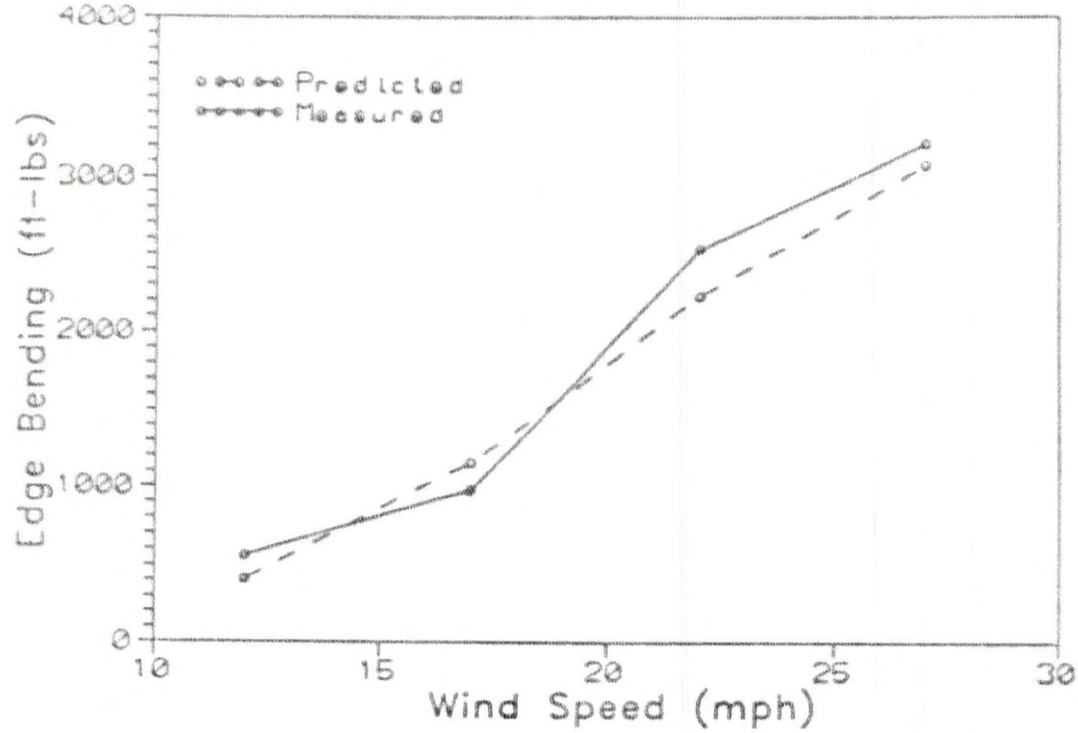


Figure 42. SERI predicted and measured edgewise bending.

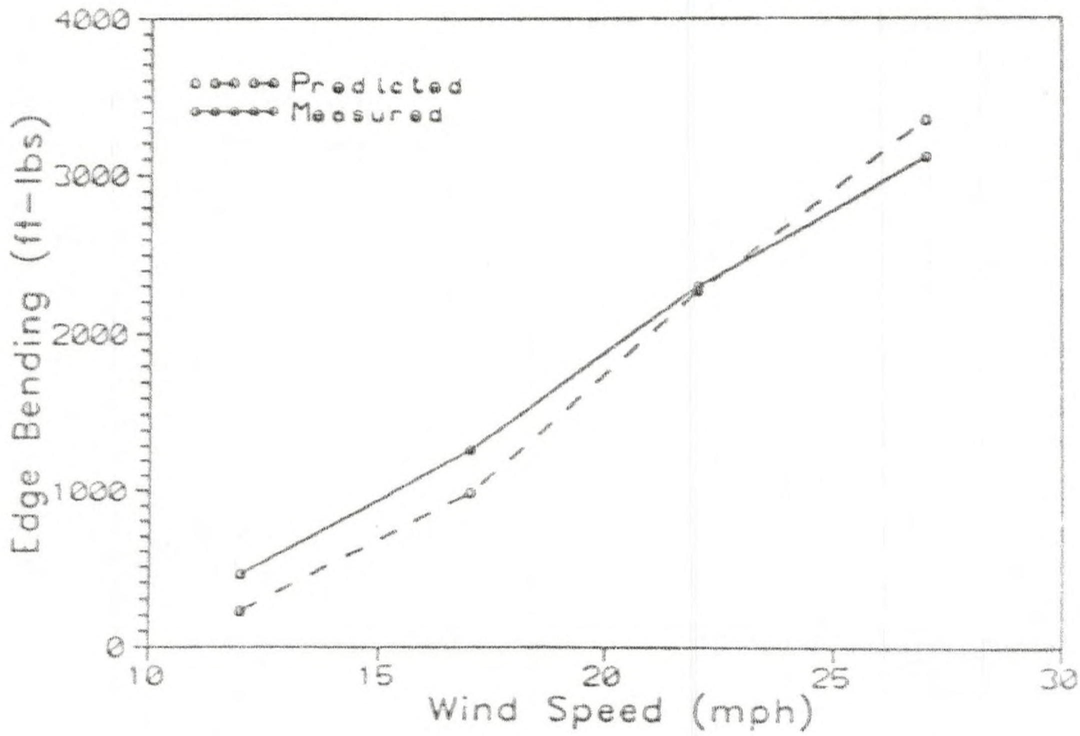


Figure 43. Aerostar predicted and measured edgewise bending.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

From the original ninety hours of tests data, 535 10-minute data sets were processed, of which 409 were considered valid. Valid as applied here, is defined as a full 10-minute data set with no distinguishable errors. Even though the 10-minute mean wind speeds are below 30 mph for the entire data set, there was a large number of higher speed gusts recorded, which should define a wide range of blade loads.

From the set of 409 valid records, 4 were selected based on meteorological parameters for comparison of measured loads to predicted FLAP loads. The experimental flapwise blade loading showed the SERI blade to be more responsive to higher wind cases than the Aerostar. Edgewise loads were almost identical for both blades at all wind speeds.

Higher flapwise loads for the SERI blade were expected on the basis of increased swept area of the SERI versus the Aerostar. The difference in swept area is approximately 10%, however the difference in flapwise loads decreases from 90% at 17 mph to 40% at 27 mph wind speeds. The edgewise loads for the Aerostar should be higher due to its' higher weight, as edgewise loads are dependent on blade weight. The resulting edgewise loads suggest that the aerodynamic differences between the blades contribute to the loading.

Two important FLAP input parameters are the blade mass and stiffness distributions. A methodology was presented in Chapter IV, to determine both the mass and stiffness distribution. The mass distribution thus obtained was within 1% of the actual blade weight. Validation of the methodology for determining the blade stiffness was not completed.

Table 9 presents the mean predicted and measured flapwise and edgewise bending loads. The largest differences between predicted and measured loads were seen at the lower wind speed cases. Other FLAP users have experienced the same difficulty, and no one has been able to explain why this occurs. The differences in mean edgewise loads are less than 15% for the higher wind speed cases. The predicted flapwise loads for both blades appear to act as if the blades were in stall between 22 and 27 mph. Neither of the blades goes into stall at wind speeds below 30 mph.

In conclusion, the FLAP code may be used to compare the relative differences of various designs, however if the analyst is interested in determining absolute values, the results are questionable.

Recommendations

The test matrix of the nine files presented in Table 5, which were selected on the basis of stability, wind speed standard deviation, and mean wind speed, should be analyzed to determine if these parameters define a complete spectrum of load cases.

The methodology of determining the blades stiffness distribution needs to be validated. SERI personnel are currently installing string pots and dial gauges in SERI's wind turbine blade test facility to accomplish this. The facility may be ready to test blades by late summer, after which the data can be used to determine the blades stiffness distribution. While the blades stiffness distribution might be determined experimentally, an analytical method would aid designers while the blade is still in the design stage, and warrants further investigation.

From the experiences gained in using the FLAP code, several things can be done to make the code more user friendly. The manual should be updated to include the coordinate system sign convention and the input variable descriptions need to be more clearly defined. The incorporation of a complete example would increase the code's useability. The required aerodynamic inputs are obtainable from the PROP code (17) and including an interface between FLAP and PROP would simplify such definitions. Additionally, a sensitivity analysis should be performed for each of the input variables.

APPENDICES

APPENDIX A

INSTRUMENTATION DATA

(**Table 10.** Instrumentation data.)

Channel Name	Sensor Location	Signal Description	Sensor Type
1RPK1V	Rotor Package	1.25 vdc reference signal	2B31L Amplifier Card
2RPK1V	Rotor Package	1.25 vdc reference signal	2B31L Amplifier Card
1RH1FB	Blade 1 Rotor Hub	Bending--Flapwise	Full-Bridge Strain Gage
1RH2FB	Blade 2 Rotor Hub	Bending--Flapwise	Full-Bridge Strain Gage
1RH3FB	Blade 3 Rotor Hub	Bending--Flapwise	Full-Bridge Strain Gage
1RH1EB	Blade 1 Rotor Hub	Bending--Edgewise	Full-Bridge Strain Gage
1RH2EB	Blade 2 Rotor Hub	Bending--Edgewise	Full-Bridge Strain Gage
1RH3EB	Blade 3 Rotor Hub	Bending--Edgewise	Full-Bridge Strain Gage
1LSSTQ	Main Low Speed Shaft	Torque	Full-Bridge Strain Gage
2RH1FB	Blade 1 Rotor Hub	Bending--Flapwise	Full-Bridge Strain Gage
2RH2FB	Blade 2 Rotor Hub	Bending--Flapwise	Full-Bridge Strain Gage
2RH3FB	Blade 3 Rotor Hub	Bending--Flapwise	Full-Bridge Strain Gage
2RH1EB	Blade 1 Rotor Hub	Bending--Edgewise	Full-Bridge Strain Gage
2RH2EB	Blade 2 Rotor Hub	Bending--Edgewise	Full-Bridge Strain Gage
2RH3EB	Blade 3 Rotor Hub	Bending--Edgewise	Full-Bridge Strain Gage
2LSSTQ	Main Low Speed Shaft	Torque	Full-Bridge Strain Gage
1LSS0B	Main Low Speed Shaft	Bending--0 deg	Full-Bridge Strain Gage
1LSS9B	Main Low Speed Shaft	Bending--90 deg	Full-Bridge Strain Gage
1NACXX	Nacelle	Accelerometer X-X	Accelerometer
1NACYY	Nacelle	Accelerometer Y-Y	Accelerometer
1YDRTQ	Yaw Drive	Torque	Full-Bridge Strain Gage
1NACAZ	Nacelle	Yaw Azimuthal Position	Rotary Potentiometer
1TWTTQ	Tower Top	Torque	Full-Bridge Strain Gage
1TWBYB	Tower Base	Bending Y-Y	Full-Bridge Strain Gage
1TWBXB	Tower Base	Bending X-X	Full-Bridge Strain Gage
1CPLPR	Control Panel	Generator Power Output	Power Transducer
2LSS0B	Main Low Speed Shaft	Bending--0 deg	Full-Bridge Strain Gage
2LSS9B	Main Low Speed Shaft	Bending--90 deg	Full-Bridge Strain Gage
1LSSAZ	Main Low Speed Shaft	Azimuthal Position	Optical Shaft Encoder
1LSSSP	Main Low Speed Shaft	RPM	Optical Shaft Encoder
2LSSAZ	Main Low Speed Shaft	Azimuthal Position	Optical Shaft Encoder
2LSSSP	Main Low Speed Shaft	RPM	Optical Shaft Encoder
1DLC2K	Data Trailer @ Pull Point	Applied Force, 2000 Lbs	Force Transducer
1DLC5H	Data Trailer @ Pull Point	Applied Force, 500 Lbs	Force Transducer
2NACXX	Nacelle	Accelerometer X-X	Accelerometer
2NACYY	Nacelle	Accelerometer Y-Y	Accelerometer
2YDRTQ	Yaw Drive	Torque	Full-Bridge Strain Gage
2NACAZ	Nacelle	Yaw Azimuthal Position	Rotary Potentiometer
2TWTTQ	Tower Top	Torque	Full-Bridge Strain Gage
2TWBYB	Tower Base	Bending Y-Y	Full-Bridge Strain Gage
2TWBXB	Tower Base	Bending X-X	Full-Bridge Strain Gage
2CPLPR	Control Panel	Generator Power Output	Power Transducer
1M31WS	MET Tower @ 30.5 m (100 ft)	Windspeed--Propvane	Propvane
1M31WD	MET Tower @ 30.5 m (100 ft)	Wind direction--Propvane	Propvane
1M23WS	MET Tower @ 23 m (75 ft)	Windspeed--Propvane	Propvane
1M23WD	MET Tower @ 23 m (75 ft)	Wind direction--Propvane	Propvane
1M21WU	MET Tower @ 21 m (68 ft)	Windspeed U--Sonic	Sonic Anemometer
1M21WV	MET Tower @ 21 m (68 ft)	Windspeed V--Sonic	Sonic Anemometer
1M21WW	MET Tower @ 21 m (68 ft)	Windspeed W--Sonic	Sonic Anemometer
1M21WT	MET Tower @ 21 m (68 ft)	Temperature--Sonic	Sonic Anemometer
1M15WS	MET Tower @ 15 m (50 ft)	Windspeed--Propvane	Propvane
1M15WD	MET Tower @ 15 m (50 ft)	Wind direction--Propvane	Propvane
1M03WS	MET Tower @ 3 m (10 ft)	Windspeed--Propvane	Propvane
1M31AM	MET Tower @ 30.5 m (100 ft)	Aspirator Monitor	Aspirator Monitor
1M03AT	MET Tower @ 3 m (10 ft)	Absolute Temperature	Temperature Sensor
1M31DT	MET Tower @ 30.5 m (100 ft)	Delta Temperature	Temperature Sensor
1D02BP	Data Trailer @ 1.5 m (5 ft)	Barometric Pressure	Pressure Sensor

Channel Name	Sensor Vendor Name	Sensor Model No.	Gage Factor	Gage R (Ohms)	V Input Range	Band-width	Gain
1RPK1V	Analog Devices				1.25 vdc	15 Hz	1
2RPK1V	Analog Devices				1.25 vdc	15 Hz	1
1RH1FB	Micro-Measurements	CEA-06-125UW-350	2.090	350	+/- 2.5 vdc	15 Hz	1000
1RH2FB	Micro-Measurements	CEA-06-125UW-350	2.090	350	+/- 2.5 vdc	15 Hz	1000
1RH3FB	Micro-Measurements	CEA-06-125UW-350	2.090	350	+/- 2.5 vdc	15 Hz	1000
1RH1EB	Micro-Measurements	CEA-06-125UW-350	2.090	350	+/- 2.5 vdc	15 Hz	1000
1RH2EB	Micro-Measurements	CEA-06-125UW-350	2.090	350	+/- 2.5 vdc	15 Hz	1000
1RH3EB	Micro-Measurements	CEA-06-125UW-350	2.090	350	+/- 2.5 vdc	15 Hz	1000
1LSSTQ	Micro-Measurements	CEA-06-187UV-350	2.050	350	+/- 2.5 vdc	15 Hz	375
2RH1FB	Micro-Measurements	CEA-06-125UW-350	2.090	350	+/- 2.5 vdc	15 Hz	1000
2RH2FB	Micro-Measurements	CEA-06-125UW-350	2.090	350	+/- 2.5 vdc	15 Hz	1000
2RH3FB	Micro-Measurements	CEA-06-125UW-350	2.090	350	+/- 2.5 vdc	15 Hz	1000
2RH1EB	Micro-Measurements	CEA-06-125UW-350	2.090	350	+/- 2.5 vdc	15 Hz	1000
2RH2EB	Micro-Measurements	CEA-06-125UW-350	2.090	350	+/- 2.5 vdc	15 Hz	1000
2RH3EB	Micro-Measurements	CEA-06-125UW-350	2.090	350	+/- 2.5 vdc	15 Hz	1000
2LSSTQ	Micro-Measurements	CEA-06-187UV-350	2.050	350	+/- 2.5 vdc	15 Hz	375
1LSS0B	Micro-Measurements	CEA-06-125UW-350	2.090	350	+/- 2.5 vdc	15 Hz	375
1LSS9B	Micro-Measurements	CEA-06-125UW-350	2.090	350	+/- 2.5 vdc	15 Hz	375
1NACXX	Endevco	2262C-25		350	+/- 2.5 vdc	15 Hz	200
1NACYY	Endevco	2262C-25			+/- 2.5 vdc	15 Hz	200
1YDRTQ	Micro-Measurements	CEA-06-187UV-350	2.050		+/- 2.5 vdc	15 Hz	250
1NACAZ	Helipot, Beckman	6671-R5K-L.25		350	+/- 2.5 vdc	15 Hz	1
1TWTTQ	Micro-Measurements	CEA-06-187UV-350	2.050		+/- 2.5 vdc	15 Hz	1000
1TWBYB	Micro-Measurements	CEA-06-W250D-350	2.020	350	+/- 2.5 vdc	15 Hz	1000
1TWBXB	Micro-Measurements	CEA-06-W250D-350	2.020	350	+/- 2.5 vdc	15 Hz	1000
1CPLPR	Ohio Semitronics	PC5-63C		350	+/- 2.5 vdc	15 Hz	1
2LSS0B	Micro-Measurements	CEA-06-125UW-350	2.090		+/- 2.5 vdc	15 Hz	375
2LSS9B	Micro-Measurements	CEA-06-125UW-350	2.090	350	+/- 2.5 vdc	15 Hz	375
1LSSAZ	Litton Systems Inc.	76LDNB-10-5-S-7		350	0 - 5 vdc	500 Hz	1
1LSSSP	Litton Systems Inc.	76LDNB-10-5-S-7			0 - 5 vdc	1 Hz	1
2LSSAZ	Litton Systems Inc.	76LDNB-10-5-S-7			0 - 5 vdc	500 Hz	1
2LSSSP	Litton Systems Inc.	76LDNB-10-5-S-7			0 - 5 vdc	1 Hz	1
1DLC2K	T-hydronics, Inc	TH-UC			0 - 5 vdc	15 Hz	50
1DLC5H	Schaevitz	FTA-1U-500			0 - 5 vdc	15 Hz	1
2NACXX	Endevco	2262C-25			+/- 2.5 vdc	15 Hz	200
2NACYY	Endevco	2262C-25			+/- 2.5 vdc	15 Hz	200
2YDRTQ	Micro-Measurements	CEA-06-187UV-350	2.050		+/- 2.5 vdc	15 Hz	250
2NACAZ	Helipot, Beckman	6671-R5K-L.25			+/- 2.5 vdc	15 Hz	1
2TWTTQ	Micro-Measurements	CEA-06-187UV-350	2.050		+/- 2.5 vdc	15 Hz	1000
2TWBYB	Micro-Measurements	CEA-06-W250D-350	2.020		+/- 2.5 vdc	15 Hz	1000
2TWBXB	Micro-Measurements	CEA-06-W250D-350	2.020		+/- 2.5 vdc	15 Hz	1000
2CPLPR	Ohio Semitronics	PC5-63C			+/- 2.5 vdc	15 Hz	1
1M31WS	R. M. Young	08003			0 - 5 vdc	15 Hz	0.3277
1M31WD	R. M. Young	08003			0 - 5 vdc	15 Hz	2
1M23WS	R. M. Young	08003			0 - 5 vdc	15 Hz	0.3277
1M23WD	R. M. Young	08003			0 - 5 vdc	15 Hz	2
1M21WU	Applied Technologies	SWS-211/3K			0 - 5 vdc	15 Hz	1
1M21WV	Applied Technologies	SWS-211/3K		350	0 - 5 vdc	15 Hz	1
1M21WW	Applied Technologies	SWS-211/3K			0 - 5 vdc	15 Hz	1
1M21WT	Applied Technologies	SWS-211/3K		350	0 - 5 vdc	15 Hz	1
1M15WS	R. M. Young	08003		350	0 - 5 vdc	15 Hz	0.3277
1M15WD	R. M. Young	08003		350	0 - 5 vdc	15 Hz	2
1M03WS	R. M. Young	08003			0 - 5 vdc	15 Hz	0.3277
1M31AM	Teledyne Geotech	327C			0 - 5 vdc	15 Hz	1
1M03AT	Teledyne Geotech	T-200			0 - 5 vdc	15 Hz	1
1M31DT	Teledyne Geotech	T-200			0 - 5 vdc	15 Hz	1
1D02BP	YSI	2014-22/31-HA-3-WH			0 - 5 vdc	15 Hz	1

Channel Name	V Excit.	Range	NB Scale Factor	NB Scale Factor Units	NB Offse Constant	NB Offset Constant Units
1RPK1V	10 vdc	+ 1.250 Vdc	1.250	V/V	0.000	V
2RPK1V	10 vdc	+ 1.250 Vdc	1.250	V/V	0.000	V
1RH1FB	10 vdc	+- -28.333 Ft-Kip	-11.333	Ft-Kip/V	0.000	V
1RH2FB	10 vdc	+- -30.228 Ft-Kip	-12.091	Ft-Kip/V	-0.038	V
1RH3FB	10 vdc	+- -32.740 Ft-Kip	-13.096	Ft-Kip/V	0.039	V
1RH1EB	10 vdc	+- -29.455 Ft-Kip	-11.782	Ft-Kip/V	0.038	V
1RH2EB	10 vdc	+- -30.730 Ft-Kip	-12.292	Ft-Kip/V	-0.018	V
1RH3EB	10 vdc	+- -30.290 Ft-Kip	-12.116	Ft-Kip/V	0.010	V
1LSSTQ	10 vdc	+- -32.615 Ft-Kip	-13.046	Ft-Kip/V	0.020	V
2RH1FB	10 vdc	+- -30.548 Ft-Kip	-12.219	Ft-Kip/V	0.040	V
2RH2FB	10 vdc	+- -32.590 Ft-Kip	-13.036	Ft-Kip/V	0.011	V
2RH3FB	10 vdc	+- -32.683 Ft-Kip	-13.073	Ft-Kip/V	0.026	V
2RH1EB	10 vdc	+- -29.460 Ft-Kip	-11.784	Ft-Kip/V	0.057	V
2RH2EB	10 vdc	+- -30.885 Ft-Kip	-12.354	Ft-Kip/V	0.000	V
2RH3EB	10 vdc	+- -33.043 Ft-Kip	-13.217	Ft-Kip/V	-0.015	V
2LSSTQ	10 vdc	+- -36.880 Ft-Kip	-14.752	Ft-Kip/V	0.025	V
1LSS0B	10 vdc	+- -20.210 Ft-Kip	-8.084	Ft-Kip/V	0.007	V
1LSS9B	10 vdc	+- 20.678 Ft-Kip	8.271	Ft-Kip/V	-0.021	V
1NACXX	10 vdc	+- 1.235 G	0.494	G/V	0.000	V
1NACYY	10 vdc	+- 1.235 G	0.494	G/V	0.000	V
1YDRTQ	5 vdc	+- 2.855 Ft-Kip	1.142	Ft-Kip/V	-0.035	V
1NACAZ	n/a	+- 180.000 Deg	98.617	Deg/V	0.008	V
1TWTTQ	15 vdc	+- -137.923 Ft-Kip	-55.169	Ft-Kip/V	0.028	V
1TWBYB	5 vdc	+- -927.910 Ft-Kip	-371.164	Ft-Kip/V	0.020	V
1TWBXB	5 vdc	+- -895.160 Ft-Kip	-358.064	Ft-Kip/V	0.040	V
1CPLPR	n/a	+- 100.058 KW	40.023	KW/V	-0.003	V
2LSS0B	10 vdc	+- -23.850 Ft-Kip	-9.540	Ft-Kip/V	-0.079	V
2LSS9B	10 vdc	+- 24.010 Ft-Kip	9.604	Ft-Kip/V	-0.022	V
1LSSAZ	5 vdc	+ 0 - 360 Deg	-72.000	Deg/V	-2.500	V
1LSSSP	5 vdc	+- 87.890 RPM	35.156	RPM/V	0.000	V
2LSSAZ	5 vdc	+ 0 - 360 Deg	-72.000	Deg/V	-2.500	V
2LSSSP	5 vdc	+- 87.890 RPM	35.156	RPM/V	0.000	V
1DLC2K	n/a	+ 0 - 2000 Lbf	1337.793	Lb/V	0.000	V
1DLC5H	n/a	+ 0 - 500 Lbf	199.304	Lb/V	-0.027	V
2NACXX	10 vdc	+- 1.253 G	0.501	G/V	0.000	V
2NACYY	10 vdc	+- 1.250 G	0.500	G/V	0.000	V
2YDRTQ	5 vdc	+- 3.475 Ft-Kip	1.390	Ft-Kip/V	-0.223	V
2NACAZ	n/a	+- 180.000 Deg	92.361	Deg/V	-0.001	V
2TWTTQ	15 vdc	+- -127.140 Ft-Kip	-50.856	Ft-Kip/V	-0.173	V
2TWBYB	5 vdc	+- -858.553 Ft-Kip	-343.421	Ft-Kip/V	-0.019	V
2TWBXB	5 vdc	+- -906.313 Ft-Kip	-362.525	Ft-Kip/V	0.014	V
2CPLPR	n/a	+- 100.059 KW	40.024	KW/V	-0.001	V
1M31WS		+ 126.475 mph	25.295	mph/V	0.006	V
1M31WD	10 vdc	+- 180.000 Deg	79.276	Deg/V	-3.292	V
1M23WS		+ 122.526 mph	24.505	mph/V	0.014	V
1M23WD	10 vdc	+- 180.000 Deg	73.961	Deg/V	-3.200	V
1M21WU		-50.00 - m/sec	20.030	m/s/V	-2.493	V
1M21WV		-50.00 - m/sec	20.017	m/s/V	-2.496	V
1M21WW		-10.00 - m/sec	4.003	m/s/V	-2.493	V
1M21WT		-50.00 - Deg C	20.008	Deg C/V	-2.498	V
1M15WS		+ 125.615 mph	25.123	mph/V	0.007	V
1M15WD	10 vdc	+- 180.000 Deg	76.550	Deg/V	-3.148	V
1M03WS		+ 125.712 m/sec	25.142	mph/V	0.011	V
1M31AM		+ 0 - 5 Vdc	1.000	V/V	0.000	V
1M03AT		+- 50.000 Deg C	20.032	Deg C/V	-2.496	V
1M31DT		+ -4.444 - Deg C	2.222	Deg C/V	-2.000	V
1D02BP	5 vdc	+ 22" - 31 " Hg	2.000	In-Hg/V	10.754	V

APPENDIX B

WINDATS CONTROL FILE TO CONVERT RAW
DATA INTO ENGINEERING UNITS

DATA DESCRIPTION:

```
     1               number of data files and output prefixes
D:\LOAD\L07260.BIL                         L07260.


      n               save .INP file
ibmpc                 source machine
notebook              data file format
integer               data type
     16               number of bits on a/d converter
     -5.000   5.000   voltage scale range
      0               header lines
     32.00000         sample rate (Hz)
    600.000           total time (seconds)
   19200              data scans
     54               channels total
     54               channels needed
```

channel	column #	name	units
2	1	1RPK1V	volt
3	2	2RPK1V	volt
4	3	1RH1FB	ft-kip
5	4	1RH2FB	ft-kip
6	5	1RH3FB	ft-kip
7	6	1RH1EB	ft-kip
8	7	1RH2EB	ft-kip
9	8	1RH3EB	ft-kip
10	9	1LSSTQ	ft-kip
11	10	2RH1FB	ft-kip
12	11	2RH2FB	ft-kip
13	12	2RH3FB	ft-kip
14	13	2RH1EB	ft-kip
15	14	2RH2EB	ft-kip
16	15	2RH3EB	ft-kip
17	16	2LSSTQ	ft-kip
18	17	1LSS0B	ft-kip
19	18	1LSS9B	ft-kip
20	19	1NACXX	g
21	20	1NACYY	g
22	21	1YDRTQ	ft-kip
23	22	1NACAZ	deg
24	23	1TWTTQ	ft-kip
25	24	1TWBYB	ft-kip
26	25	1TWBXB	ft-kip
27	26	1CPLPR	kW
28	27	2LSS0B	ft-kip
29	28	2LSS9B	ft-kip
30	29	1LSSAZ	deg
31	30	1LSSSP	rpm
32	31	2LSSAZ	deg
33	32	2LSSSP	rpm
34	33	2NACXX	g

[illegible]	[illegible]	[illegible]	g
36	35	2YDRTQ	ft-kip
37	36	2NACAZ	deg
38	37	2TWTTQ	ft-kip
39	38	2TWBYB	ft-kip
40	39	2TWBXB	ft-kip
41	40	2CPLPR	kW
42	41	1M31WS	mph
43	42	1M31WD	deg
44	43	1M23WS	mph
45	44	1M23WD	deg
46	45	1M21WU	m/s
47	46	1M21WV	m/s
48	47	1M21WW	m/s
49	48	1M21WT	deg C
50	49	1M15WS	mph
51	50	1M15WD	deg
52	51	1M03WS	m/s
53	52	1M03WT	deg C
54	53	1M31DT	deg C
55	54	1D02BP	in Hg

DATA PREPARATION NEEDS:

y			prepare data
n	n	n	save .FLT, .PRE, .LIM files
n			filter
n			decimate
n			pre-average
y			scale
n			limit

DATA PREPARATION SPECIFICATIONS:

channel	gain	offset	max value	temp fctr
2	1.2500	-0.10000E-02	0.00000	0.00000
3	1.2500	-0.50000E-02	0.00000	0.00000
4	-11.333	0.10600	0.00000	0.00000
5	-12.091	-0.30000E-02	0.00000	0.00000
6	-13.096	-0.48000E-01	0.00000	0.00000
7	-11.782	0.25662	0.00000	-0.543E-02
8	-12.292	0.10362	0.00000	-0.286E-02
9	-12.116	0.28723	0.00000	-0.700E-02
10	-13.046	0.97100	0.00000	0.00000
11	-12.219	-0.10000E-02	0.00000	0.00000
12	-13.036	-0.20000E-02	0.00000	0.00000
13	-13.073	0.51000E-01	0.00000	0.00000
14	-11.784	0.69459	0.00000	-0.1526E-01
15	-12.354	0.79781	0.00000	-0.1924E-01
16	-13.217	0.34612	0.00000	-0.9450E-02
17	-14.752	0.94900	0.00000	0.00000
18	-8.0840	0.64000E-01	0.00000	0.00000
19	8.2710	-0.23000E-01	0.00000	0.00000

20	0.49400	0.30900	0.00000	0.00000
21	0.49400	0.26700	0.00000	0.00000
22	1.1420	0.52000E-01	0.00000	0.00000
23	98.617	-0.80000E-02	0.00000	0.00000
24	-55.169	-0.11300	0.00000	0.00000
25	-371.16	-0.38000E-01	0.00000	0.00000
26	-358.06	0.18000E-01	0.00000	0.00000
27	40.023	0.30000E-02	0.00000	0.00000
28	-9.5400	0.47000E-01	0.00000	0.00000
29	9.6040	0.33000E-01	0.00000	0.00000
30	-72.000	2.5000	0.00000	0.00000
31	35.156	0.00000	0.00000	0.00000
32	-72.000	2.5000	0.00000	0.00000
33	35.156	0.00000	0.00000	0.00000
34	0.50100	-0.58000E-01	0.00000	0.00000
35	0.50000	-0.16000E-01	0.00000	0.00000
36	1.3900	0.13500	0.00000	0.00000
37	92.361	-0.53000E-01	0.00000	0.00000
38	-50.856	-0.20000E-01	0.00000	0.00000
39	-343.42	0.30000E-01	0.00000	0.00000
40	-362.52	0.70000E-02	0.00000	0.00000
41	40.024	0.10000E-02	0.00000	0.00000
42	25.295	0.62000E-01	0.00000	0.00000
43	79.276	3.6880	0.00000	0.00000
44	24.505	0.55000E-01	0.00000	0.00000
45	73.961	3.6100	0.00000	0.00000
46	20.030	2.4930	0.00000	0.00000
47	20.017	2.4960	0.00000	0.00000
48	4.0030	2.4930	0.00000	0.00000
49	20.008	2.4980	0.00000	0.00000
50	25.123	0.60000E-01	0.00000	0.00000
51	76.550	3.5440	0.00000	0.00000
52	25.142	0.53000E-01	0.00000	0.00000
53	20.032	2.5740	0.00000	0.00000
54	2.2220	2.0560	0.00000	0.00000
55	2.0000	-10.678	0.00000	0.00000

COMPUTED CHANNEL NEEDS:

y	add computed channels
y	save .CMP file
n	compute multi-channel averages
n	compute vector sums and phases
n	compute sums
y	compute differences
y	compute products
y	compute ratios
n	compute a yaw rate
n	compute a time channel
n	compute an azimuth channel
n	compute Richardson's number

COMPUTED CHANNEL SOURCES:

	2	number of differences			
new ch	name	units	minuend	subtrhd	sep-dist
56	1YAWER	deg	23	45	1.000
57	2YAWER	deg	37	45	1.000
	2	number of products			
new ch	name	units	source-channels		multplr
58	1LSSPR	kW	10	31	0.142
59	2LSSPR	kW	17	33	0.142
	2	number of ratios			
new ch	name	units	numerator	denomnatr	factor
60	1DTEFF		27	58	1.000
61	2DTEFF		41	59	1.000

DATA ANALYSIS NEEDS:

n analyze data

APPENDIX C

TYPICAL WINDATS STATISTICS FILE

RAW DATA STATISTICS: L07240.INP

(units may still be in volts or counts)

Channel	name	units	mean	standard dev	coef of var
2	1RPK1V	volt	1.2633	0.13031E-01	0.10315E-01
3	2RPK1V	volt	1.2652	0.13052E-01	0.10316E-01
4	1RH1FB	ft-kip	-0.45375	0.21235	-0.46798
5	1RH2FB	ft-kip	-0.55290	0.20477	-0.37036
6	1RH3FB	ft-kip	-0.55375	0.19806	-0.35767
7	1RH1EB	ft-kip	-0.18966	0.31313	-1.6510
8	1RH2EB	ft-kip	-0.20443	0.30843	-1.5087
9	1RH3EB	ft-kip	-0.20140	0.31817	-1.5798
10	1LSSTQ	ft-kip	-0.53033E-01	0.20126	3.7949
11	2RH1FB	ft-kip	-0.32422	0.17792	-0.54878
12	2RH2FB	ft-kip	-0.33724	0.15865	-0.47045
13	2RH3FB	ft-kip	-0.26549	0.15893	-0.59862
14	2RH1EB	ft-kip	-0.44693E-01	0.42519	-9.5135
15	2RH2EB	ft-kip	-0.53107E-01	0.41310	-7.7786
16	2RH3EB	ft-kip	-0.12513	0.38854	-3.1051
17	2LSSTQ	ft-kip	0.24677	0.15773	0.63917
18	1LSS0B	ft-kip	0.84050E-01	0.36403	4.3312
19	1LSS9B	ft-kip	0.53113E-01	0.37068	6.9792
20	1NACXX	g	0.25390	0.68108E-01	0.26825
21	1NACYY	g	0.49445	0.58867E-01	0.11906
22	1YDRTQ	ft-kip	-0.10457	0.31737	-3.0350
23	1NACAZ	deg	0.22647E-01	0.82550E-03	0.36451E-01
24	1TWTTQ	ft-kip	0.28932E-01	0.43984E-01	1.5203
25	1TWBYB	ft-kip	0.29465E-01	0.52417E-01	1.7790
26	1TWBXB	ft-kip	-0.29069	0.94682E-01	-0.32571
27	1CPLPR	kW	1.3871	0.35838	0.25837
28	2LSS0B	ft-kip	0.15694E-01	0.27357	17.431
29	2LSS9B	ft-kip	0.31962E-01	0.95845E-03	0.29987E-01
30	1LSSAZ	deg	-0.22384E-02	1.4467	-646.31
31	1LSSSP	rpm	1.3396	0.15039E-01	0.11227E-01
32	2LSSAZ	deg	-0.23713E-02	1.4456	-609.62
33	2LSSSP	rpm	1.3381	0.14960E-01	0.11180E-01
34	2NACXX	g	-0.15027	0.48997E-01	-0.32606
35	2NACYY	g	-0.10690	0.41445E-01	-0.38768
36	2YDRTQ	ft-kip	0.31181E-02	0.17759	56.956
37	2NACAZ	deg	-0.45663E-03	0.28073E-02	-6.1479
38	2TWTTQ	ft-kip	0.35457E-01	0.41049E-01	1.1577
39	2TWBYB	ft-kip	0.11579	0.45535E-01	0.39326
40	2TWBXB	ft-kip	-0.28546	0.76311E-01	-0.26733
41	2CPLPR	kW	1.1448	0.31158	0.27218
42	1M31WS	mph	1.0928	0.23392	0.21405
43	1M31WD	deg	3.7115	0.16479	0.44400E-01
44	1M23WS	mph	1.0513	0.19839	0.18870
45	1M23WD	deg	3.6404	0.19010	0.52219E-01
46	1M21WU	m/s	3.0178	0.12441	0.41227E-01
47	1M21WV	m/s	2.3039	0.12601	0.54694E-01

48	1M21WW	m/s	3.5686	0.68164	0.19101
49	1M21WT	deg C	4.5436	0.20283	0.44640E-01
50	1M15WS	mph	0.72565	0.11846	0.16324
51	1M15WD	deg	3.5863	0.16673	0.46492E-01
52	1M03WS	m/s	0.83271	0.14336	0.17216
53	1M03WT	deg C	4.1676	0.43154E-01	0.10355E-01
54	1M31DT	deg C	1.9068	0.23785E-01	0.12474E-01
55	1D02BP	in Hg	3.8660	0.39893E-01	0.10319E-01

Channel	name	minimum	min scan#	maximum	max scan#
2	1RPK1V	1.2621	93	1.2645	1486
3	2RPK1V	1.2639	909	1.2666	2205
4	1RH1FB	-1.5727	725	0.27817	8238
5	1RH2FB	-1.4381	168	0.20691	8263
6	1RH3FB	-1.5660	9006	0.14572	8250
7	1RH1EB	-0.94009	2119	0.52963	228
8	1RH2EB	-0.94711	2110	0.46860	2128
9	1RH3EB	-1.0431	869	0.50858	8224
10	1LSSTQ	-0.52139	173	0.57419	8217
11	2RH1FB	-1.1145	759	0.35049	7973
12	2RH2FB	-0.99915	7800	0.20767	7957
13	2RH3FB	-0.95703	268	0.33188	7964
14	2RH1EB	-1.0658	733	0.89890	7825
15	2RH2EB	-0.98984	7831	0.72250	8829
16	2RH3EB	-0.95657	335	0.61661	7917
17	2LSSTQ	-0.14313	212	0.68069	3911
18	1LSS0B	-1.7209	138	1.6458	202
19	1LSS9B	-1.2433	5816	1.7117	107
20	1NACXX	-0.78735E-01	217	0.58929	183
21	1NACYY	0.23041	176	0.80551	281
22	1YDRTQ	-1.8054	281	1.0219	5828
23	1NACAZ	0.19684E-01	871	0.25635E-01	5066
24	1TWTTQ	-0.85144E-01	8219	0.32593	281
25	1TWBYB	-0.14221	6373	0.22964	6363
26	1TWBXB	-0.68634	257	-0.41046E-01	5690
27	1CPLPR	0.49484	8220	2.2543	175
28	2LSS0B	-1.0620	6994	1.1168	6691
29	2LSS9B	0.27924E-01	6994	0.35706E-01	6998
30	1LSSAZ	-2.5087	1903	2.5009	8951
31	1LSSSP	1.3168	1488	1.3586	214
32	2LSSAZ	-2.5064	3292	2.5006	1901
33	2LSSSP	1.3181	8396	1.3608	180
34	2NACXX	-0.38162	6575	0.10010	6565
35	2NACYY	-0.30121	151	0.75531E-01	6625
36	2YDRTQ	-0.99579	7837	0.85449	8247
37	2NACAZ	-0.61035E-02	2014	0.64087E-02	6573
38	2TWTTQ	-0.14603	8247	0.25345	7837
39	2TWBYB	-0.56000E-01	8233	0.28366	138
40	2TWBXB	-0.59708	6574	-0.81482E-01	8163
41	2CPLPR	0.27939	3918	1.8523	215
42	1M31WS	0.60547	8208	1.7029	43

43	1M31WD	3.2442	8667	4.3442	8097
44	1M23WS	0.51010	4479	1.7177	690
45	1M23WD	3.0988	2783	4.2798	8084
46	1M21WU	2.6239	4768	3.5750	692
47	1M21WV	1.7711	8072	2.7327	2821
48	1M21WW	1.1806	4217	4.9998	48
49	1M21WT	3.9983	317	4.9998	122
50	1M15WS	0.39627	4799	1.1104	799
51	1M15WD	3.0685	7831	4.2410	4780
52	1M03WS	0.42694	8141	1.3316	816
53	1M03WT	4.1563	9190	4.1769	64
54	1M31DT	1.8869	9107	1.9308	774
55	1D02BP	3.8614	46	3.8715	7237

PREPARED DATA STATS: L07240.PRE

Channel	name	units	mean	standard dev	coef of var
2	1RPK1V	volt	1.5804	0.16302E-01	0.10315E-01
3	2RPK1V	volt	1.5828	0.16328E-01	0.10316E-01
4	1RH1FB	ft-kip	6.3322	2.4068	0.38010
5	1RH2FB	ft-kip	6.6246	2.4759	0.37374
6	1RH3FB	ft-kip	6.5317	2.5936	0.39708
7	1RH1EB	ft-kip	3.2107	3.6893	1.1491
8	1RH2EB	ft-kip	2.6616	3.7912	1.4244
9	1RH3EB	ft-kip	3.2062	3.8550	1.2024
10	1LSSTQ	ft-kip	10.396	2.6278	0.25277
11	2RH1FB	ft-kip	4.0105	2.1741	0.54210
12	2RH2FB	ft-kip	4.4484	2.0682	0.46494
13	2RH3FB	ft-kip	4.2028	2.0778	0.49439
14	2RH1EB	ft-kip	2.9571	5.0106	1.6944
15	2RH2EB	ft-kip	2.9059	5.1035	1.7563
16	2RH3EB	ft-kip	2.2316	5.1354	2.3012
17	2LSSTQ	ft-kip	9.0598	2.3284	0.25700
18	1LSS0B	ft-kip	-0.46930	2.9428	-6.2708
19	1LSS9B	ft-kip	0.28216	3.0659	10.866
20	1NACXX	g	0.34200E-02	0.33621E-01	9.8305
21	1NACYY	g	0.12598E-01	0.28971E-01	2.2997
22	1YDRTQ	ft-kip	-0.13084	0.36244	-2.7702
23	1NACAZ	deg	3.0222	0.84072E-01	0.27818E-01
24	1TWTTQ	ft-kip	-8.6019	2.4281	-0.28228
25	1TWBYB	ft-kip	-6.8539	19.455	-2.8385
26	1TWBXB	ft-kip	107.31	33.903	0.31594
27	1CPLPR	kW	55.394	14.343	0.25893
28	2LSS0B	ft-kip	0.22230	2.6098	11.740
29	2LSS9B	ft-kip	-0.33093E-03	0.86436E-02	-26.119
30	1LSSAZ	deg	180.14	104.18	0.57831
31	1LSSSP	rpm	47.093	0.52871	0.11227E-01
32	2LSSAZ	deg	180.15	104.10	0.57785
33	2LSSSP	rpm	47.043	0.52595	0.11180E-01

34	2NACXX	g	-0.21183E-01	0.24536E-01	-1.1583
35	2NACYY	g	-0.17456E-01	0.20716E-01	-1.1868
36	2YDRTQ	ft-kip	-0.80447E-01	0.24686	-3.0686
37	2NACAZ	deg	4.8524	0.26407	0.54420E-01
38	2TWTTQ	ft-kip	-3.4813	2.0878	-0.59973
39	2TWBYB	ft-kip	-29.119	15.635	-0.53693
40	2TWBXB	ft-kip	02.40	27.664	0.27017
41	2CPLPR	kW	45.778	12.471	0.27242
42	1M31WS	mph	26.251	5.9163	0.22537
43	1M31WD	deg	2.4505	12.707	5.1853
44	1M23WS	mph	24.612	4.8609	0.19750
45	1M23WD	deg	2.8655	13.783	4.8099
46	1M21WU	m/s	10.517	2.4152	0.22966
47	1M21WV	m/s	-3.8394	2.4774	-0.64527
48	1M21WW	m/s	4.3066	2.7250	0.63274
49	1M21WT	deg C	40.933	3.9709	0.97008E-01
50	1M15WS	mph	16.899	2.9752	0.17606
51	1M15WD	deg	3.8025	12.446	3.2730
52	1M03WS	m/s	19.805	3.6036	0.18196
53	1M03WT	deg C	32.049	0.33974	0.10601E-01
54	1M31DT	deg C	-0.31115	0.29913E-01	-0.96135E-01
55	1D02BP	in Hg	29.104	0.30012	0.10312E-01

COMPUTED CHANNEL STATS: L07240.CMP

Channel	name	units	mean	standard dev	coef of var
56	1YAWER	deg	0.15670	13.774	87.904
57	2YAWER	deg	1.9869	13.746	6.9185
58	1LSSPR	kW	69.591	17.800	0.25579
59	2LSSPR	kW	60.573	15.744	0.25992
60	1DTEFF		0.79590	0.46945E-01	0.58984E-01
61	2DTEFF		0.75277	0.36689E-01	0.48738E-01

Channel	name	minimum	min scan#	maximum	max scan#
2	1RPK1V	1.5788	93	1.5819	1486
3	2RPK1V	1.5811	909	1.5845	2205
4	1RH1FB	-1.9625	8238	19.014	725
5	1RH2FB	-2.5622	8263	17.328	168
6	1RH3FB	-2.6286	8250	19.788	9006
7	1RH1EB	-5.2639	228	12.052	2119
8	1RH2EB	-5.6113	2128	11.791	2110
9	1RH3EB	5.3958	8224	13.404	869
10	1LSSTQ	3.5982	8217	17.891	173
11	2RH1FB	-4.2338	7973	13.667	759
12	2RH2FB	-2.6551	7957	13.077	7800
13	2RH3FB	-3.6066	7964	13.243	268
14	2RH1EB	-8.1619	7825	14.990	733
15	2RH2EB	-6.6758	8829	14.478	7831

16	2RH3EB	-7.5719	7917	13.221	335
17	2LSSTQ	2.6599	3911	14.813	212
18	1LSS0B	-13.095	202	14.122	138
19	1LSS9B	-10.440	5816	14.001	107
20	1NACXX	-0.16091	217	0.16909	183
21	1NACYY	-0.11786	176	0.16624	281
22	1YDRTQ	-2.0732	281	1.1556	5828
23	1NACAZ	2.7301	871	3.3170	5066
24	1TWTTQ	-24.988	281	-2.3092	8219
25	1TWBYB	-81.152	6363	56.866	6373
26	1TWBXB	17.920	5690	248.97	257
27	1CPLPR	19.685	8220	90.105	175
28	2LSS0B	-10.282	6691	10.504	6994
29	2LSS9B	-0.39150E-01	6994	0.35588E-01	6998
30	1LSSAZ	-0.65918E-01	8951	360.63	1903
31	1LSSSP	46.295	1488	47.764	214
32	2LSSAZ	-0.43945E-01	1901	360.46	3292
33	2LSSSP	46.338	8396	47.840	180
34	2NACXX	-0.13708	6575	0.10426	6565
35	2NACYY	-0.11460	151	0.73766E-01	6625
36	2YDRTQ	-1.4689	7837	1.1030	8247
37	2NACAZ	4.3314	2014	5.4870	6573
38	2TWTTQ	-14.568	7837	5.7481	8247
39	2TWBYB	-86.769	138	29.877	8233
40	2TWBXB	28.451	8163	215.36	6574
41	2CPLPR	11.142	3918	74.095	215
42	1M31WS	13.924	8208	41.683	43
43	1M31WD	-34.630	8667	52.574	8097
44	1M23WS	11.348	4479	40.940	690
45	1M23WD	-37.221	2783	50.130	8084
46	1M21WU	2.6220	4768	21.672	692
47	1M21WV	-14.511	8072	4.7380	2821
48	1M21WW	-5.2536	4217	10.035	48
49	1M21WT	30.017	317	50.057	122
50	1M15WS	8.6240	4799	26.565	799
51	1M15WD	-35.860	7831	53.893	4780
52	1M03WS	9.6028	8141	32.349	816
53	1M03WT	31.818	9190	32.230	64
54	1M31DT	-0.35574	9107	-0.25809	774
55	1D02BP	29.097	46	29.117	7237

COMPUTED CHANNEL STATS: L07240.CMP

Channel	name	minimum	min scan#	maximum	max scan#
56	1YAWER	-47.084	8084	40.327	2783
57	2YAWER	-45.474	8084	42.524	2783
58	1LSSPR	23.835	8217	120.46	173
59	2LSSPR	17.724	3910	99.251	212
60	1DTEFF	0.62234	8245	1.0337	9212
61	2DTEFF	0.55518	3930	0.88139	7966

APPENDIX D

FORTRAN PROGRAMS

```
      PROGRAM DIRECT

C.....THIS PROGRAM IS USED TO READ A FILE CREATED USING
C.....( D /1 > D.LST) AND PROCESS THE FILE SUCH THAT JUST
C.....THE FILE NAMES AND EXTENSIONS ARE PRINTED TO A FILE
C.....DD.LST.

      INTEGER*4 I
      CHARACTER*12 FNAME
      CHARACTER*8 FILE
      CHARACTER*4 EXT

      OPEN(UNIT = 1, FILE = 'D.LST' , STATUS = 'OLD')
      OPEN(UNIT = 9, FILE = 'DD.LST' , STATUS = 'UNKNOWN')

      READ(1,5)
    5 FORMAT(//)

      DO 100 I = 1, 600
      READ(1,10, END =99)FILE,EXT
      FNAME = CHARNB(FILE)//EXT
      IF(EXT.EQ.'.STS')THEN
      WRITE(9,15)FNAME
      ENDIF
  100 CONTINUE

   10 FORMAT(2X,A8,A4)
   15 FORMAT(A12)

   99 CLOSE(UNIT = 1)
      CLOSE(UNIT = 9)
      STOP
      END
```

```
      PROGRAM DATAS2

C.....THIS PROGRAM IS USED TO READ *.STS FILES AND SORT THEM
C.....FOR INPUT INTO 'FILE EXPRESS'. IT ALSO COMPUTES TWO
C.....ADDITIONAL CHANNELS: SONIC WIND SPEED AND MAXWS/MEANWS


C.....'NCHAN' IS THE NUMBER OF DATA CHANNELS THAT ARE READ

      INTEGER NCHAN
      PARAMETER( NCHAN = 63)
      INTEGER I
      INTEGER J
      INTEGER CHAN(NCHAN)
      CHARACTER*25 CNAME(NCHAN)
      CHARACTER*10 CUNIT(NCHAN)
      REAL MEAN(NCHAN)
      REAL STDEV(NCHAN)
      REAL COV(NCHAN)
      REAL MIN(NCHAN)
      INTEGER NMIN(NCHAN)
      REAL MAX(NCHAN)
      INTEGER NMAX(NCHAN)


C.....'NCOUNT' IS THE NUMBER OF FILES THAT WILL BE ADDED TO
C......THE OUTPUT FILE.

      INTEGER NCOUNT
      CHARACTER*12 FNAME(600)

      OPEN(UNIT = 1, FILE = 'DD.LST' , STATUS = 'OLD')
      NCOUNT = 0

      DO 5 I = 1, 600
      READ(1,*, END = 99)FNAME(I)
      NCOUNT = NCOUNT + 1
    5 CONTINUE
   99 CONTINUE
      CLOSE(UNIT =1)


      OPEN(UNIT = 9, FILE = 'STATS.DAT', STATUS = 'UNKNOWN')

      DO 6 J = 1,NCOUNT
      WRITE(*,*)FNAME(J)
      OPEN(UNIT = 2, FILE = FNAME(J), STATUS = 'OLD')

C....SKIP OVER THE FIRST 'I' LINES.

        DO 100 I = 1,69
        READ(2,*)
```

```
  100 CONTINUE

C.....READ IN THE CHANNEL NUMBER, NAMES, UNITS, AND VALUES.

      DO 101 I = 2,55

      READ(2,10)CHAN(I),CNAME(I),CUNIT(I),MEAN(I),
     +     STDEV(I),COC(I),MIN(I),NMIN(I),MAX(I),NMAX(I)
  101 CONTINUE

      DO 102 I = 1,7
      READ(2,*)
  102 CONTINUE

      DO 103 I = 56,61
      READ(2,10)CHAN(I),CNAME(I),CUNIT(I),MEAN(I),
     +     STDEV(I),COV(I),MIN(I),NMIN(I),MAX(I),NMAX(I)
  103 CONTINUE

   10 FORMAT(I4,2X,A25,A10,3(1X,G14.5),2(1X,G14.5,1X,I5))

C.....COMPUTE ADDITIONAL CHANNELS

C.....CHANNEL 62 - SONIC WIND SPEED (46^2 + 47^2)/44

      CHAN(62) = 62
      CNAME(62) = 'S_PRAT    '
      CUNIT(62) = 'DIMLES'
      MEAN(62)=((MEAN(46)**2+MEAN(47)**2)**.5)*
     +          2.236936/MEAN(44)
      STDEV(62) = 0.0
      COV(62) = 0.0
      MIN(62) = 0.0
      NMIN(62) = 0
      MAX(62) = 0.0
      NMAX(62) = 0

C.....CHANNEL 63 - MAX WINDSPEED/MEAN WIND SPEED

      CHAN(63) = 63
      CNAME(63) = 'P_MRAT    '
      CUNIT(63)= 'DIMLES'
      MEAN(63) = MAX(44)/MEAN(44)
      STDEV(63) = 0.0
      COV(63) = 0.0
      MIN(63) = 0.0
      NMIN(63) = 0
      MAX(63) = 0.0
      NMAX(63) = 0

      DO 104 I = 2,NCHAN
      WRITE(9,50)FNAME(J),CHAN(I),CNAME(I),CUNIT(I),MEAN(I),
```

```
  +       STDEV(I),COV(I),MIN(I),NMIN(I),MAX(I),NMAX(I)
104 CONTINUE
 50
    FORMAT(A12,',' I4,',',A10,',' A6,',' 3(F14.5,','),
  +        F14.5,',' I5,',',F14.5,',' I5)
    CLOSE(UNIT = 2)
  6 CONTINUE
    STOP
    END
```

APPENDIX E

SORTED *.STS FILES WITH FOUR CALCULATED CHANNELS

(**Table 11.** Sorted statistics files.)

BAD FILES		FILE NAME	AEROSTAR POWER (kW)	SERI POWER (kW)	23 m WIND SPEED (mph)	23 m WIND SPEED (cov)	PEAK/ MEAN WIND SPEED	SONIC/ MEAN WIND SPEED	SERI YAW ERROR (deg)	AEROSTAR YAW ERROR (deg)
	1	L07240.STS	45.78	55.39	24.61	0.1975	1.663	1.018	0.16	1.99
	2	L072410.STS	40.56	48.63	23.06	0.2560	1.823	1.042	9.31	7.23
	3	L072411.STS	41.55	47.95	22.22	0.2384	2.139	1.071	10.09	9.02
	4	L072412.STS	43.22	47.55	22.54	0.2568	1.782	1.074	12.51	12.46
	5	L072413.STS	47.50	52.53	24.33	0.2264	1.791	1.048	6.87	7.02
	6	L072414.STS	43.15	47.69	22.45	0.2635	1.891	1.057	5.78	4.66
	7	L072415.STS	35.23	37.70	20.00	0.2651	1.789	1.067	12.51	10.04
	8	L072416.STS	43.29	47.67	23.11	0.2503	1.768	1.061	15.42	8.18
	9	L072417.STS	50.64	58.13	26.02	0.2294	1.789	1.063	11.85	8.27
	10	L072418.STS	50.74	53.58	25.09	0.2619	1.914	1.061	10.73	10.40
	11	L072419.STS	51.40	57.26	25.87	0.2176	1.731	1.056	10.18	12.86
	12	L07242.STS	36.52	41.23	20.71	0.2068	1.587	1.026	3.63	4.07
	13	L072420.STS	43.45	51.86	23.86	0.2692	2.034	1.035	-1.40	2.43
	14	L072421.STS	43.62	50.01	22.88	0.2780	1.980	1.051	4.15	3.57
	15	L072422.STS	41.91	50.03	22.80	0.3144	1.823	1.022	4.58	-1.03
	16	L072423.STS	36.59	39.74	21.26	0.2788	2.006	1.036	8.10	6.50
	17	L072424.STS	36.02	42.69	21.01	0.3188	2.054	1.056	21.27	4.44
	18	L072425.STS	37.18	38.90	20.28	0.2470	1.768	1.042	15.51	8.54
	19	L072426.STS	33.84	33.27	19.61	0.2702	1.881	1.060	18.59	12.42
	20	L072427.STS	37.41	40.87	20.80	0.3677	2.169	1.044	14.33	11.15
	21	L07243.STS	46.69	56.46	25.25	0.2304	1.761	1.032	9.15	7.21
	22	L07244.STS	37.58	45.98	21.88	0.2633	1.851	1.045	8.62	6.69
	23	L07245.STS	34.89	43.28	20.89	0.3032	2.225	1.027	5.55	3.63
	24	L07246.STS	31.91	42.89	20.74	0.2858	2.010	1.028	5.69	0.79
	25	L07247.STS	47.57	50.80	24.70	0.2405	1.767	1.056	16.45	6.79
	26	L07248.STS	39.13	39.66	22.09	0.3387	1.899	1.045	13.88	6.32
	27	L07249.STS	42.70	47.27	23.67	0.2508	1.783	1.026	11.61	7.42
	28	L07250.STS	39.10	41.11	22.20	0.3277	1.795	1.037	7.16	10.21
	29	L07251.STS	28.51	34.81	18.11	0.2975	2.217	1.052	5.30	11.56
	30	L072510.STS	29.90	31.92	18.65	0.3305	2.229	1.034	14.39	9.12
	31	L072511.STS	39.82	45.92	22.43	0.2836	1.931	1.049	12.83	6.05
	32	L072512.STS	45.53	51.21	23.89	0.2682	1.727	1.049	14.54	10.80
	33	L072513.STS	42.01	49.06	23.06	0.2600	1.988	1.057	13.79	11.56
	34	L072514.STS	40.95	46.07	23.03	0.2824	1.831	1.073	12.22	17.10
	35	L072515.STS	44.71	50.64	23.50	0.2425	1.783	1.048	6.36	10.07
	36	L072516.STS	50.31	54.80	25.44	0.2108	1.841	1.038	6.79	11.19
	37	L072517.STS	40.24	46.02	21.74	0.2804	1.874	1.056	9.32	10.60
	38	L072518.STS	46.25	57.48	24.44	0.2528	1.770	1.064	10.41	11.56
	39	L072519.STS	46.13	51.56	24.36	0.2419	1.989	1.050	12.38	13.55
	40	L07252.STS	20.89	28.46	16.99	0.3101	1.965	1.052	8.87	10.32
	41	L072520.STS	45.50	52.91	23.97	0.2918	1.941	1.067	9.05	10.21
	42	L072521.STS	46.02	51.59	23.46	0.2598	1.957	1.041	3.61	4.44
	43	L072522.STS	37.33	41.73	21.37	0.2503	1.789	1.057	19.43	13.26
	44	L072523.STS	40.02	44.76	21.80	0.3017	1.993	1.051	8.80	7.28
	45	L072524.STS	44.38	55.24	24.02	0.2636	1.660	1.035	11.25	5.34
	46	L072525.STS	36.40	41.36	20.53	0.2862	1.870	1.089	17.20	11.30
	47	L072526.STS	42.59	47.73	22.78	0.2607	1.873	1.061	9.27	10.48
	48	L072527.STS	35.48	40.03	20.65	0.2396	1.812	1.052	12.78	8.41
	49	L072528.STS	35.77	40.58	20.22	0.2752	1.952	1.089	13.67	12.17
	50	L072529.STS	34.58	40.00	20.41	0.2695	1.957	1.020	0.33	-0.81

BAD FILES		FILE NAME	AEROSTAR POWER (kW)	SERI POWER (kW)	23 m WIND SPEED (mph)	23 m WIND SPEED (cov)	PEAK/ MEAN WIND SPEED	SONIC/ MEAN WIND SPEED	SERI YAW ERROR (deg)	AEROSTAR YAW ERROR (deg)
	51	L07253.STS	34.60	38.98	20.12	0.2626	1.798	1.070	15.19	10.57
	52	L072530.STS	39.54	46.84	22.17	0.2760	1.898	1.044	7.23	9.10
	53	L072531.STS	39.85	46.92	22.24	0.2903	1.862	1.088	7.92	18.61
	54	L072532.STS	50.12	55.15	25.56	0.2661	1.815	1.053	-0.85	11.68
	55	L072533.STS	35.45	35.66	19.63	0.3048	2.229	1.083	10.22	14.50
	56	L072534.STS	45.63	52.19	23.61	0.2549	1.747	1.076	10.55	14.84
	57	L072535.STS	34.11	41.04	20.64	0.2753	1.783	1.092	15.59	20.03
	58	L072536.STS	39.53	47.32	21.96	0.2329	1.853	1.079	6.10	13.37
	59	L072537.STS	42.10	45.82	22.11	0.2810	1.870	1.069	8.02	14.29
	60	L072538.STS	37.83	43.11	21.88	0.3060	1.947	1.057	10.86	10.25
	61	L072539.STS	34.01	37.39	20.88	0.2609	1.923	1.095	24.36	20.95
	62	L07254.STS	37.32	42.87	21.05	0.2634	1.762	1.055	14.56	12.26
	63	L072540.STS	43.02	48.85	23.76	0.2579	1.858	1.083	15.93	21.49
	64	L072541.STS	50.10	54.61	25.09	0.2782	1.803	1.082	4.99	11.91
	65	L072542.STS	52.05	60.07	26.16	0.2251	1.711	1.089	8.74	15.41
	66	L072543.STS	42.64	50.10	23.28	0.2205	1.652	1.090	13.93	20.62
	67	L072544.STS	38.33	47.07	22.32	0.2995	1.861	1.091	13.76	14.56
	68	L072545.STS	40.95	48.00	23.35	0.2575	1.757	1.034	5.03	11.23
	69	L072547.STS	37.31	45.71	21.90	0.2732	1.941	1.078	13.12	12.45
	70	L072548.STS	31.56	32.63	20.30	0.3114	2.278	1.057	18.96	24.02
	71	L072549.STS	32.83	39.30	21.85	0.3066	2.010	1.065	12.02	12.92
	72	L07255.STS	32.96	36.85	19.98	0.3190	1.996	1.062	13.22	12.84
	73	L072550.STS	35.94	38.48	21.24	0.2693	1.950	1.058	7.80	9.55
	74	L072551.STS	43.09	49.70	23.37	0.2509	1.723	1.042	5.21	3.13
	75	L072552.STS	37.15	42.82	21.77	0.3048	1.930	1.050	11.73	9.67
	76	L072553.STS	47.51	53.22	25.30	0.2313	1.687	1.027	7.75	6.39
	77	L072554.STS	45.86	51.91	23.93	0.2637	1.810	1.055	5.63	8.14
	78	L072555.STS	53.02	58.96	26.96	0.2389	1.708	1.055	11.33	13.84
	79	L072556.STS	46.69	58.94	24.39	0.2487	1.925	1.038	5.10	7.63
	80	L072557.STS	49.30	54.29	24.74	0.2382	1.881	1.054	7.67	10.19
	81	L072558.STS	46.36	56.17	25.06	0.2369	1.740	1.047	7.35	9.86
	82	L072559.STS	53.60	60.17	27.59	0.2186	1.838	1.029	4.24	6.76
	83	L07256.STS	18.42	24.58	15.75	0.4111	2.283	1.051	9.14	5.98
	84	L072560.STS	52.54	61.57	28.09	0.2190	1.649	1.054	12.05	14.57
	85	L072561.STS	53.45	60.19	26.90	0.2317	1.664	1.046	9.20	11.71
	86	L072562.STS	50.01	53.59	25.87	0.2702	1.848	1.083	17.91	20.43
*****	87	L072563.STS	44.44	9.51	23.77	0.2694	3.481	0.889	37.00	18.48
*****	88	L072565.STS	43.27	10.38	22.58	0.2460	3.191	1.107	41.36	20.91
*****	89	L072566.STS	36.38	13.95	21.42	0.3033	2.301	1.111	52.56	23.10
*****	90	L072567.STS	49.33	7.00	27.19	0.2174	2.628	1.074	37.39	25.11
*****	91	L072568.STS	50.25	5.86	25.75	0.2423	1.958	1.087	37.33	24.04
*****	92	L072569.STS	50.21	6.39	25.32	0.2202	2.459	1.081	38.05	20.81
	93	L07257.STS	22.70	25.45	16.34	0.3924	2.380	1.042	10.39	8.00
*****	94	L072570.STS	50.17	5.92	25.65	0.2567	2.422	1.116	43.54	23.81
*****	95	L072571.STS	55.46	3.06	28.09	0.2666	2.603	1.083	34.03	19.26
*****	96	L072572.STS	57.88	1.61	27.68	0.2707	2.032	1.102	33.52	21.99
*****	97	L072573.STS	55.39	2.70	27.99	0.2468	2.574	1.102	35.73	20.03
*****	98	L072574.STS	57.86	1.58	29.28	0.2041	1.715	1.096	38.97	22.54
*****	99	L072575.STS	56.26	2.81	23.87	0.1954	1.624	1.120	38.85	19.36
	100	L07258.STS	27.72	28.95	18.83	0.3494	2.085	1.101	27.65	20.71

BAD FILES		FILE NAME	AEROSTAR POWER (kW)	SERI POWER (kW)	23 m WIND SPEED (mph)	23 m WIND SPEED (cov)	PEAK/ MEAN WIND SPEED	SONIC/ MEAN WIND SPEED	SERI YAW ERROR (deg)	AEROSTAR YAW ERROR (deg)
	101	L07259.STS	32.82	38.71	20.55	0.3678	2.079	1.005	7.19	2.31
	102	L07260.STS	34.46	34.90	19.52	0.2263	1.655	1.099	15.12	20.43
*****	103	L07261.STS	137.96	-0.00	41.17	0.0738	2.780	1.375	497.50	591.67
	104	L072610.STS	30.69	32.68	18.56	0.2746	1.777	1.061	13.00	9.80
	105	L072611.STS	34.76	39.51	20.21	0.2217	1.811	1.047	8.45	9.43
	106	L072612.STS	26.57	37.41	19.31	0.3253	2.498	1.074	16.47	18.52
	107	L072613.STS	31.20	36.40	19.80	0.3318	1.988	1.087	16.45	19.12
	108	L072614.STS	36.24	44.61	21.62	0.2713	1.708	1.051	15.26	13.92
	109	L072615.STS	38.06	43.82	21.15	0.2318	2.001	1.044	9.91	9.41
	110	L072616.STS	36.63	46.19	21.26	0.2651	1.892	1.045	8.69	8.23
	111	L072617.STS	42.17	45.94	23.05	0.2458	1.897	1.059	22.03	17.11
	112	L072618.STS	41.90	46.42	23.01	0.2678	1.769	1.060	19.20	14.27
	113	L072619.STS	35.77	41.60	20.60	0.2561	1.833	1.058	17.28	16.10
	114	L07262.STS	31.97	33.28	19.97	0.2690	1.841	1.080	10.07	9.04
	115	L072620.STS	42.99	49.42	23.48	0.2721	1.979	1.063	12.33	15.97
	116	L072621.STS	55.60	59.61	27.97	0.2315	1.700	1.063	16.36	19.98
	117	L072622.STS	54.60	58.33	27.16	0.2009	1.707	1.072	17.68	21.27
	118	L072623.STS	47.35	53.77	24.73	0.2355	1.790	1.048	11.84	15.40
	119	L072624.STS	43.62	49.30	23.74	0.2671	1.854	1.081	18.72	21.76
	120	L072625.STS	47.16	56.69	25.47	0.2423	1.920	1.088	19.56	21.61
	121	L072626.STS	53.92	61.30	27.55	0.1972	1.610	1.060	17.38	19.38
	122	L072627.STS	54.39	56.11	27.42	0.2425	1.929	1.082	19.44	14.79
	123	L072628.STS	53.22	58.35	26.31	0.2484	1.814	1.083	18.59	8.45
	124	L072629.STS	55.02	58.64	26.91	0.2450	1.738	1.067	15.77	5.57
	125	L07263.STS	26.45	28.69	18.08	0.2944	1.910	1.116	15.54	13.12
	126	L072630.STS	54.53	58.14	27.17	0.2451	1.874	1.063	17.33	7.15
	127	L072631.STS	51.81	53.94	26.53	0.2623	1.908	1.089	21.19	14.25
	128	L072632.STS	49.99	54.35	27.85	0.3054	1.964	1.085	12.14	14.00
	129	L072633.STS	53.12	63.58	27.43	0.2225	1.744	1.084	12.88	14.18
	130	L072634.STS	51.42	54.23	25.19	0.2437	1.673	1.100	15.90	17.20
	131	L072635.STS	52.59	59.83	25.89	0.2352	1.724	1.070	6.41	7.68
	132	L072636.STS	53.63	56.83	25.93	0.2657	1.807	1.091	12.60	12.56
	133	L07264.STS	27.58	32.83	18.52	0.2738	1.961	1.090	16.11	11.88
	134	L07265.STS	26.06	27.96	18.08	0.3310	1.942	1.081	17.55	12.41
	135	L07266.STS	28.73	31.89	18.52	0.2865	1.975	1.110	23.45	17.63
	136	L07267.STS	21.72	22.89	16.79	0.2726	1.958	1.089	14.31	13.33
	137	L07268.STS	25.70	31.67	18.19	0.2900	2.016	1.095	10.72	8.49
	138	L07269.STS	19.66	23.46	16.85	0.2365	1.882	1.084	19.24	21.30
	139	L07270.STS	44.73	54.81	24.13	0.2186	1.582	1.062	14.85	20.06
	140	L072710.STS	51.00	54.73	24.65	0.2311	1.740	1.090	10.41	5.13
	141	L072711.STS	36.78	46.29	21.98	0.2632	2.126	1.105	17.58	14.16
	142	L072712.STS	50.41	52.52	24.34	0.2358	1.888	1.083	5.98	3.38
	143	L072713.STS	50.96	54.66	25.18	0.2721	1.915	1.066	6.09	0.25
	144	L072714.STS	46.56	56.30	25.51	0.2706	2.100	1.088	9.86	4.03
	145	L072715.STS	42.18	51.34	23.10	0.2722	1.825	1.096	14.43	8.60
	146	L072716.STS	48.20	53.49	24.63	0.2616	1.938	1.099	17.55	11.72
	147	L072717.STS	50.27	58.87	26.32	0.2390	1.753	1.096	15.98	10.14
	148	L072718.STS	47.27	54.01	24.52	0.2417	1.936	1.106	16.37	10.52
	149	L072719.STS	49.92	56.69	25.73	0.2365	1.899	1.090	14.55	8.69
	150	L07272.STS	39.48	49.25	23.03	0.2519	1.999	1.089	17.96	24.78

BAD FILES		FILE NAME	AEROSTAR POWER (kW)	SERI POWER (kW)	23 m WIND SPEED (mph)	23 m WIND SPEED (cov)	PEAK/ MEAN WIND SPEED	SONIC/ MEAN WIND SPEED	SERI YAW ERROR (deg)	AEROSTAR YAW ERROR (deg)
	151	L072720.STS	52.46	59.64	27.56	0.2661	1.774	1.094	14.93	9.07
	152	L072721.STS	50.37	55.52	25.93	0.2653	1.819	1.093	18.74	12.89
	153	L072722.STS	49.65	55.88	24.93	0.2179	1.847	1.108	17.40	11.56
	154	L072723.STS	47.36	54.38	24.61	0.2219	1.799	1.094	18.35	12.51
	155	L072724.STS	46.26	49.85	22.93	0.2415	1.834	1.112	17.69	11.84
	156	L072725.STS	33.95	37.04	19.72	0.2638	2.073	1.132	20.87	16.78
	157	L072726.STS	38.52	47.41	22.77	0.2636	1.859	1.123	21.26	21.66
	158	L072727.STS	40.48	46.19	22.06	0.2442	1.735	1.129	22.10	21.73
	159	L072728.STS	36.94	42.79	21.28	0.2531	1.791	1.119	19.31	16.66
	160	L072729.STS	32.07	35.09	19.53	0.2738	2.064	1.137	19.91	16.05
	161	L07273.STS	43.14	53.63	24.48	0.2550	1.851	1.074	10.80	20.57
	162	L072730.STS	41.96	41.84	21.70	0.2364	1.911	1.125	23.12	17.56
	163	L072731.STS	27.90	28.79	17.58	0.2703	1.977	1.181	22.49	23.17
	164	L072732.STS	29.19	33.75	18.83	0.2522	2.014	1.114	7.24	10.17
	165	L072733.STS	36.87	46.00	21.57	0.2512	1.761	1.104	5.77	6.77
	166	L072734.STS	40.02	46.66	21.56	0.2441	1.734	1.104	5.12	6.11
	167	L072735.STS	38.25	43.67	20.99	0.2737	1.894	1.094	1.12	1.05
	168	L072736.STS	32.66	40.24	19.78	0.2604	1.893	1.117	9.62	5.15
	169	L072737.STS	33.30	34.67	19.52	0.2351	1.760	1.096	14.63	5.79
	170	L072738.STS	38.24	39.42	20.21	0.2327	1.733	1.094	14.77	4.20
	171	L072739.STS	37.78	38.12	20.18	0.2272	1.792	1.117	18.66	7.96
	172	L07274.STS	47.71	52.33	23.87	0.2488	1.842	1.074	-0.39	-2.68
	173	L072740.STS	34.08	39.17	19.81	0.2632	1.864	1.103	11.14	2.82
	174	L072741.STS	36.81	42.20	20.79	0.2641	1.846	1.088	12.81	5.73
	175	L072742.STS	31.24	34.07	18.52	0.3474	2.021	1.116	16.02	8.96
	176	L072743.STS	34.11	38.16	19.40	0.2615	1.848	1.099	14.40	7.34
	177	L072744.STS	35.03	39.68	19.77	0.2826	2.016	1.127	12.66	5.60
	178	L072745.STS	37.71	45.36	21.21	0.3014	1.909	1.098	12.34	5.30
	179	L072746.STS	43.04	44.52	21.41	0.2680	1.838	1.105	14.87	7.86
	180	L072747.STS	34.17	33.39	19.27	0.2825	2.074	1.097	14.16	5.44
	181	L072748.STS	26.31	31.64	17.72	0.2624	1.834	1.104	10.85	4.28
	182	L072749.STS	38.16	44.27	21.43	0.2564	1.867	1.052	4.97	10.23
	183	L07275.STS	50.47	59.79	26.35	0.2426	1.761	1.067	8.22	2.93
	184	L072751.STS	38.82	46.48	22.29	0.2534	1.834	1.059	9.24	15.31
	185	L072752.STS	36.56	40.05	20.76	0.2911	2.071	1.048	11.50	16.26
	186	L072753.STS	46.16	52.69	24.43	0.2185	1.667	1.053	13.90	16.74
	187	L072754.STS	32.78	33.16	19.43	0.2773	2.017	1.098	19.54	22.86
	188	L072755.STS	34.73	40.41	21.80	0.2839	1.793	1.076	19.09	26.25
	189	L072756.STS	39.45	41.51	21.82	0.2407	1.934	1.083	17.63	24.77
	190	L072757.STS	36.36	45.45	21.99	0.3319	2.054	1.061	15.71	22.83
	191	L072758.STS	33.25	43.49	20.70	0.3041	2.039	1.079	12.91	20.01
	192	L072759.STS	36.17	41.10	20.93	0.2564	1.953	1.069	11.95	19.03
	193	L07276.STS	53.10	59.97	26.37	0.2319	1.826	1.079	11.53	6.25
	194	L072760.STS	39.68	45.37	21.86	0.2418	1.977	1.059	12.66	19.70
	195	L072761.STS	33.78	44.44	20.98	0.2622	2.064	1.068	13.28	20.29
	196	L072762.STS	47.32	55.53	25.86	0.2533	1.937	1.050	11.47	18.46
	197	L072763.STS	50.30	59.12	26.17	0.2212	1.637	1.056	11.19	18.18
	198	L072764.STS	53.38	55.24	25.65	0.2347	1.833	1.057	11.26	18.23
	199	L072765.STS	51.33	58.37	26.60	0.2607	1.790	1.071	13.47	20.44
	200	L072766.STS	51.85	57.76	27.01	0.2528	1.809	1.080	17.47	24.25

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	201	L072767.STS	52.33	56.47	25.75	0.2222	1.655	1.071	17.07	20.74
	202	L072768.STS	51.87	59.27	26.85	0.2458	1.699	1.068	18.33	21.96
	203	L072769.STS	50.30	57.62	24.91	0.2285	1.756	1.068	13.88	17.48
	204	L07277.STS	51.13	56.65	25.48	0.2417	1.778	1.080	14.80	9.52
	205	L072770.STS	51.51	61.14	26.30	0.2475	1.830	1.058	9.25	16.68
	206	L072771.STS	56.33	61.32	27.25	0.2183	1.700	1.050	8.30	16.90
	207	L072772.STS	52.01	58.67	25.91	0.2179	1.797	1.066	13.92	21.86
	208	L072773.STS	57.77	63.24	28.61	0.2160	1.687	1.061	10.89	17.80
	209	L072774.STS	50.07	56.69	25.67	0.2636	2.061	1.080	10.63	17.48
	210	L072775.STS	53.67	63.61	27.63	0.2301	1.864	1.064	8.69	15.48
	211	L072776.STS	49.89	57.35	26.37	0.2642	1.861	1.069	12.93	19.70
	212	L072777.STS	54.93	56.90	26.42	0.2367	1.742	1.073	12.10	18.82
	213	L072778.STS	47.85	56.52	25.47	0.2423	1.868	1.071	12.41	19.08
	214	L072779.STS	54.64	62.33	27.84	0.2183	1.772	1.071	12.55	19.19
	215	L07278.STS	51.56	57.49	25.36	0.2163	1.714	1.089	15.33	10.05
	216	L072780.STS	47.54	56.22	25.82	0.2463	1.733	1.085	16.00	22.37
	217	L072781.STS	46.23	54.58	24.19	0.2545	1.784	1.076	14.43	14.88
	218	L072782.STS	47.48	53.45	23.96	0.2411	1.660	1.098	17.78	18.24
	219	L072783.STS	48.27	54.66	24.03	0.2439	1.812	1.084	15.13	15.57
	220	L072784.STS	45.44	49.62	24.84	0.2628	2.049	1.081	20.27	20.72
	221	L072785.STS	38.50	47.97	22.38	0.2014	1.667	1.097	22.29	22.72
	222	L07279.STS	49.68	52.46	24.28	0.2534	2.111	1.089	13.44	8.16
	223	L07280.STS	47.74	56.05	24.69	0.2694	1.796	1.084	11.85	17.09
	224	L072810.STS	54.20	59.16	27.43	0.2437	1.713	1.076	12.07	17.91
	225	L072811.STS	53.57	60.47	27.56	0.2248	1.709	1.065	13.99	15.87
	226	L072812.STS	49.79	55.14	24.72	0.2272	1.690	1.084	14.01	15.38
	227	L072813.STS	51.07	56.81	25.52	0.2162	1.622	1.082	14.18	15.55
	228	L072814.STS	41.45	47.43	22.72	0.2705	1.932	1.101	15.99	17.36
	229	L072815.STS	36.76	51.38	22.77	0.1863	1.444	1.097	20.73	22.10
	230	L072816.STS	16.67	18.33	15.89	0.1768	1.418	1.066	7.91	6.48
	231	L072818.STS	19.93	23.97	18.39	0.2429	1.703	1.065	14.77	10.56
	232	L072819.STS	8.85	13.96	13.57	0.3997	2.154	1.074	17.78	11.08
	233	L07282.STS	48.79	56.40	25.54	0.2514	1.865	1.069	12.35	17.56
	234	L072821.STS	18.87	20.58	16.80	0.2776	1.813	1.064	12.84	9.12
	235	L072822.STS	19.33	21.16	16.71	0.2526	1.850	1.040	10.22	6.10
	236	L072823.STS	14.80	19.95	16.24	0.2675	1.880	1.010	0.33	3.35
	237	L072824.STS	26.27	31.68	18.21	0.2782	2.044	0.984	2.00	-0.78
	238	L072826.STS	35.44	39.02	20.89	0.2242	1.861	0.975	15.49	11.73
	239	L072827.STS	37.66	41.92	21.63	0.2386	1.664	0.984	14.02	13.76
	240	L072828.STS	32.93	43.69	20.32	0.2590	1.890	1.002	12.64	15.62
	241	L072829.STS	35.24	39.57	20.88	0.2485	1.827	1.003	16.87	19.87
	242	L07283.STS	51.06	57.17	25.96	0.2419	1.730	1.080	12.66	17.87
	243	L072830.STS	25.73	30.00	18.42	0.2870	1.870	1.000	22.76	22.50
	244	L072831.STS	31.33	38.57	19.82	0.2781	1.934	1.002	15.02	13.26
	245	L072832.STS	32.17	33.27	19.29	0.3160	1.925	1.002	13.72	14.59
	246	L072833.STS	32.33	38.33	20.33	0.2370	1.762	1.008	13.10	17.44
	247	L072834.STS	25.73	36.05	18.65	0.2500	1.782	1.001	10.95	11.82
	248	L072835.STS	26.51	29.39	17.89	0.2942	1.940	1.018	17.06	17.92
	249	L072836.STS	36.39	42.09	21.24	0.2496	1.729	1.004	14.33	15.20
	250	L072837.STS	31.11	37.98	19.78	0.2608	1.780	0.995	14.35	15.23

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	251	L072838.STS	23.51	24.27	16.94	0.2594	1.824	1.021	18.98	19.84
	252	L072839.STS	30.00	37.12	19.88	0.2315	1.732	1.020	21.90	22.76
	253	L07284.STS	51.88	59.40	26.71	0.2438	1.895	1.083	10.42	15.62
	254	L072840.STS	27.04	27.23	17.85	0.2673	1.994	1.034	18.34	19.18
	255	L072841.STS	34.63	38.40	20.33	0.2636	1.847	1.015	19.15	19.97
	256	L072842.STS	35.23	44.54	21.23	0.2846	2.038	0.993	14.42	16.85
	257	L072843.STS	37.11	42.94	21.39	0.2771	1.807	1.031	12.48	21.60
	258	L072844.STS	36.45	40.97	21.29	0.2277	1.890	1.025	17.53	26.63
	259	L072845.STS	37.63	48.08	21.90	0.2405	1.804	1.016	9.53	18.40
	260	L072846.STS	37.03	42.94	21.33	0.2573	1.960	1.035	12.98	24.01
	261	L072847.STS	33.48	40.60	20.18	0.2434	1.848	1.022	15.84	26.18
	262	L072848.STS	41.22	45.07	22.29	0.2856	1.788	1.029	15.03	25.35
	263	L072849.STS	41.34	50.16	22.75	0.2372	1.723	1.020	12.12	22.41
	264	L07285.STS	60.58	64.46	28.98	0.2103	1.803	1.067	9.76	14.98
	265	L072850.STS	54.66	58.58	26.64	0.2097	1.644	0.997	7.45	15.50
	266	L072851.STS	42.96	44.91	22.32	0.2616	1.820	1.010	12.88	20.35
	267	L072852.STS	41.81	52.03	23.25	0.2368	1.814	1.014	12.57	20.03
	268	L072853.STS	44.43	52.44	23.53	0.2322	1.858	1.024	14.74	22.18
	269	L072854.STS	48.52	57.41	24.93	0.1997	1.702	1.007	13.49	20.92
	270	L072855.STS	44.25	49.92	22.43	0.2133	1.802	1.022	6.37	19.19
	271	L072856.STS	44.63	50.45	23.46	0.2573	1.798	1.026	4.89	17.98
	272	L072857.STS	51.61	59.94	26.72	0.2385	1.624	1.011	3.91	16.99
	273	L072858.STS	49.14	57.59	24.77	0.2242	1.716	1.016	2.47	15.55
	274	L072859.STS	54.45	60.18	26.19	0.2394	1.866	1.020	5.51	16.31
	275	L07286.STS	55.31	58.34	27.08	0.2298	1.855	1.073	10.58	15.78
	276	L07287.STS	51.05	55.94	26.32	0.2965	2.063	1.075	12.22	16.85
	277	L07288.STS	47.18	56.42	25.38	0.2751	1.967	1.065	8.35	11.26
	278	L07289.STS	49.17	57.58	25.50	0.2314	1.931	1.081	12.35	18.19
	279	L07290.STS	54.15	61.20	26.66	0.1908	1.548	1.073	13.73	18.40
	280	L072910.STS	37.46	42.95	21.41	0.3127	2.065	1.091	10.62	8.20
	281	L072911.STS	38.83	40.89	21.11	0.2578	2.080	1.107	13.31	10.92
	282	L072912.STS	32.71	38.50	20.56	0.2457	1.845	1.106	17.41	17.36
	283	L072913.STS	32.50	35.90	19.23	0.2802	2.073	1.119	3.17	10.83
	284	L072914.STS	35.56	40.50	20.19	0.2797	1.892	1.102	4.21	6.49
	285	L072915.STS	41.36	47.83	21.78	0.2316	1.728	1.076	-0.20	2.08
	286	L072916.STS	37.58	43.78	21.41	0.2491	1.911	1.078	2.74	5.04
	287	L072917.STS	34.13	41.52	20.34	0.2615	1.815	1.097	6.75	4.05
	288	L072918.STS	31.65	35.19	19.36	0.2361	1.888	1.103	9.02	5.11
	289	L072919.STS	33.57	37.78	19.79	0.2362	1.878	1.093	10.76	3.59
	290	L07292.STS	37.13	43.35	22.06	0.2490	1.844	1.106	21.36	28.86
	291	L072920.STS	34.67	41.85	21.22	0.2400	1.906	1.087	11.53	4.38
	292	L072921.STS	31.98	35.01	19.32	0.2723	1.813	1.096	8.52	0.65
	293	L072922.STS	29.44	34.91	19.22	0.2617	1.856	1.096	15.59	5.09
	294	L072923.STS	23.14	29.88	17.77	0.2291	1.857	1.085	11.42	0.92
	295	L072924.STS	25.32	25.93	17.41	0.2731	2.082	1.094	12.68	2.19
	296	L072925.STS	22.96	25.76	16.61	0.3054	2.058	1.116	14.02	3.53
	297	L072926.STS	25.94	25.26	17.84	0.3099	2.011	1.090	12.95	3.43
	298	L072927.STS	20.08	20.28	16.10	0.3199	2.311	1.115	17.64	15.01
	299	L072928.STS	16.99	21.76	15.72	0.3807	2.259	1.125	11.14	11.39
	300	L072929.STS	16.71	22.71	15.86	0.3089	2.109	1.171	17.47	21.17

BAD FILES		FILE NAME	AEROSTAR POWER (kW)	SERI POWER (kW)	23 m WIND SPEED (mph)	23 m WIND SPEED (cov)	PEAK/ MEAN WIND SPEED	SONIC/ MEAN WIND SPEED	SERI YAW ERROR (deg)	AEROSTAR YAW ERROR (deg)
	301	L07293.STS	35.22	38.85	21.25	0.2632	1.914	1.140	22.70	29.28
	302	L072930.STS	12.46	15.54	14.07	0.3194	2.500	1.170	15.27	22.42
	303	L072931.STS	11.80	14.50	13.64	0.3326	2.136	1.146	5.77	11.03
	304	L072932.STS	20.77	21.30	16.16	0.2945	2.159	1.121	7.51	4.26
	305	L072933.STS	22.94	20.86	16.42	0.2666	1.987	1.118	10.08	0.90
	306	L072934.STS	26.71	26.50	17.29	0.2875	2.134	1.128	9.71	-0.32
	307	L072935.STS	23.78	29.18	17.66	0.2857	2.120	1.104	8.64	-1.38
	308	L072936.STS	22.24	21.25	16.26	0.2986	1.995	1.118	11.65	2.75
	309	L072937.STS	28.19	33.14	19.66	0.2398	1.747	1.094	15.34	8.03
	310	L072938.STS	19.19	22.24	16.03	0.2723	1.917	1.148	18.90	12.40
	311	L072939.STS	13.90	14.87	14.68	0.2806	1.887	1.148	9.79	17.28
	312	L07294.STS	32.05	33.39	19.16	0.3206	2.159	1.139	14.28	20.56
	313	L072940.STS	9.87	10.20	13.30	0.2831	2.029	1.198	12.84	19.56
	314	L072941.STS	9.81	10.53	12.54	0.2915	1.802	1.182	7.89	13.72
	315	L072942.STS	14.92	13.55	14.08	0.3069	2.189	1.199	16.39	17.22
	316	L072943.STS	12.00	15.07	13.72	0.3602	2.114	1.157	0.76	8.61
	317	L072944.STS	15.28	17.07	14.48	0.3514	2.329	1.128	6.38	10.84
	318	L072945.STS	13.82	16.34	14.67	0.2742	1.960	1.130	7.33	7.55
	319	L072946.STS	17.09	21.53	15.46	0.3198	1.999	1.099	5.27	5.27
	320	L072947.STS	1.13	18.05	14.53	0.3418	1.976	1.106	6.12	1.18
	321	L072948.STS	-1.75	19.58	15.24	0.2981	1.936	1.080	13.46	70.06
	322	L072949.STS	-0.19	19.41	15.98	0.2569	1.972	1.077	14.96	98.94
	323	L07295.STS	41.44	47.55	22.61	0.2638	1.789	1.091	7.37	12.20
	324	L072950.STS	-0.19	23.45	17.61	0.2302	1.746	1.091	16.89	100.90
	325	L072951.STS	-0.21	23.31	17.12	0.2589	1.874	1.097	18.11	102.26
	326	L072952.STS	14.68	20.65	16.32	0.2390	1.869	1.140	19.91	18.00
	327	L072953.STS	15.79	15.38	14.90	0.2638	1.852	1.141	16.38	12.93
	328	L072954.STS	14.67	17.45	14.84	0.2901	1.931	1.127	9.28	11.61
	329	L072955.STS	11.98	12.88	13.56	0.2998	2.007	1.142	6.37	9.14
	330	L072956.STS	14.62	15.85	14.17	0.3070	2.095	1.137	8.89	12.32
	331	L072957.STS	11.21	12.46	12.81	0.3109	2.213	1.204	15.57	18.29
	332	L072958.STS	6.69	7.01	11.82	0.3154	1.944	1.145	9.00	12.00
	333	L072959.STS	10.58	16.29	13.71	0.2687	1.802	1.112	3.87	7.55
	334	L07296.STS	50.45	54.46	25.54	0.2656	1.898	1.068	6.20	6.52
	335	L072960.STS	16.23	17.10	15.33	0.2561	2.115	1.119	8.76	8.61
	336	L072961.STS	10.42	13.13	13.38	0.2768	2.020	1.137	13.54	11.02
	337	L072962.STS	14.04	11.87	13.83	0.2593	1.769	1.120	12.36	8.25
	338	L072963.STS	9.97	10.93	13.76	0.2452	1.779	1.100	10.36	6.14
	339	L072964.STS	5.79	7.38	11.52	0.2523	1.897	1.133	8.34	3.32
	340	L072965.STS	3.87	4.07	10.24	0.2542	1.939	1.094	7.46	-3.86
	341	L072966.STS	2.62	2.92	9.87	0.2505	1.843	1.090	13.34	-12.13
	342	L072967.STS	1.72	1.36	9.51	0.2699	1.771	1.146	-14.52	-21.05
	343	L072968.STS	8.11	6.08	11.89	0.3780	1.998	1.002	12.62	16.18
	344	L07297.STS	44.90	48.67	23.75	0.2886	1.866	1.080	8.81	6.33
	345	L072970.STS	10.83	13.33	13.03	0.3483	2.334	1.051	7.53	2.00
	346	L072971.STS	13.24	15.41	13.81	0.3234	1.994	1.041	10.40	4.79
	347	L072972.STS	17.32	21.61	16.06	0.2701	1.785	0.998	14.95	26.32
	348	L072973.STS	18.51	24.20	15.49	0.2623	1.916	0.988	2.03	-1.45
	349	L072974.STS	10.87	13.98	12.61	0.3441	2.236	1.044	20.03	13.08
	350	L072975.STS	10.41	12.82	12.63	0.3855	2.402	1.051	12.03	4.38

BAD FILES		FILE NAME	AEROSTAR POWER (kW)	SERI POWER (kW)	23 m WIND SPEED (mph)	23 m WIND SPEED (cov)	PEAK/ MEAN WIND SPEED	SONIC/ MEAN WIND SPEED	SERI YAW ERROR (deg)	AEROSTAR YAW ERROR (deg)
	351	L072976.STS	8.63	10.43	11.85	0.4570	2.476	1.083	22.30	12.37
	352	L072977.STS	20.61	22.50	16.29	0.2863	1.932	0.964	-0.52	-4.12
	353	L072978.STS	8.95	8.59	12.62	0.3375	2.031	1.102	16.88	10.46
	354	L072979.STS	15.19	14.78	14.79	0.3136	1.981	1.070	18.32	15.13
	355	L07298.STS	45.72	49.75	22.93	0.2267	1.882	1.091	8.83	6.37
	356	L072980.STS	16.57	18.94	15.41	0.3070	2.038	1.081	19.51	21.98
	357	L072981.STS	17.34	20.95	15.71	0.2610	1.775	1.089	10.40	23.13
	358	L072982.STS	21.75	25.06	16.51	0.3174	2.126	1.063	4.74	18.21
	359	L072983.STS	17.36	17.90	15.44	0.2951	2.015	1.091	19.26	23.22
	360	L072984.STS	30.73	42.32	20.35	0.2581	1.845	1.122	21.48	25.66
	361	L072986.STS	37.53	45.91	21.33	0.2574	2.070	1.090	9.88	18.16
	362	L072987.STS	32.31	43.46	20.80	0.2576	1.889	1.087	10.15	18.39
	363	L072988.STS	41.64	45.23	21.41	0.2295	1.878	1.087	8.14	16.37
	364	L072989.STS	31.56	39.29	19.32	0.3565	2.251	1.126	16.19	24.40
	365	L07299.STS	44.22	48.26	23.06	0.2378	1.864	1.095	12.33	9.89
	366	L072990.STS	31.03	43.28	20.25	0.2586	2.032	1.116	19.51	27.59
	367	L07300.STS	34.45	40.10	20.40	0.2442	1.819	1.113	13.94	14.62
	368	L07301.STS	31.09	34.60	18.65	0.2848	1.980	1.125	16.82	17.37
*****	369	L073010.STS	33.00	16.33	19.91	0.2610	2.664	1.109	59.13	10.38
*****	370	L073011.STS	31.16	17.09	19.29	0.2915	2.615	1.094	63.22	12.57
*****	371	L073012.STS	26.06	19.66	17.21	0.2815	2.549	1.144	73.78	16.85
*****	372	L073013.STS	21.44	22.56	16.81	0.2365	2.581	1.135	76.35	11.24
*****	373	L073014.STS	26.23	19.55	16.96	0.3051	2.421	1.159	71.83	13.11
*****	374	L073015.STS	33.13	16.08	18.25	0.3660	3.418	1.118	55.87	6.85
*****	375	L073016.STS	32.02	16.21	19.78	0.3277	3.227	1.102	57.40	6.93
*****	376	L073017.STS	23.99	20.45	17.45	0.2884	3.604	1.156	74.32	13.35
*****	377	L073018.STS	32.77	15.88	18.88	0.3610	2.600	1.131	59.31	9.58
*****	378	L073019.STS	33.83	15.57	20.64	0.3183	2.978	1.109	57.41	8.54
*****	379	L07302.STS	30.87	36.82	18.94	0.2326	1.768	1.136	9.58	15.58
*****	380	L073020.STS	26.99	19.23	18.16	0.2598	2.525	1.128	69.47	11.68
*****	381	L073021.STS	25.28	20.23	16.86	0.3179	3.333	1.145	81.89	22.07
*****	382	L073022.STS	37.04	13.74	21.20	0.2477	2.019	1.104	50.43	8.12
*****	383	L073023.STS	45.58	9.10	22.21	0.2044	2.010	1.116	40.58	9.70
*****	384	L073024.STS	32.09	16.39	19.25	0.2525	3.312	1.118	61.99	13.21
*****	385	L073025.STS	26.28	19.39	18.31	0.2783	2.311	1.137	75.55	19.35
*****	386	L073026.STS	35.37	14.72	20.52	0.2787	3.050	1.123	62.68	17.98
*****	387	L073027.STS	24.52	20.16	18.39	0.2344	1.512	1.177	85.03	26.92
*****	388	L07303.STS	28.00	18.49	17.86	0.2941	5.194	4.260	72.56	18.57
*****	389	L07304.STS	1.51	18.19	15.89	0.7178	2.798	4.957	250.54	192.59
*****	390	L07305.STS	24.85	20.80	17.07	0.2778	3.291	1.136	74.08	14.29
*****	391	L07306.STS	30.36	17.24	18.17	0.3465	2.955	1.150	70.33	19.32
*****	392	L07307.STS	28.79	18.11	18.14	0.2936	3.396	1.150	69.32	16.18
*****	393	L07308.STS	31.21	17.02	18.67	0.2901	3.550	1.131	64.39	13.93
*****	394	L07309.STS	25.85	19.55	17.76	0.3351	3.937	1.132	72.73	16.04
	395	L07310.STS	45.07	57.02	26.53	0.2390	1.763	1.128	19.63	29.54
*****	396	L07311.STS	79.71	-14.02	-0.66	-2.2878	-54.684	-239.820	270.08	341.22
	397	L073110.STS	54.76	62.24	28.30	0.2057	1.653	1.127	20.00	27.46
	398	L073111.STS	47.00	55.41	24.52	0.1819	1.694	1.151	15.33	20.59
	399	L073112.STS	54.10	59.35	26.40	0.1999	1.570	1.136	12.08	14.69
	400	L07312.STS	51.28	61.78	27.67	0.1919	1.646	1.124	19.79	28.11

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	401	L07313.STS	59.00	62.86	28.86	0.2082	1.632	1.121	16.04	21.35
	402	L07314.STS	58.53	64.69	29.62	0.1858	1.687	1.121	21.78	27.09
	403	L07315.STS	54.33	63.09	28.77	0.1963	1.603	1.136	23.78	29.07
	404	L07316.STS	53.82	61.91	28.49	0.1887	1.572	1.135	26.61	29.12
	405	L07317.STS	52.58	57.45	26.49	0.2078	1.670	1.158	26.57	27.22
	406	L07318.STS	49.97	58.57	26.98	0.2286	1.675	1.148	24.52	31.33
	407	L07319.STS	52.21	60.20	26.13	0.1934	1.585	1.142	22.01	31.60
	408	L08010.STS	56.72	60.62	26.41	0.2051	1.627	1.136	16.58	13.32
	409	L08011.STS	55.77	60.61	25.97	0.2039	1.783	1.129	16.30	13.04
	410	L080110.STS	37.43	41.27	20.95	0.2595	1.853	1.137	5.65	7.79
	411	L080111.STS	30.66	34.45	19.01	0.2687	1.915	1.139	3.44	-4.18
	412	L080112.STS	30.02	31.62	18.74	0.2526	1.776	1.116	14.71	-3.24
	413	L080113.STS	32.58	37.13	19.10	0.2459	2.000	1.117	14.99	1.97
	414	L080114.STS	33.88	36.24	19.49	0.2492	1.701	1.088	9.87	-1.24
	415	L080115.STS	25.95	36.85	18.38	0.2550	1.874	1.081	4.83	-3.39
	416	L080116.STS	27.82	33.60	18.02	0.3422	2.017	1.102	8.23	0.02
	417	L080117.STS	28.34	33.29	18.74	0.2719	1.940	1.106	13.62	8.92
	418	L080118.STS	27.82	32.22	18.37	0.296[illegible]	2.128	1.127	21.09	12.23
	419	L080119.STS	33.51	33.19	18.90	0.2927	2.013	1.134	21.29	13.52
	420	L08012.STS	54.84	60.69	26.00	0.2119	1.629	1.120	11.42	8.19
	421	L080120.STS	22.77	27.17	17.27	0.2626	1.344	1.150	18.01	11.26
	422	L080121.STS	18.75	20.86	15.59	0.3717	2.316	1.188	19.03	18.70
	423	L080122.STS	10.39	11.83	13.15	0.3441	2.233	1.252	20.14	29.30
	424	L080123.STS	10.95	17.63	14.52	0.3216	2.401	1.207	15.42	23.19
	425	L080124.STS	19.74	18.83	15.65	0.2831	2.123	1.187	1.64	11.55
	426	L080125.STS	4.95	6.38	12.60	0.3059	1.847	1.265	44.59	39.43
*****	427	L080126.STS	-0.14	-0.42	7.17	0.3685	2.254	1.396	51.87	48.05
	428	L080127.STS	4.05	1.43	9.03	0.5831	2.856	1.240	3.14	-6.54
*****	429	L080128.STS	-0.08	-0.33	5.26	0.3602	2.181	1.907	66.13	34.31
*****	430	L080129.STS	-0.24	-0.32	5.07	0.3049	1.878	1.867	75.96	41.33
	431	L08013.STS	55.10	58.87	26.84	0.2436	1.608	1.114	6.73	3.53
*****	432	L080130.STS	-0.19	-0.33	4.41	0.4050	2.032	2.062	92.27	68.02
*****	433	L080131.STS	-0.19	-0.32	3.82	0.3539	1.813	2.084	132.71	114.74
*****	434	L080132.STS	-0.19	-0.32	3.41	0.2191	1.509	2.401	90.29	72.44
*****	435	L080133.STS	-0.19	-0.34	2.23	0.7014	3.940	2.943	31.73	13.49
*****	436	L080134.STS	-0.19	-0.33	7.00	0.1925	1.522	1.299	9.19	-25.21
*****	437	L080135.STS	-0.19	-0.32	8.90	0.1625	1.477	1.310	31.29	-9.36
*****	438	L080136.STS	-0.19	-0.32	7.59	0.3102	2.023	1.450	28.44	0.40
*****	439	L080137.STS	-0.19	2.12	9.24	0.2165	1.702	1.320	24.63	-3.40
*****	440	L080138.STS	-0.19	1.47	8.41	0.2597	1.875	1.286	16.18	-11.86
*****	441	L080139.STS	-0.19	2.11	8.59	0.2850	2.206	1.288	17.32	-10.73
	442	L08014.STS	57.71	64.33	27.56	0.1985	1.694	1.115	10.42	7.28
*****	443	L080140.STS	-0.19	1.08	7.58	0.2264	1.699	1.333	15.00	-13.07
*****	444	L080141.STS	-0.19	0.40	7.36	0.2295	1.742	1.387	16.97	-10.55
*****	445	L080142.STS	-0.19	0.34	7.39	0.2186	1.790	1.389	16.19	-11.85
*****	446	L080143.STS	-0.19	0.10	7.56	0.2195	1.825	1.364	19.29	-10.38
*****	447	L080144.STS	-0.19	-0.22	7.01	0.2612	2.095	1.368	18.17	-13.89
*****	448	L080145.STS	-0.19	-0.26	7.18	0.2268	1.866	1.352	20.79	-12.53
*****	449	L080146.STS	-0.19	-0.32	5.93	0.2514	1.912	1.537	28.23	-3.80
*****	450	L080147.STS	-0.19	-0.32	6.33	0.2347	1.713	1.466	26.03	-5.99

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*****	451	L080148.STS	-0.19	-0.32	5.34	0.2350	1.755	1.515	20.35	-11.61
*****	452	L080149.STS	-0.19	-0.32	6.22	0.2309	1.819	1.395	19.67	-11.99
	453	L08015.STS	43.51	49.86	23.14	0.2652	2.019	1.140	14.65	11.57
*****	454	L080150.STS	-0.19	-0.32	5.98	0.1867	1.564	1.339	5.39	-19.04
*****	455	L080151.STS	-0.19	-0.32	5.83	0.2134	1.617	1.282	-0.12	-24.54
*****	456	L080152.STS	-0.19	-0.32	5.82	0.1801	1.497	1.393	10.74	-13.66
*****	457	L080153.STS	-0.19	-0.33	5.21	0.2032	1.696	1.572	16.34	-8.02
*****	458	L080154.STS	-0.20	-0.33	5.88	0.2796	1.632	1.436	14.67	-8.19
*****	459	L080155.STS	-0.20	-0.33	6.23	0.1870	1.503	1.071	-14.07	-27.91
*****	460	L080156.STS	-0.20	-0.33	4.92	0.2834	1.800	1.284	2.87	1.48
*****	461	L080157.STS	-0.21	-0.33	4.56	0.2087	1.801	1.048	27.17	24.81
*****	462	L080158.STS	-0.20	-0.34	3.68	0.2738	1.707	1.382	56.08	63.87
*****	463	L080159.STS	20.94	15.88	16.81	0.2483	1.732	1.130	19.52	31.29
	464	L08016.STS	41.50	44.35	21.77	0.2428	1.796	1.157	13.60	10.53
*****	465	L080160.STS	3.73	1.21	69.18	0.0493	1.745	1.787	81.72	96.49
	466	L080161.STS	30.79	33.91	19.34	0.2440	1.786	1.117	16.57	20.94
	467	L080162.STS	33.38	39.05	20.52	0.2431	1.851	1.066	2.26	3.34
	468	L080163.STS	27.75	29.54	18.02	0.3405	2.230	1.076	10.89	9.44
	469	L080164.STS	25.08	28.05	17.39	0.2760	1.729	1.133	16.33	14.74
	470	L080165.STS	27.30	37.21	18.62	0.3077	1.843	1.095	13.60	13.67
	471	L080166.STS	33.59	41.92	20.68	0.3365	1.942	1.048	2.20	1.93
	472	L080167.STS	30.03	34.08	18.64	0.2586	1.933	1.077	12.78	7.57
	473	L080168.STS	25.33	31.13	17.66	0.3206	2.018	1.096	12.02	10.17
	474	L080169.STS	32.31	41.88	20.61	0.3006	1.908	1.072	0.83	6.34
	475	L08017.STS	34.01	39.52	19.95	0.2501	1.949	1.186	16.92	16.25
	476	L080170.STS	28.53	32.60	18.44	0.3419	2.097	1.088	1.99	10.96
	477	L080171.STS	32.79	32.19	19.40	0.3164	1.958	1.126	12.71	21.14
	478	L080172.STS	37.35	42.40	21.25	0.3092	1.919	1.083	5.38	11.30
	479	L080173.STS	40.22	47.99	22.28	0.2310	1.847	1.070	9.24	11.30
	480	L080174.STS	39.11	44.52	21.98	0.3507	2.114	1.066	5.59	6.66
	481	L080175.STS	45.65	52.14	24.07	0.2692	1.748	1.039	14.12	3.36
	482	L080176.STS	44.97	58.44	24.26	0.2488	1.810	1.051	12.31	3.20
	483	L080177.STS	49.17	53.97	24.32	0.2384	1.945	1.062	16.99	7.98
	484	L080178.STS	42.22	46.11	22.81	0.2853	1.951	1.079	19.79	11.31
	485	L080179.STS	49.32	55.70	25.11	0.2348	1.729	1.077	15.25	10.73
	486	L080180.STS	46.37	54.79	24.47	0.2351	1.802	1.077	14.66	12.78
	487	L080181.STS	45.17	51.87	23.38	0.2665	1.829	1.102	16.98	15.68
	488	L080182.STS	51.47	57.67	25.79	0.2007	1.574	1.072	13.80	16.31
	489	L080183.STS	51.30	58.03	26.57	0.2267	1.779	1.074	12.81	17.87
	490	L080184.STS	47.41	53.09	24.61	0.2659	1.876	1.095	13.59	19.33
	491	L080185.STS	57.58	61.10	27.53	0.2068	1.603	1.086	11.10	16.87
	492	L080186.STS	51.79	57.26	26.11	0.2602	1.808	1.084	10.84	16.63
	493	L080187.STS	40.93	47.66	21.82	0.2465	1.796	1.108	10.91	16.71
	494	L080188.STS	48.49	49.69	22.83	0.2507	1.668	1.082	9.19	15.02
	495	L080189.STS	49.09	57.[illegible]1	25.12	0.2488	1.695	1.085	11.19	17.04
	496	L080190.STS	50.39	60.03	25.51	0.2249	1.990	1.074	8.54	14.41
	497	L080191.STS	51.39	56.81	25.47	0.2430	1.636	1.086	9.17	17.16
	498	L080192.STS	50.57	55.95	25.19	0.2511	1.712	1.085	7.18	16.83
	499	L080193.STS	51.29	59.95	25.49	0.2200	1.654	1.081	7.50	17.17
	500	L080194.STS	47.03	53.60	24.55	0.2572	1.787	1.083	8.03	17.72

BAD FILES		FILE NAME	AEROSTAR POWER (kW)	SERI POWER (kW)	23 m WIND SPEED (mph)	23 m WIND SPEED (cov)	PEAK/ MEAN WIND SPEED	SONIC/ MEAN WIND SPEED	SERI YAW ERROR (deg)	AEROSTAR YAW ERROR (deg)
*****	451	L080148.STS	-0.19	-0.32	5.34	0.2350	1.755	1.515	20.35	-11.61
*****	452	L080149.STS	-0.19	-0.32	6.22	0.2309	1.819	1.395	19.67	-11.99
	453	L08015.STS	43.51	49.86	23.14	0.2652	2.019	1.140	14.65	11.57
*****	454	L080150.STS	-0.19	-0.32	5.98	0.1867	1.564	1.339	5.39	-19.04
*****	455	L080151.STS	-0.19	-0.32	5.83	0.2134	1.617	1.282	-0.12	-24.54
*****	456	L080152.STS	-0.19	-0.32	5.82	0.1801	1.497	1.393	10.74	-13.66
*****	457	L080153.STS	-0.19	-0.33	5.21	0.2032	1.696	1.572	16.34	-8.02
*****	458	L080154.STS	-0.20	-0.33	5.88	0.2796	1.632	1.436	14.67	-8.19
*****	459	L080155.STS	-0.20	-0.33	6.23	0.1870	1.503	1.071	-14.07	-27.91
*****	460	L080156.STS	-0.20	-0.33	4.92	0.2834	1.800	1.284	2.87	1.48
*****	461	L080157.STS	-0.21	-0.33	4.56	0.2087	1.801	1.048	27.17	24.81
*****	462	L080158.STS	-0.20	-0.34	3.68	0.2738	1.707	1.382	56.08	63.87
*****	463	L080159.STS	20.94	15.88	16.81	0.2483	1.732	1.130	19.52	31.29
	464	L08016.STS	41.50	44.35	21.77	0.2428	1.796	1.157	13.60	10.53
*****	465	L080160.STS	3.73	1.21	69.18	0.0493	1.745	1.787	81.72	96.49
	466	L080161.STS	30.79	33.91	19.34	0.2440	1.786	1.117	16.57	20.94
	467	L080162.STS	33.38	39.05	20.52	0.2431	1.851	1.066	2.26	3.34
	468	L080163.STS	27.75	29.54	18.02	0.3405	2.230	1.076	10.89	9.44
	469	L080164.STS	25.08	28.05	17.39	0.2760	1.729	1.133	16.33	14.74
	470	L080165.STS	27.30	37.21	18.62	0.3077	1.843	1.095	13.60	13.67
	471	L080166.STS	33.59	41.92	20.68	0.3365	1.942	1.048	2.20	1.93
	472	L080167.STS	30.03	34.08	18.64	0.2586	1.933	1.077	12.78	7.57
	473	L080168.STS	25.33	31.13	17.66	0.3206	2.018	1.096	12.02	10.17
	474	L080169.STS	32.31	41.88	20.61	0.3006	1.908	1.072	0.83	6.34
	475	L08017.STS	34.01	39.52	19.95	0.2501	1.949	1.186	16.92	16.25
	476	L080170.STS	28.53	32.60	18.44	0.3419	2.097	1.088	1.99	10.96
	477	L080171.STS	32.79	32.19	19.40	0.3164	1.958	1.126	12.71	21.14
	478	L080172.STS	37.35	42.40	21.25	0.3092	1.919	1.083	5.38	11.30
	479	L080173.STS	40.22	47.99	22.28	0.2310	1.847	1.070	9.24	11.30
	480	L080174.STS	39.11	44.52	21.98	0.3507	2.114	1.066	5.59	6.66
	481	L080175.STS	45.65	52.14	24.07	0.2692	1.748	1.039	14.12	3.36
	482	L080176.STS	44.97	58.44	24.26	0.2488	1.810	1.051	12.31	3.20
	483	L080177.STS	49.17	53.97	24.32	0.2384	1.945	1.062	16.99	7.98
	484	L080178.STS	42.22	46.11	22.81	0.2853	1.951	1.079	19.79	11.31
	485	L080179.STS	49.32	55.70	25.11	0.2348	1.729	1.077	15.25	10.73
	486	L080180.STS	46.37	54.79	24.47	0.2351	1.802	1.077	14.66	12.78
	487	L080181.STS	45.17	51.87	23.38	0.2665	1.829	1.102	16.98	15.68
	488	L080182.STS	51.47	57.67	25.79	0.2007	1.574	1.072	13.80	16.31
	489	L080183.STS	51.30	58.03	26.57	0.2267	1.779	1.074	12.81	17.87
	490	L080184.STS	47.41	53.09	24.61	0.2659	1.876	1.095	13.59	19.33
	491	L080185.STS	57.58	61.10	27.53	0.2068	1.603	1.086	11.10	16.87
	492	L080186.STS	51.79	57.26	26.11	0.2602	1.808	1.084	10.84	16.63
	493	L080187.STS	40.93	47.66	21.82	0.2465	1.796	1.108	10.91	16.71
	494	L080188.STS	48.49	49.69	22.83	0.2507	1.668	1.082	9.19	15.02
	495	L080189.STS	49.09	57.21	25.12	0.2488	1.695	1.085	11.19	17.04
	496	L080190.STS	50.39	60.03	25.51	0.2249	1.990	1.074	8.54	14.41
	497	L080191.STS	51.39	56.81	25.47	0.2430	1.636	1.086	9.17	17.16
	498	L080192.STS	50.57	55.95	25.19	0.2511	1.712	1.085	7.18	16.83
	499	L080193.STS	51.29	59.95	25.49	0.2200	1.654	1.081	7.50	17.17
	500	L080194.STS	47.03	53.60	24.55	0.2572	1.787	1.083	8.03	17.72

BAD FILES		FILE NAME	AEROSTAR POWER (kW)	SERI POWER (kW)	23 m WIND SPEED (mph)	23 m WIND SPEED (cov)	PEAK/ MEAN WIND SPEED	SONIC/ MEAN WIND SPEED	SERI YAW ERROR (deg)	AEROSTAR YAW ERROR (deg)
	501	L080195.STS	50.22	60.58	25.89	0.1845	1.473	1.108	18.82	28.54
	502	L080196.STS	6.96	10.46	13.44	0.1571	1.303	1.335	36.90	59.20
	503	L08020.STS	26.12	29.37	17.38	0.2542	1.845	1.172	10.48	13.29
	504	L08021.STS	30.45	35.76	19.47	0.2690	1.706	1.161	24.10	29.01
	505	L080210.STS	12.88	15.01	13.73	0.3211	3.521	1.132	8.24	1.55
	506	L080211.STS	16.43	17.40	14.64	0.2971	3.293	1.122	10.46	1.38
	507	L080212.STS	12.27	12.34	12.63	0.3030	7.299	1.214	13.11	11.31
	508	L080213.STS	12.08	12.94	13.81	0.3150	4.571	1.170	12.82	10.94
	509	L080214.STS	13.65	14.45	13.41	0.2824	4.316	1.183	5.36	12.04
	510	L080215.STS	17.02	21.00	15.37	0.2513	4.149	1.117	13.57	7.47
*****	511	L080216.STS	11.25	11.11	12.67	0.3165	4.870	1.203	14.23	8.66
*****	512	L080217.STS	8.76	6.88	11.75	0.3106	5.168	1.212	15.37	11.62
	513	L080218.STS	7.72	10.59	12.18	0.3220	4.339	1.209	12.65	20.20
	514	L080219.STS	7.66	9.99	12.15	0.3198	4.524	1.194	13.28	16.05
	515	L08022.STS	24.83	30.26	17.20	0.2977	1.884	1.135	16.51	13.19
	516	L080220.STS	3.28	3.94	9.32	0.2610	5.811	1.254	15.18	15.93
	517	L080221.STS	5.83	5.67	10.78	0.1639	1.395	1.227	18.86	18.56
	518	L080223.STS	10.38	12.96	13.00	0.3074	4.854	1.194	12.16	20.36
	519	L080224.STS	7.77	8.98	11.47	0.3098	5.595	1.235	10.77	21.96
	520	L080225.STS	5.26	6.15	10.76	0.2601	5.624	1.192	12.41	15.75
	521	L080226.STS	6.99	7.45	10.91	0.2717	5.316	1.184	11.23	10.67
	522	L080227.STS	4.05	4.72	10.73	0.2640	5.443	1.239	14.63	21.14
	523	L080228.STS	2.97	3.53	9.28	0.3257	9.565	7.674	17.81	27.20
	524	L080229.STS	3.47	3.18	9.40	0.3167	4.791	1.173	11.91	5.48
*****	525	L08023.STS	13.20	16.66	13.88	0.3806	2.244	1.247	25.07	18.22
	526	L080230.STS	4.29	4.30	10.00	0.2820	6.513	1.147	11.50	9.86
	527	L080231.STS	3.92	6.29	9.89	0.2458	6.023	1.170	6.82	8.19
*****	528	L080233.STS	3.84	3.78	10.11	0.2803	5.020	1.207	16.16	20.78
	529	L080234.STS	3.81	3.90	9.94	0.2833	6.073	1.227	13.93	20.78
	530	L0802[illegible].STS	4.16	4.33	10.22	0.2985	6.102	1.213	11.77	21.63
	531	L08024.STS	17.74	19.76	15.23	0.3007	1.939	1.150	7.15	6.63
*****	532	L08025.STS	16.88	16.80	14.62	0.2806	1.951	1.179	16.49	9.94
	533	L08026.STS	13.98	15.19	14.07	0.2632	1.987	1.139	10.85	3.24
	534	L08027.STS	14.69	13.50	13.72	0.3564	5.033	1.148	15.57	6.95
	535	L08029.STS	9.16	9.99	12.54	0.3254	5.966	1.153	5.99	3.21

APPENDIX F

FLAP INPUT FILES

```
AEROSTAR ROTOR
52 FT. DIAMETER ROTOR
XX ft/s case
ALENTH     6.6
ALPHA0    -4.0
BETA0      4.0
BLSHNK     1.5
BLTIP     24.60
CHI       -4.0
CSBMAC    -0.10
DRGFRM    -0.01
HUBHT     75.
HUBRAD     1.97
KSHADW     1
NBLADS     3
NPANEL    11
OMEGA     48.0
PHIAMP     0.0
PHIOMG     0.0
PHI0       6.77
PSIZER    20.0
SHERXP     0.127
THETAP     0.0
THETAT     0.0
TSUBP      0.025
TSUB0      0.025
VHUB      32.27
XLEFT      0.0      2.46     4.92     7.38     9.84    12.30
          14.76    17.22    19.68    22.14    24.60
WEIGHT   170.0     80.0     26.00    20.00    18.00    17.34
          16.60    15.60    14.43    13.00    12.00
AEIARE   173.44    60.01    21.27    10.50     4.47     1.69
           0.59     0.35     0.26     0.10     0.06
AIEMAS     0.0      0.0      0.0      0.0      0.0      0.0
           0.0      0.0      0.0      0.0      0.0
AIFMAS     0.0      0.0      0.0      0.0      0.0      0.0
           0.0      0.0      0.0      0.0      0.0
AOFFST     0.0      0.0      0.0      0.0      0.0      0.0
           0.0      0.0      0.0      0.0      0.0
ACHORD     3.80     3.58     3.36     3.14     2.92     2.70
           2.48     2.26     2.04     1.80     1.60
ATWIST     8.40     7.56     6.72     5.88     5.04     4.20
           3.36     2.52     1.68     0.84     0.0
ACLALF     5.82     5.82     5.82     5.88     6.05     6.05
           6.18     6.23     6.23     6.23     6.23
ACLMAX     1.29     1.29     1.29     1.29     1.43     1.43
           1.51     1.55     1.55     1.55     1.55
ACDZER     0.0089   0.0089   0.0089   0.0089   0.0089   0.0089
           0.0089   0.0089   0.0089   0.0089   0.0089
AESBAC     0.0      0.0      0.0      0.0      0.0      0.0
           0.0      0.0      0.0      0.0      0.0
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SERI ROTOR
52 FT. DIAMETER ROTOR
XX ft/s case
ALENTH    6.6
ALPHA0   -2.4
BETA0     4.0
BLSHNK    1.5
BLTIP    26.00
CHI      -4.0
CSBMAC   -0.06
DRGFRM    0.006
HUBHT    75.
HUBRAD    1.97
KSHADW    1
NBLADS    3
NPANEL   11
OMEGA    48.0
PHIAMP    0.0
PHIOMG    0.0
PHI0      5.77
PSIZER   10.
SHERXP    0.127
THETAP    0.0
THETAT    0.0
TSUBP     0.025
TSUB0     0.025
VHUB     32.27
XLEFT     0.0       2.00    4.00     6.00     8.00    16.00
         17.00     18.00   22.00    24.00    26.00
WEIGHT  172.21     56.78   36.17    24.53    22.47    16.17
         25.42     25.42   11.59     6.41     2.38
AEIARE  113.95     35.87   15.82     4.16     2.41     0.50
          0.41      0.33    0.11     0.05     0.02
AIEMAS    0.0       0.0     0.0      0.0      0.0      0.0
          0.0       0.0     0.0      0.0      0.0
AIFMAS    0.0       0.0     0.0      0.0      0.0      0.0
          0.0       0.0     0.0      0.0      0.0
AOFFST    0.0       0.0     0.0      0.0      0.0      0.0
          0.0       0.0     0.0      0.0      0.0
ACHORD    1.38      1.85    3.06     3.64     3.53     2.69
          2.55      2.41    1.79     1.44     1.08
ATWIST   30.0      29.9    23.0     17.28    12.59     2.16
          1.57      1.11    0.14     0.02     0.0
ACLALF    4.00      4.08    4.15     4.23     4.31     4.62
          4.65      4.69    4.85     4.92     5.00
ACLMAX    1.40      1.40    1.40     1.40     1.40     1.29
          1.27      1.26    1.20     1.15     1.10
ACDZER    0.007     0.007   0.007    0.007    0.007    0.007
          0.007     0.007   0.007    0.007    0.007
AESBAC    0.0       0.0     0.0      0.0      0.0      0.0
          0.0       0.0     0.0      0.0      0.0
```
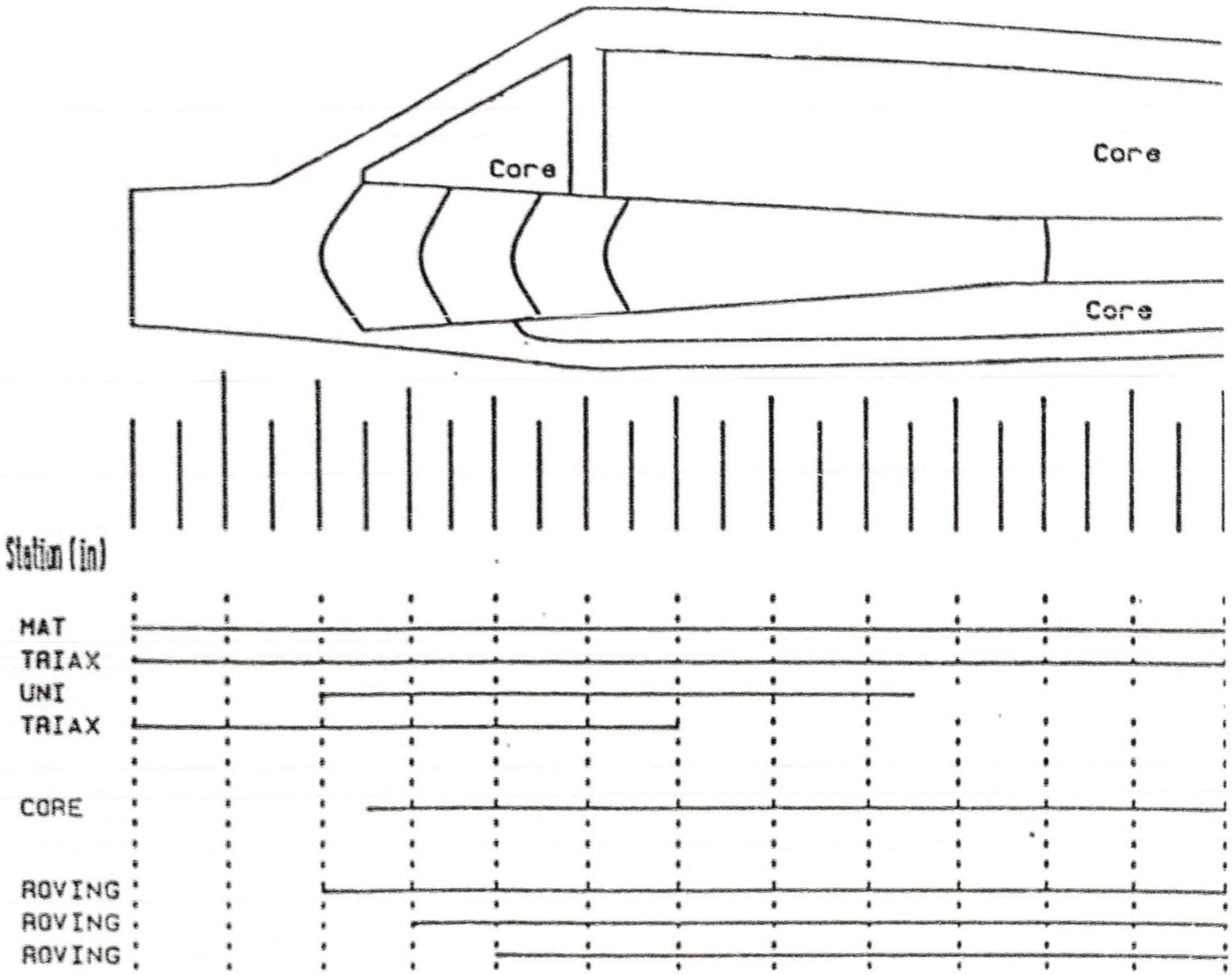

APPENDIX G

WIND TURBINE BLADE LAMINATION SCHEDULE

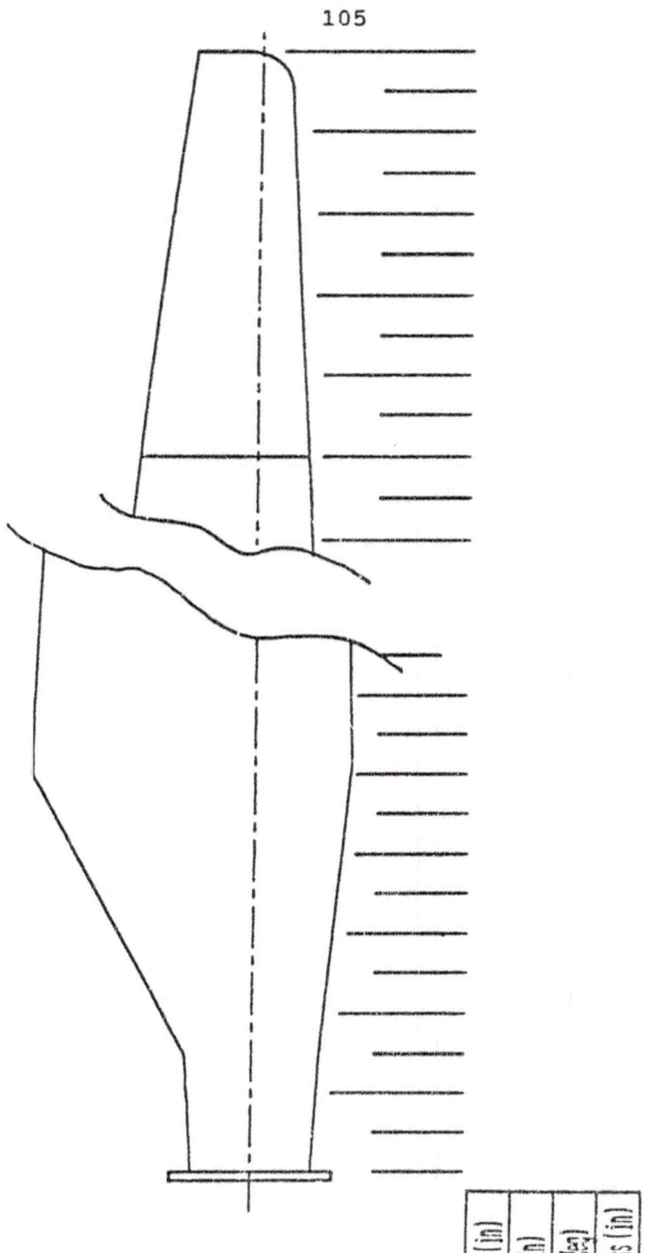
(**Figure 44.** Lamination schedule.)


Core
Core
Core
Station (in)
MAT
TRIAX
UNI
TRIAX
CORE
ROVING
ROVING
ROVING

APPENDIX H

WIND TURBINE BLADE PLANFORM

(**Figure 45.** Planform.)


105
Station (in)
Chord (in)
Twist (deg)
Thickness (in)

APPENDIX I

SERI 7.9 m AND AEROSTAR 7.5 m BLADE WEIGHT DISTRIBUTION

(**Table 12.** SERI 7.9 m blade weight distribution.)

(**Table 13.** Aerostar 7.5 m blade weight distribution.)

7.4 a [illegible] Thin Airfoil Weight Distribution

Center of Weight	12	36	60	84	108	132	156	180	204	228	252	276	300	Total
Square Footage	1.644	1.306	1.611	1.733	1.662	1.574	1.459	1.334	1.231	1.093	0.935	0.758	0.593	16.333
% of Blade Surface	0.084	0.080	0.099	0.105	0.102	0.096	0.089	0.082	0.075	0.067	0.057	0.046	0.036	1.000
Gelcoat	1.93	2.40	2.97	3.15	3.06	2.88	2.70	2.49	2.25	2.01	1.71	1.38	1.09	30.00
1 oz Chopped Mat	1.96	2.45	3.02	3.23	3.12	2.95	2.75	2.54	2.31	2.05	1.75	1.42	1.11	30.66
20 oz Triax	2.62	3.27	4.03	4.31	4.16	3.94	3.67	3.39	3.08	2.73	2.34	1.90	1.48	40.92
20 oz Triax	2.62	3.27	4.03											9.92
1 oz Chopped Mat			0.56	1.33	1.27	1.12	1.05	0.96	0.88	0.56	0.40			7.73
Foam Core			0.30	0.73	0.69	0.66	0.63	0.56	0.51	0.37	0.33			4.50
Coremat		0.32	0.78	0.84	0.81	0.77	0.72	0.66	0.60	0.37	0.27			6.14
Uni	33.90	32.73	23.63	15.10	6.75	4.95	4.16	2.78	2.78	1.39	1.39	1.39	1.14	132.60
1 oz Mat	1.96	2.45	3.02	3.23	3.12	2.95	2.75	2.54	2.31	2.05	1.75	1.42	1.11	30.66
20 oz Triax	2.62	3.27	4.03	4.31	2.08									16.31
22 oz Triax	2.62	3.27	4.03	4.31	4.16	3.94	3.67	3.39	3.08	2.73	2.34	1.90	1.48	40.92
Main Shear Web	3.23	4.90	4.48	4.28	3.80	3.50	3.20	3.63	2.80	2.40	1.30			35.03
Tip Shear Web											0.44	0.89	0.44	1.77
Blade/Tip Pipe											4.00			4.00
Main Aft Rib			1.50											1.50
Weight Tubes									0.45	0.90	0.60	0.33		2.48
Int Paste Lam	0.07	0.27	0.41	0.27	0.27	0.27	0.27	0.27	1.87	5.27	8.96	3.03	0.13	21.36
Joining Adhesive	12.10	6.35	5.61	4.23	3.17	3.17	3.17	3.17	4.83	5.45	6.17	4.10	2.38	64.00
Root Overwrap	3.10	2.10	0.80											6.00
														0.00
Tip Mechanism										10.00	20.00	9.52		39.52
Metal Root	117.00													117.00
Total (fixed)	117.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00	20.00	9.52	0.00	156.52
Total (variable)	67.09	67.85	62.66	49.13	36.38	31.10	28.72	25.75	27.75	28.41	33.85	17.66	10.35	485.88
TOTAL	184.09	67.85	62.66	49.13	36.38	31.10	28.72	25.75	27.75	38.41	53.85	27.18	10.35	642.40
% of Total	28.66	10.66	9.75	7.65	5.66	4.84	4.47	4.01	4.32	5.98	8.38	4.23	1.61	100.00

7.5 m Aerostar Weight Distribution

Center of Weight	12	36	60	84	108	132	156	180	204	228	252	276	Total
Square Yardage	1.019	1.654	1.688	1.591	1.494	1.397	1.299	1.202	1.105	1.008	0.911	0.825	14.993
% of Blade Surface	0.068	0.097	0.113	0.106	0.100	0.093	0.087	0.080	0.074	0.067	0.061	0.055	1.001
Gelcoat lb	1.65	2.35	2.74	2.57	2.43	2.26	2.11	1.94	1.80	1.63	1.48	1.33	24.28
1 st Lamination	3.87	9.45	13.00	12.29	11.60	10.99	10.37	9.76	9.14	8.53	7.91	7.09	113.95
1 st Blade Rovings	10.21	11.03	7.84	7.13	6.95	6.77	6.59	6.40	6.22	6.04	2.75	1.55	79.48
2 nd Blade Rovings	13.38	15.02	15.90	15.52	14.44	10.02	7.83	5.12	3.07				99.30
Root Rovings	47.00	40.00											87.00
I-Beams	3.00	9.00	13.00	12.00	11.00	10.00	9.00	8.00	7.00	4.00			86.00
Wt Tubes & Tip Locks										11.45	18.90	4.01	34.36
Adhesive	21.00	17.00	16.00	15.00	14.00	13.00	12.00	11.00	13.00	14.00	17.00	7.00	170.00
Tip Mechanism										12.00	25.00	8.00	45.00
Root Metal	97.00												97.00
Total (fixed)	97.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.00	25.00	8.00	142.00
Total (variable)	100.06	103.85	68.48	64.51	60.42	53.04	47.90	42.22	39.23	45.65	48.04	20.98	694.37
TOTAL	197.06	103.85	68.48	64.51	60.42	53.04	47.90	42.22	39.23	57.65	73.04	28.98	836.37
% of Total	23.56	12.42	8.19	7.71	7.22	6.34	5.73	5.05	4.69	6.89	8.73	3.47	100.00

APPENDIX J

WEIGHT DISTRIBUTIONS USED AS FLAP INPUTS

(**Table 14.** FLAP weight distribution.)

(**Figure 46.** SERI 7.9 m weight distribution.)

(**Figure 47.** Aerostar 7.5 m weight distribution.)

BLADE: 7.9 SERI THIN AIRFOIL

BLADE POSITION

12	36	60	84	108	132	156	180	204	228	252	276	300		
117														
									10	20	9.52		156.52	fixed
67.09	67.05	62.64	49.13	36.38	31.10	28.72	25.75	27.75	28.41	33.85	17.66	10.35	485.88	variabl
184.09	67.05	62.64	49.13	36.38	31.10	28.72	25.75	27.75	38.41	53.85	27.18	10.35	642.40	TOTAL

AVERAGE VARIABLE WEIGHT PER FOOT OVER THE INTERVAL

58.5													
								0	5	10	4.76	0	fixed
33.545	33.525	31.32	24.565	18.19	15.55	14.36	12.875	13.875	14.205	16.925	8.83	5.175	variabl
92.045	33.525	31.32	24.565	18.19	15.55	14.36	12.875	13.875	19.205	26.925	13.59	5.175	

WEIGHT AT THIS POSITION

0	24	48	72	96	120	144	166	192	216	240	264	288	312	
33.545	33.535	32.4225	27.9425	21.3775	16.87	14.955	13.6175	13.375	14.04	15.565	12.8775	7.0025	2.5875	
117									1	7	7.00	0.75		
150.545	33.535	32.4225	27.9425	21.3775	16.87	14.955	13.6175	13.375	15.04	22.565	19.8775	7.7525	2.5875	
	184.08	65.9575	60.365	49.32	38.2475	31.825	28.5725	26.9925	28.415	37.605	42.4425	27.63	10.34	631.7925
				109.685		70.0725		55.565						

INTERVALS USED FOR FLAP INPUT

0	24	48	72	96	120				216	240	264	288	312	
150.545	33.535	32.4225	27.9425	21.3775	16.87				15.04	22.565	19.8775	7.7525	2.5875	
	184.08	65.9575	60.365	49.32	38.2475				127.64	37.605	42.4425	27.63	10.34	643.6275

BLADE: 7.5 m AEROSTAR

BLADE POSITION

12	36	60	84	108	132	156	180	204	228	252	276		
97									12	25	8	142	fixed
100.06	103.85	68.48	64.51	60.42	53.04	47.90	42.22	39.23	45.65	48.04	20.98	694.38	variabl
197.06	103.85	68.48	64.51	60.42	53.04	47.90	42.22	39.23	57.65	73.04	28.98	836.38	TOTAL

AVERAGE VARIABLE WEIGHT PER FOOT OVER THE INTERVAL

48.5												
									6	12.5	4	fixed
50.03	51.925	34.24	32.255	30.21	26.52	23.95	21.11	19.615	22.825	24.02	10.49	variabl
98.53	51.925	34.24	32.255	30.21	26.52	23.95	21.11	19.615	28.825	36.52	14.49	

WEIGHT AT THIS POSITION

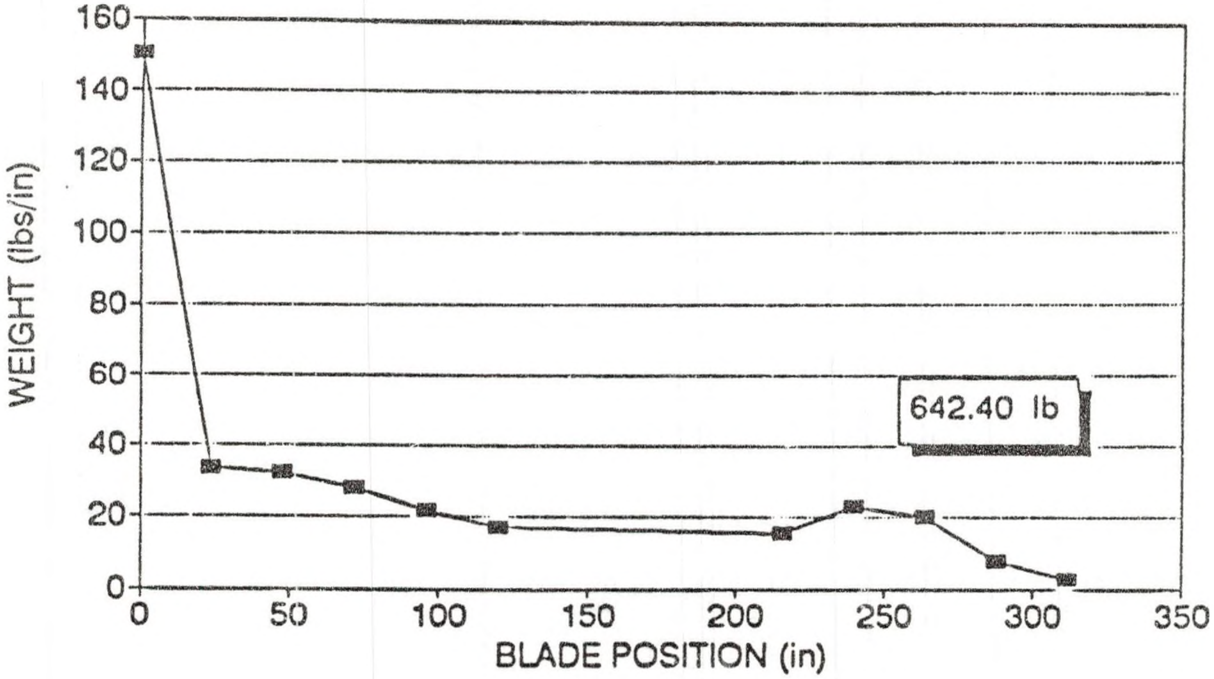
0	24	48	72	96	120	144	166	192	216	240	264	291.6	
50.03	50.9775	43.0825	33.2475	31.2325	28.365	25.235	22.53	20.3625	21.22	23.4225	17.255	5.245	
97										20	2.50	0.20	
147.03	50.9775	43.0825	33.2475	31.2325	28.365	25.235	22.53	20.3625	21.22	43.4225	19.755	5.445	
	198.0075	94.06	76.33	64.48	59.5975	53.6	47.765	42.8925	41.5825	64.6425	63.1775	28.98	835.115
				140.81		113.1975		90.6575			127.82		

INTERVALS USED FOR FLAP INPUT

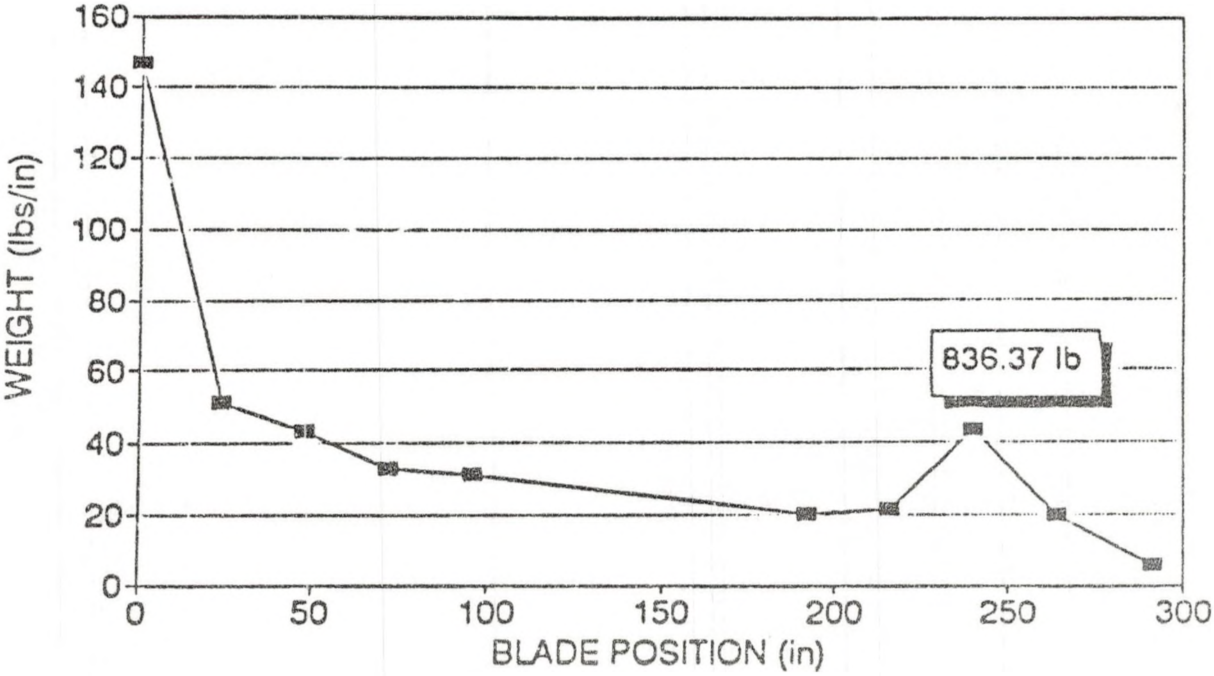
0	24	48	72	96				192	216	240	264	291.6	
147.03	50.9775	43.0825	33.2475	31.2325				20.3625	21.22	43.4225	19.755	5.445	
	198.0075	94.06	76.33	64.48				206.38	41.5825	64.6425	63.1775	28.98	837.66

WEIGHT DISTRIBUTION

7.9 m SERI THIN AIRFOIL



7.5 m Aerostar



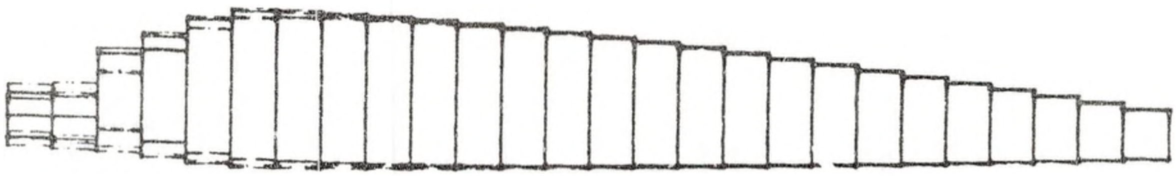
APPENDIX K

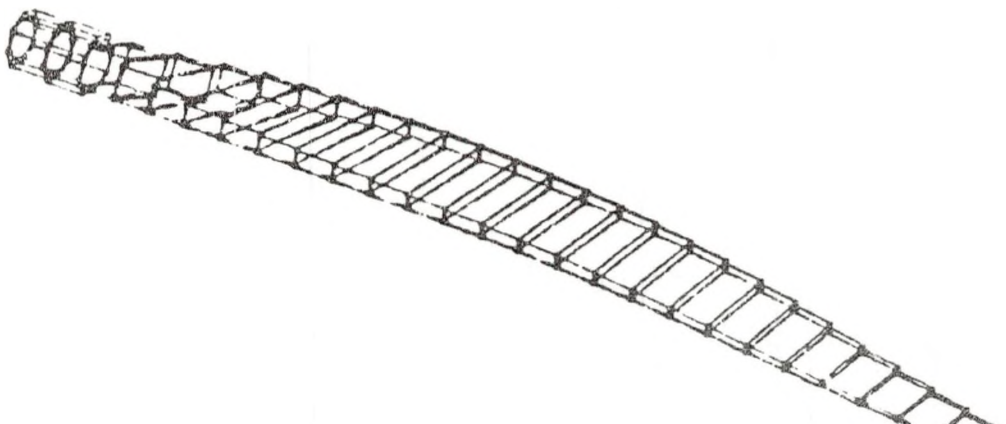
FINITE ELEMENT MODEL: SERI BLADE

(**Figure 48.** SERI 7.9 m finite element model.)

Station (in)	Chord (in)	Twist (deg)	Thicknes (in)	Trailing Edge Ratio (%)	Leading Edge Ratio (%)	Trailing Edge (in)	Leading Edge (in)	Ellipse Area (in2)	% of Area
0	16.50	N/A	16.50	0.50	0.50	8.25	8.25	213.72	2.39
6	17.13	N/A	17.13	0.50	0.50	8.57	8.57	230.35	2.58
12	17.83	N/A	17.83	0.50	0.50	8.92	8.92	249.56	2.80
18	18.50	N/A	18.50	0.50	0.50	9.25	9.25	268.67	3.01
24	22.15	29.85	17.18	0.55	0.45	12.18	9.97	298.72	3.35
30	25.79	28.83	15.85	0.59	0.41	15.22	10.57	320.89	3.59
36	29.43	26.28	14.53	0.63	0.37	18.54	10.89	335.68	3.76
42	33.08	24.60	13.21	0.65	0.35	21.50	11.58	343.03	3.84
48	36.72	23.00	11.89	0.67	0.33	24.60	12.12	342.73	3.84
54	40.36	21.46	10.56	0.69	0.31	27.85	12.51	334.57	3.75
60	44.00	20.00	9.24	0.70	0.30	30.80	13.20	319.15	3.57
66	43.89	18.61	8.95	0.70	0.30	30.72	13.17	308.36	3.45
72	43.68	17.28	8.64	0.70	0.30	30.58	13.10	296.26	3.32
78	43.41	16.01	8.32	0.70	0.30	30.39	13.02	283.52	3.18
84	43.09	14.81	7.99	0.70	0.30	30.16	12.93	270.27	3.03
90	42.73	13.67	7.68	0.70	0.30	29.91	12.82	257.61	2.89
96	42.33	12.59	7.52	0.70	0.30	29.63	12.70	249.88	2.80
102	41.89	11.57	7.36	0.70	0.30	29.32	12.57	242.02	2.71
108	41.42	10.61	7.19	0.70	0.30	28.99	12.43	233.78	2.62
114	40.92	9.70	7.01	0.70	0.30	28.64	12.28	225.18	2.52
120	40.40	8.85	6.84	0.70	0.30	28.28	12.12	216.92	2.43
126	39.84	8.04	6.66	0.70	0.30	27.89	11.95	208.29	2.33
132	39.27	7.29	6.48	0.70	0.30	27.49	11.78	199.76	2.24
138	38.66	6.58	6.30	0.70	0.30	27.06	11.60	191.19	2.14
144	38.03	5.93	6.12	0.70	0.30	26.62	11.41	182.70	2.05
150	37.38	5.31	5.94	0.70	0.30	26.17	11.21	174.30	1.95
156	36.71	4.74	5.75	0.70	0.30	25.70	11.01	165.70	1.86
162	36.02	4.22	5.57	0.70	0.30	25.21	10.81	157.50	1.76
168	35.30	3.73	5.40	0.70	0.30	24.71	10.59	149.64	1.68
174	34.57	3.28	5.23	0.70	0.30	24.20	10.37	141.93	1.59
180	33.81	2.87	5.06	0.70	0.30	23.67	10.14	134.30	1.50
186	33.04	2.50	4.89	0.70	0.30	23.13	9.91	126.83	1.42
192	32.25	2.16	4.72	0.70	0.30	22.58	9.68	119.49	1.34
198	31.44	1.85	4.55	0.70	0.30	22.01	9.43	112.30	1.26
204	30.61	1.57	4.38	0.70	0.30	21.43	9.18	105.25	1.18
210	29.76	1.33	4.21	0.70	0.30	20.83	8.93	98.35	1.10
216	28.90	1.11	4.03	0.70	0.30	20.23	8.67	91.43	1.02
222	28.02	0.91	3.86	0.70	0.30	19.61	8.41	84.90	0.95
228	27.13	0.74	3.70	0.70	0.30	18.99	8.14	78.80	0.88
234	26.21	0.59	3.53	0.70	0.30	18.35	7.86	72.63	0.81
240	25.29	0.47	3.35	0.70	0.30	17.70	7.59	66.51	0.74
246	24.34	0.36	3.18	0.70	0.30	17.04	7.30	60.76	0.68
252	23.38	0.27	3.01	0.70	0.30	16.37	7.01	55.24	0.62
258	22.41	0.20	2.85	0.70	0.30	15.69	6.72	50.14	0.56
264	21.42	0.14	2.68	0.70	0.30	14.99	6.43	45.06	0.50
270	20.42	0.09	2.52	0.70	0.30	14.29	6.13	40.39	0.45
276	19.40	0.06	2.35	0.70	0.30	13.58	5.82	35.79	0.40
282	18.37	0.03	2.19	0.70	0.30	12.86	5.51	31.58	0.35
288	17.32	0.02	2.04	0.70	0.30	12.12	5.20	27.74	0.31
294	16.26	0.01	1.88	0.70	0.30	11.38	4.88	24.00	0.27
300	15.19	0.00	1.75	0.70	0.30	10.63	4.56	20.87	0.23
306	14.10	0.00	1.62	0.70	0.30	9.87	4.23	17.93	0.20
312	13.00	0.00	1.50	0.70	0.30	9.10	3.90	15.31	0.17
								8927.446	100

RAD STATION	GROUP #	78 % THICK H	CHORD LENGTH B	WALL THICK TH	WALL THICK TB	ZA	YA	TWIST THETA	CONNECT NODE pt.	NODE ELEMENT
0	1	12.87	16.50	2.1875	--	0.000	0	N/A		
6	2	RI-6.56	RI-8.56	2.0000	1	0.000	0	N/A	1 - 3	1
12	3	13.91	17.83	1.8125	0.9554	0.000	0	N/A		
18	4	RI-7.62	RO-9.25	1.6250	0.9107	0.000	0	N/A	3 - 5	2
24	5	13.40	22.15	1.4375	0.8661	4.430	0	29.85		
30	6	12.36	25.79	1.2500	0.8214	5.158	0	28.83	5 - 7	3
36	7	11.33	29.43	1.0625	0.7768	5.886	0	26.28		
42	8	10.30	33.08	0.8750	0.7322	6.616	0	24.60	7 - 9	4
48	9	9.27	36.72	0.6875	0.6875	7.344	0	23.00		
54	10	8.24	40.36	0.6728	--	8.072	0	21.46	9 - 11	5
60	11	7.21	44.00	0.6581	--	8.800	0	20.00		
66	12	6.98	43.89	0.6434	--	8.778	0	18.61	11-13	6
72	13	6.74	43.68	0.6287	--	8.736	0	17.28		
78	14	6.49	43.41	0.6140	--	8.682	0	16.01	13-15	7
84	15	6.23	43.09	0.5993	--	8.618	0	14.81		
90	16	5.99	42.73	0.5846	--	8.546	0	13.67	15-17	8
96	17	5.87	42.33	0.5699	--	8.466	0	12.59		
102	18	5.74	41.89	0.5551	--	8.378	0	11.57	17-19	9
108	19	5.61	41.42	0.5404	--	8.284	0	10.61		
114	20	5.47	40.92	0.5257	--	8.184	0	9.70	19-21	10
120	21	5.34	40.40	0.5110	--	8.080	0	8.85		
126	22	5.19	39.84	0.4963	--	7.968	0	8.04	21-23	11
132	23	5.05	39.27	0.4816	--	7.854	0	7.29		
138	24	4.91	38.66	0.4669	--	7.732	0	6.58	23-25	12
144	25	4.77	38.03	0.4522	--	7.606	0	5.93		
150	26	4.63	37.38	0.4375	--	7.476	0	5.31	25-27	13
156	27	4.49	36.71	0.4228	--	7.342	0	4.74		
162	28	4.34	36.02	0.4081	--	7.204	0	4.22	27-29	14
168	29	4.21	35.30	0.3934	--	7.060	0	3.73		
174	30	4.08	34.57	0.3787	--	6.914	0	3.28	29-31	15
180	31	3.95	33.81	0.3640	--	6.762	0	2.87		
186	32	3.81	33.04	0.3493	--	6.608	0	2.50	31-33	16
192	33	3.68	32.25	0.3346	--	6.450	0	2.16		
198	34	3.55	31.44	0.3199	--	6.288	0	1.85	33-35	17
204	35	3.42	30.61	0.3051	--	6.122	0	1.57		
210	36	3.28	29.76	0.2904	--	5.952	0	1.33	35-37	18
216	37	3.14	28.90	0.2757	--	5.780	0	1.11		
222	38	3.01	28.02	0.2610	--	5.604	0	0.91	37-39	19
228	39	2.89	27.13	0.2463	--	5.426	0	0.74		
234	40	2.75	26.21	0.2316	--	5.242	0	0.59	39-41	20
240	41	2.61	25.29	0.2169	--	5.058	0	0.47		
246	42	2.48	24.34	0.2022	--	4.868	0	0.36	41-43	21
252	43	2.35	23.38	0.1875	--	4.676	0	0.27		
258	44	2.22	22.41	0.1875	--	4.482	0	0.20	43-45	22
264	45	2.09	21.42	0.1875	--	4.284	0	0.14		
270	46	1.97	20.42	0.1875	--	4.084	0	0.09	45-47	23
276	47	1.83	19.40	0.1875	--	3.880	0	0.06		
282	48	1.71	18.37	0.1875	--	3.674	0	0.03	47-49	24
288	49	1.59	17.32	0.1875	--	3.464	0	0.02		
294	50	1.47	16.26	0.1875	--	3.252	0	0.01	49-51	25
300	51	1.37	15.19	0.1875	--	3.038	0	0.00		
306	52	1.26	14.10	0.1875	--	2.820	0	0.00	51-53	26
312	53	1.17	13.00	0.1875	--	2.600	0	0.00		





APPENDIX L

BLADE DEFLECTION TESTS AND CALCULATED STIFFNESS DISTRIBUTIONS

(**Table 15.** SERI 7.9 m deflection test.)

(**Table 16.** Aerostar 7.5 m deflection test.)

(**Figure 49.** SERI 7.9 m deflection curve.)

(**Figure 50.** Aerostar 7.5 m deflection curve.)

(**Table 17.** Blade stiffness distributions.)

POINT LOADED 7.9 m SERI DEFLECTION TEST

DATE : 10 APRIL 91

MEASUREMENTS TAKEN AT THE 30% CHORD LINE
BLADE IN VERTICAL POSITION.

	LOAD: (lbs)	TARE	605	1220	TARE	590	1220	TARE
STATION NUMBER	STATION (in)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
0	0	24	24	24	28	28	28	28
2	12	89	89	89	92	94	93	94
4	24	76	75	74	78	78	78	78
6	36	100	98	100	103	102	100	102
8	48	144	142	144	146	144	144	146
10	60	181	180	182	184	184	183	186
12	72	197	196	196	202	199	198	201
14	84	205	203	202	209	208	205	208
16	96	212	207	205	214	211	207	214
18	108	217	210	206	219	215	207	220
20	120	221	213	207	224	217	207	225
22	132	225	215	206	228	218	206	228
24	144	229	215	203	231	219	203	232
26	156	232	215	198	234	218	198	234
28	168	237	214	193	238	219	193	240
30	180	240	213	187	241	218	187	243
32	192	243	210	179	245	214	178	246
34	204							
36	216	249	204	158	252	208	158	252
38	228							
40	240	255	194	132	257	198	132	259
42	252	257	188	116	258	192	118	262
44	264							
46	276							
48	288							
50	300							
52	312							
		JIM	JIM	BOB	BOB	BOB	BOB	BOB

NOTE: STATION 34 AND 38 - NOT ABLE TO READ

POINT LOADED 7.5 m AEROSTAR DEFLECTION TEST

DATE : 14 APRIL 91

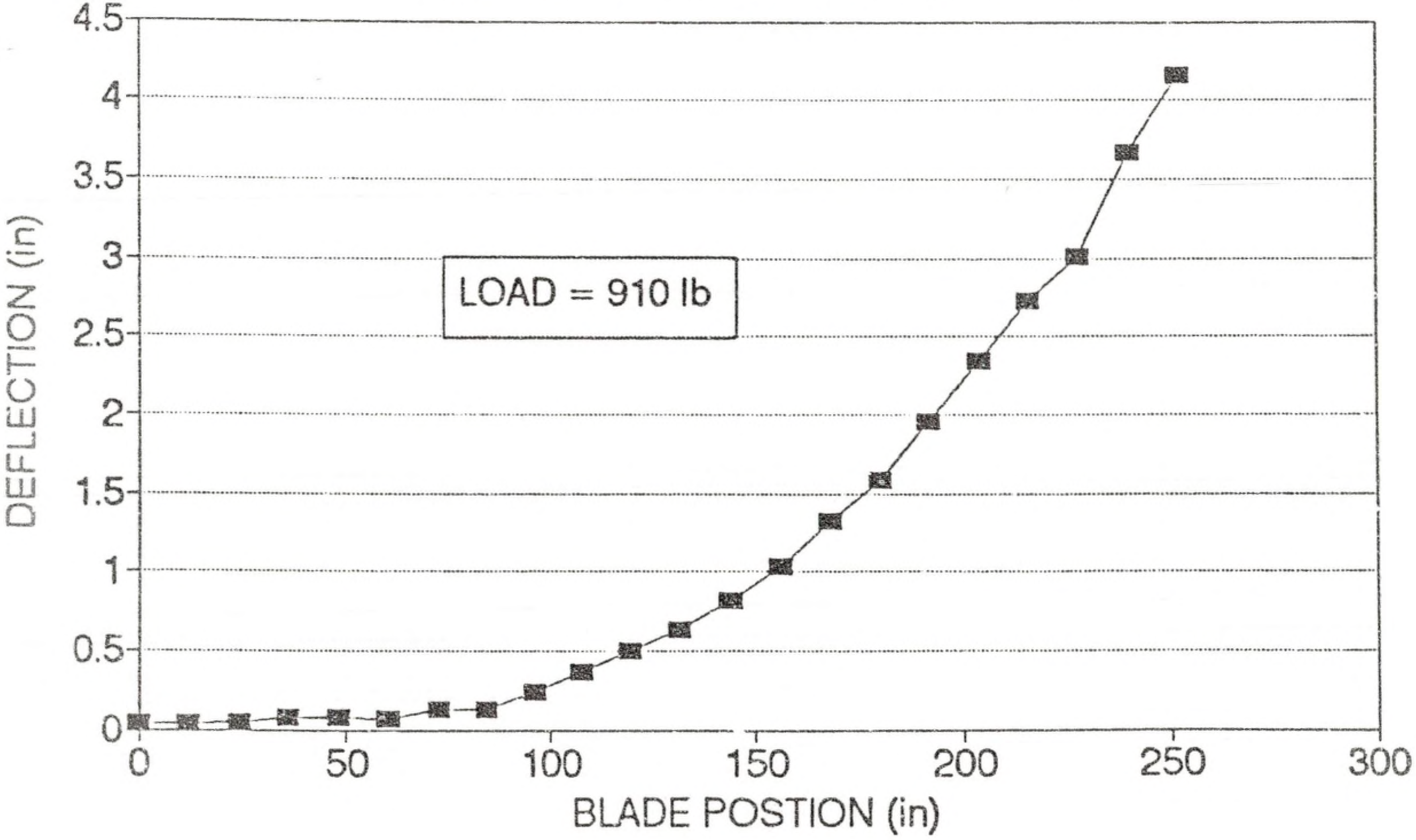
MEASUREMENTS TAKEN AT THE 30% CHORD LINE WITH THE TRAILING EDGE UP AND THE BLADE MOUNTED IN THE HORIZONTAL POSITION.

	LOAD: (lbs)	TARE	501	998	TARE	489	1002	TARE
STATION NUMBER	STATION (in)	(in)	(in)	(in)	(in)	(in)	(in)	(in)
0a	0	17.3125	17.1875	17.125	17.1563	17.1563	17.1563	17.1563
0b	0	17.375	17.1875	17.0938	17.1563	17.125	17.0938	17.1563
1	12	20.125	19.875	19.7813	19.75	19.7813	19.75	19.8125
2	24	20.125	19.8125	19.625	19.6875	19.625	19.625	19.6875
3	36	21.4375	21.0625	20.75	20.8438	20.8438	20.7813	20.875
4	48	23.5625	23.125	22.8125	22.9375		22.8125	22.9063
5	60	24.4375	23.9375	23.5625	23.6875	23.625	23.5625	23.6875
6	72	24.75	24.125	23.6875	23.9063	23.8125	23.6875	23.875
7		24.75	24.0313	23.5625	23.8125	23.6875	23.5	23.7813
8	96	24.5625	23.75	23.125	23.5	23.3438	23.1563	23.4688
9	108	24.375	23.4375	22.7188	23.1875	23	22.7188	23.1875
10	120	24.1875	23.125	22.3438	22.9063	22.6563	22.3125	22.9063
11	132	24.0625	22.875	21.9688	22.6875	22.375	21.9688	22.6563
12	144	23.9375	22.675	21.5938	22.4375	22.0625	21.5938	22.4375
13	156	23.8125	22.3125	21.1563	22.1875	21.6875	21.125	22.1563
14	168	23.625	21.9375	20.625	21.9375	21.3438	20.625	21.875
15	180	23.4375	21.5625	20.0625	21.5938	20.875	20.0313	21.5313
16	192	23.1875	21.1875	19.4688	21.2813	20.4063	19.4688	21.25
17	204	23.125	20.875	19	21.0938	20.0938	18.9688	21.0625
18	216	23.125	20.625	18.5313	21.9375	19.8125	18.5313	20.9063
19	228	23.0313	20.2813	17.9688	20.75	19.4375	17.9688	20.7188
20	240	22.9375	19.9688	17.4063	20.5625	19.0625	17.4063	20.5313
TC	247	22.9688	19.7813	17.0938	20.5	18.875	17.0625	20.4375
22	264							
23	276							
24	288							
25	291.6							

NOTE: WHEN INCREASING THE LOAD FROM 501 TO 998 THE TEST STAND MOVED, THEREFORE THE RESULTS MAYBE IN ERROR.

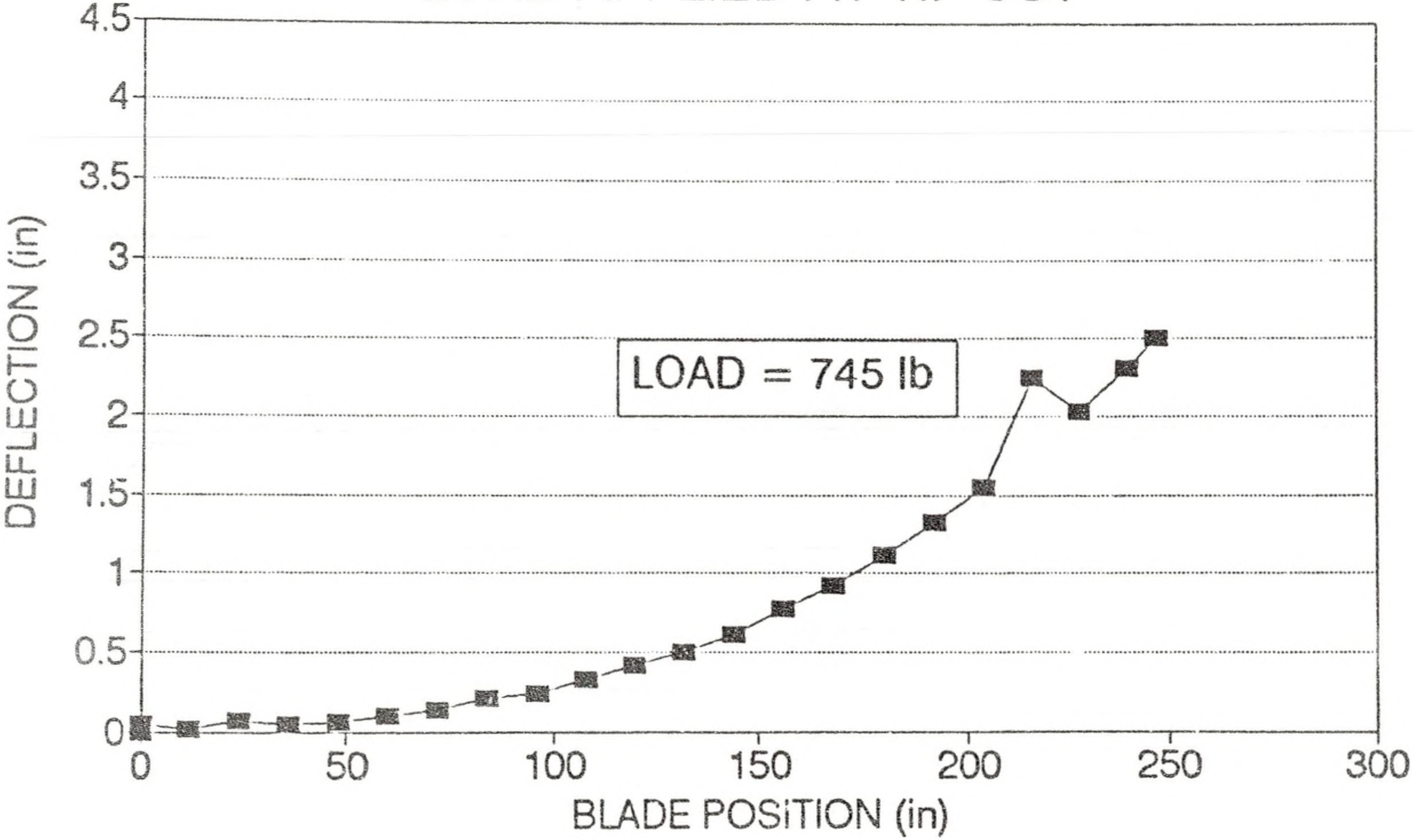
7.9 m SERI DEFLECTION TEST

LOAD APPLIED AT TIP CUT



7.5 m AEROSTAR DEFLECTION TEST

LOAD APPLIED AT TIP CUT

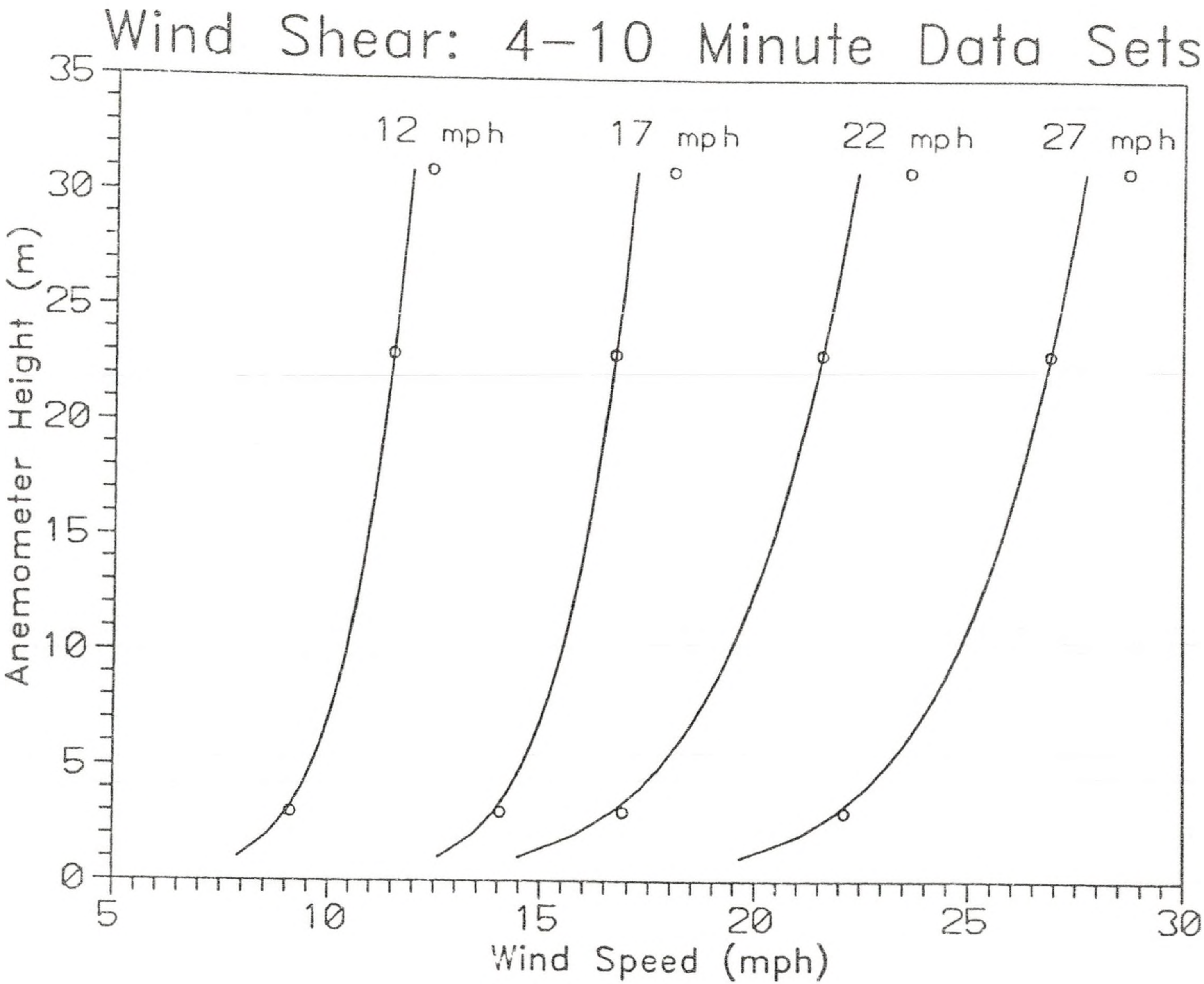


7.9m SERI	LOAD = 910 lbs				7.5 m AEROSTAR	LOAD = 745 lbs			
STAT (in)	X6 DEF (in)	DIFF (in)	MOMENT (in-lbs)	M/Y'' EI (psi)	STAT (in)	X5 DEF (in)	DIFF (in)	MOMENT (in-lbs)	M/Y" EI (psi)
0	0.0019	0.0349	229320	1.37E+09	0	0.0345	0.0284	184015	1.12E+10
12	0.0367	0.0179	218400	1.85E+09	12	0.0061	0.0078	175075	3.90E+10
24	0.0547	0.0089	207480	3.31E+09	24	0.0139	0.0278	166135	1.03E+10
36	0.0636	0.0081	196560	3.52E+10	36	0.0417	0.0372	157195	7.31E+09
48	0.0717	0.0152	185640	3.75E+09	48	0.0789	0.0404	148255	6.34E+09
60	0.0869	0.0295	174720	1.75E+09	60	0.1193	0.0414	139315	5.82E+09
72	0.1164	0.0500	163800	1.14E+09	72	0.1606	0.0431	130375	5.22E+09
84	0.1664	0.0756	152880	8.56E+08	84	0.2038	0.0481	121435	4.36E+09
96	0.2421	0.1050	141960	6.93E+08	96	0.2519	0.0580	112495	3.35E+09
108	0.3471	0.1369	131040	5.90E+08	108	0.3099	0.0735	103555	2.43E+09
120	0.4840	0.1701	120120	5.20E+08	120	0.3834	0.0949	94615	1.72E+09
132	0.6541	0.2036	109200	4.69E+08	132	0.4783	0.1215	85675	1.22E+09
144	0.8578	0.2368	98280	4.27E+08	144	0.5998	0.1521	76735	8.72E+08
156	1.0945	0.2692	87360	3.88E+08	156	0.7519	0.1844	67795	6.35E+08
168	1.3637	0.3011	76440	3.46E+08	168	0.9363	0.2157	58855	4.71E+08
180	1.6648	0.3333	65520	2.94E+08	180	1.1520	0.2424	49915	3.56E+08
192	1.9980	0.3672	54600	2.33E+08	192	1.3944	0.2602	40975	2.72E+08
204	2.3652	0.4051	43680	1.67E+08	204	1.6546	0.2640	32035	2.10E+08
216	2.7704	0.4503	32760	1.05E+08	216	1.9186	0.2480	23095	1.61E+08
228	3.2206	0.5067	21840	5.62E+07	228	2.1666	0.2057	14155	1.19E+08
240	3.7273	0.5797	10920	2.17E+07	240	2.3723	2.3723	5215	3.80E+06
252	4.3071	0.6758	0	0.00E+00	247	2.4597	2.4597	0	0.00E+00

APPENDIX M

WIND SHEAR PROFILES OF FOUR DATA SETS

(**Figure 51.** Wind shear profiles.)


Wind Shear: 4-10 Minute Data Sets
12 mph
17 mph
22 mph
27 mph
Anemometer Height (m)
Wind Speed (mph)
0
5
10
15
20
25
30
35
5
10
15
20
25
30

APPENDIX N

WINDATS CONTROL FILES:
SERI BLADE BINNED ON
AZIMUTH AND WIND SPEED

DATA DESCRIPTION:

4	number of data files and output prefixes

c:\scott\7-9\data\1072629.dat	72629saz.
c:\scott\7-9\data\1072733.dat	72733saz.
c:\scott\7-9\data\1072822.dat	72822saz.
c:\scott\7-9\data\1072964.dat	72964saz.

n	save .INP file
ibmpc	source machine
B	data file format
R	data type
0	header lines
32.00000	sample rate (Hz)
600.000	total time (seconds)
19200	data scans
60	channels total
37	channels needed

channel	column #	name	units
2	1	1RPK1V	volt
4	3	1RH1FB	ft-kip
5	4	1RH2FB	ft-kip
6	5	1RH3FB	ft-kip
7	6	1RH1EB	ft-kip
8	7	1RH2EB	ft-kip
9	8	1RH3EB	ft-kip
10	9	1LSSTQ	ft-kip
18	17	1LSS0B	ft-kip
19	18	1LSS9B	ft-kip
20	19	1NACXX	g
21	20	1NACYY	g
22	21	1YDRTQ	ft-kip
23	22	1NACAZ	deg
24	23	1TWTTQ	ft-kip
25	24	1TWBYB	ft-kip
26	25	1TWBXB	ft-kip
27	26	1CPLPR	kW
30	29	AZIMUTH	deg
31	30	1LSSSP	rpm
42	41	1M31WS	mph
43	42	1M31WD	deg
44	43	1M23WS	mph
45	44	1M23WD	deg
46	45	1M21WU	m/s
47	46	1M21WV	m/s
48	47	1M21WW	m/s
49	48	1M21WT	deg C
50	49	1M15WS	mph
51	50	1M15WD	deg
52	51	1M03WS	m/s
53	52	1M03WT	deg C

54	53	1M31DT	deg C
55	54	1D02BP	in Hg
56	55	1YAWER	deg
58	57	1LSSPR	kW
60	59	1DTEFF	

DATA PREPARATION NEEDS:

n prepare data

COMPUTED CHANNEL NEEDS:

n add computed channels

DATA ANALYSIS NEEDS:

y	analyze data
n	remove mean
n	detrend
n	per-revolution average
y	azimuth average
n	harmonic least squares fit
y	get residuals from az-avg or hlsf
n	bin in time domain
n	bin per-rev averages
n	make power spectra

DATA ANALYSIS SPECIFICATIONS:

19200 40 number of scans, azimuth bins for azimuth averaging

19200 number of scans for az-avg residuals

DATA DESCRIPTION:

```
      4             number of data files and output prefixes
C:\SK\79\DAT\1072629.dat                 72629SWS.
c:\SK\79\DAT\1072733.dat                 72733SWS.
c:\SK\79\DAT\1072822.dat                 72822SWS.
c:\SK\79\DAT\1072964.dat                 72964SWS.

      n             save .INP file
ibmpc               source machine
B                   data file format
R                   data type
      0             header lines
     32.00000       sample rate (Hz)
    600.000         total time (seconds)
  19200             data scans
     60             channels total
     37             channels needed
```

channel	column #	name	units
2	1	1RPK1V	volt
4	3	1RH1FB	ft-kip
5	4	1RH2FB	ft-kip
6	5	1RH3FB	ft-kip
7	6	1RH1EB	ft-kip
8	7	1RH2EB	ft-kip
9	8	1RH3EB	ft-kip
10	9	1LSSTQ	ft-kip
18	17	1LSS0B	ft-kip
19	18	1LSS9B	ft-kip
20	19	1NACXX	g
21	20	1NACYY	g
22	21	1YDRTQ	ft-kip
23	22	1NACAZ	deg
24	23	1TWTTQ	ft-kip
25	24	1TWBYB	ft-kip
26	25	1TWBXB	ft-kip
27	26	1CPLPR	kW
30	29	AZIMUTH	deg
31	30	1LSSSP	rpm
42	41	1M31WS	mph
43	42	1M31WD	deg
44	43	1M23WS	mph
45	44	1M23WD	deg
46	45	1M21WU	m/s
47	46	1M21WV	m/s
48	47	1M21WW	m/s
49	48	1M21WT	deg C
50	49	1M15WS	mph
51	50	1M15WD	deg
52	51	1M03WS	m/s
53	52	1M03WT	deg C
54	53	1M31DT	deg C

55	54	1D02BP	in Hg
56	55	1YAWER	deg
58	57	1LSSPR	kW
60	59	1DTEFF	

DATA PREPARATION NEEDS:

y			prepare data
y	y	y	save .FLT, .PRE, .LIM files
n			filter
n			decimate
n			pre-average
n			scale
y			limit

DATA PREPARATION SPECIFICATIONS:

1 number of channels for limiting data

ch #	min	max	# bins
44	0.0000	50.0000	10

COMPUTED CHANNEL NEEDS:

n add computed channels

DATA ANALYSIS NEEDS:

n analyze data

APPENDIX O

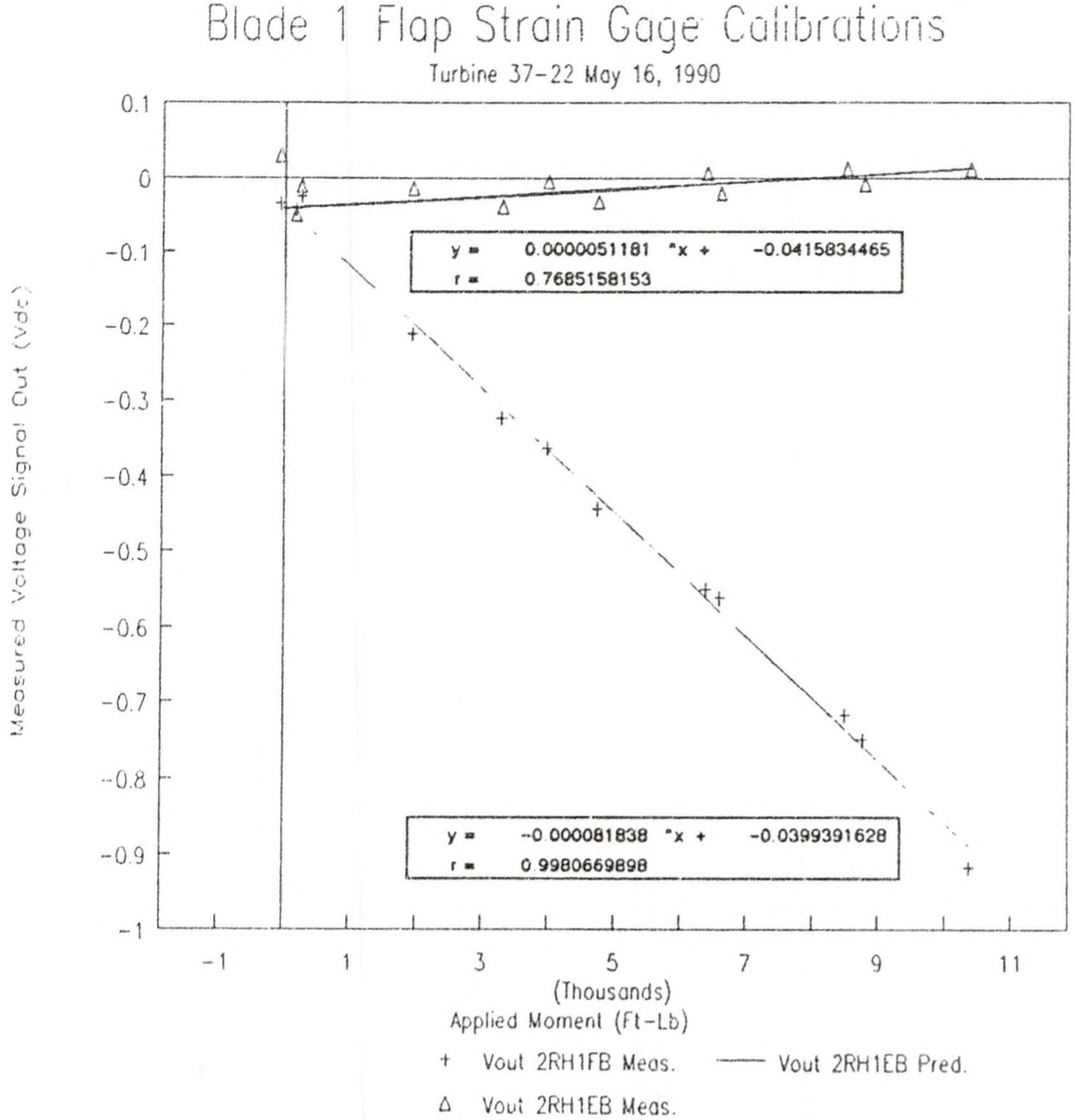
SERI AND AEROSTAR BLADE 1, FLAP AND EDGE STRAIN GAUGE CALIBRATION CURVES

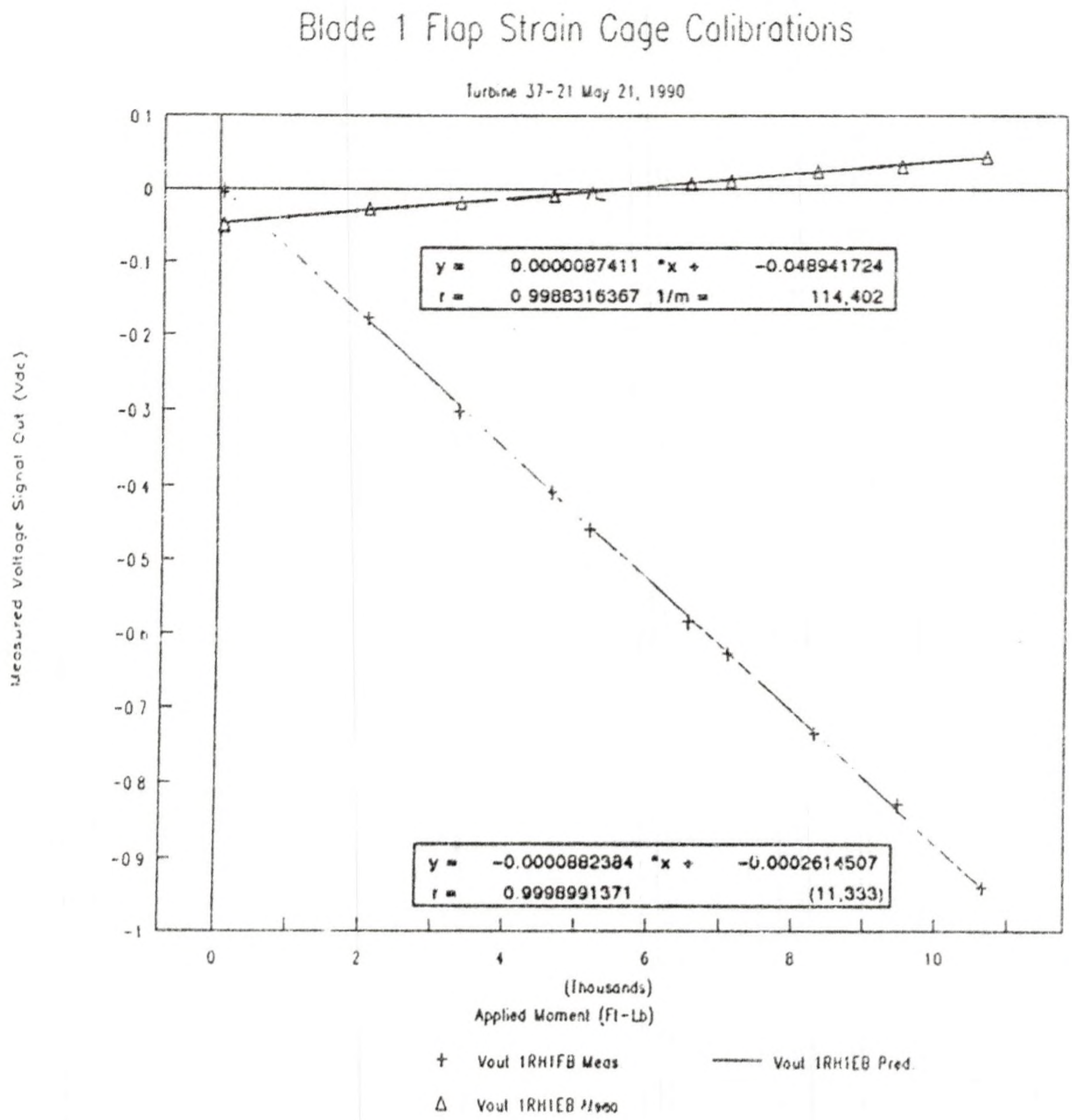
(**Figure 52.** Aerostar, blade 1 flap, strain gauge calibration curve.)

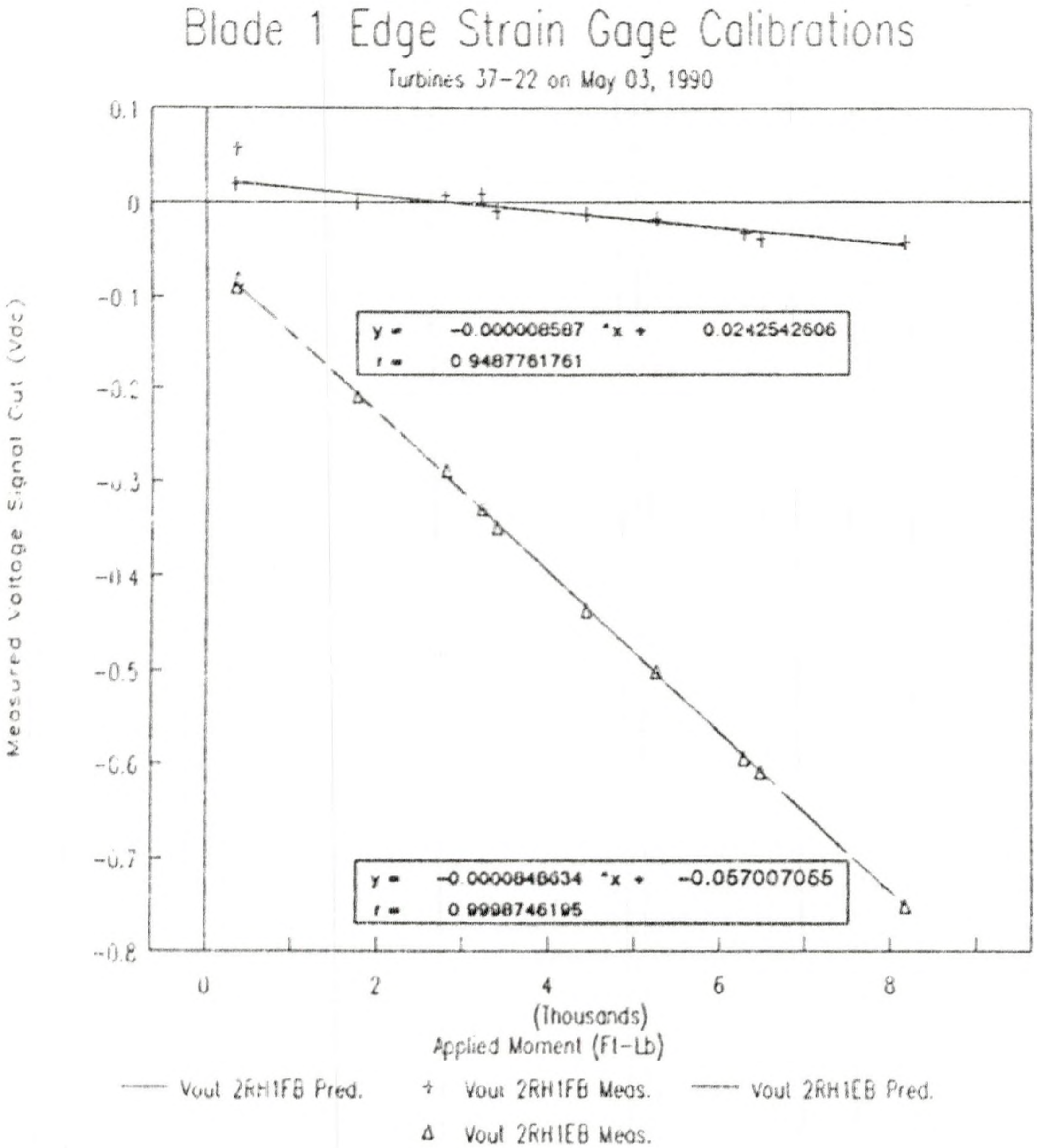
(**Figure 53.** SERI, blade 1 flap, strain gauge calibration curve.)

(**Figure 54.** Aerostar, blade 1 edge, strain gauge calibration curve.)

(**Figure 55.** SERI, blade 1 edge, strain gauge calibration curve.)

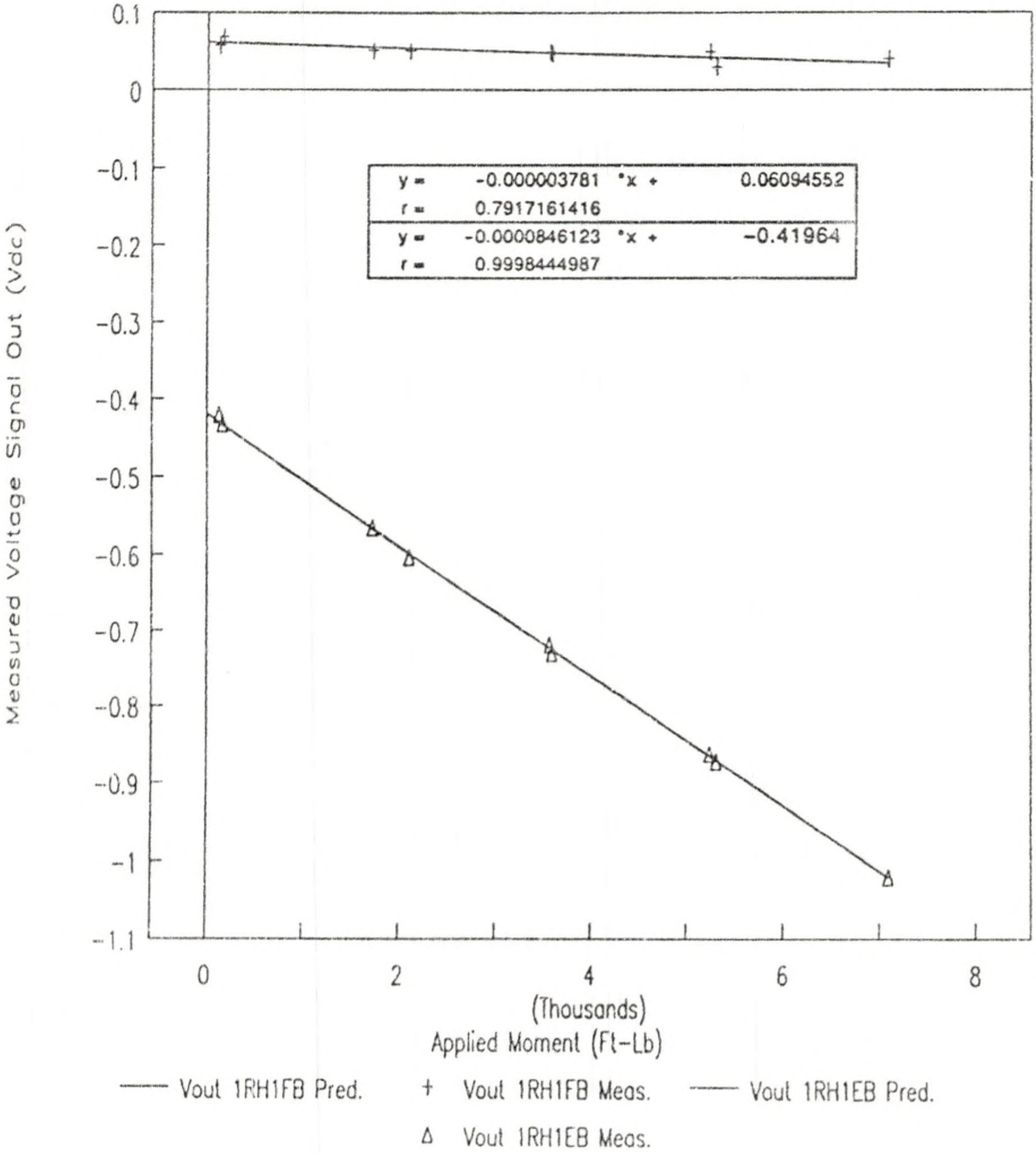

Blade 1 Flap Strain Gage Calibrations
Turbine 37-22 May 16, 1990
y = 0.0000051181 *x + -0.0415834465
r = 0.7685158153
y = -0.000081838 *x + -0.0399391628
r = 0.9980669898
Measured Voltage Signal Out (Vdc)
(Thousands)
Applied Moment (Ft-Lb)
+ Vout 2RH1FB Meas.
Vout 2RH1EB Pred.
Δ Vout 2RH1EB Meas.


Blade 1 Flap Strain Gage Calibrations
Turbine 37-21 May 21, 1990
y = 0.0000087411 *x + -0.048941724
r = 0.9988316367 1/m = 114,402
y = -0.0000882384 *x + -0.0002614507
r = 0.9998991371 (11,333)
Measured Voltage Signal Out (Vdc)
(Thousands)
Applied Moment (Ft-Lb)
Vout 1RH1FB Meas
Vout 1RH1EB Pred.
Vout 1RH1EB


Blade 1 Edge Strain Gage Calibrations
Turbines 37-22 on May 03, 1990
Measured Voltage Signal Out (Vdc)
y = -0.000008587 *x + 0.0242542606
r = 0.9487761761
y = -0.0000848634 *x + -0.057007065
r = 0.9998746195
(Thousands)
Applied Moment (Ft-Lb)
Vout 2RH1FB Pred.
Vout 2RH1FB Meas.
Vout 2RH1EB Pred.
Vout 2RH1EB Meas.

Blade 1 Edge Strain Gage Calibrations

1RH1EB Turbine 37-21 on July 27, 1990

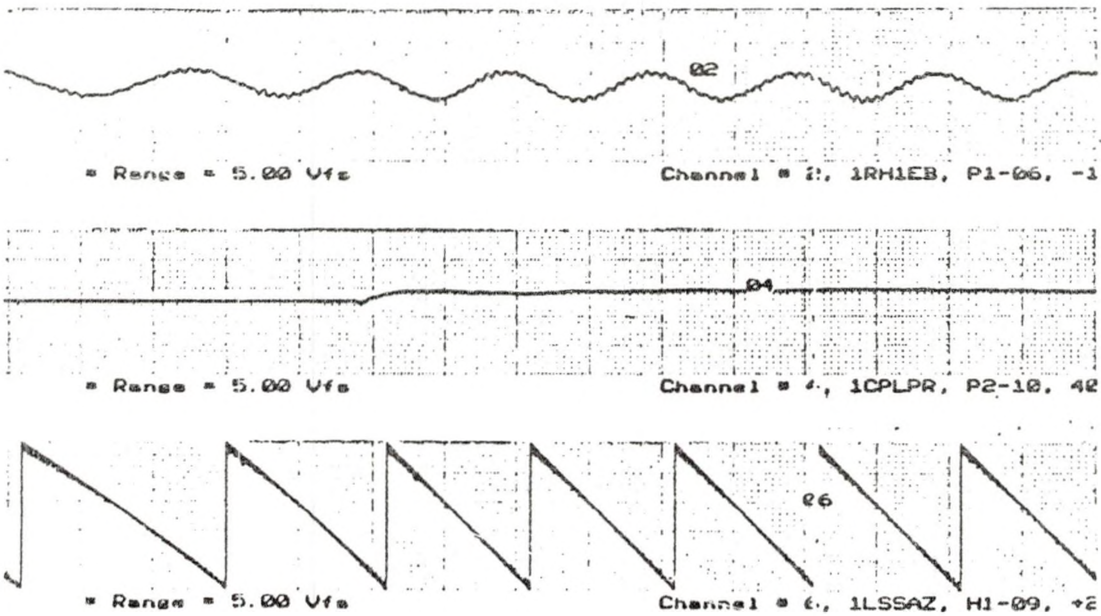


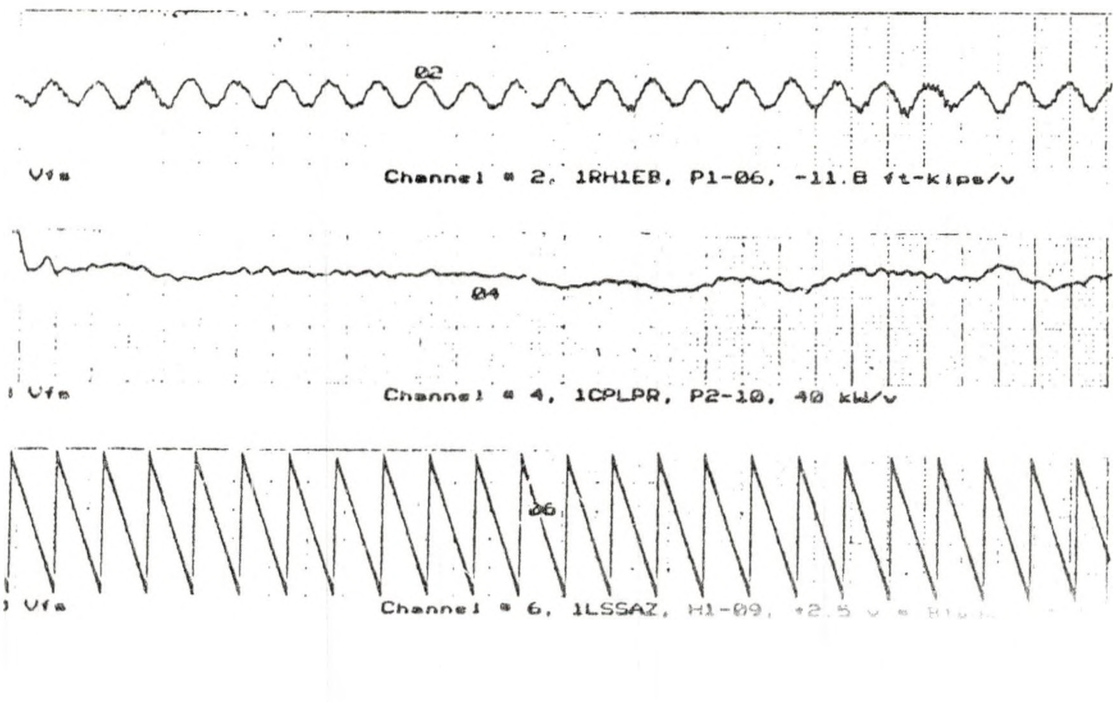
APPENDIX P

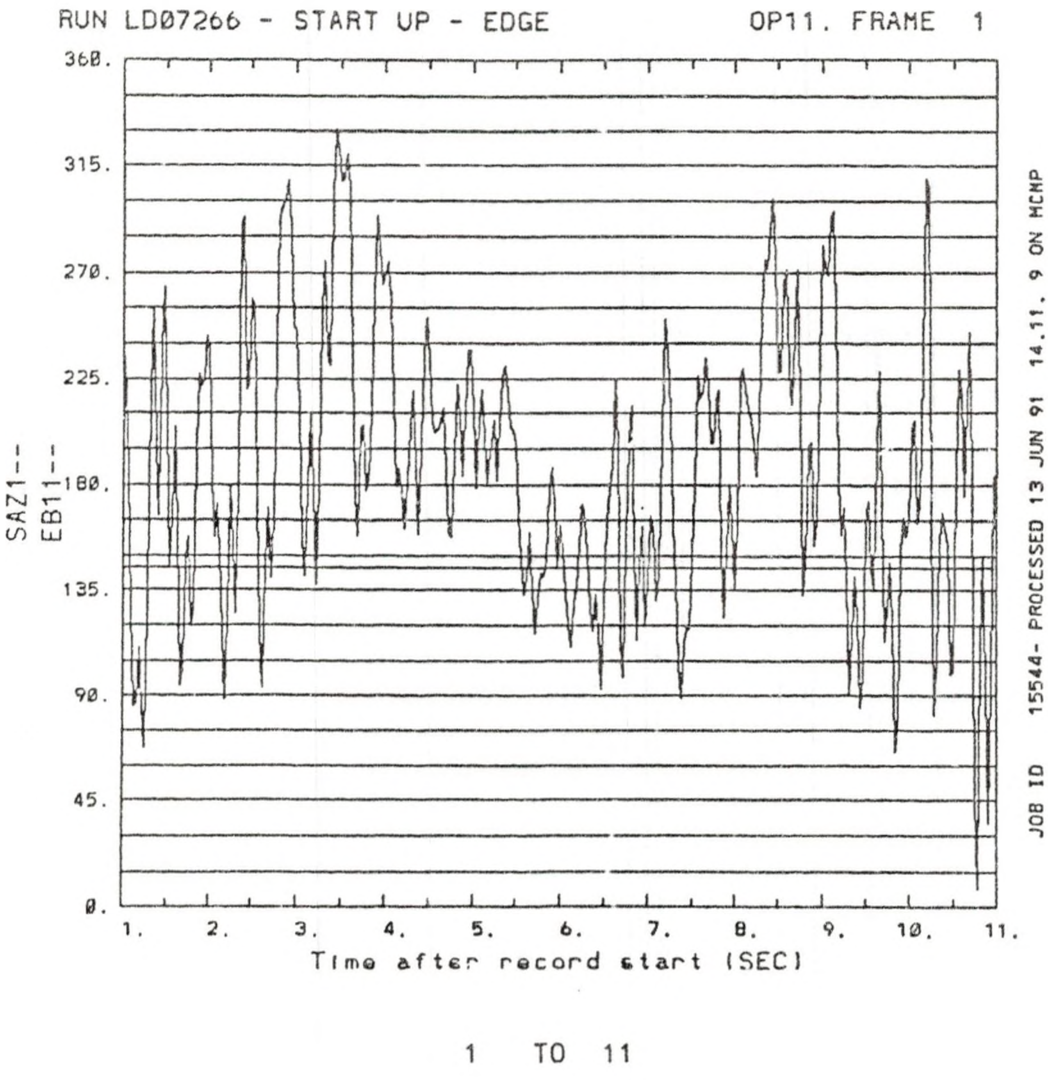
SAMPLE STRIP CHART OF EDGE BENDING, POWER OUTPUT, AND BLADE AZIMUTH

(**Figure 56.** Typical strip chart records.)

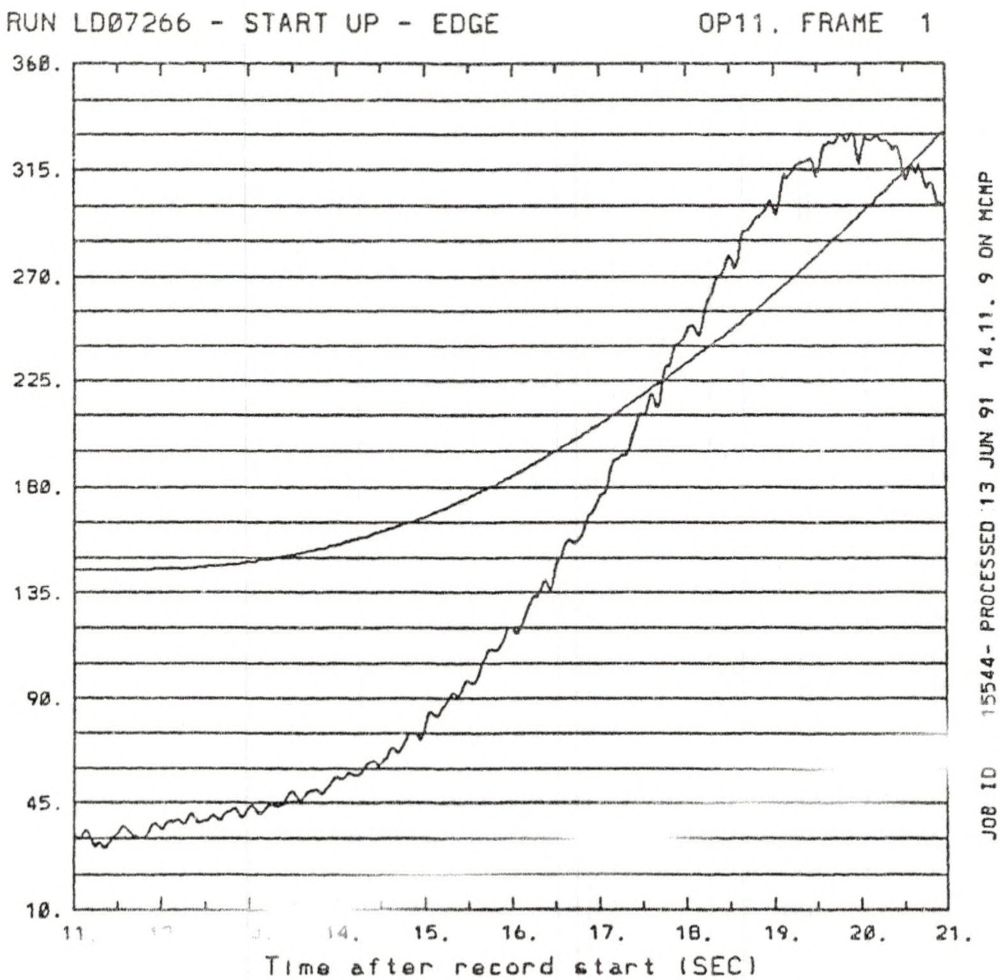
(**Figure 57.** 2-minute start-up record of edge bending versus azimuth.)


02
Range = 5.00 Vfs
Channel # 2, 1RH1EB, P1-06, -1
04
Range = 5.00 Vfs
Channel # 4, 1CPLPR, P2-10, 40
06
Range = 5.00 Vfs
Channel # 6, 1LSSAZ, H1-09, +2


02
Vfs
Channel # 2, 1RH1EB, P1-06, -11.8 ft-kips/v
04
Vfs
Channel # 4, 1CPLPR, P2-10, 40 kW/v
06
Vfs
Channel # 6, 1LSSAZ, H1-09, +2.5 v

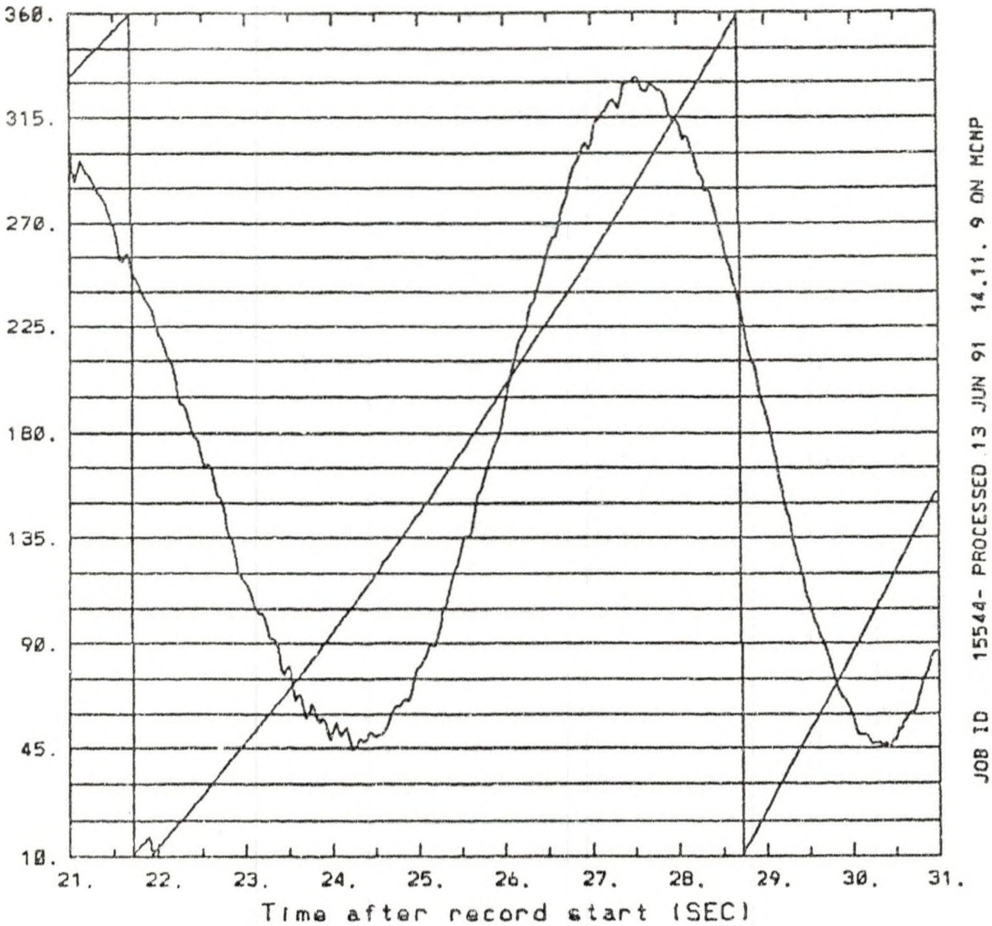

RUN LD07266 - START UP - EDGE
OP11. FRAME 1
360.
315.
270.
225.
180.
135.
90.
45.
0.
SAZ1--
EB11--
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
Time after record start (SEC)
JOB ID 15544- PROCESSED 13 JUN 91 14.11. 9 ON MCMP

1 TO 11

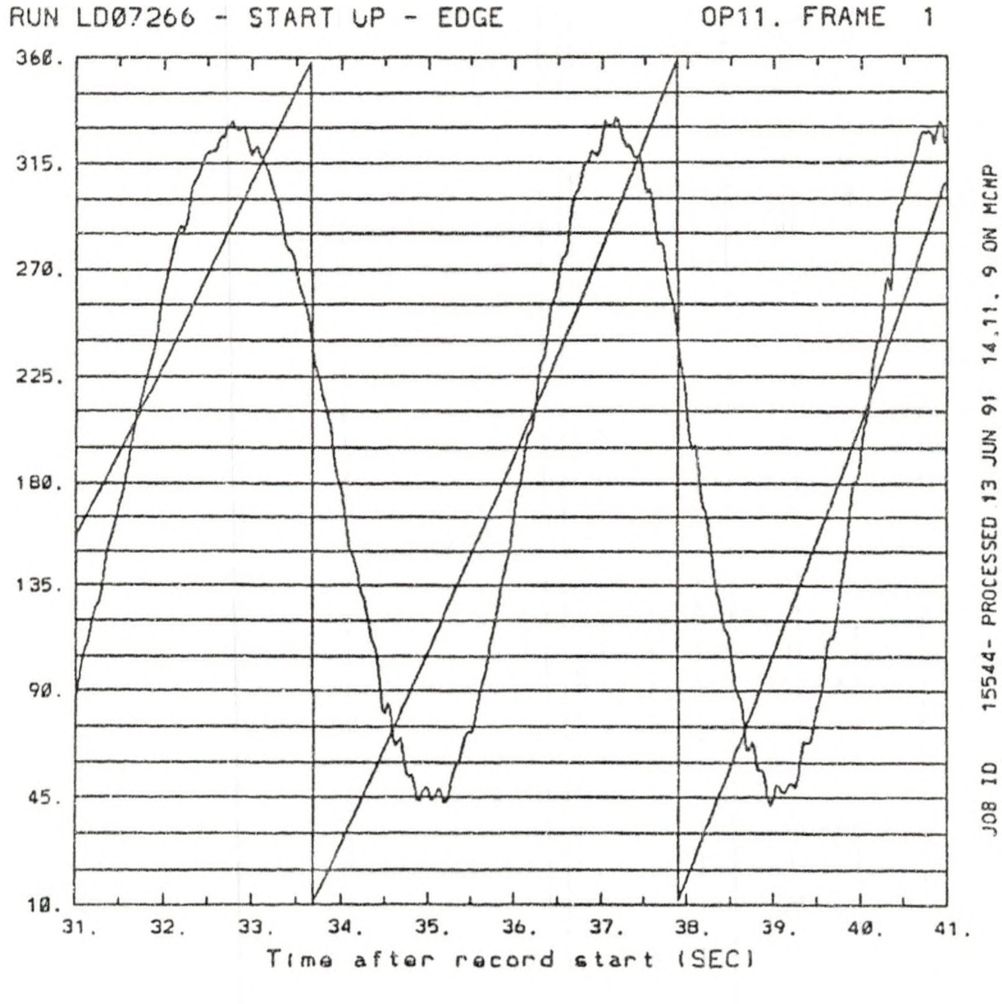

RUN LDØ7266 - START UP - EDGE
OP11. FRAME 1
36Ø.
315.
27Ø.
225.
18Ø.
135.
9Ø.
45.
1Ø.
11.
14.
15.
16.
17.
18.
19.
2Ø.
21.
Time after record start (SEC)
JOB ID 15544- PROCESSED 13 JUN 91 14.11. 9 ON MCMP

11 TO 21

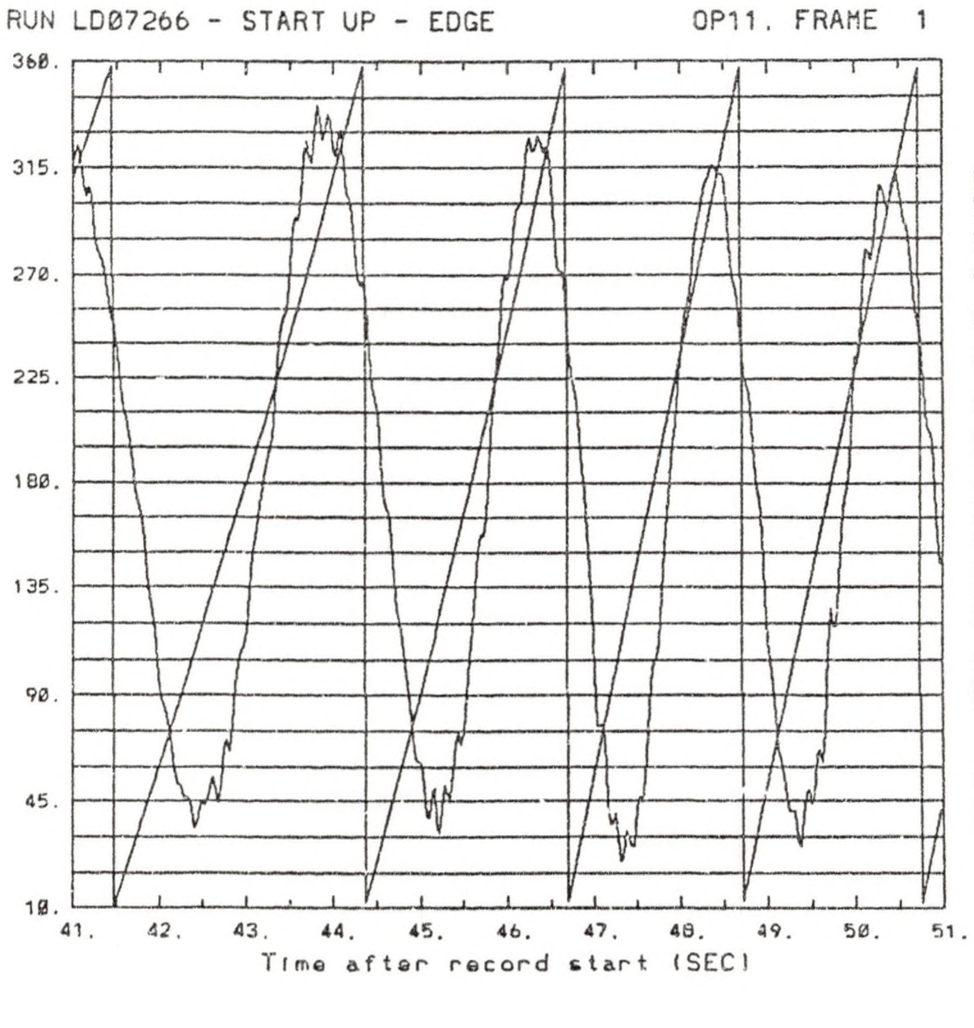
RUN LDØ7266 - START UP - EDGE OP11. FRAME 1



21 TO 31

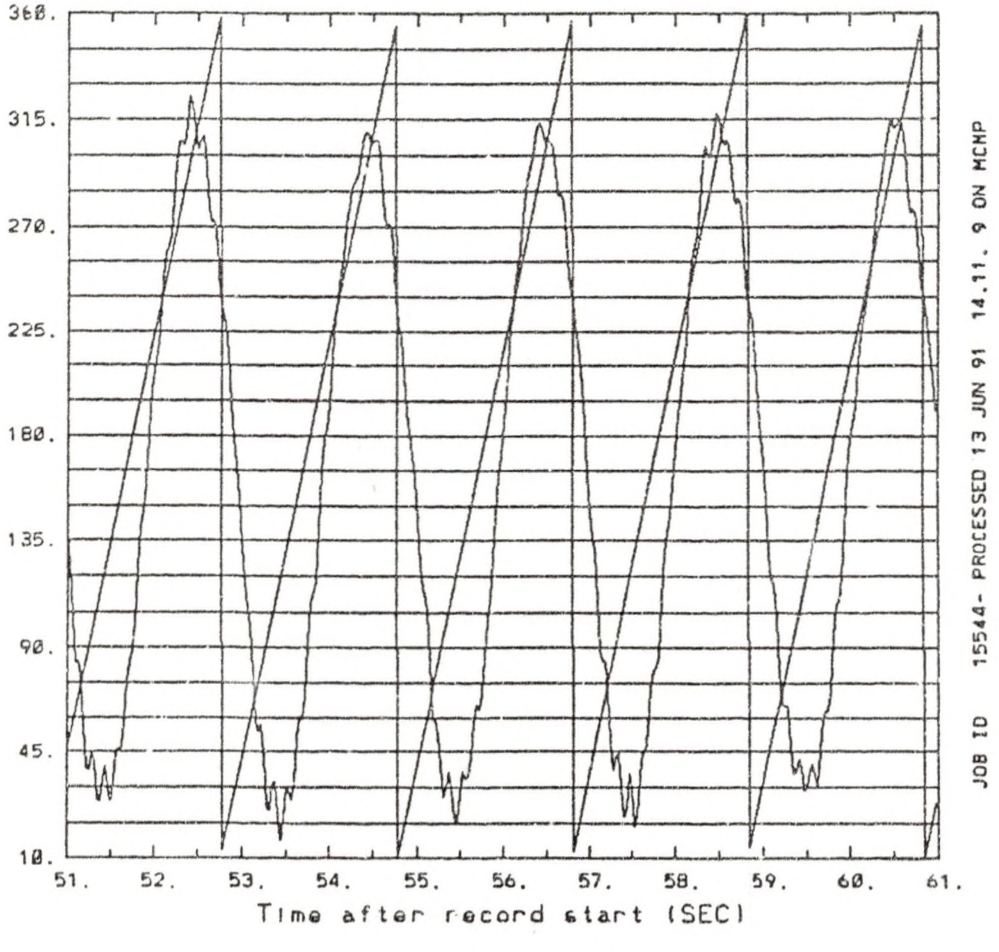

RUN LD07266 - START UP - EDGE
OP11. FRAME 1
360.
315.
270.
225.
180.
135.
90.
45.
10.
31.
32.
33.
34.
35.
36.
37.
38.
39.
40.
41.
Time after record start (SEC)
JOB ID 15544- PROCESSED 13 JUN 91 14.11. 9 ON MCMP

31 TO 41

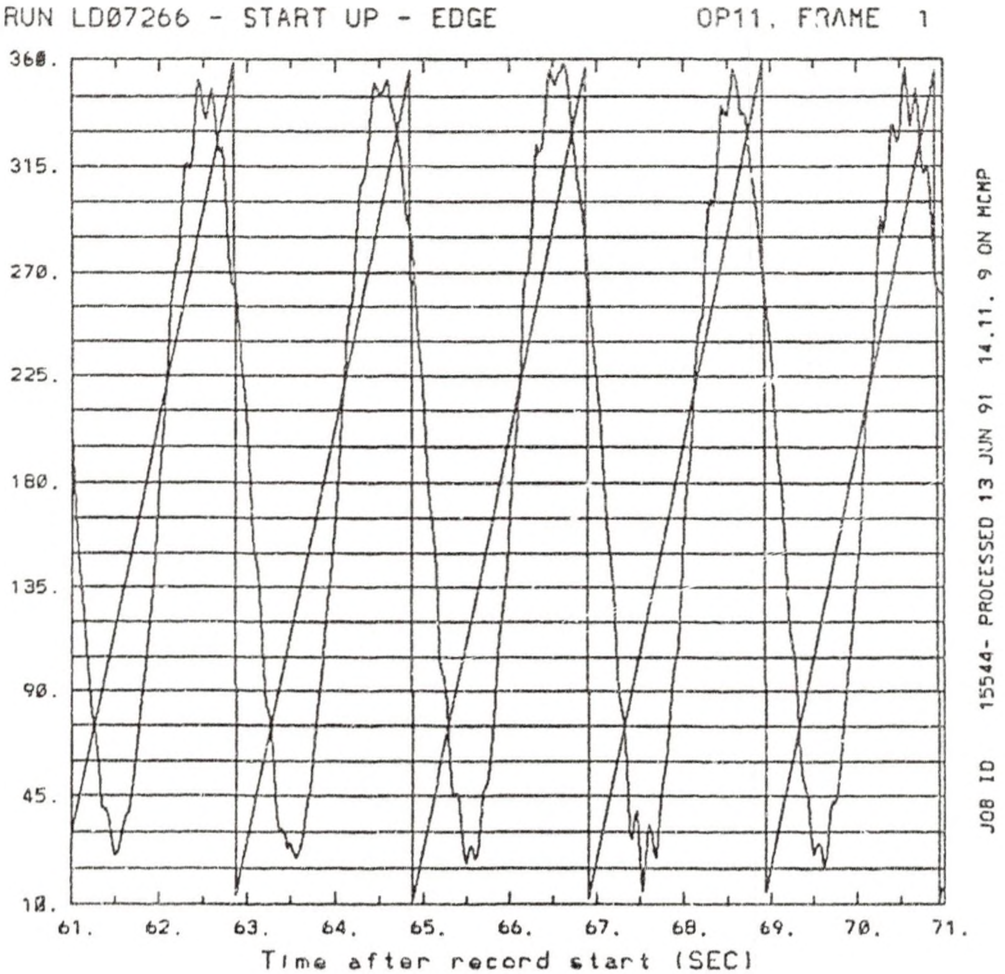

RUN LD07266 - START UP - EDGE
OP11. FRAME 1
360.
315.
270.
225.
180.
135.
90.
45.
10.
41.
42.
43.
44.
45.
46.
47.
48.
49.
50.
51.
Time after record start (SEC)
JOB ID 15544- PROCESSED 13 JUN 91 14.11. 9 ON MCMP

41 TO 51

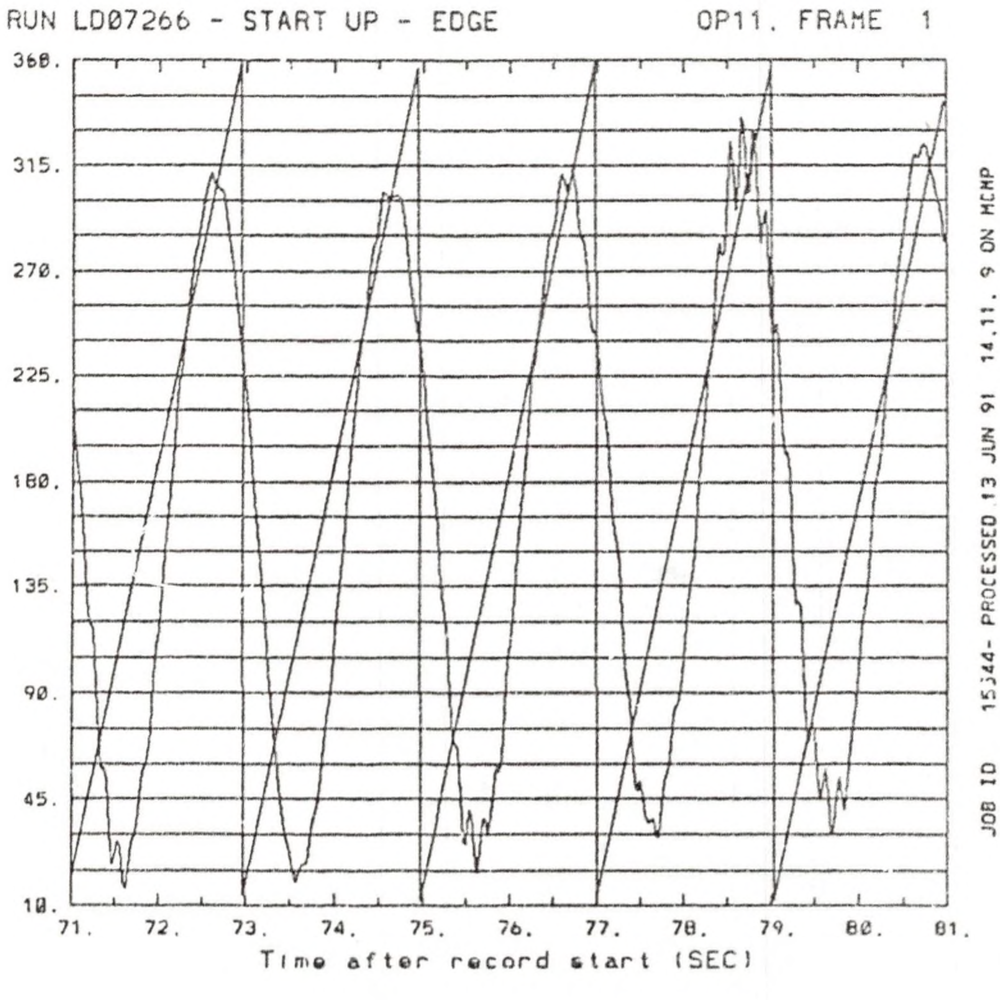
RUN LDØ7266 - START UP - EDGE OP11. FRAME 1



51 TO 61

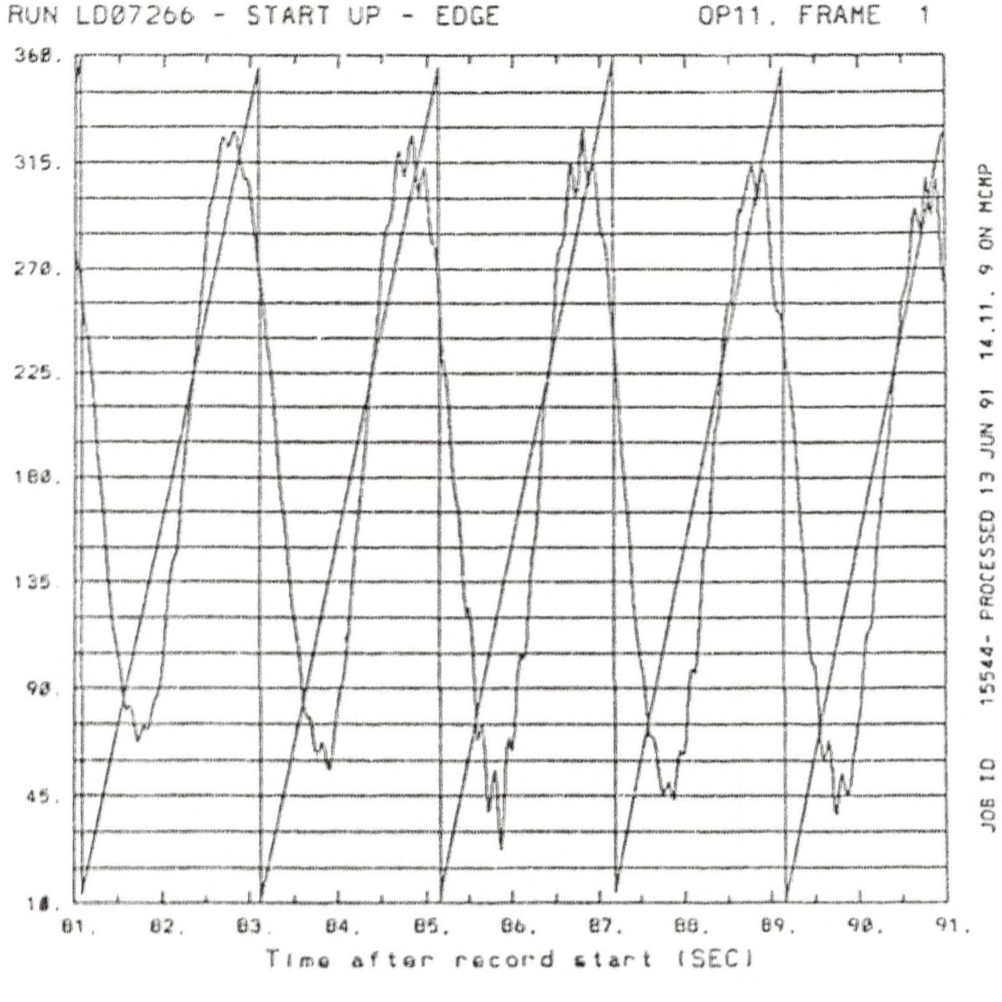

RUN LDØ7266 - START UP - EDGE
OP11. FRAME 1
36Ø.
315.
27Ø.
225.
18Ø.
135.
9Ø.
45.
1Ø.
61.
62.
63.
64.
65.
66.
67.
68.
69.
7Ø.
71.
Time after record start (SEC)
JOB ID 15544- PROCESSED 13 JUN 91 14.11. 9 ON MCMP

61 TO 71



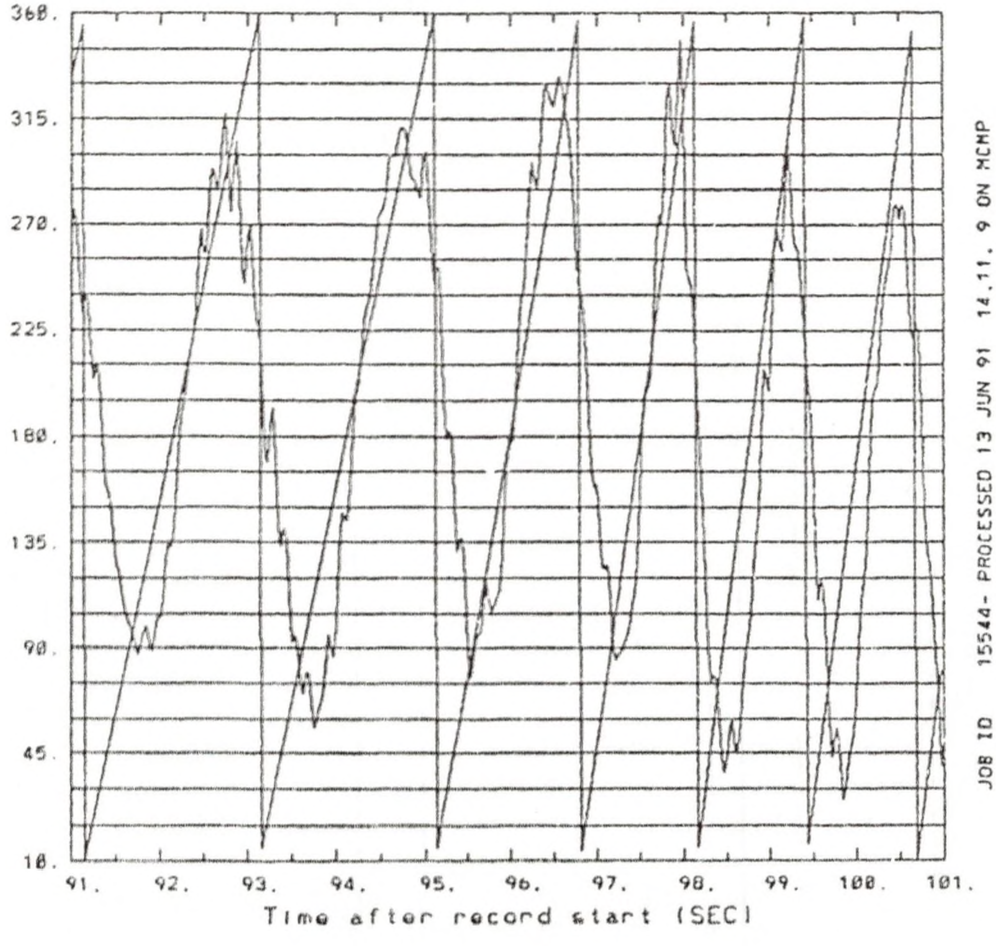
RUN LD07266 - START UP - EDGE
OP11. FRAME 1
360.
315.
270.
225.
180.
135.
90.
45.
10.
71.
72.
73.
74.
75.
76.
77.
78.
79.
80.
81.
Time after record start (SEC)
JOB ID 15344- PROCESSED 13 JUN 91 14.11. 9 ON MCMP

71 TO 81

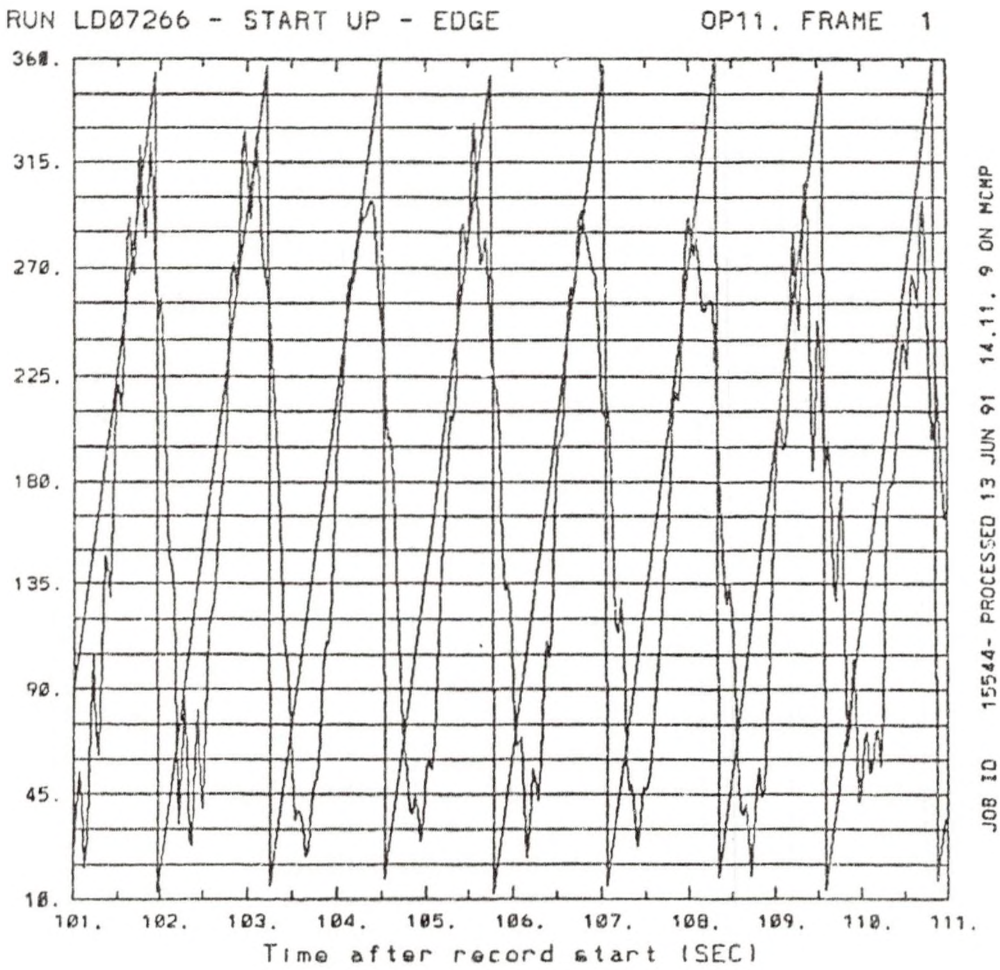

RUN LD07266 - START UP - EDGE
OP11, FRAME 1
360.
315.
270.
225.
180.
135.
90.
45.
10.
81. 82. 83. 84. 85. 86. 87. 88. 89. 90. 91.
Time after record start (SEC)
JOB ID 15544- PROCESSED 13 JUN 91 14.11. 9 ON MCMP

81 TO 91

RUN LD07266 - START UP - EDGE OP11. FRAME 1

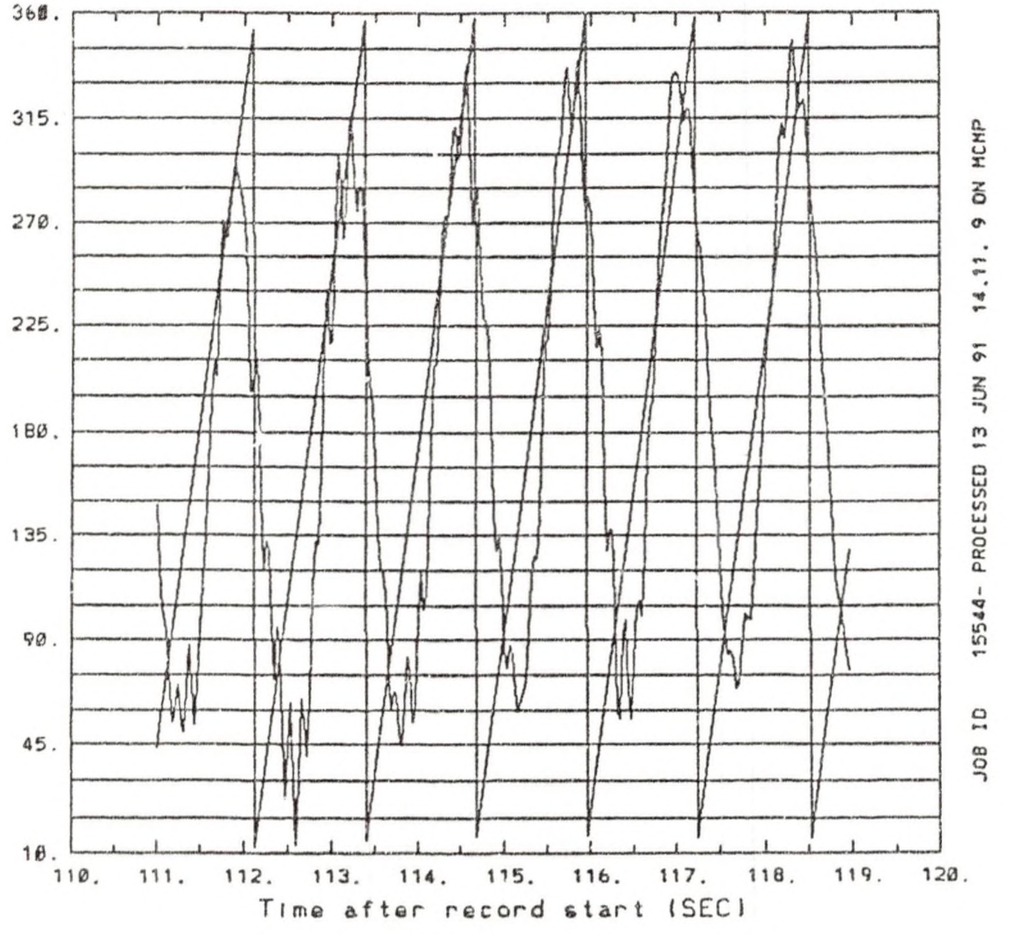


91 TO 101


RUN LD07266 - START UP - EDGE
OP11. FRAME 1
360.
315.
270.
225.
180.
135.
90.
45.
10.
101.
102.
103.
104.
105.
106.
107.
108.
109.
110.
111.
Time after record start (SEC)
JOB ID 15544- PROCESSED 13 JUN 91 14.11. 9 ON MCMP

101 TO 111

RUN LDØ7266 - START UP - EDGE OP11. FRAME 1



111 TO 119

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