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WIND TUNNEL TEST OF TELEDYNE GEOTECH MODEL 1564B CUP ANEMOMETER (U)

by

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A Technical Report

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Wind Tunnel Experiment

A wind tunnel experiment was designed to better understand the relationship between the 0-25 mph and the 0-50 mph regression lines for the Teledyne Geotech model 1564B cup anemometers. Three Teledyne Geotech model 1564B anemometers with cup assemblies were tested at 2 mph increments at increasing flow rates, and the corresponding output voltages were recorded. Sufficient time was allowed to ensure that the wind tunnel was stabilized at each increment. Regression lines were then fitted to the data, and wind speed predictions were made for "high" and "low" wind speeds. The "high" values were chosen to be the half and full scale voltage readings of 2.5V and 5.0V. The "low" wind speeds were chosen to be near 6 mph to approximate speeds commonly observed at the F-Area (figure 1) 200 ft meteorological tower from 1982-1986 (Laurinat, 1987). These predictions were then compared.

Threshold effects result in a non-linear portion of the calibration curve at very low wind speeds. The proposed baffles will be used to investigate this effect. In this experiment, to determine the effect of low wind speeds, regression equations were determined including and excluding 0-5 mph data points.

Results

Plots of flow versus voltage and resultant linear regression lines are shown in plots 1-6. Plots 1-3 show data and regression lines for 0-25 mph and plots 4-6 for 0-50 mph. Regression equations are written at the bottom of each plot. The square of the correlation coefficient (R^2) is nearly equal for each plot and ranges from 0.9996 to 0.9998. Differences between the 0-25 and 0-50 mph regression lines are not easily distinguishable in these plots.

Table A and figure 2 each show "high" wind speed predictions based on regression equations for 0-25, 5-25, 0-50, 5-50 mph data at 2.5 volt and 5.0 volt (half and full scale). The 5-25 and 5-50 mph regression equations were used to eliminate the non-linear effects of the anemometer at low wind speeds.

Table B and figure 3 each show "low" wind speed predictions for values near 6 mph. These predictions were made for the 0-25, 5-25, 0-50, and 5-50 mph regression equations and were compared to the actual flow rate of the wind tunnel. These comparisons are shown as percent errors based on comparisons with the actual flow rate as determined by the fan rotation rate.

Discussion

R-squared values for each regression line (plots 1-6) show that an accurate "fit" for the data were made. The highly linear response of the Teledyne Geotech anemometer is reflected in the R-squared term which, by itself, is not a good statistical measure of the differences between these regression lines.

In all cases, the 25 mph regression lines predicted higher speeds than the 50 mph regression lines (Table A). The corresponding differences of these regression lines demonstrate a range of percentages from 2.1 to 3.1% with the lower percentages shown for the non-threshold regression lines.

Executive Summary

The Department of Energy (DOE) Environment, Safety and Health Compliance Assessment (Tiger Team) of the Savannah River Site (SRS) questioned the method by which wind speed sensors (cup anemometers) are calibrated by the Environmental Technology Section (ETS). The Tiger Team member was concerned that calibration data was generated by running the wind tunnel to only 25 miles per hour (mph) when speeds exceeding 50 mph are readily obtainable. A wind tunnel experiment was conducted and confirmed the validity of the practice.

Wind speeds common to SRS (6 mph) were predicted more accurately by 0-25 mph regression equations than 0-50 mph regression equations. Higher wind speeds were slightly overpredicted by the 0-25 mph regression equations when compared to 0-50 mph regression equations. However, the greater benefit of more accurate lower wind speed predictions accuracy outweigh the benefit of slightly better high (extreme) wind speed predictions. Therefore, it is concluded that 0-25 mph regression equations should continue to be utilized by ETS at SRS.

Introduction

The Environmental Technology Section (ETS) at the Savannah River Site (SRS) operates a network of nine 200ft towers that are used for gathering meteorological data for emergency response. These meteorological data are stored as a data base which is also used for climatological and dosimetric studies. Variables measured consist of wind speed and direction (horizontal and vertical), temperature, and dew point. Calibration of meteorological instrumentation are conducted by ETS personnel twice a year.

During the Department of Energy Tiger Team audit, concerns were raised about the calibration of SRS cup anemometers. Wind speed is measured by ETS with Teledyne Geotech model 1564B cup anemometers, which are calibrated in the ETS wind tunnel. Linear regression lines are fitted to data points of tunnel speed versus anemometer output voltages up to 25 mph. The regression coefficients are then implemented into the data acquisition computer software when an instrument is installed in the field. The concern raised was that since the wind tunnel at SRS is able to generate a maximum wind speed higher than 25 mph, errors may be introduced in not using the full range of the wind tunnel.

The wind tunnel at SRS has been calibrated by T. Lockhart (1989) and is traceable to the National Institute of Standards and Testing (NIST). The maximum obtainable flow rate is near 52 mph. Since the response of anemometers above the starting starting threshold is a linear relationship of wind speed to output voltage (Lockhart, 1989), and >25 mph wind speeds are rather uncommon (Hunter, 1989) at SRS, a regression line is obtained from tunnel speeds below 25 mph. This regression line should be more appropriate for predicting lower wind speeds more accurately.

The policy of using wind tunnel speeds up to approximately half the maximum possible wind tunnel speeds was based on an earlier study (Addis, 1985). To study the effects of low wind speeds on the cup anemometers and bivanes, the installation of a honeycomb baffle was proposed. The 1985 study demonstrated that if the maximum flow rate of the wind tunnel was decreased to 25 mph by the introduction of baffles, the effect on the regression coefficients would be minimal. The purpose of this present study was to verify that the results of the previous study are applicable to the new Teledyne Geotech cup anemometers and provide a more rigorous defense of this policy.

The low wind speed predictions made by the 0-25 mph regression line (Table B) differed from the actual wind speed from -0.35 to 1.36%, compared with 4.02 to 5.29% for the 0-50 mph regression line. Similarly, the range of errors for the 5-25 mph regression line was 1.65 to 2.57% and the range was 6.88 to 7.64% for the 5-50 regression line. In both cases, the 25 mph regression lines were considerably more accurate than the 50 mph regression lines regardless of anemometer non-linearity.

Conclusions

The 25 mph regression line predictions are significantly more accurate for low wind speeds than 50 mph regression line predictions. The result of using a lower wind speed regression equation for wind speed calculations is minimal since it produces higher wind speed errors of only 2 to 3% than the 50 mph regression line. The results of this study validate the practice of using lower wind speed regression equations for the full range of wind speeds. However, it does suggest that further work should be done to investigate the non linear region. Future installation of a baffle system should allow a better understanding of threshold characteristics and thus better regression equations for Teledyne Geotech model 1564B anemometers. The response above threshold values is essentially linear which allows acceptable accuracy for extreme wind speeds by the 25 mph regression line.

References

Addis, R. P. 1985. Memorandum: "Effect of Lowering the Wind Tunnel Operating Threshold" Technical Division, Savannah River Laboratory E.I. DuPont de Nemours Co, Inc.

Hunter, C. H. 1989. "Meteorology and Air Quality " in Reactor Operation Environmental Information Document, Volume III Meteorology, Surface Hydrology, Transport and Impacts (U) *draft* WSRC-RP-89-817 Westinghouse Savannah River Company.

Laurinat, J. E. 1987. "Average Wind Statistics for SRP Area Meteorological Towers" Savannah River Laboratory E.I. DuPont de Nemours Co, Inc. DPST 87-341.

Lockhart, T.J. 1989. Quality Assurance Handbook for Air Pollution Measurement Systems Volume IV Meteorological Instruments EPA 68-02-4553 Research Triangle Park, North Carolina.

Table A. High Wind Speed Predictions

	2.5v			5.0v		
instr #	0-25mph	%diff	0-50mph	0-25mph	%diff	0-50mph
2254	56.452	2.64	54.998	113.162	3.08	109.781
2110	56.240	2.55	54.839	112.611	2.97	109.358
2260	55.978	2.34	54.697	112.129	2.74	109.138

	2.5v			5.0v		
instr #	5-25mph	%diff	5-50mph	5-25mph	%diff	5-50mph
2254	56.085	2.17	54.894	112.249	2.64	109.366
2110	55.914	2.14	54.743	111.799	2.59	108.974
2260	55.754	2.09	54.611	111.570	2.55	108.795

A comparison of the results of using both threshold and non-threshold regression equations for wind speed predictions at 2.5 and 5.0 volts. Percentage differences between the 25 and 50 ranges are also shown.

Table B. Low wind speed predictions

Instr. #	actual	0-25mph	%err	0-50mph	%err
2254	6.000	5.979	-0.35	6.241	4.02
2110	5.946	5.958	1.20	6.208	4.41
2260	6.034	6.116	1.36	6.353	5.29

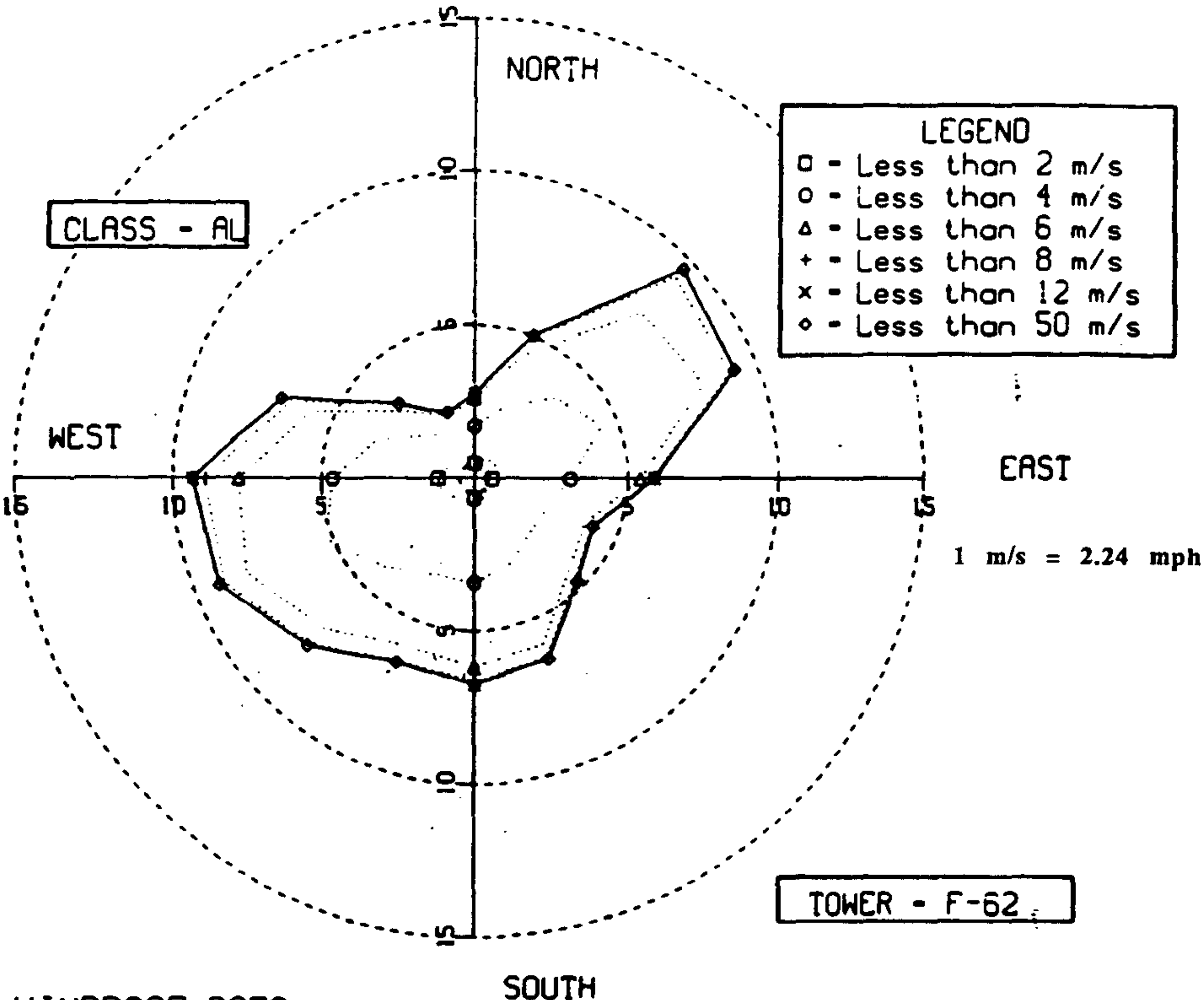
Instr. #	actual	5-25mph	%err	5-50mph	%err
2254	6.000	6.099	1.65	6.413	6.88
2110	5.946	6.065	2.00	6.369	7.11
2260	6.034	6.189	2.57	6.495	7.69

A comparison of percentage errors between both threshold and non-threshold regression equation predictions for low wind speeds and actual wind tunnel speeds.

FIGURE 1.

WINDROSE 82-86 60-MIN F-AREA (OA)

PLOT AND TABLE INDICATE DIRECTION FROM WHICH THE WIND BLOWS



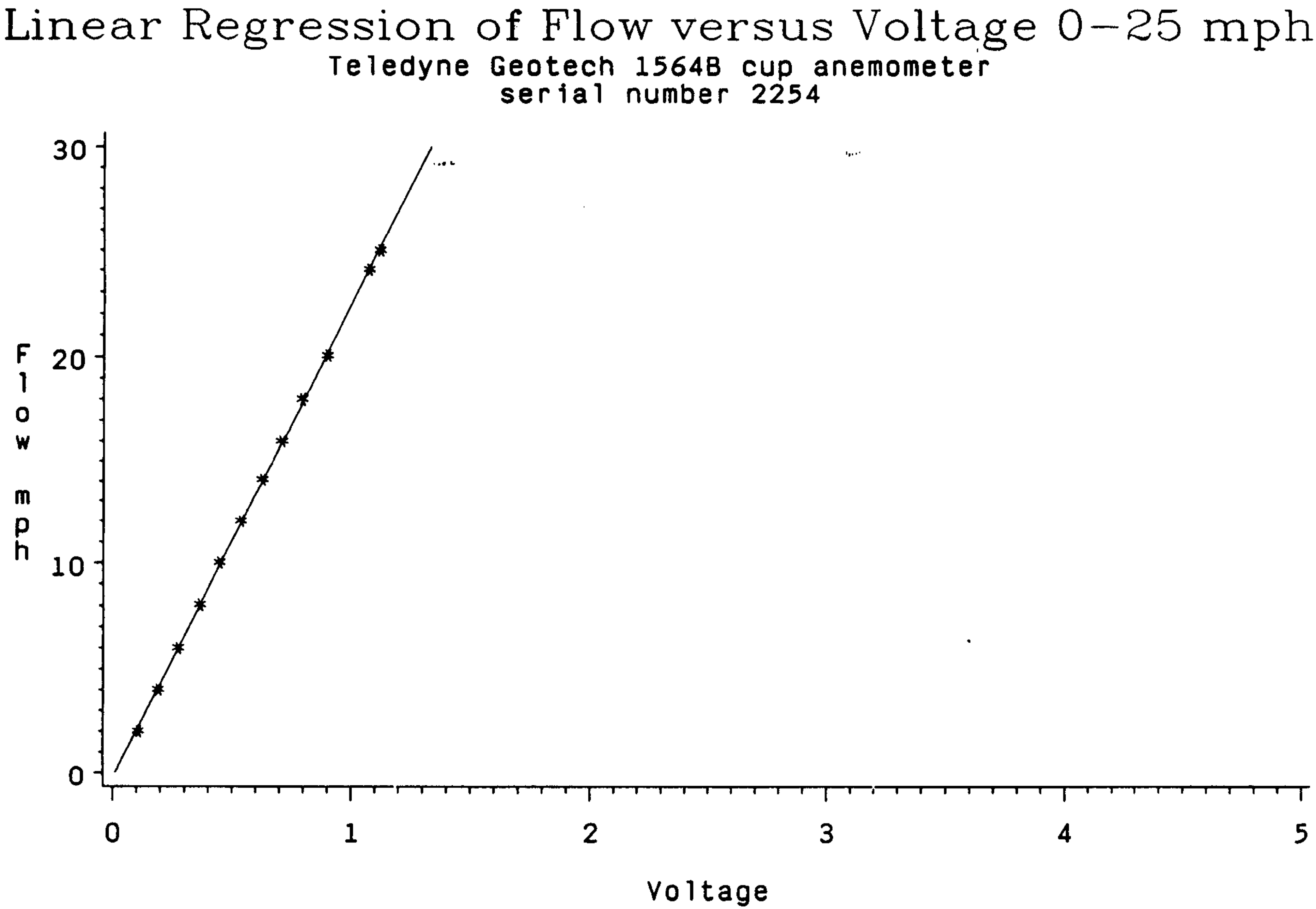
WINDROSE DATA

MINIMUM DATE MMDDYY 10182
MINIMUM TIME ZULU 0008
ENTRIES ALL CLASSES 33331

MAXIMUM DATE MMDDYY 123186
MAXIMUM TIME ZULU 2400
ENTRIES THIS CLASS 33331

0 0 0 0 0 0 0 0 0 0 0

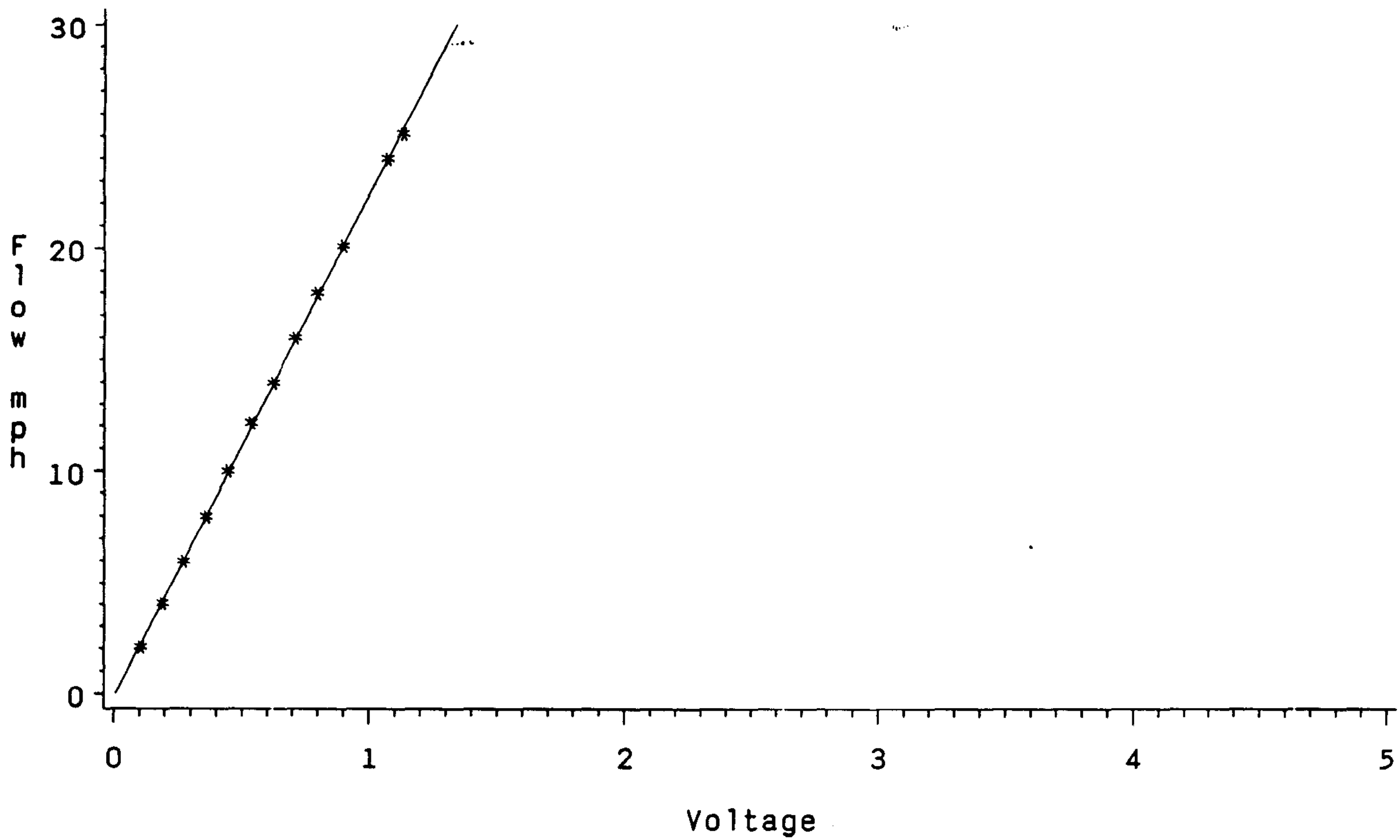
	***** SPEED IN METERS/SEC				*****		AVERAGE	TOTAL	***** PERCENT TIME WIND @ SPEED					*****	
DIRECTION	0-2	2-4	4-6	6-8	8-12	>12	SPEED	TOT	0-2	2-4	4-6	6-8	8-12	>12	TOTAL
N	168	400	305	43	7	0	2.58	923	0.50	1.20	0.92	0.13	0.02	0.00	2.77
NNE	216	624	620	207	12	1	3.04	1680	0.65	1.87	1.86	0.62	0.04	0.00	5.04
NE	273	975	1301	539	116	5	3.53	3209	0.82	2.93	3.90	1.62	0.35	0.02	9.63
ENE	281	1210	1217	310	68	0	3.20	3086	0.84	3.63	3.65	0.93	0.20	0.00	9.26
E	199	841	759	150	6	0	3.10	1955	0.60	2.52	2.28	0.45	0.02	0.00	5.87
ESE	195	664	435	87	5	0	2.81	1386	0.59	1.99	1.31	0.26	0.02	0.00	4.16
SE	189	666	591	110	29	0	3.02	1585	0.57	2.00	1.77	0.33	0.09	0.00	4.76
SSE	239	782	941	139	27	0	3.06	2128	0.72	2.35	2.82	0.42	0.08	0.00	6.38
S	222	920	917	166	28	0	3.08	2253	0.67	2.76	2.75	0.50	0.08	0.00	6.76
SSW	262	875	830	180	21	0	2.97	2168	0.79	2.63	2.49	0.54	0.06	0.00	6.50
SW	293	1073	954	231	29	0	2.95	2580	0.88	3.22	2.86	0.69	0.09	0.00	7.74
WSW	377	1365	967	274	54	2	2.92	3039	1.13	4.10	2.90	0.82	0.16	0.01	9.12
W	389	1149	1054	383	148	0	3.02	3123	1.17	3.45	3.16	1.15	0.44	0.00	9.37
WNW	315	798	816	259	105	0	3.04	2293	0.95	2.39	2.45	0.78	0.32	0.00	6.88
NW	214	441	390	95	9	0	2.68	1149	0.64	1.32	1.17	0.29	0.03	0.00	3.45
NNW	162	338	242	30	2	0	2.53	774	0.49	1.01	0.73	0.09	0.01	0.00	2.32
NO DIRECT	0	0	0	0	0	0	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AVG SPEED	1.16	2.92	4.83	6.65	8.92	14.13	3.02								
TOT ENTRY	3994	3121	2339	3203	668	8		33331							



Plot 1. Regression equation MPH=-0.259 + 22.684(VOLTAGE)
R-squared=0.9997

Linear Regression of Flow versus Voltage 0-25 mph

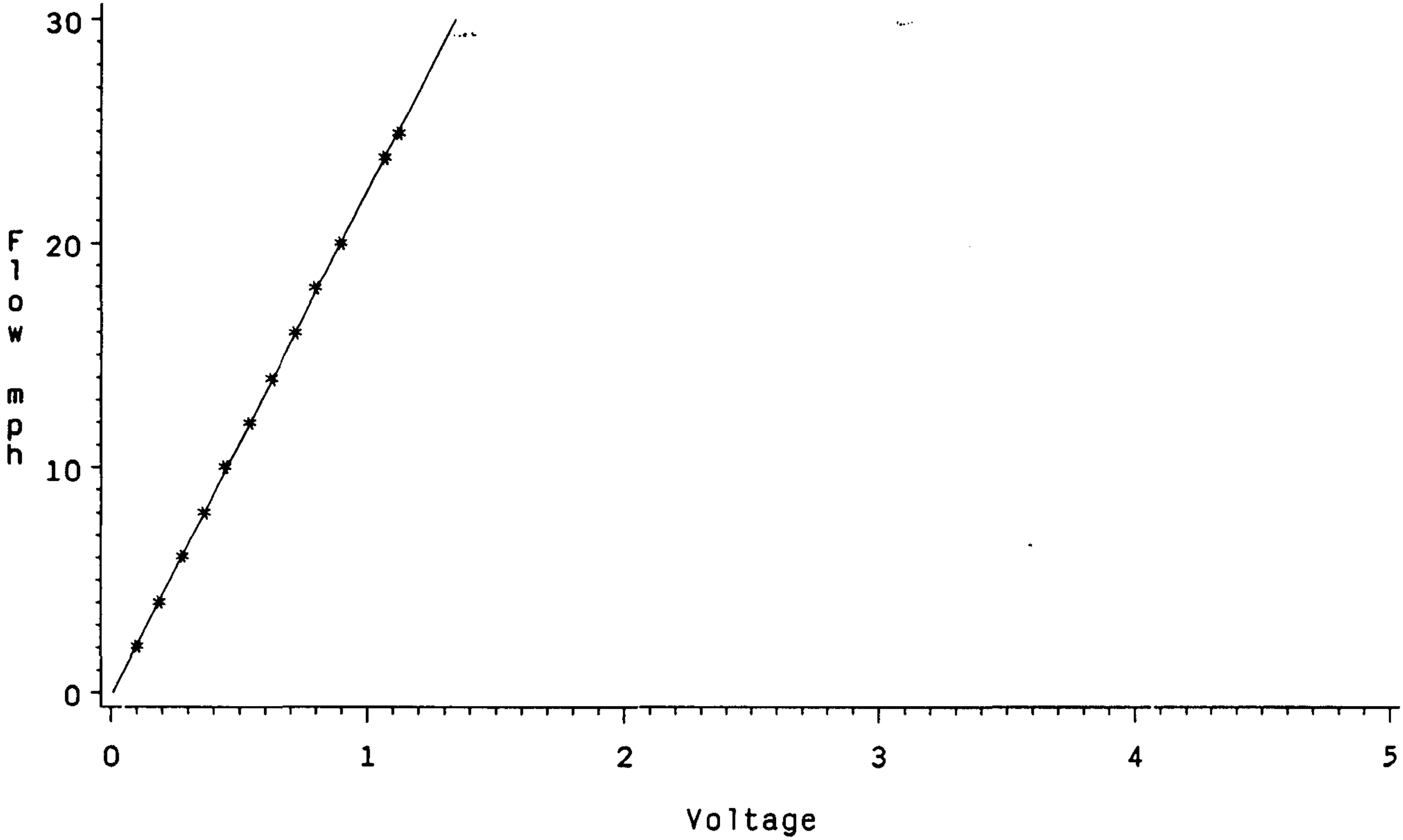
Teledyne Geotech 1564B cup anemometer
serial number 2110



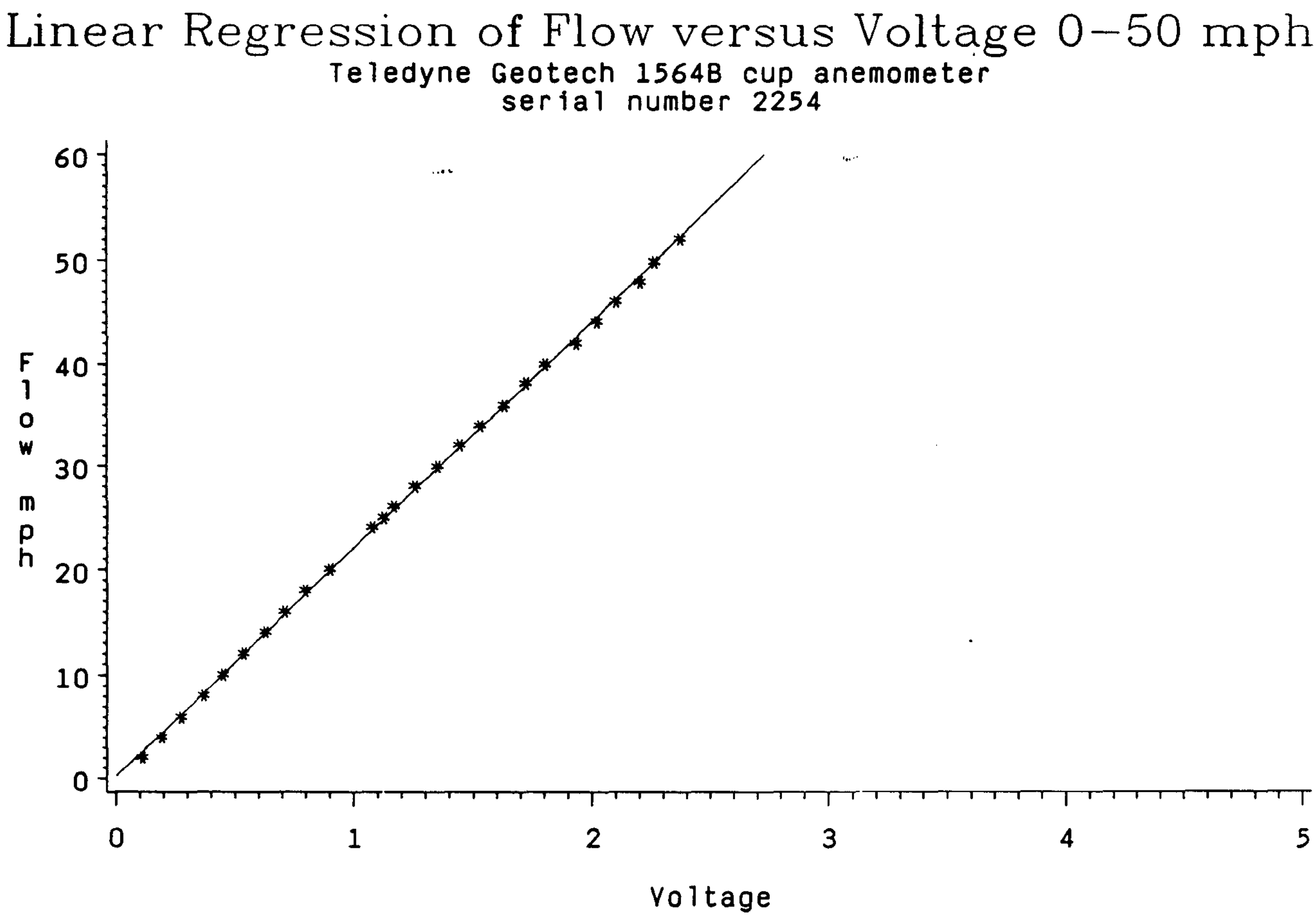
Plot 2. Regression equation MPH=-0.130 + 22.548(VOLTAGE)
R-squared=0.9997

Linear Regression of Flow versus Voltage 0–25 mph

Teledyne Geotech 1564B cup anemometer
serial number 2260

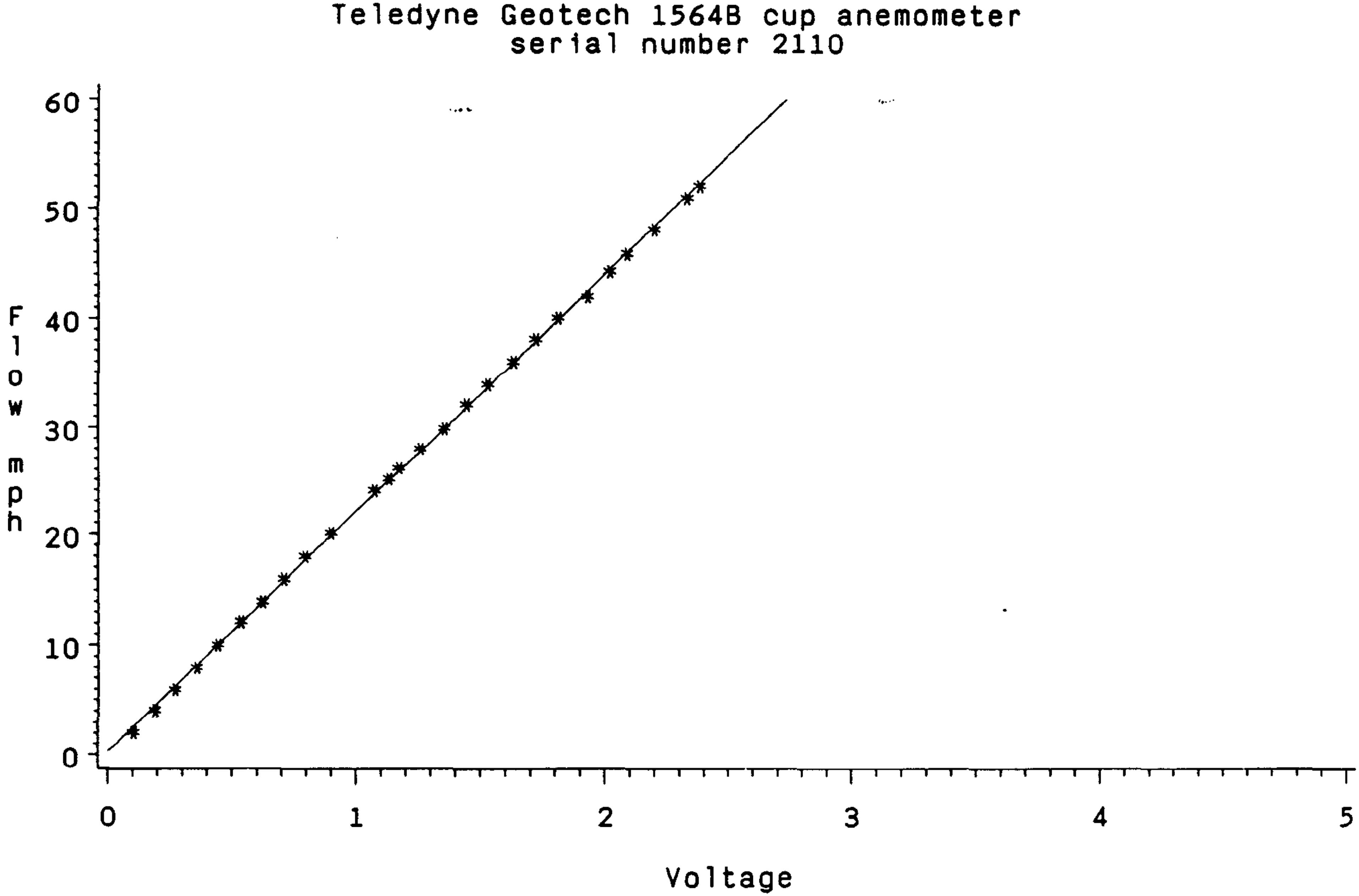


Plot 3. Regression equation MPH=-0.173 + 22.460(VOLTAGE)
R-squared=0.9998

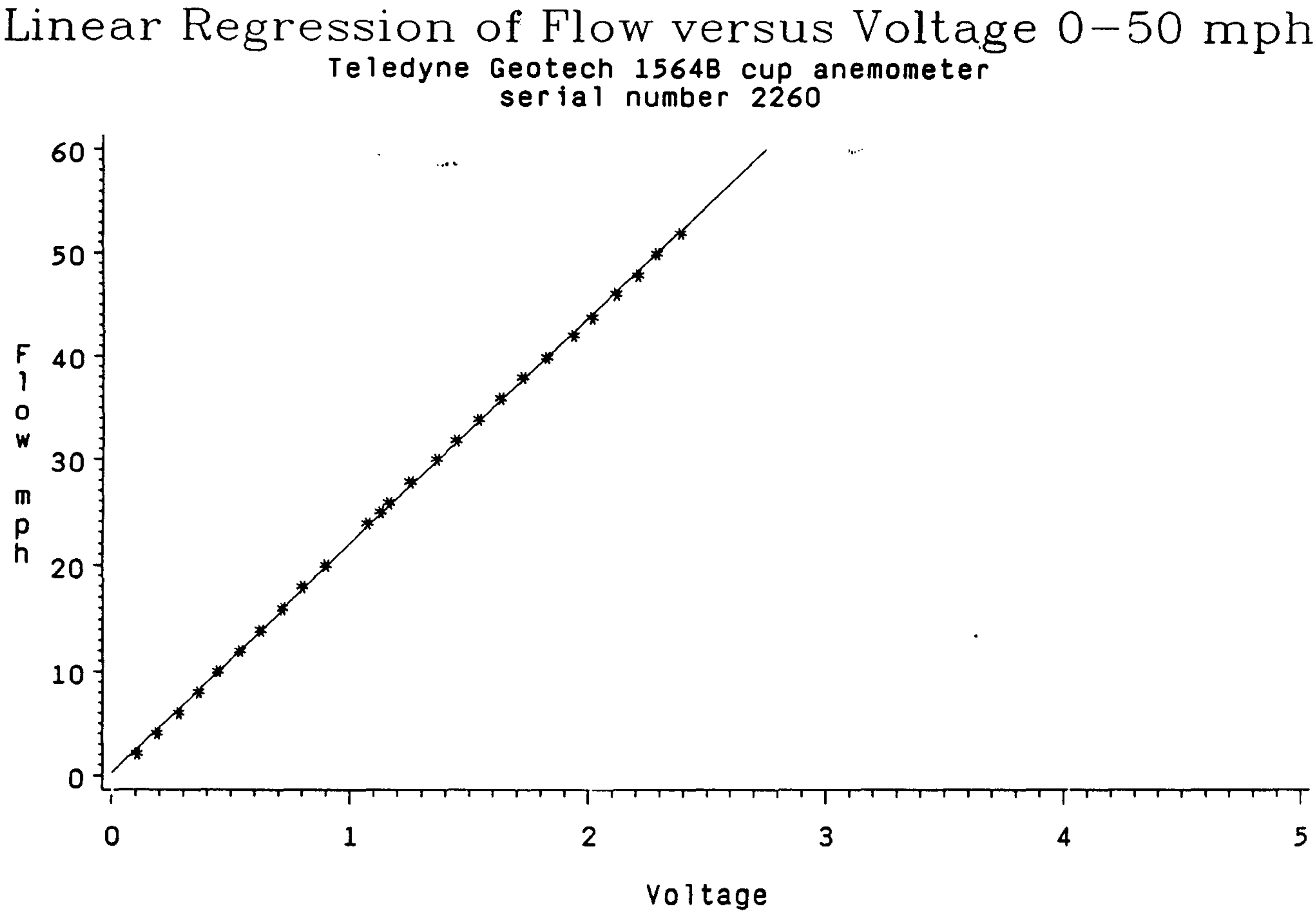


Plot 4. Regression equation MPH=0.215 + 21.913(VOLTAGE)
R-squared=0.9996

Linear Regression of Flow versus Voltage 0–50 mph



Plot 5. Regression equation MPH=0.320 + 21.808(VOLTAGE)
R-squared=0.9997



Plot 6. Regression equation MPH=0.255 + 21.777(VOLTAGE)
R-squared=0.9997

High Wind Speed Predictions

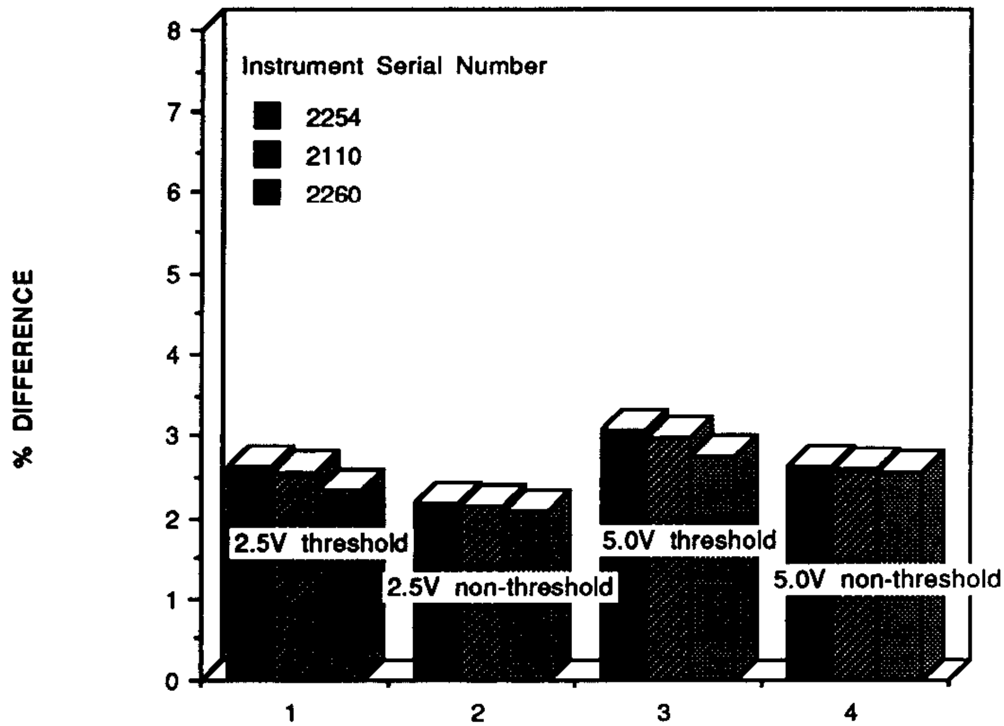


Figure 2. Graphical representation of data from Table A.

Low Wind Speed Prediction Errors

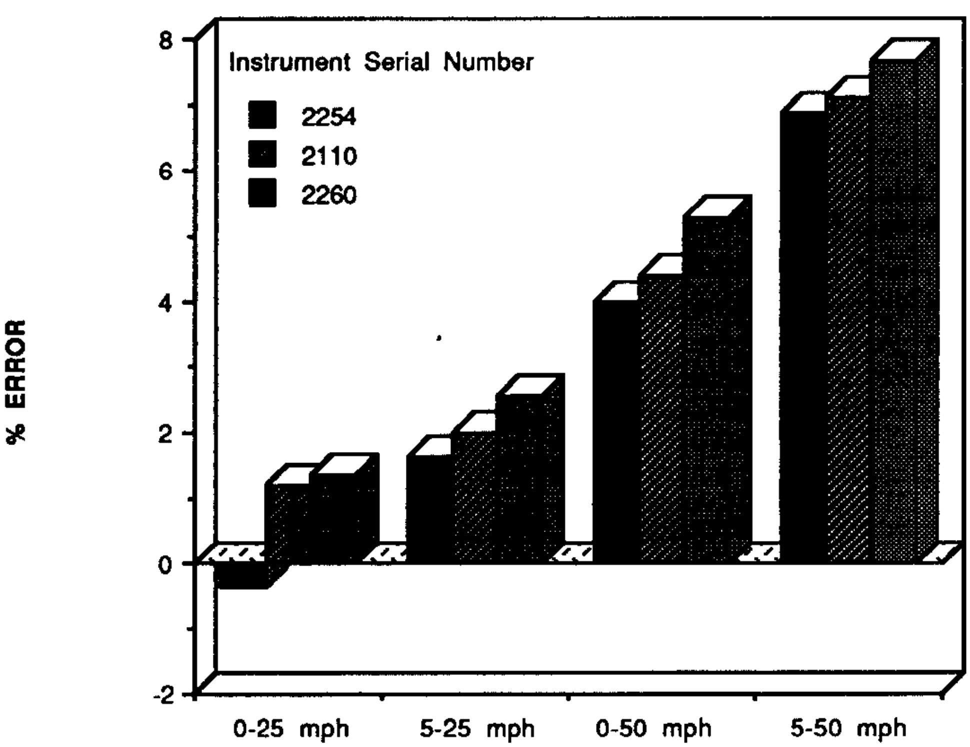


Figure 3. Graphical representation of data from Table B.