Test Report:

Full-Scale Bending Tests of Strongwell's SE28 Fiberglass-Reinforced Polymer Poles

Submitted to:

STRONGWELL

May 2003

E | D | M
EDM International, Inc.

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REPORT ON FULL-SCALE TESTING OF STRONGWELL'S SE28 FRP POLES

Prepared for: Strongwell, Bristol, VA
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1.0 INTRODUCTION

EDM International, Inc. (EDM) is the recognized leader in providing pole testing services to the electric utility industry. During the past two decades, EDM has tested more poles than any other institution in North America. Strongwell contracted with EDM to conduct independent testing for the purposes of assessing the bending strength of its 80ft SE28 pole. The tests were designed to determine the ultimate capacity of the pole under pure bending load, which is one of the primary load applications for utility pole structures. The testing was conducted at EDM's laboratory and test facility in Fort Collins, CO, between April 7 through 10, 2003.

2.0 POLE PREPARATION

Ten 80-SE28 poles were manufactured by Strongwell and shipped to EDM's test facility for the express purpose of conducting destructive bending tests on them. All of the poles were single piece with a constant taper from tip to butt. The SE28 pole has a 12-sided polygonal geometry with alternating flats having a constant and variable width from tip to butt.

3.0 TEST SETUPS

EDM's test facility is equipped with a pole holding fixture, loading system, electronic load and deflection measuring sensors, and a computerized data acquisition system. Figure 4.1 is a schematic of the pole test setup used for the bending load tests.

4.0 BENDING LOAD TESTING

4.1 Test Procedure

For testing, the principles established in ASTM D1036 were followed. The pole was clamped in a horizontal cantilever arrangement with the load cable attached approximately two feet from the pole tip (refer to Fig. 3.1). Load was applied at a constant rate of deformation. Loading and deflection data were captured and recorded electronically multiple times each second up through the time of failure. Deflection measurements were taken near the pole tip and at two points below the groundline. The below groundline measurements were used to calculate the magnitude of base

rotation that resulted from the stretching of the anchor straps. Five of the poles were tested with their constant width flat on the compression and tension faces and the other five poles were tested with their variable width faces on the compression and tension faces.

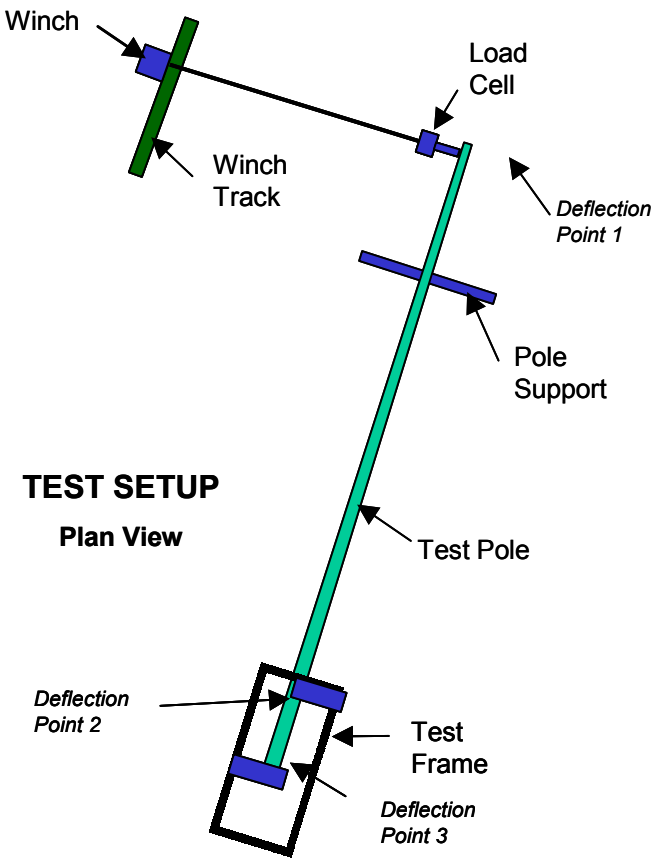


Figure 4-1 – Bending Test Setup

4.2 Test Data

Data sheets for each individual load test are included in Appendix A. Graphs of the load vs. deflection data are provided immediately following each data sheet. Note, the tip deflections used for this purpose have been adjusted to compensate for the measured base rotations. Other test data include digital still images that were taken of the test setup and following each test. The still images are provided in Appendix B.

4.3 Test Results

The purpose of these tests was to quantify the bending strength and stiffness characteristics of this SE28 pole. For each pole tested, maximum bending stress values were calculated for both the point of failure and the groundline based on the

maximum load realized during the test and the section properties of the pole as established by Strongwell. Modulus of Elasticity values was also calculated for each pole tested. These were generated by first fitting a linear regression line to each load-deflection data set. The slopes of these lines were then used to calculate an effective pole deflection under a given load and compared to the deflection results of the pole as modeled in *PLS-POLE* with an assumed MOE. Lastly, the ratio of the two results was multiplied by the assumed MOE value to obtain an estimated MOE value for the pole as tested. A summary of the test results for all ten tests is provided in Table 4.1.

4.4 Summary

All of the ten poles tested were of a single design (SE28) and length (80 ft) and are marketed as having a 2812 lb tip load capacity. The pole cross section is a 12-sided polygon with varying widths on alternating sides. Five of the poles were tested by orienting them with their constant width sides on the compression/tension faces and five of the poles were tested with their variable width sides on the compression/tension faces. Results from both sets of tests show that the pole is significantly stronger than the 2812 lb rated strength. The average of the breaking loads for the set of five constant width flats was 3969 lbs with the weakest one breaking at 3808 lbs. The average of the breaking loads for the set of five variable width flats was 3796 lbs with the weakest one breaking at 3612 lbs. The COV's for the constant- and variable-sided test sets was 3.5% and 4.3% respectively, which demonstrates good quality control in the manufacturing process. The MOE values averaged 4518 and 4296 ksi for these same two data sets with COVs of 3.6% for both.

Table 4-1 – Summary of Test Results

Test #	Test Flat	Elev @ Break	Max Load	Projected Deflection @ 2812#		Stress		MOE (ksi)
				Tip	Load Pt	@ GL	@ Break	
1	C	69.5	4190.0	161.4	152.9	29,395	29,424	4650
2	C	70.79	3943.0	176.6	167.3	27,567	27,545	4250
3	C	61.66	3943.0	163.9	155.2	27,619	27,781	4580
4	C	65	3963.0	162.4	153.9	27,802	27,970	4620
5	C	65.5	3808.0	167.1	158.4	26,678	26,829	4490
		Ave	3969.4	166.3	157.5	27812		4518
		StdDev	138.0			986		161
		COV	3.5%			3.5%		3.6%
		5%LEL	3742.4			26190		4252
		5% LTL	3723.8			26008		4223
7	V	69.08	4002.0	165.3	156.6	26,488	26,534	4540
8	V	63.38	3746.0	180.0	170.5	24,727	24,999	4170
9	V	67.33	3923.0	180.4	170.9	25,912	26,040	4160
10	V	69.42	3698.0	173.3	164.2	24,519	24,546	4330
11	V	63.5	3612.0	175.3	166.1	23,990	24,274	4280
		Ave	3796.2	174.9	165.7	25127		4296
		StdDev	161.7			1036		154
		COV	4.3%			4.1%		3.6%
		5%LEL	3530.3			23423		4042
		5%LTL	3508.5			23232		4014

Note – “Projected Deflection @ 2812#” values are calculated based on the MOE values shown in the table.

APPENDIX A – TEST DATA

Following are the data sheets from the individual load tests accompanied by plots of the load vs. deflection relationships for these tests. The second graph in each series is the same as the first, except that both ends have been truncated to eliminate the non-linearities associated with both test start up and buckling failure. Linear trend lines and their equations are shown on these graphs. The slopes of these trend lines were used in conjunction with results from PLS-POLE modeling to establish the moduli of elasticity values that are included in the Summary of Test Results, Table 4-1.

Strongwell
FRP Pole
Destructive Bending Tests

Sheet No. 1
Date 7-Apr-03
Time 11:15

Static Bending Test

Test No. 1 **Length** 80 **Flat** C

C= Constant, V= Variable

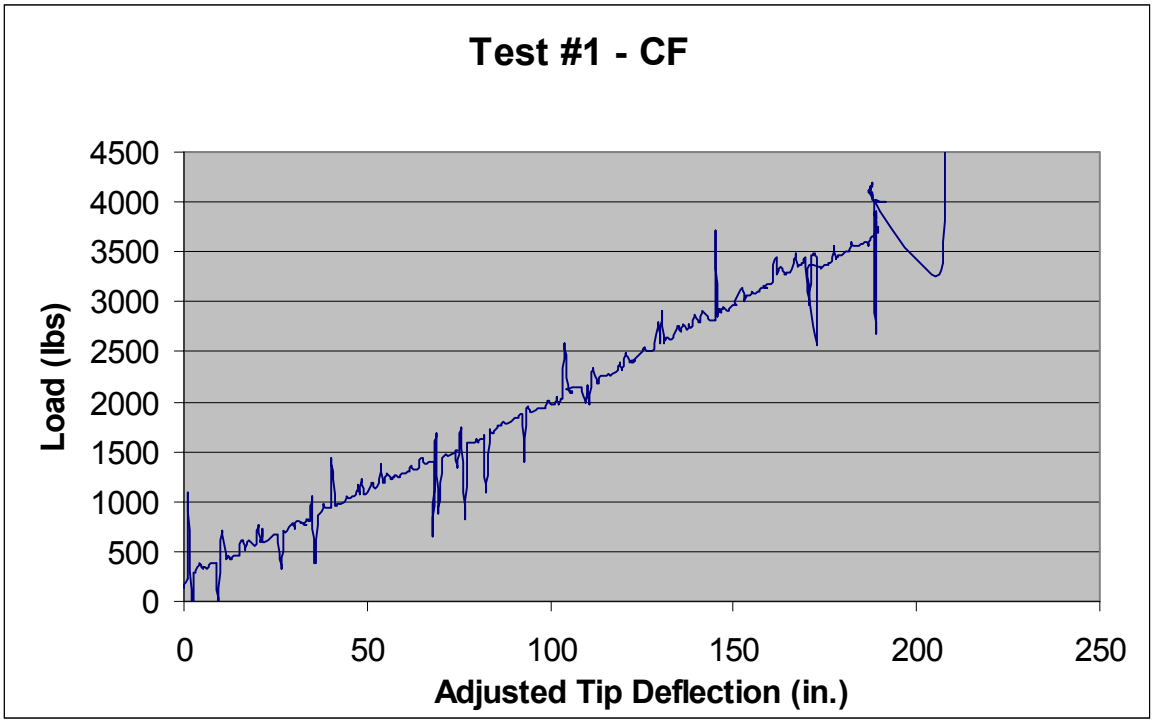
Actual Pole Length	80.00	(ft)
Distance- Butt to G.L.	9.92	(ft)
Distance Tip to Load Point	2.00	(ft)
Distance G.L. to Failure Point	0.67	(ft)
G.L. Diameter (flat-to-flat)	22.27	(in)
Diameter @ Failure Point (flat-to-flat)	22.15	(in)
Maximum Load @ Failure	4190	(lbs)
Distance Tip to Defl. Pt. 1	29.00	(in)
Distance between Butt Defl Pts 2 & 3	92.50	(in)
Adjusted Horizontal Deflection @ 2812# *Deflection Point 1*	143.65	(in)

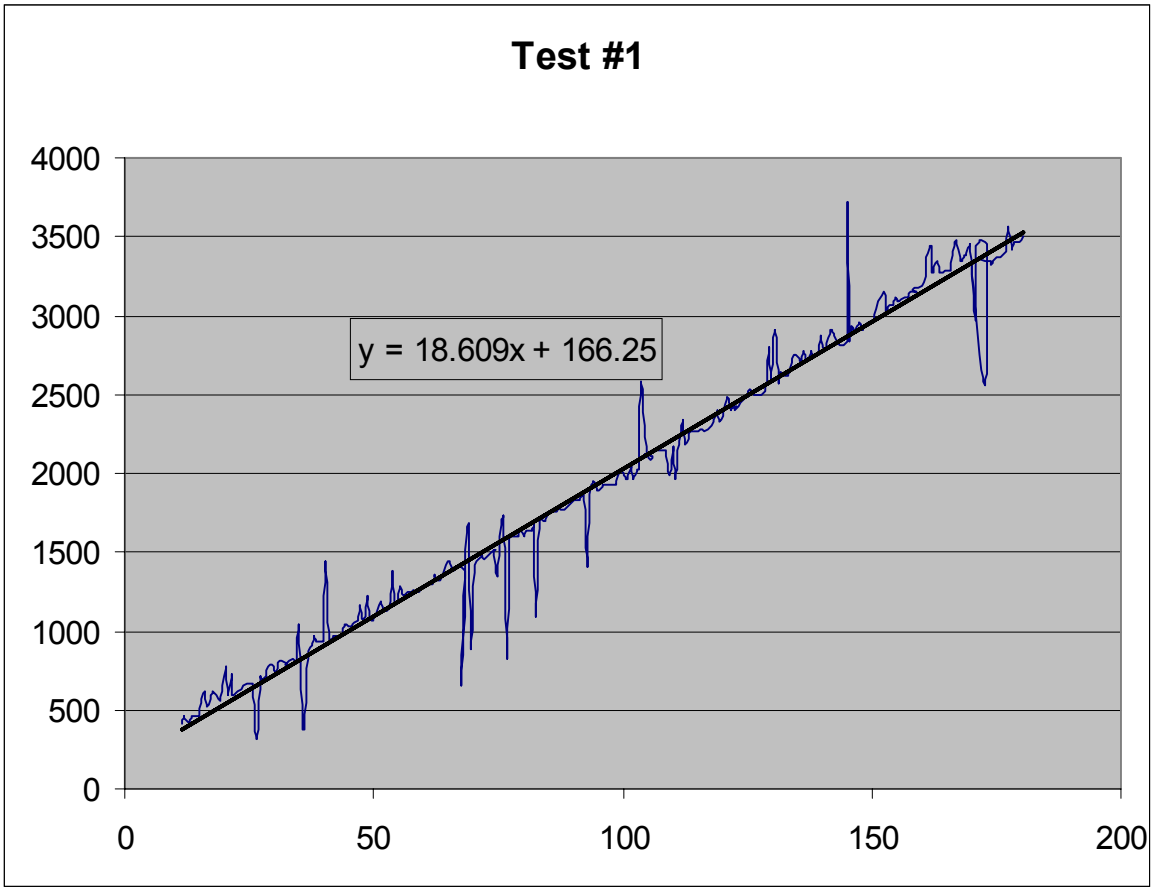
Defl. Pt.	Defl. (in)
1	156.53
2	0.68
3	0.79

Results	Moment (ft-lbs)	S (in3)	Stress (psi)
@ GL	285,255	116.45	29,395
@ Break	282,448	115.19	29,424

Location	Diameter (f-f)
Tip	9.22
GL	22.27
Break	22.15
Butt	24.12

Comments: Pole #1
Buckling Failure


Test #1 - CF
Load (lbs)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
50
100
150
200
250
Adjusted Tip Deflection (in.)


Test #1
y = 18.609x + 166.25
4000
3500
3000
2500
2000
1500
1000
500
0
0
50
100
150
200

Strongwell
FRP Pole
Destructive Bending Tests

Sheet No. 2
Date 7-Apr-03
Time 12:30

Static Bending Test

Test No. 2 **Length** 80 **Flat** C

C= Constant, V= Variable

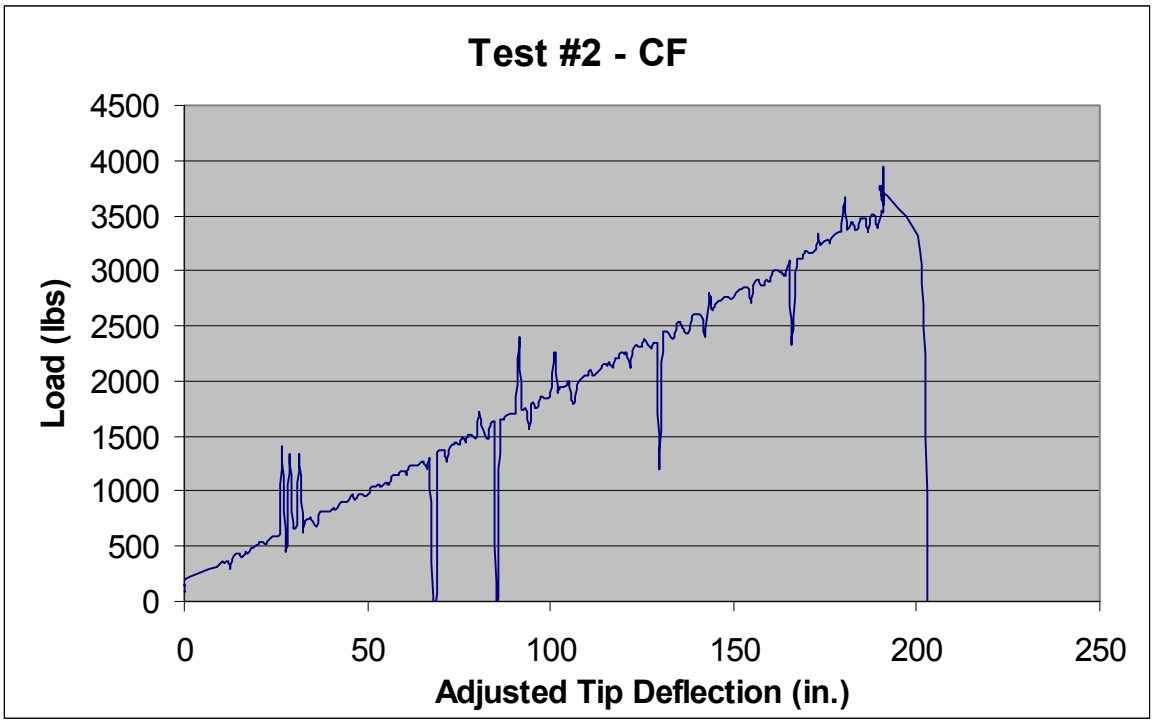
Actual Pole Length	80.08	(ft)
Distance- Butt to G.L.	9.83	(ft)
Distance Tip to Load Point	2.17	(ft)
Distance G.L. to Failure Point	-0.54	(ft)
G.L. Diameter (flat-to-flat)	22.29	(in)
Diameter @ Failure Point (flat-to-flat)	22.39	(in)
Maximum Load @ Failure	3943	(lbs)
Distance Tip to Defl. Pt. 1	31.00	(in)
Distance between Butt Defl Pts 2 & 3	94.00	(in)
Adjusted Horizontal Deflection @ 2812# *Deflection Point 1*	150.83	(in)

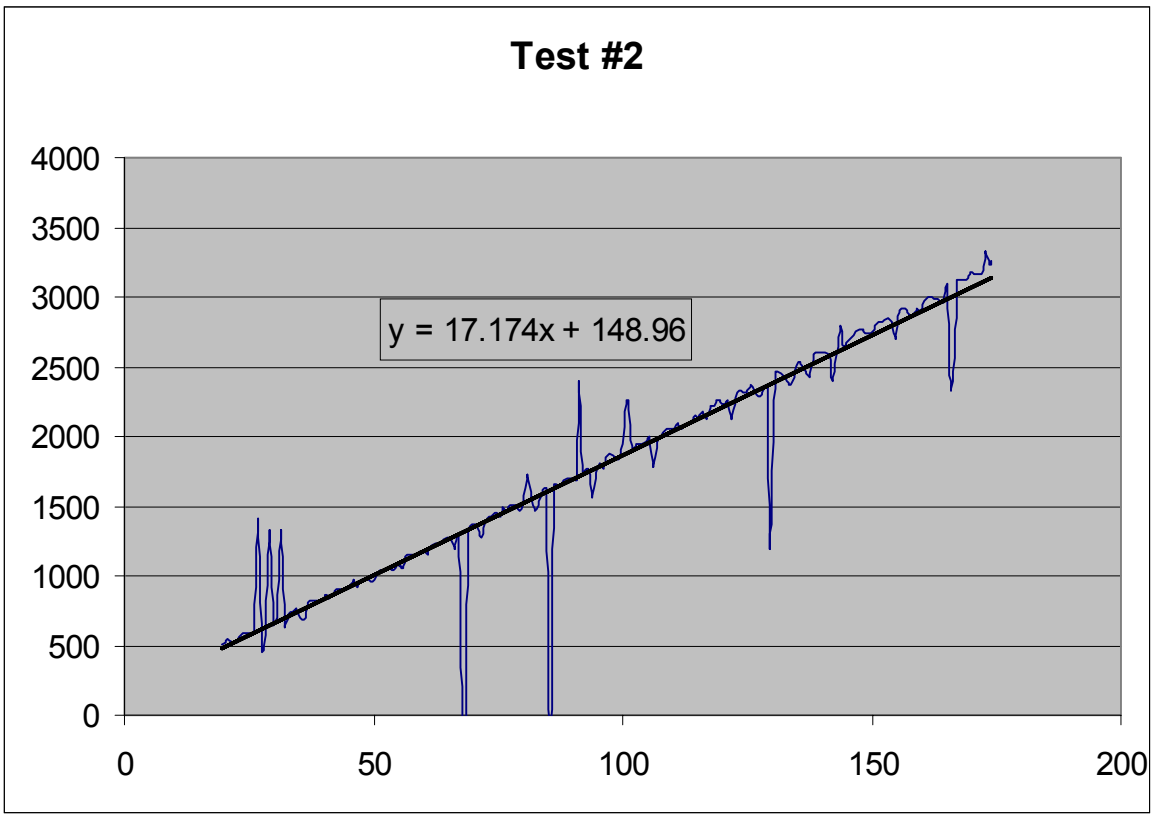
Defl. Pt.	Defl. (in)
1	167.55
2	0.91
3	1.03

Results	Moment (ft-lbs)	S (in3)	Stress (psi)
@ GL	268,439	116.85	27,567
@ Break	270,569	117.87	27,545

Location	Diameter (f-f)
Tip	9.22
GL	22.29
Break	22.39
Butt	24.12

Comments: Pole #13
Buckling Failure


Test #2 - CF
Load (lbs)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
50
100
150
200
250
Adjusted Tip Deflection (in.)


Test #2
y = 17.174x + 148.96
4000
3500
3000
2500
2000
1500
1000
500
0
0
50
100
150
200

Strongwell
FRP Pole
Destructive Bending Tests

Sheet No. 3
Date 7-Apr-03
Time 14:30

Static Bending Test

Test No. 3 **Length** 80 **Flat** C

C= Constant, V= Variable

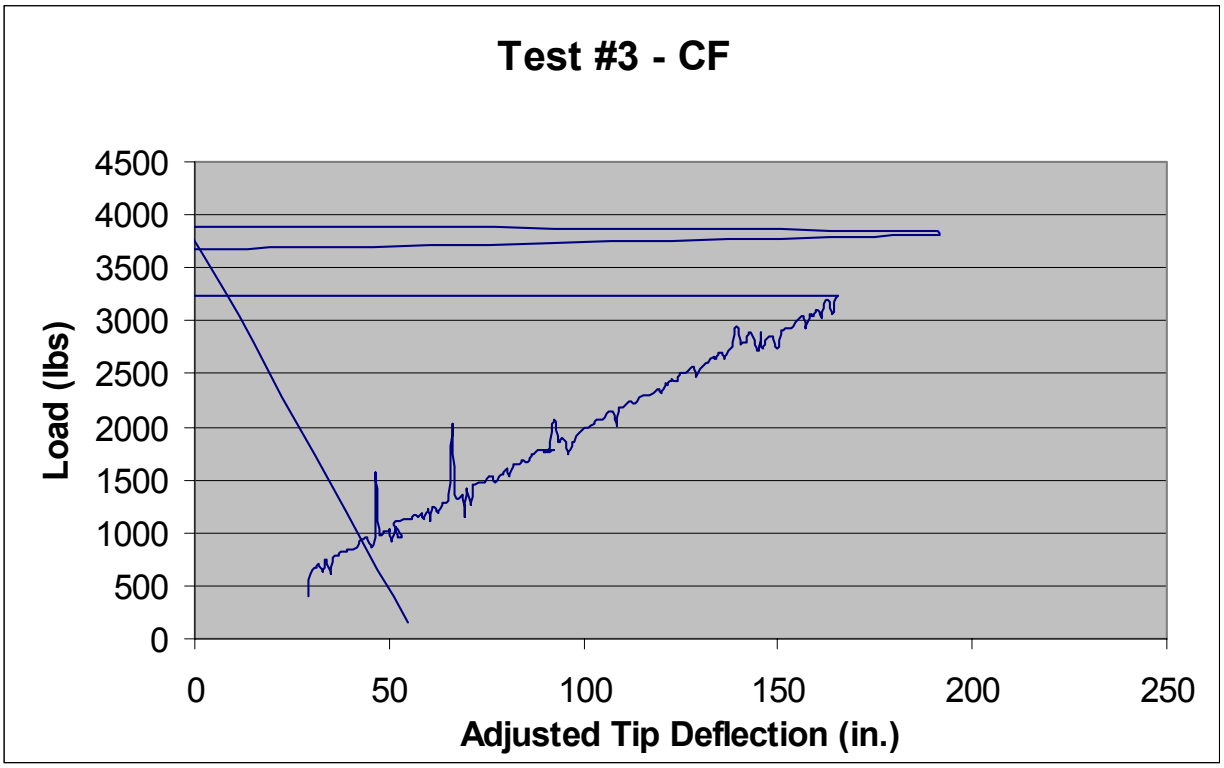
Actual Pole Length	80.04	(ft)
Distance- Butt to G.L.	10.88	(ft)
Distance Tip to Load Point	2.17	(ft)
Distance G.L. to Failure Point	7.50	(ft)
G.L. Diameter (flat-to-flat)	22.09	(in)
Diameter @ Failure Point (flat-to-flat)	20.70	(in)
Maximum Load @ Failure	3943	(lbs)
Distance Tip to Defl. Pt. 1	31.50	(in)
Distance between Butt Defl Pts 2 & 3	94.75	(in)
Adjusted Horizontal Deflection @ 2812# *Deflection Point 1*	146.03	(in)

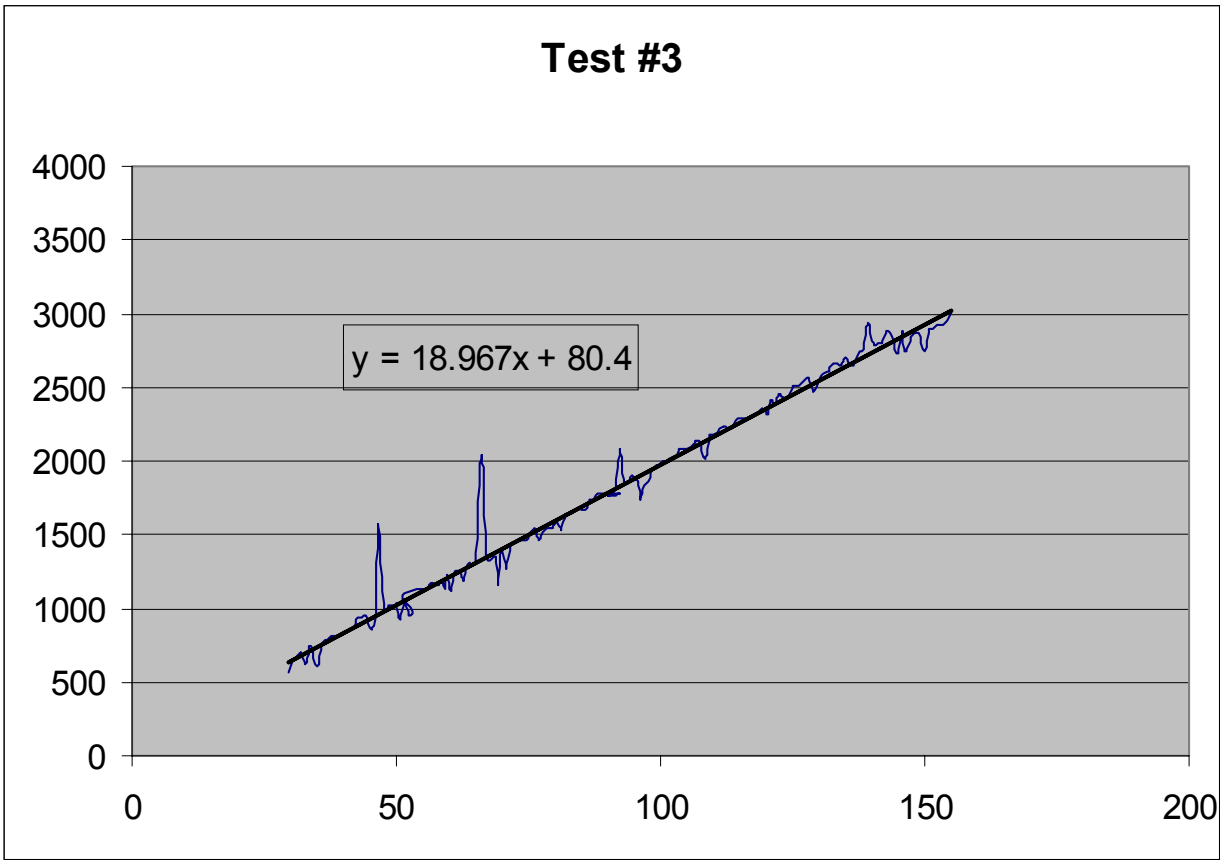
Defl. Pt.	Defl. (in)
1	157.64
2	0.68
3	0.70

Results	Moment (ft-lbs)	S (in3)	Stress (psi)
@ GL	264,142	114.76	27,619
@ Break	234,569	101.32	27,781

Location	Diameter (f-f)
Tip	9.22
GL	22.09
Break	20.70
Butt	24.12

Comments: Pole #3
Buckling Failure


Test #3 - CF
Load (lbs)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
50
100
150
200
250
Adjusted Tip Deflection (in.)


Test #3
y = 18.967x + 80.4
4000
3500
3000
2500
2000
1500
1000
500
0
0
50
100
150
200

Strongwell
FRP Pole
Destructive Bending Tests

Sheet No. 4
Date 7-Apr-03
Time 16:45

Static Bending Test

Test No. 4 **Length** 80 **Flat** C
C= Constant, V= Variable

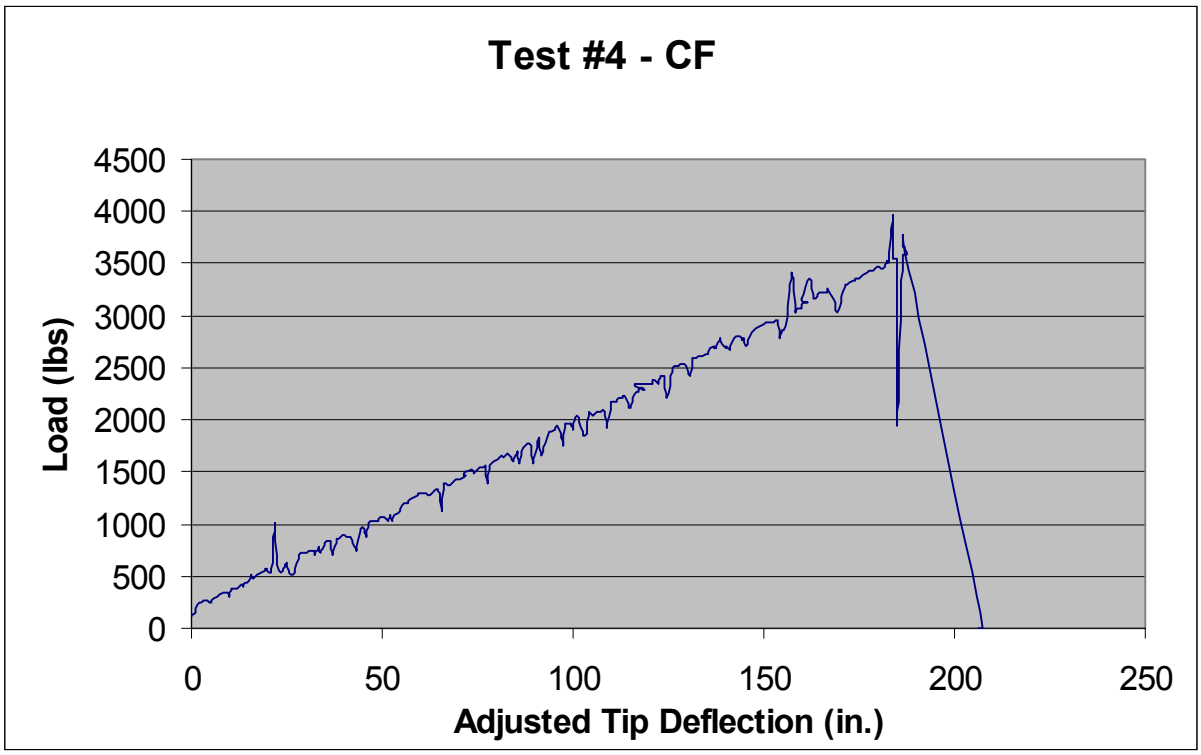
Actual Pole Length	80.00	(ft)
Distance- Butt to G.L.	9.92	(ft)
Distance Tip to Load Point	2.00	(ft)
Distance G.L. to Failure Point	5.08	(ft)
G.L. Diameter (flat-to-flat)	22.27	(in)
Diameter @ Failure Point (flat-to-flat)	21.33	(in)
Maximum Load @ Failure	3963	(lbs)
Distance Tip to Defl. Pt. 1	30.00	(in)
Distance between Butt Defl Pts 2 & 3	93.75	(in)
Adjusted Horizontal Deflection @ 2812# *Deflection Point 1*	142.80	(in)

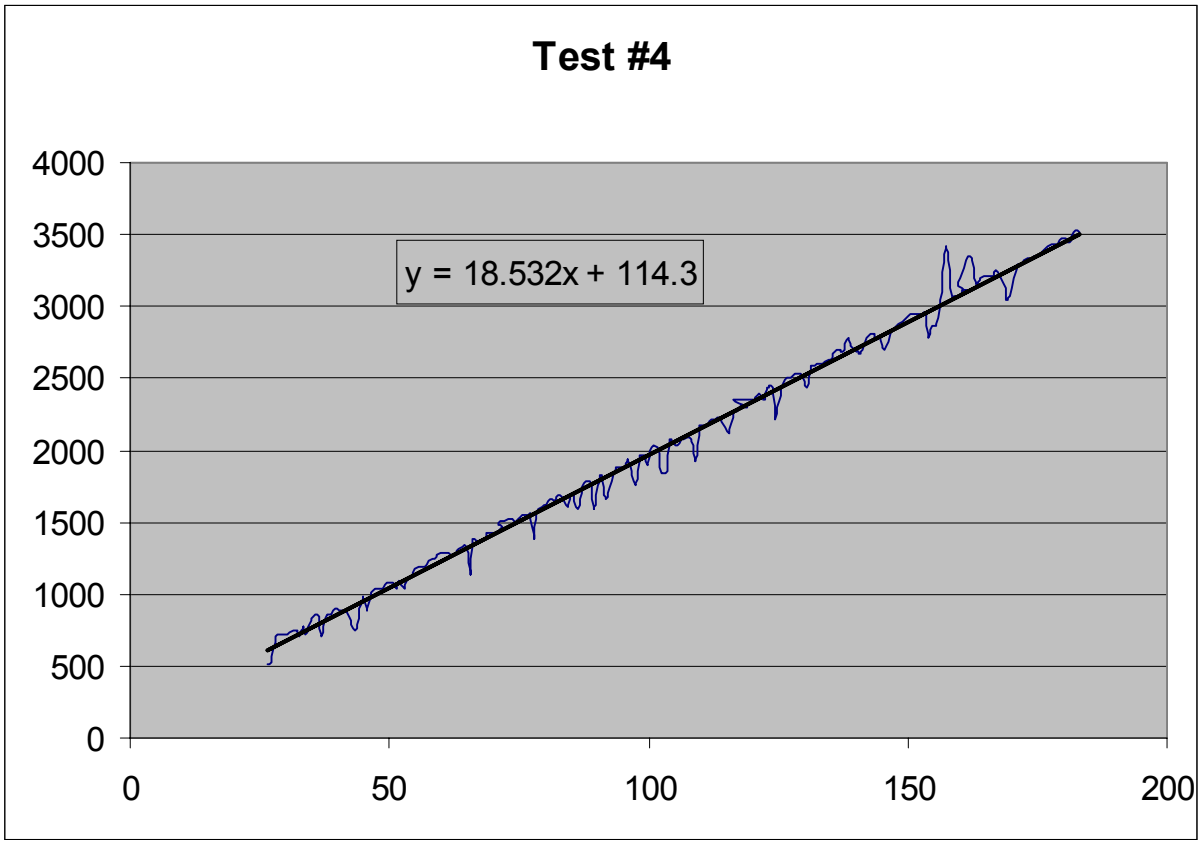
Defl. Pt.	Defl. (in)
1	153.19
2	0.52
3	0.68

Results	Moment (ft-lbs)	S (in3)	Stress (psi)
@ GL	269,801	116.45	27,802
@ Break	249,669	107.12	27,970

Location	Diameter (f-f)
Tip	9.22
GL	22.27
Break	21.33
Butt	24.12

Comments: Pole #6
Buckling Failure


Test #4 - CF
Load (lbs)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
50
100
150
200
250
Adjusted Tip Deflection (in.)


Test #4
y = 18.532x + 114.3
4000
3500
3000
2500
2000
1500
1000
500
0
0
50
100
150
200

Strongwell
FRP Pole
Destructive Bending Tests

Sheet No. 10
Date 10-Apr-03
Time 9:35

Static Bending Test

Test No. 5 **Length** 80 **Flat** C

C= Constant, V= Variable

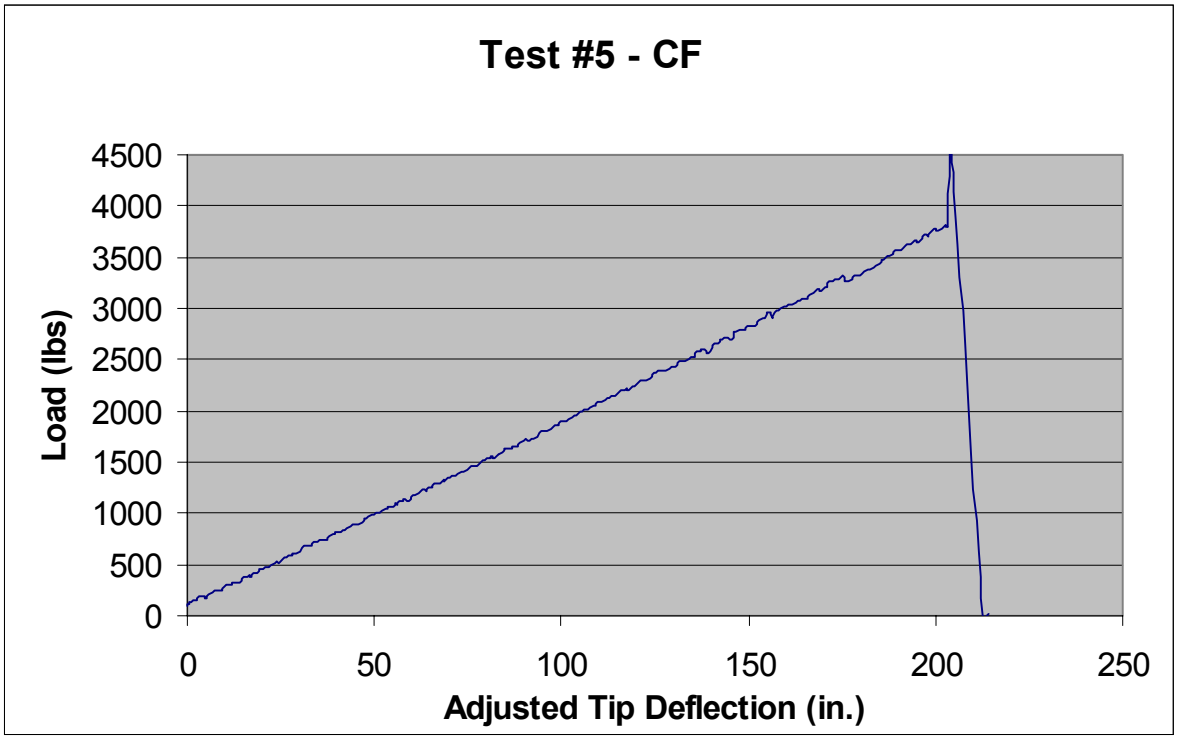
Actual Pole Length	80.08	(ft)
Distance- Butt to G.L.	9.92	(ft)
Distance Tip to Load Point	2.04	(ft)
Distance G.L. to Failure Point	4.67	(ft)
G.L. Diameter (flat-to-flat)	22.27	(in)
Diameter @ Failure Point (flat-to-flat)	21.40	(in)
Maximum Load @ Failure	3808	(lbs)
Distance Tip to Defl. Pt. 1	37.50	(in)
Distance between Butt Defl Pts 2 & 3	93.50	(in)
Adjusted Horizontal Deflection @ 2812# *Deflection Point 1*	148.97	(in)

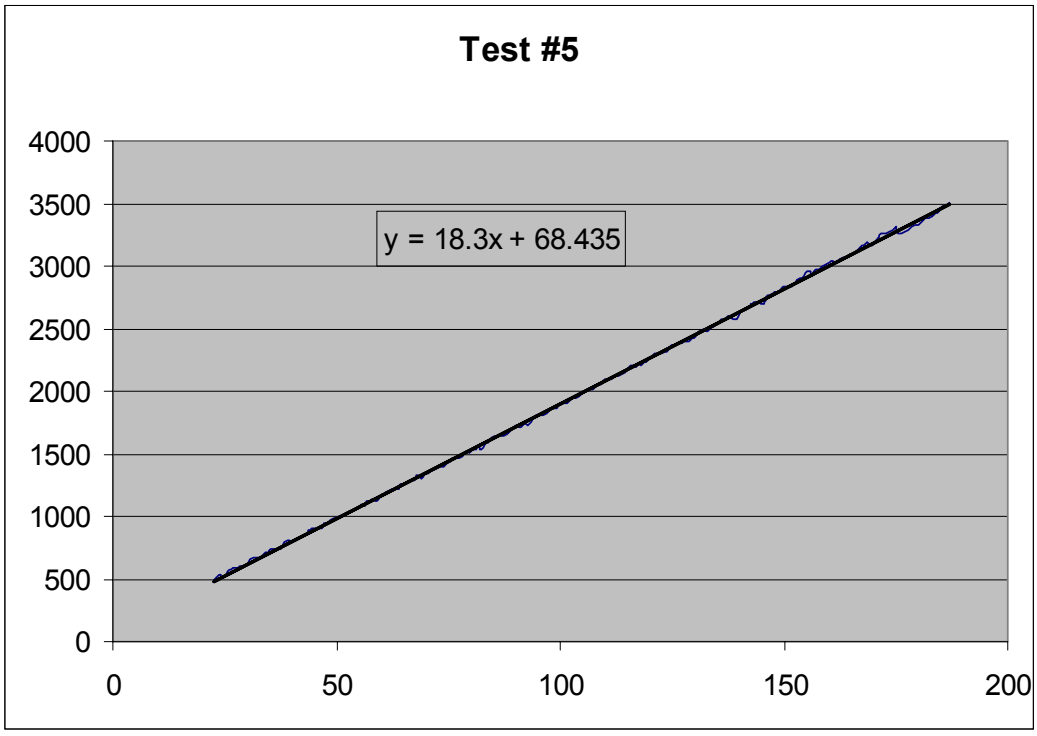
Defl. Pt.	Defl. (in)
1	160.40
2	0.66
3	0.67

Results	Moment (ft-lbs)	S (in3)	Stress (psi)
@ GL	259,401	116.68	26,678
@ Break	241,618	108.07	26,829

Location	Diameter (f-f)
Tip	9.22
GL	22.27
Break	21.40
Butt	24.12

Comments: Pole #8
Buckling Failure


Test #5 - CF
Load (lbs)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
50
100
150
200
250
Adjusted Tip Deflection (in.)


Test #5
y = 18.3x + 68.435
4000
3500
3000
2500
2000
1500
1000
500
0
0
50
100
150
200

Strongwell
FRP Pole
Destructive Bending Tests

Sheet No. 5
Date 8-Apr-03
Time 11:20

Static Bending Test

Test No. 7 **Length** 80 **Flat** V
C= Constant, V= Variable

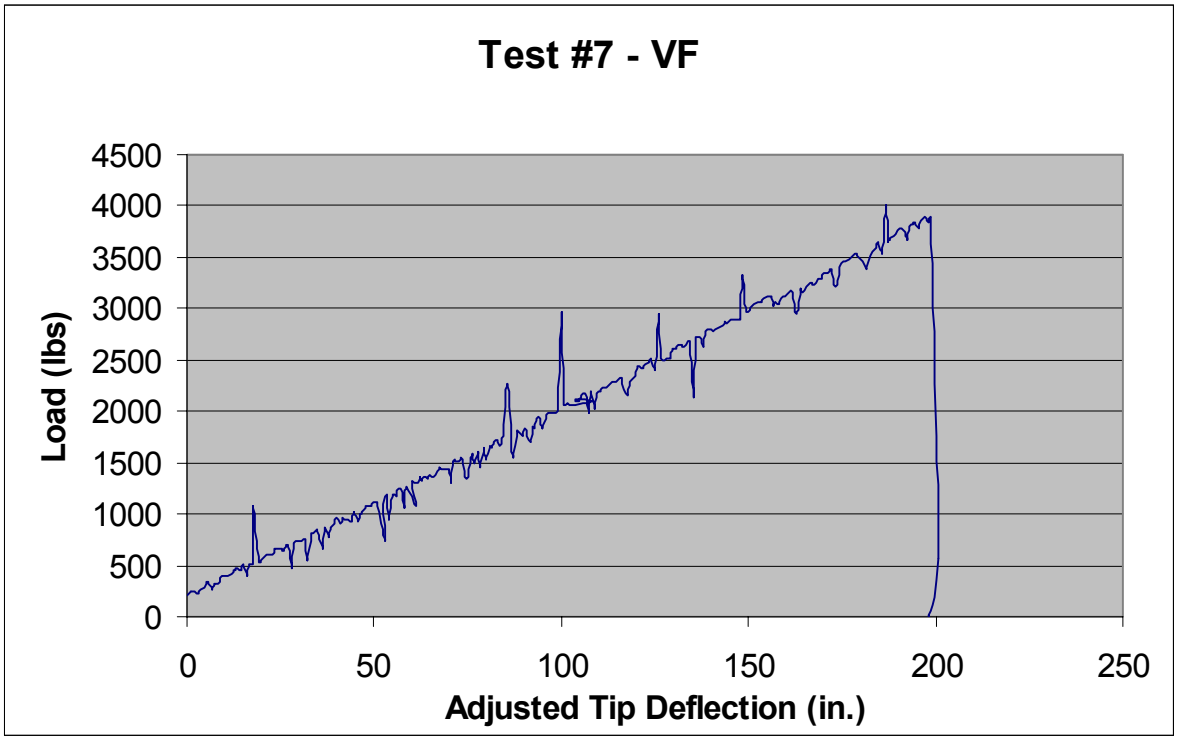
Actual Pole Length	80.04	(ft)
Distance- Butt to G.L.	10.12	(ft)
Distance Tip to Load Point	2.25	(ft)
Distance G.L. to Failure Point	0.83	(ft)
G.L. Diameter (flat-to-flat)	21.06	(in)
Diameter @ Failure Point (flat-to-flat)	20.92	(in)
Maximum Load @ Failure	4002	(lbs)
Distance Tip to Defl. Pt. 1	37.00	(in)
Distance between Butt Defl Pts 2 & 3	93.00	(in)
Adjusted Horizontal Deflection @ 2812# *Deflection Point 1*	141.26	(in)

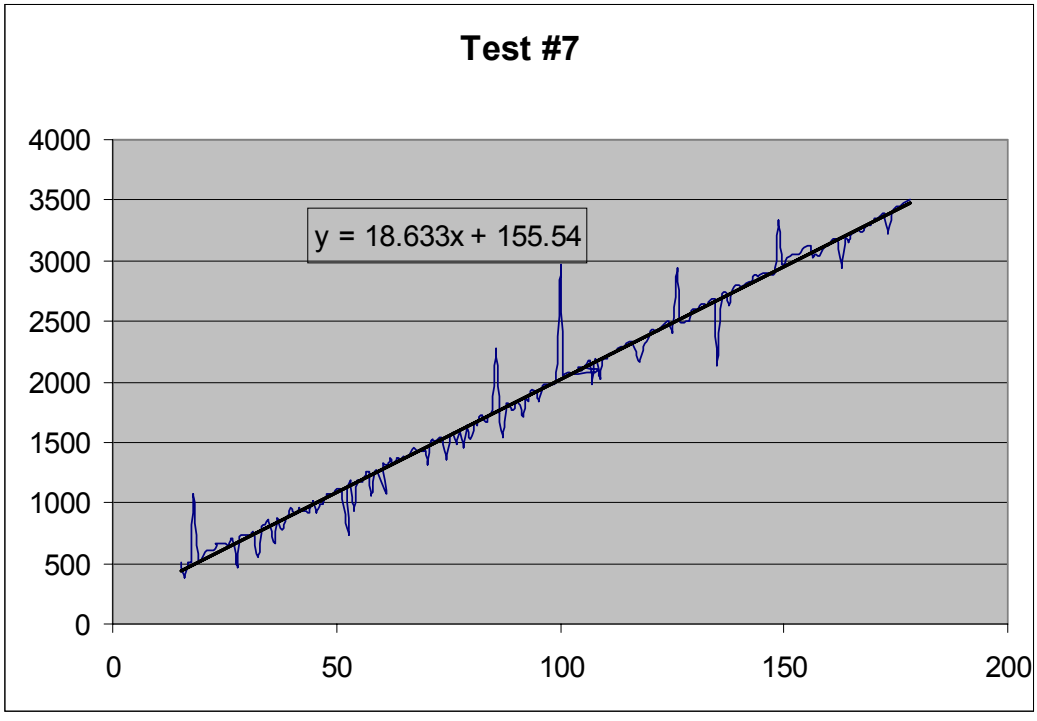
Defl. Pt.	Defl. (in)
1	157.19
2	0.72
3	1.13

Results	Moment (ft-lbs)	S (in3)	Stress (psi)
@ GL	270,815	122.69	26,488
@ Break	267,494	120.97	26,534

Location	Diameter (f-f)
Tip	9.79
GL	21.06
Break	20.92
Butt	22.69

Comments: Pole #7
Buckling Failure


Test #7 - VF
Load (lbs)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
50
100
150
200
250
Adjusted Tip Deflection (in.)


Test #7
y = 18.633x + 155.54
4000
3500
3000
2500
2000
1500
1000
500
0
0
50
100
150
200

Strongwell
FRP Pole
Destructive Bending Tests

Sheet No. 6
Date .8-Apr-03
Time 13:20

Static Bending Test

Test No. 8 **Length** 80 **Flat** V

C= Constant, V= Variable

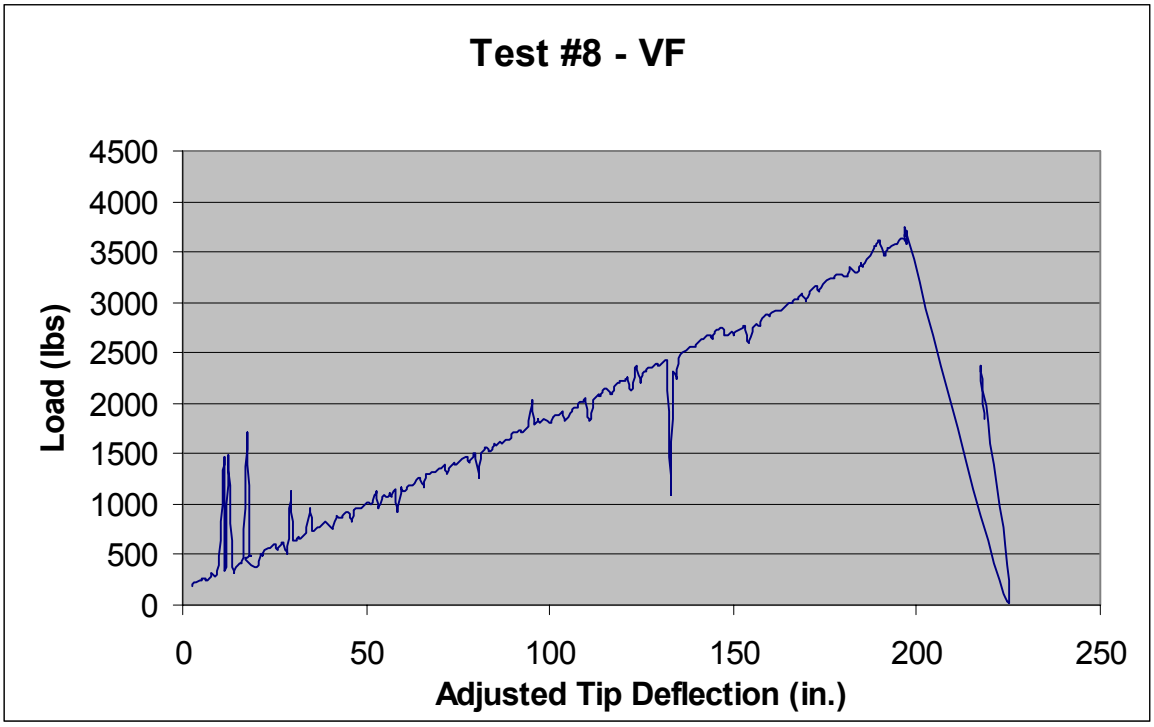
Actual Pole Length	80.00	(ft)
Distance- Butt to G.L.	10.12	(ft)
Distance Tip to Load Point	2.46	(ft)
Distance G.L. to Failure Point	6.50	(ft)
G.L. Diameter (flat-to-flat)	21.06	(in)
Diameter @ Failure Point (flat-to-flat)	20.01	(in)
Maximum Load @ Failure	3746	(lbs)
Distance Tip to Defl. Pt. 1	38.00	(in)
Distance between Butt Defl Pts 2 & 3	94.75	(in)
Adjusted Horizontal Deflection @ 2812# *Deflection Point 1*	157.98	(in)

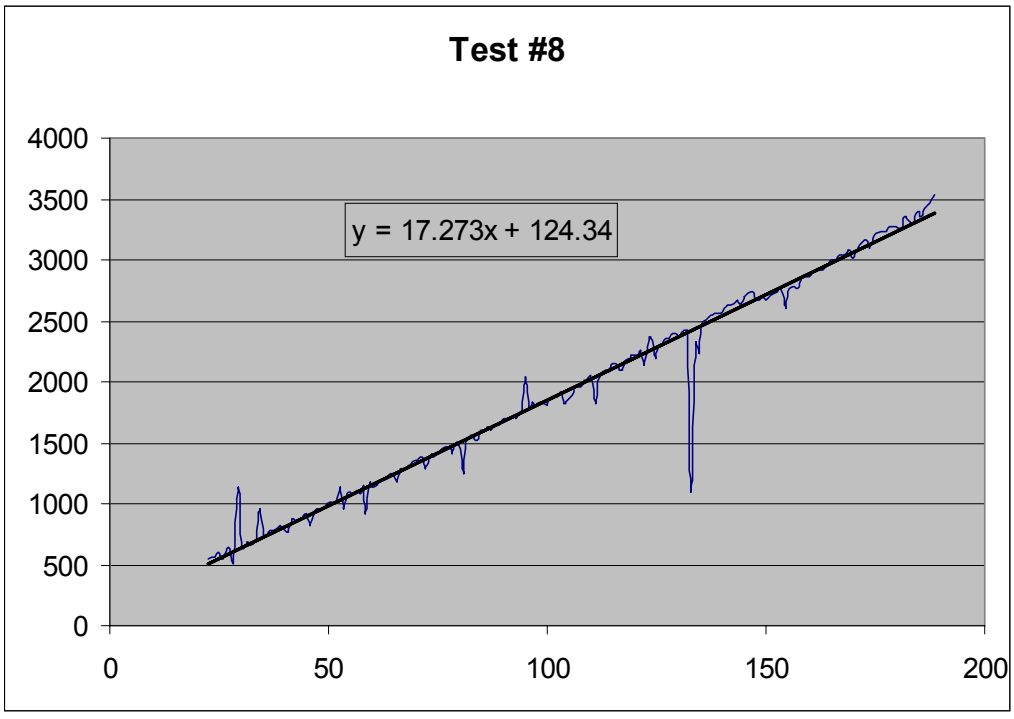
Defl. Pt.	Defl. (in)
1	178.10
2	1.03
3	1.35

Results	Moment (ft-lbs)	S (in3)	Stress (psi)
@ GL	252,562	122.57	24,727
@ Break	228,213	109.55	24,999

Location	Diameter (f-f)
Tip	9.79
GL	21.06
Break	20.01
Butt	22.69

Comments: Pole #4
Buckling Failure


Test #8 - VF
Load (lbs)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
50
100
150
200
250
Adjusted Tip Deflection (in.)


Test #8
y = 17.273x + 124.34
4000
3500
3000
2500
2000
1500
1000
500
0
0
50
100
150
200

Strongwell
FRP Pole
Destructive Bending Tests

Sheet No. 7
Date 8-Apr-03
Time 16:20

Static Bending Test

Test No. 9 **Length** 80 **Flat** V

C= Constant, V= Variable

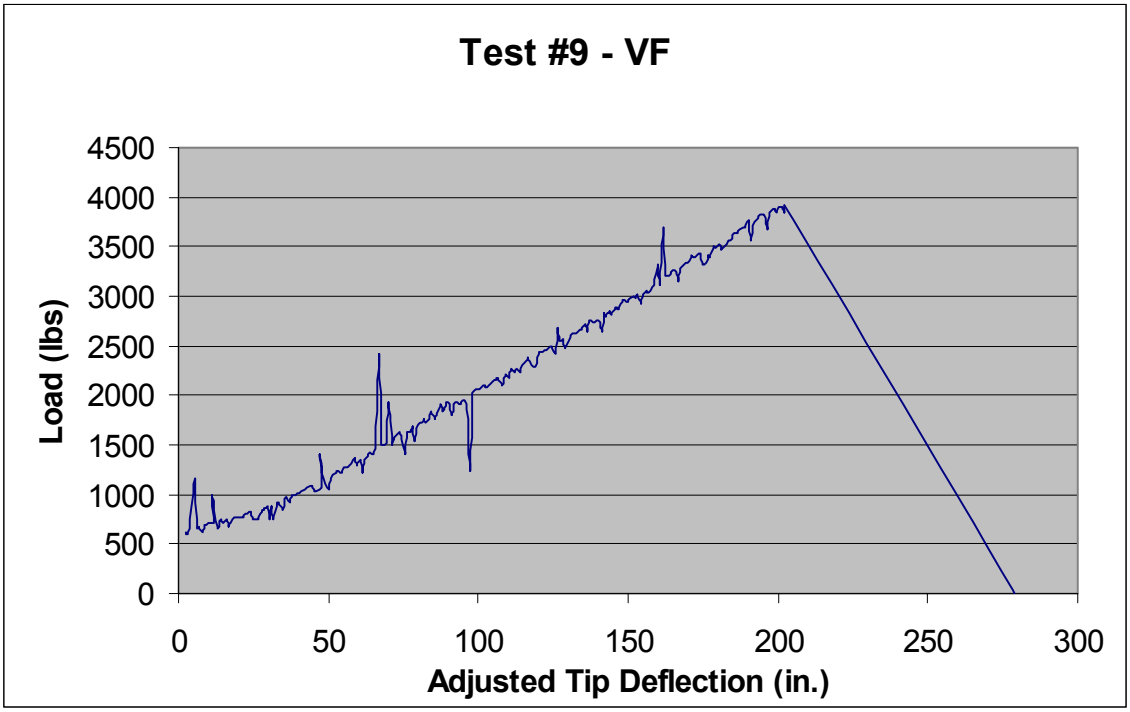
Actual Pole Length	80.08	(ft)
Distance- Butt to G.L.	10.25	(ft)
Distance Tip to Load Point	2.38	(ft)
Distance G.L. to Failure Point	2.50	(ft)
G.L. Diameter (flat-to-flat)	21.04	(in)
Diameter @ Failure Point (flat-to-flat)	20.63	(in)
Maximum Load @ Failure	3923	(lbs)
Distance Tip to Defl. Pt. 1	36.50	(in)
Distance between Butt Defl Pts 2 & 3	95.25	(in)
Adjusted Horizontal Deflection @ 2812# *Deflection Point 1*	144.69	(in)

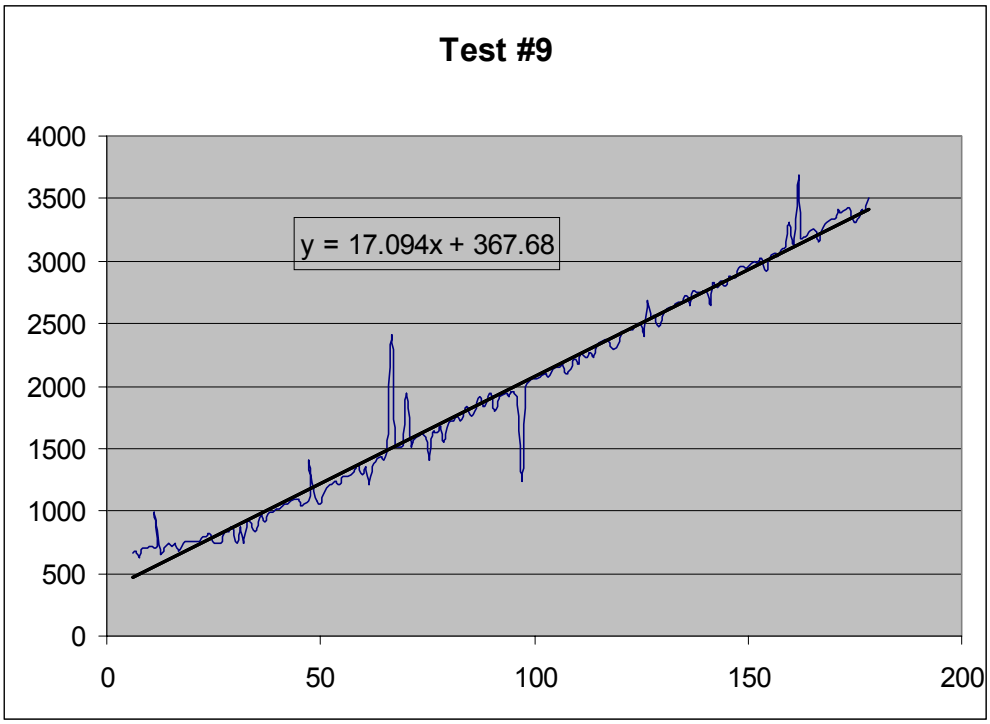
Defl. Pt.	Defl. (in)
1	159.65
2	0.72
3	1.06

Results	Moment (ft-lbs)	S (in3)	Stress (psi)
@ GL	264,606	122.54	25,912
@ Break	254,799	117.42	26,040

Location	Diameter (f-f)
Tip	9.79
GL	21.04
Break	20.63
Butt	22.69

Comments: Pole #2
Buckling Failure


Test #9 - VF
Load (lbs)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
50
100
150
200
250
300
Adjusted Tip Deflection (in.)


Test #9
y = 17.094x + 367.68
4000
3500
3000
2500
2000
1500
1000
500
0
0
50
100
150
200

Strongwell
FRP Pole
Destructive Bending Tests

Sheet No. 8
Date 8-Apr-03
Time 18:30

Static Bending Test

Test No. 10 **Length** 80 **Flat** V

C= Constant, V= Variable

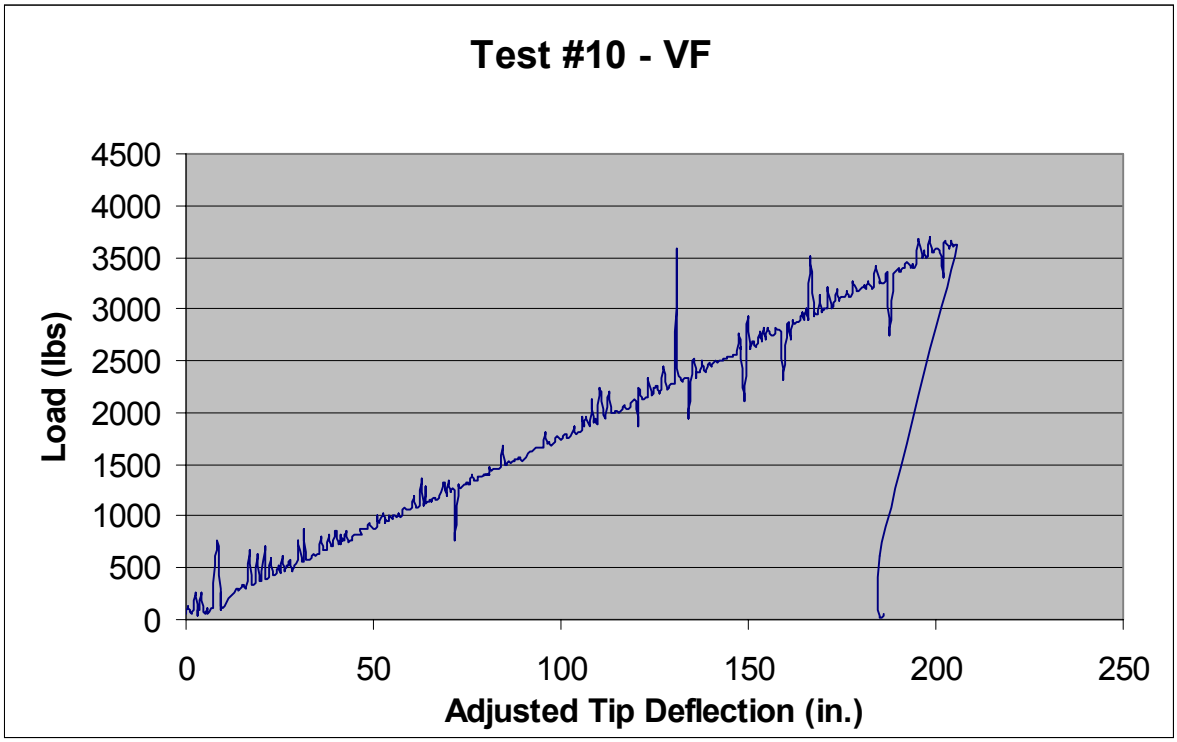
Actual Pole Length	80.06	(ft)
Distance- Butt to G.L.	10.15	(ft)
Distance Tip to Load Point	2.12	(ft)
Distance G.L. to Failure Point	0.50	(ft)
G.L. Diameter (flat-to-flat)	21.05	(in)
Diameter @ Failure Point (flat-to-flat)	20.97	(in)
Maximum Load @ Failure	3698	(lbs)
Distance Tip to Defl. Pt. 1	32.50	(in)
Distance between Butt Defl Pts 2 & 3	95.25	(in)
Adjusted Horizontal Deflection @ 2812# *Deflection Point 1*	155.13	(in)

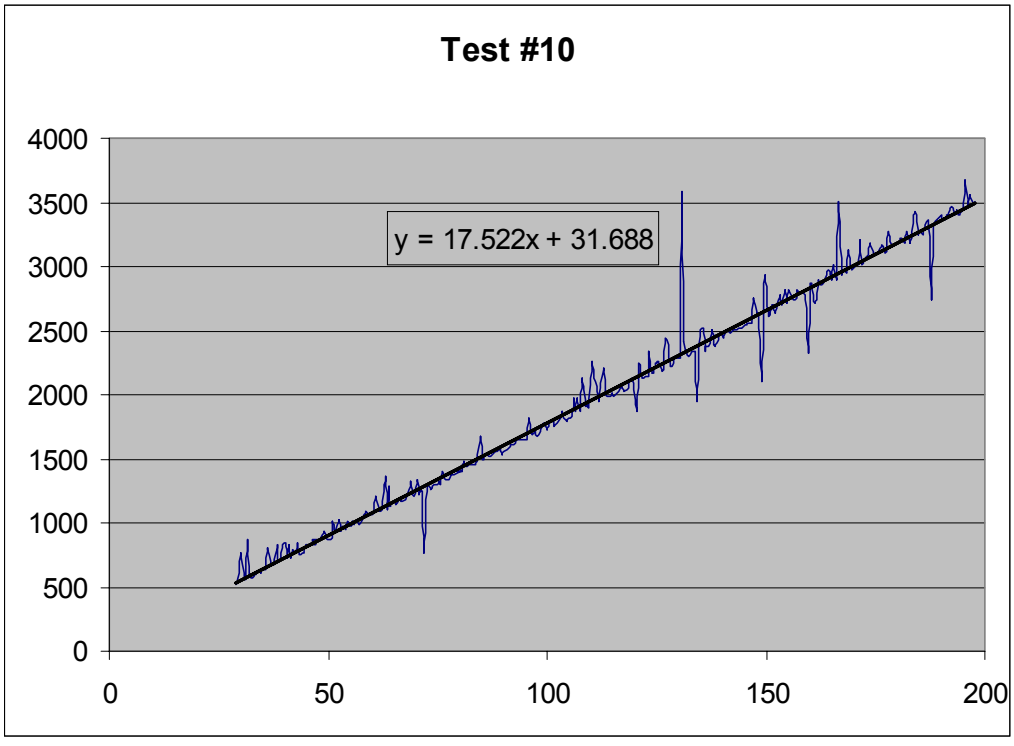
Defl. Pt.	Defl. (in)
1	168.50
2	0.62
3	0.96

Results	Moment (ft-lbs)	S (in3)	Stress (psi)
@ GL	250,687	122.69	24,519
@ Break	248,838	121.65	24,546

Location	Diameter (f-f)
Tip	9.79
GL	21.05
Break	20.97
Butt	22.69

Comments: Pole #10
Buckling Failure


Test #10 - VF
Load (lbs)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
50
100
150
200
250
Adjusted Tip Deflection (in.)


Test #10
y = 17.522x + 31.688
4000
3500
3000
2500
2000
1500
1000
500
0
0
50
100
150
200

Strongwell
FRP Pole
Destructive Bending Tests

Sheet No. 11
Date 10-Apr-03
Time 11:15

Static Bending Test

Test No. 11 **Length** 80 **Flat** V

C= Constant, V= Variable

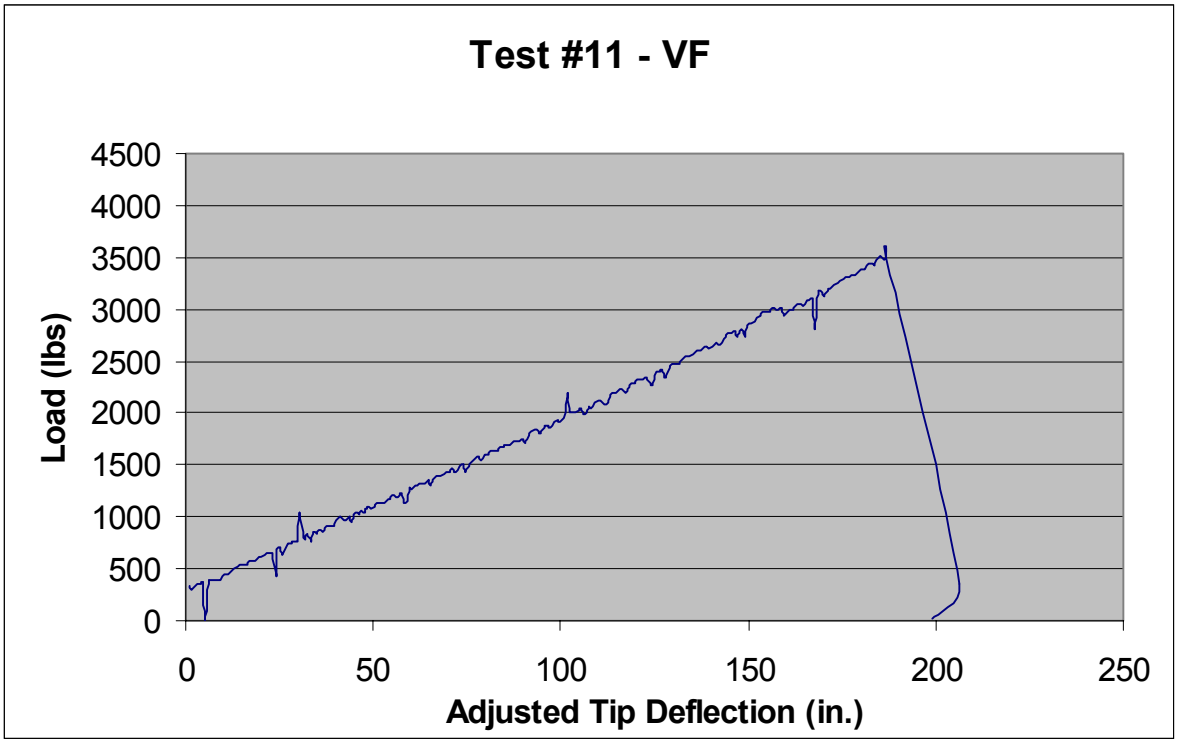
Actual Pole Length	80.08	(ft)
Distance- Butt to G.L.	10.08	(ft)
Distance Tip to Load Point	1.98	(ft)
Distance G.L. to Failure Point	6.50	(ft)
G.L. Diameter (flat-to-flat)	21.06	(in)
Diameter @ Failure Point (flat-to-flat)	20.01	(in)
Maximum Load @ Failure	3612	(lbs)
Distance Tip to Defl. Pt. 1	30.75	(in)
Distance between Butt Defl Pts 2 & 3	92.50	(in)
Adjusted Horizontal Deflection @ 2812# *Deflection Point 1*	148.16	(in)

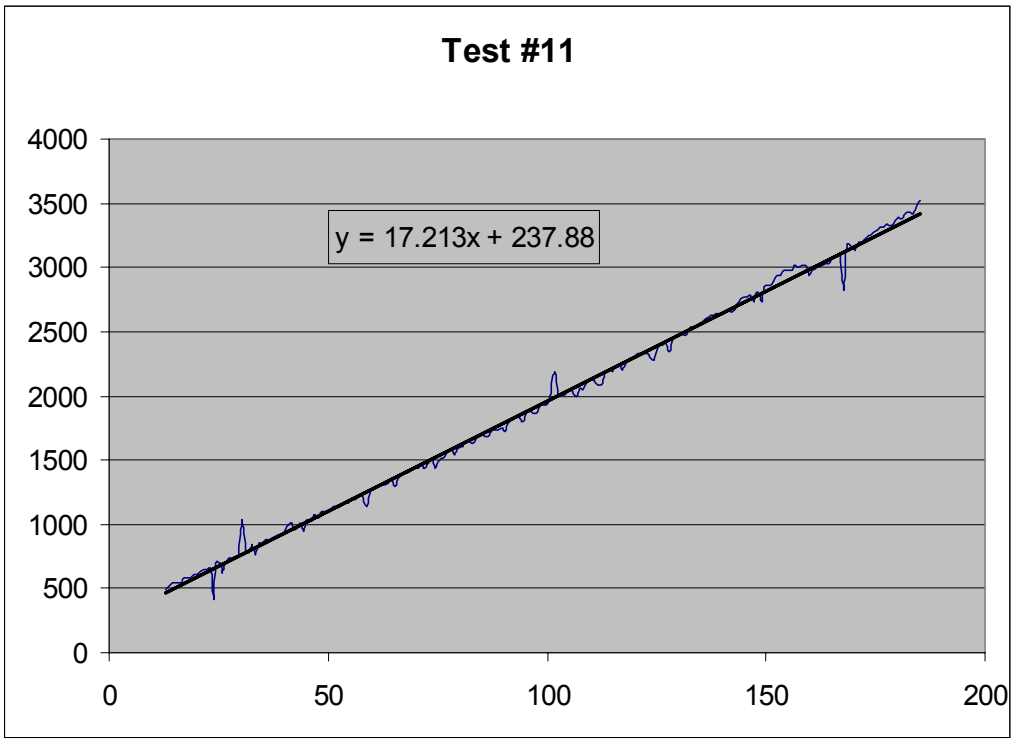
Defl. Pt.	Defl. (in)
1	157.10
2	0.42
3	0.60

Results	Moment (ft-lbs)	S (in3)	Stress (psi)
@ GL	245,688	122.89	23,990
@ Break	222,210	109.85	24,274

Location	Diameter (f-f)
Tip	9.79
GL	21.06
Break	20.01
Butt	22.69

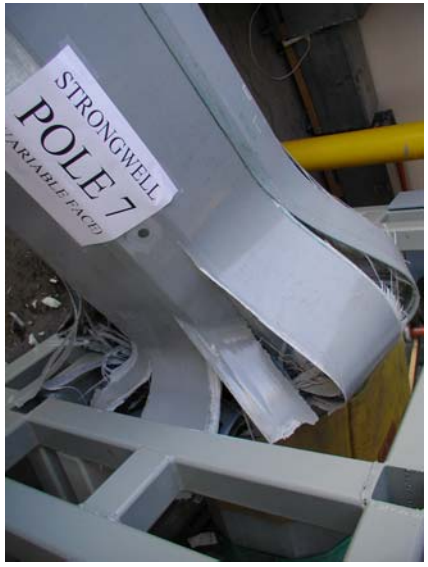
Comments: Pole #10
Buckling Failure


Test #11 - VF
Load (lbs)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
50
100
150
200
250
Adjusted Tip Deflection (in.)


Test #11
y = 17.213x + 237.88
4000
3500
3000
2500
2000
1500
1000
500
0
0
50
100
150
200

APPENDIX B – TEST PHOTOGRAPHS

Test Setup			Test Setup
Test Setup			Test Setup
Test Setup			Test Setup – Pole under load

Failure – Test #5	Failure – Test #3	Failure – Test #1
		
		
Failure – Test #7	Failure – Test #4	Failure – Test #2

Failure – Test #8			Failure – Test #9
Failure – Test #10			Failure – Test #11