Test Report:

Buckling Strength 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 TO DEVELOP LOCAL BUCKLING CAPACITIES

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 10 and May 5, 2003.

2.0 POLE PREPARATION

Four 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 to develop their buckling strength characteristics. Two of the poles were tested as full-length specimens as part of the ten-pole test series that was conducted between April 7 and 10, 2003. 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 of constant and variable widths from tip to butt.

All of the new tests that were conducted were on poles with lengths less than their original 80 feet. The poles were reduced in length by cutting off a portion of the butt ends. Pole lengths of 70, 60, 50 and 40 feet were tested across their fixed width flats and 60, 50 and 40-ft poles were tested across their variable width flats.

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.

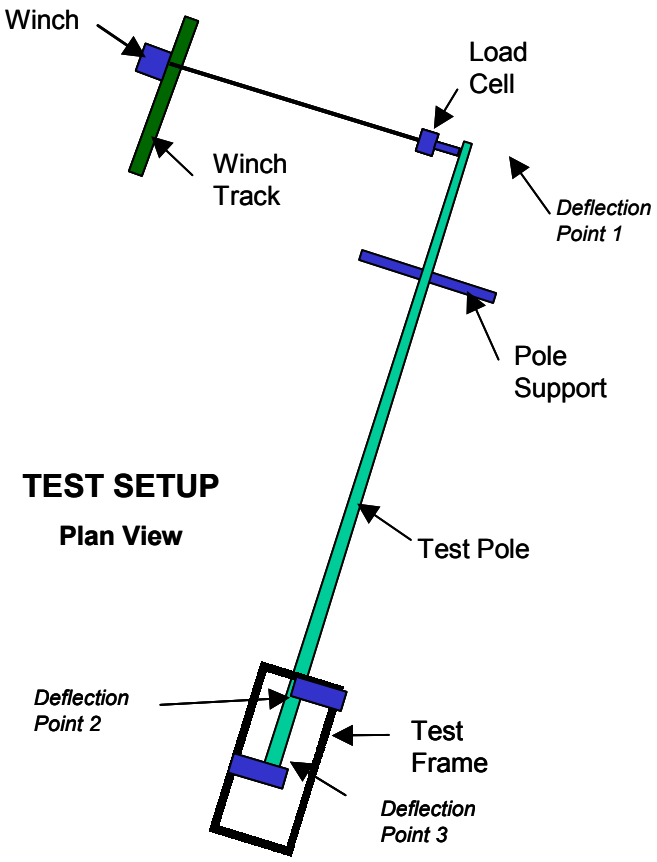


Figure 3-1 – Test Setup

4.0 BENDING LOAD TESTING

4.1 Test Procedure

After being cut to length, 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. Two of the poles (pole nos. 8 and 11) were used for testing the section with its constant width flat on the compression and tension faces and the other two poles (pole nos. 10 and 12) were used for testing the section with its variable width faces on the compression and tension faces.

The original test plan called for testing poles in lengths of 15, 20, 30, 40, 50, 60 and 70 feet in length across both their constant and variable width flats. In the end, four lengths

of poles were tested across their constant width flats: 70, 60, 50 and 40-ft and three lengths of poles were tested across their variable width flats: 60, 50 and 40-feet. Damage to one of the poles during transit prevented testing a 70-foot pole across its variable width flats. Poles shorter than 40 feet were to be tested using a steel pole top extender provided by Strongwell. The first attempt at testing a 20-ft pole ended when the pole failed prematurely in shear at the connection between the pole and the extender. The failure was a connection problem and was not caused by any defect in the pole itself. No further attempts were made at testing shorter length poles.

4.2 Test Data

Data sheets for each individual load test are included in Appendix A. The test data for the original 80-foot length poles are also included. Graphs of the load vs. deflection data are provided immediately following each data sheet. Note that 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. Figure 4-1 is a plot of the calculated bending stress for each pole at the point of failure vs. the distance from the pole's tip to the point of failure.

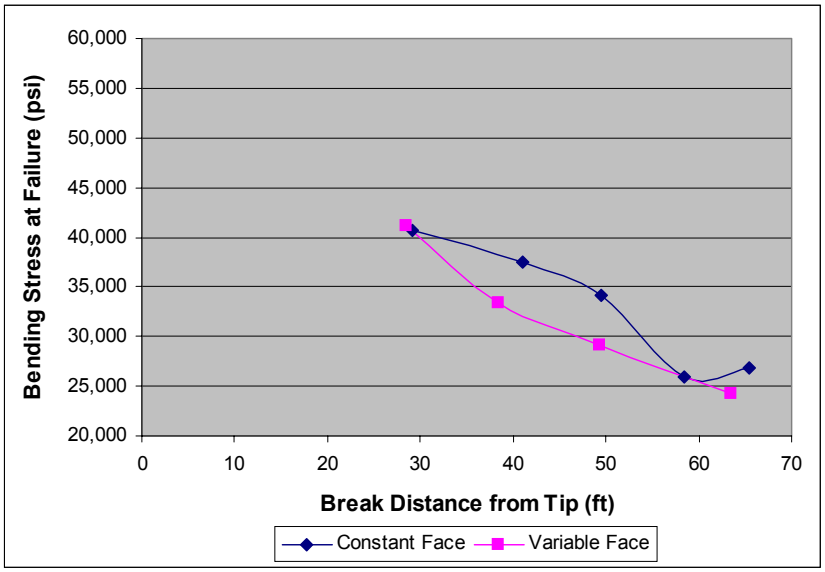


Figure 4-1 – Bending Stress at Point of Failure

4.3 Test Results

The test results suggest that there is a direct relationship between the maximum bending stress that can be developed in a pole at a given elevation and the width of the tension/ compression flat at that elevation. The narrower the width, the higher the fiber stress that can be achieved (note – there appears to be some type of anomaly with the value obtained for the 70-foot constant face width test). A plot of bending stress vs. face width is likely to provide better insight into this relationship.

Table 4-1 – Summary of Test Results

Test #	Pole Length	Test Flat	Elev @ Break	Max Load	Net Defl @ 2812	Stress @ GL	Stress @ Break
5	80	C	65.5	3808	149.0	26,678	26,829
6A	70	C	58.46	3671	123.7	25,899	25,881
5A	60	C	49.5	4967	79.5	34,200	34,140
6B	50	C	41.1	5684	52.8	37,259	37,449
5B	40	C	29.12	6895	29.1	41,053	40,686
11	80	V	63.5	3612	148.2	23,990	24,274
11A	60	V	49.33	4408	77.2	29,258	29,186
12B	50	V	38.42	5324	55.7	33,636	33,352
11B	40	V	28.5	7160	34.2	42,203	41,201

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.

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

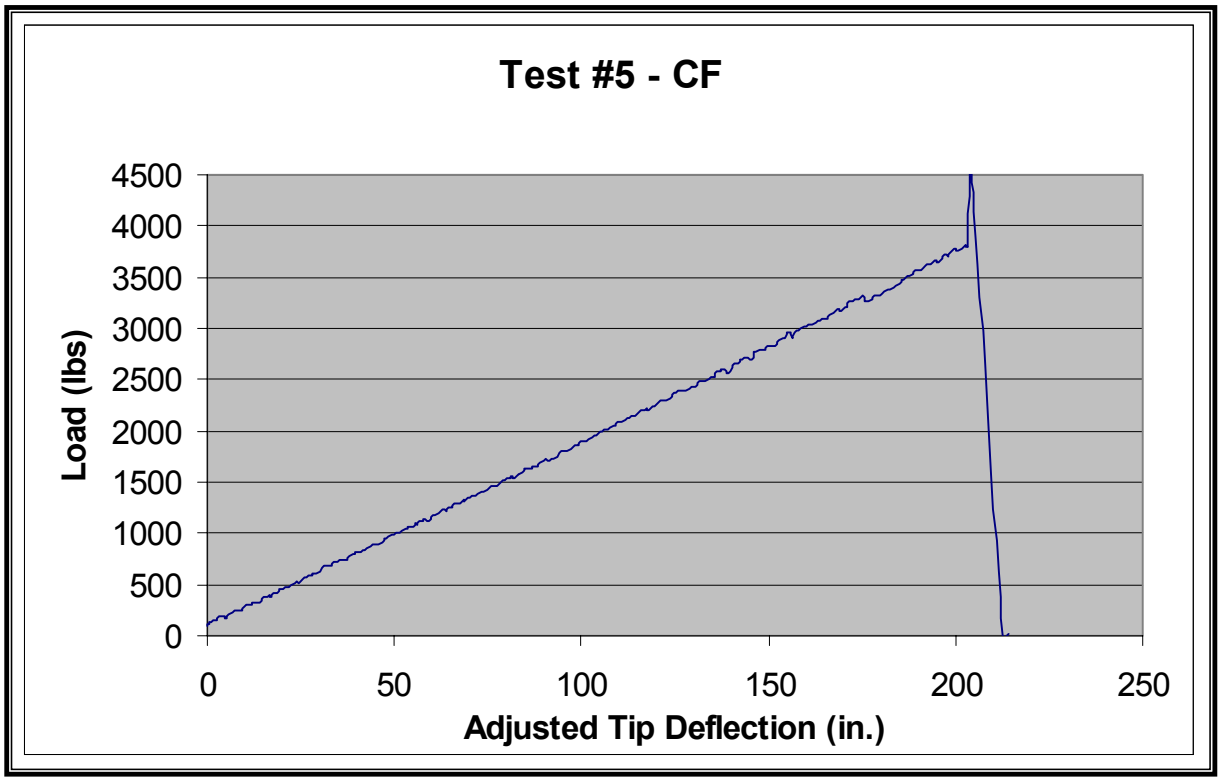
Actual Pole Length	80.08	(ft)
Distance- Butt to G.L.	9.92	(ft)
Distance Tip to Load Point	2.04	(ft)
Distance G.L. to Failure Point	4.67	(ft)
G.L. Diameter (flat-to-flat)	22.27	(in)
Diameter @ Failure Point (flat-to-flat)	21.40	(in)
Maximum Load @ Failure	3808	(lbs)
Distance Tip to Defl. Pt. 1	37.50	(in)
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.)

Strongwell
FRP Pole
Destructive Bending Tests

Sheet No. 12
Date 10-Apr-03
Time 15:15

Static Bending Test

Test No. 6A **Length** 70 **Flat** C

C= Constant, V= Variable

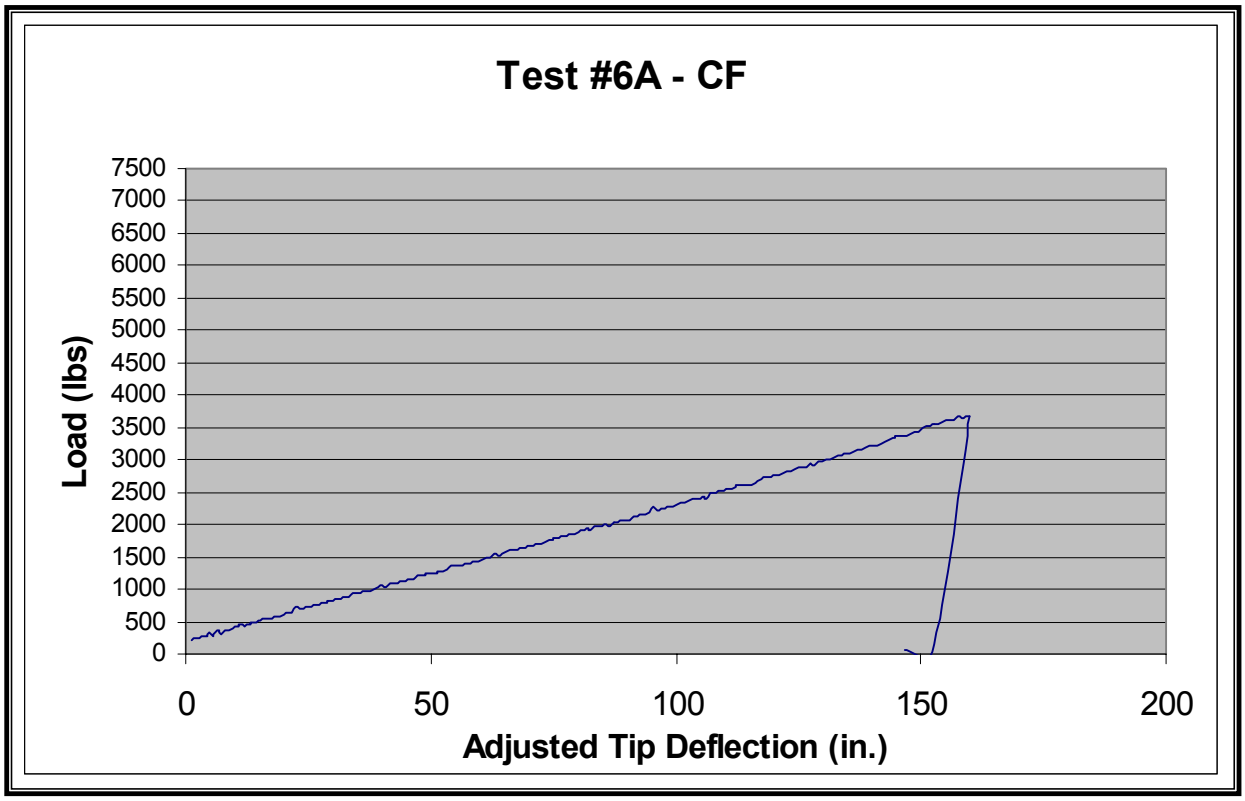
Actual Pole Length	70.02	(ft)
Distance- Butt to G.L.	10.31	(ft)
Distance Tip to Load Point	2.08	(ft)
Distance G.L. to Failure Point	1.25	(ft)
G.L. Diameter (flat-to-flat)	20.34	(in)
Diameter @ Failure Point (flat-to-flat)	20.11	(in)
Maximum Load @ Failure	3671	(lbs)
Distance Tip to Defl. Pt. 1	33.75	(in)
Distance between Butt Defl Pts 2 & 3	90.50	(in)
Adjusted Horizontal Deflection @ 2812# *Deflection Point 1*	123.65	(in)

Defl. Pt.	Defl. (in)
1	137.66
2	0.76
3	1.10

Results	Moment (ft-lbs)	S (in3)	Stress (psi)
@ GL	211,560	98.00	25,904
@ Break	206,971	95.95	25,885

Location	Diameter (f-f)
Tip	9.22
GL	20.34
Break	20.11
Butt	22.26

Comments: Pole #8
Buckling Failure


Test #6A - CF
Load (lbs)
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
50
100
150
200
Adjusted Tip Deflection (in.)

Strongwell
FRP Pole
Destructive Bending Tests

Sheet No. 13
Date 1-May-03
Time 15:00

Static Bending Test

Test No. 5A **Length** 60 **Flat** C

C= Constant, V= Variable

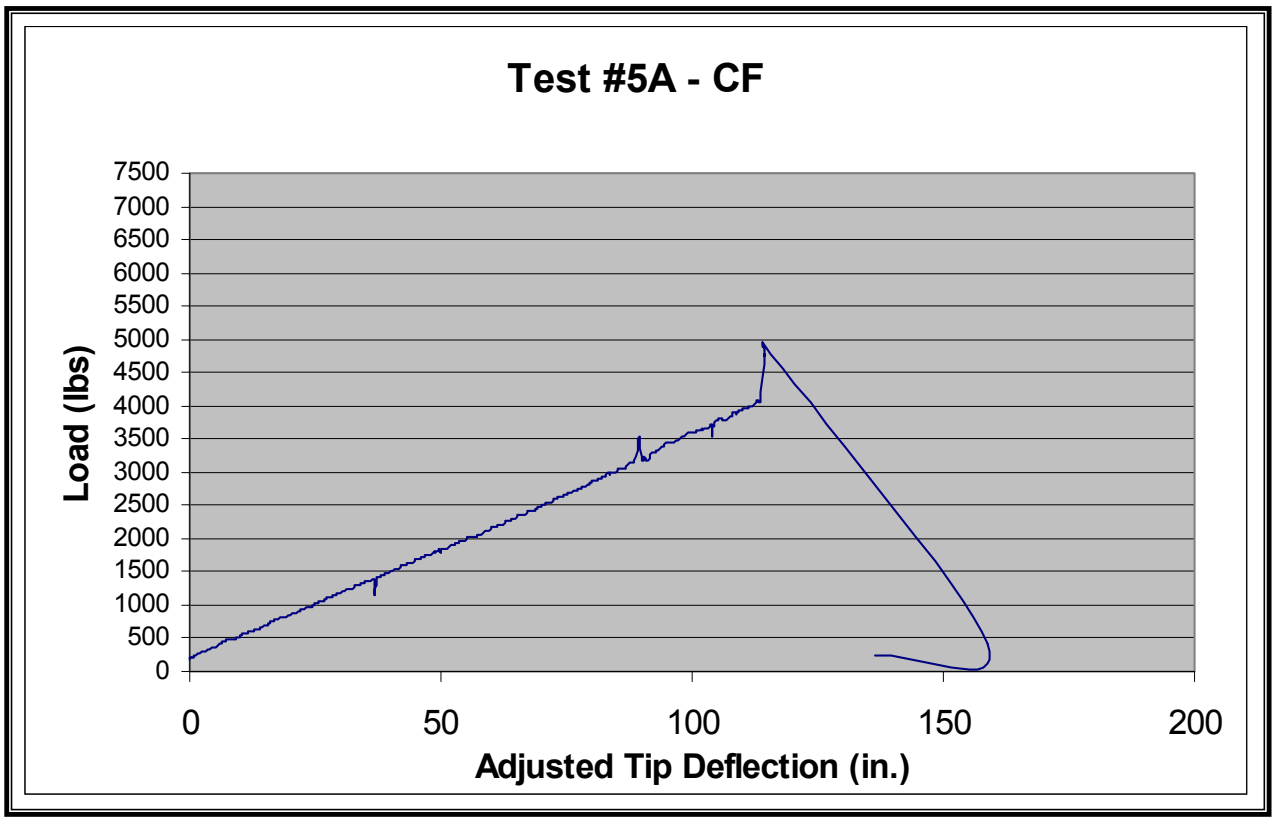
Actual Pole Length	60.08	(ft)
Distance- Butt to G.L.	10.08	(ft)
Distance Tip to Load Point	2.42	(ft)
Distance G.L. to Failure Point	0.50	(ft)
G.L. Diameter (flat-to-flat)	18.53	(in)
Diameter @ Failure Point (flat-to-flat)	18.44	(in)
Maximum Load @ Failure	4967	(lbs)
Distance Tip to Defl. Pt. 1	32.00	(in)
Distance between Butt Defl Pts 2 & 3	94.00	(in)
Adjusted Horizontal Deflection @ 2812# *Deflection Point 1*	79.51	(in)

Defl. Pt.	Defl. (in)
1	89.35
2	0.69
3	0.94

Results	Moment (ft-lbs)	S (in3)	Stress (psi)
@ GL	236,330	82.92	34,200
@ Break	233,846	82.19	34,140

Location	Diameter (f-f)
Tip	9.22
GL	18.53
Break	18.44
Butt	20.41

Comments: Pole #8
Buckling Failure


Test #5A - CF
Load (lbs)
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
50
100
150
200
Adjusted Tip Deflection (in.)

Strongwell
FRP Pole
Destructive Bending Tests

Sheet No. 15
Date 2-May-03
Time 9:10

Static Bending Test

Test No. 6B **Length** 50 **Flat** C

C= Constant, V= Variable

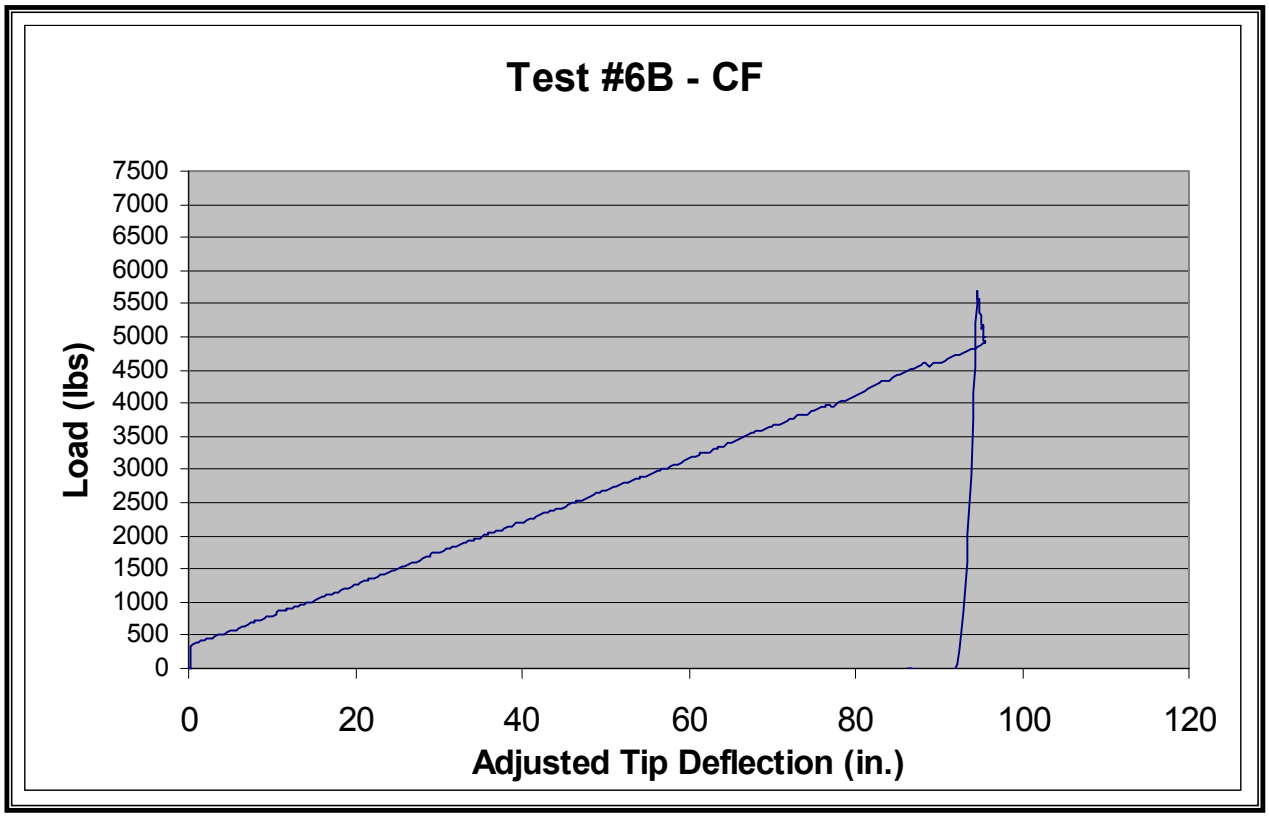
Actual Pole Length	50.25	(ft)
Distance- Butt to G.L.	9.90	(ft)
Distance Tip to Load Point	2.42	(ft)
Distance G.L. to Failure Point	-0.75	(ft)
G.L. Diameter (flat-to-flat)	16.74	(in)
Diameter @ Failure Point (flat-to-flat)	16.88	(in)
Maximum Load @ Failure	5684	(lbs)
Distance Tip to Defl. Pt. 1	34.00	(in)
Distance between Butt Defl Pts 2 & 3	95.00	(in)
Adjusted Horizontal Deflection @ 2812# *Deflection Point 1*	52.82	(in)

Defl. Pt.	Defl. (in)
1	59.41
2	0.87
3	0.52

Results	Moment (ft-lbs)	S (in3)	Stress (psi)
@ GL	215,594	69.44	37,259
@ Break	219,857	70.45	37,449

Location	Diameter (f-f)
Tip	9.22
GL	16.74
Break	16.88
Butt	18.58

Comments: Pole #11
Buckling Failure


Test #6B - CF
Load (lbs)
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
20
40
60
80
100
120
Adjusted Tip Deflection (in.)

Strongwell
FRP Pole
Destructive Bending Tests

Sheet No. 18
Date 5-May-03
Time 12:00

Static Bending Test

Test No. 5B **Length** 40 **Flat** C

C= Constant, V= Variable

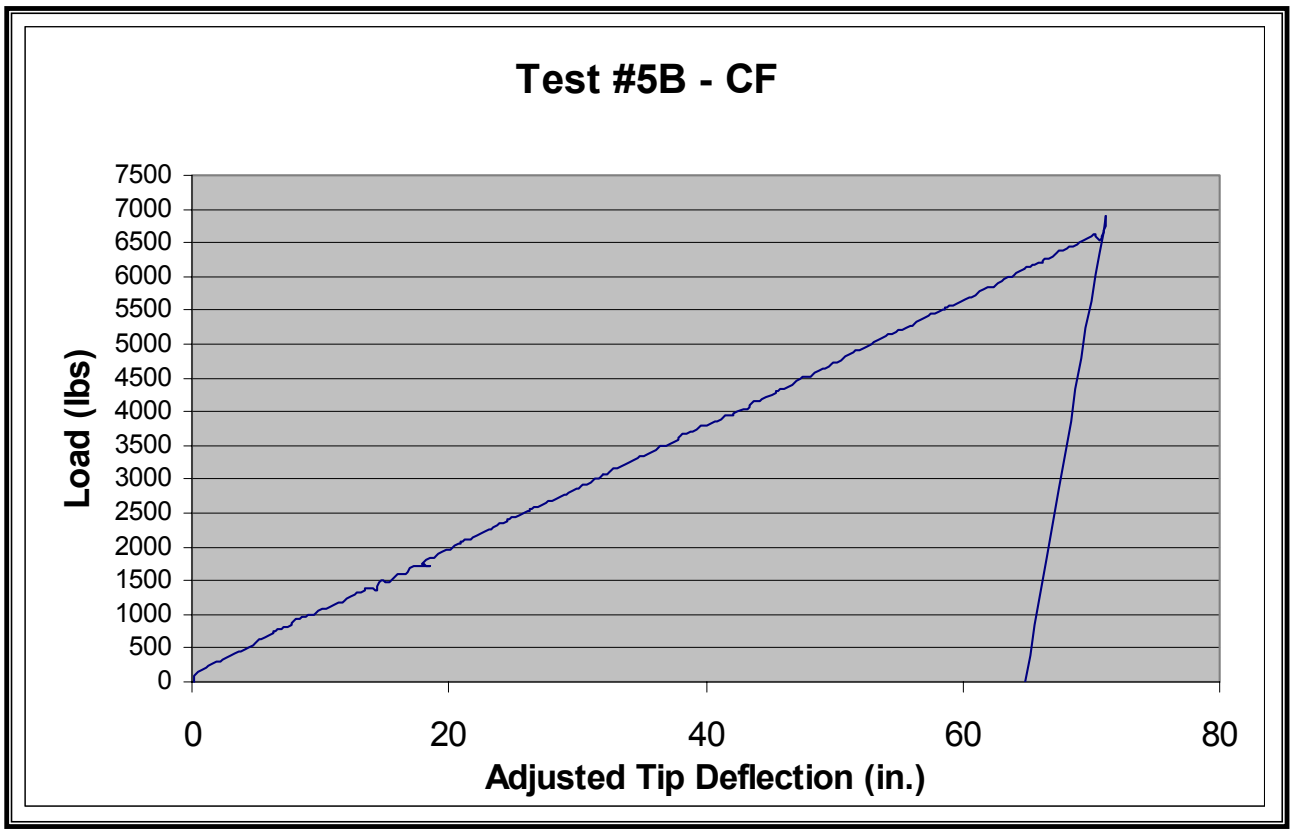
Actual Pole Length	30.04	(ft)
Distance- Butt to G.L.	10.25	(ft)
Distance Tip to Load Point	2.25	(ft)
Distance G.L. to Failure Point	0.67	(ft)
G.L. Diameter (flat-to-flat)	12.91	(in)
Diameter @ Failure Point (flat-to-flat)	12.78	(in)
Maximum Load @ Failure	6895	(lbs)
Distance Tip to Defl. Pt. 1	33.00	(in)
Distance between Butt Defl Pts 2 & 3	95.00	(in)
Adjusted Horizontal Deflection @ 2812# *Deflection Point 1*	30.36	(in)

Defl. Pt.	Defl. (in)
1	32.10
2	0.21
3	0.60

Results	Moment (ft-lbs)	S (in3)	Stress (psi)
@ GL	120,938	43.10	33,668
@ Break	116,319	42.32	32,979

Location	Diameter (f-f)
Tip	9.22
GL	12.91
Break	12.78
Butt	14.82

Comments: Pole #8
Buckling Failure


Test #5B - CF
Load (lbs)
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
20
40
60
80
Adjusted Tip Deflection (in.)

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

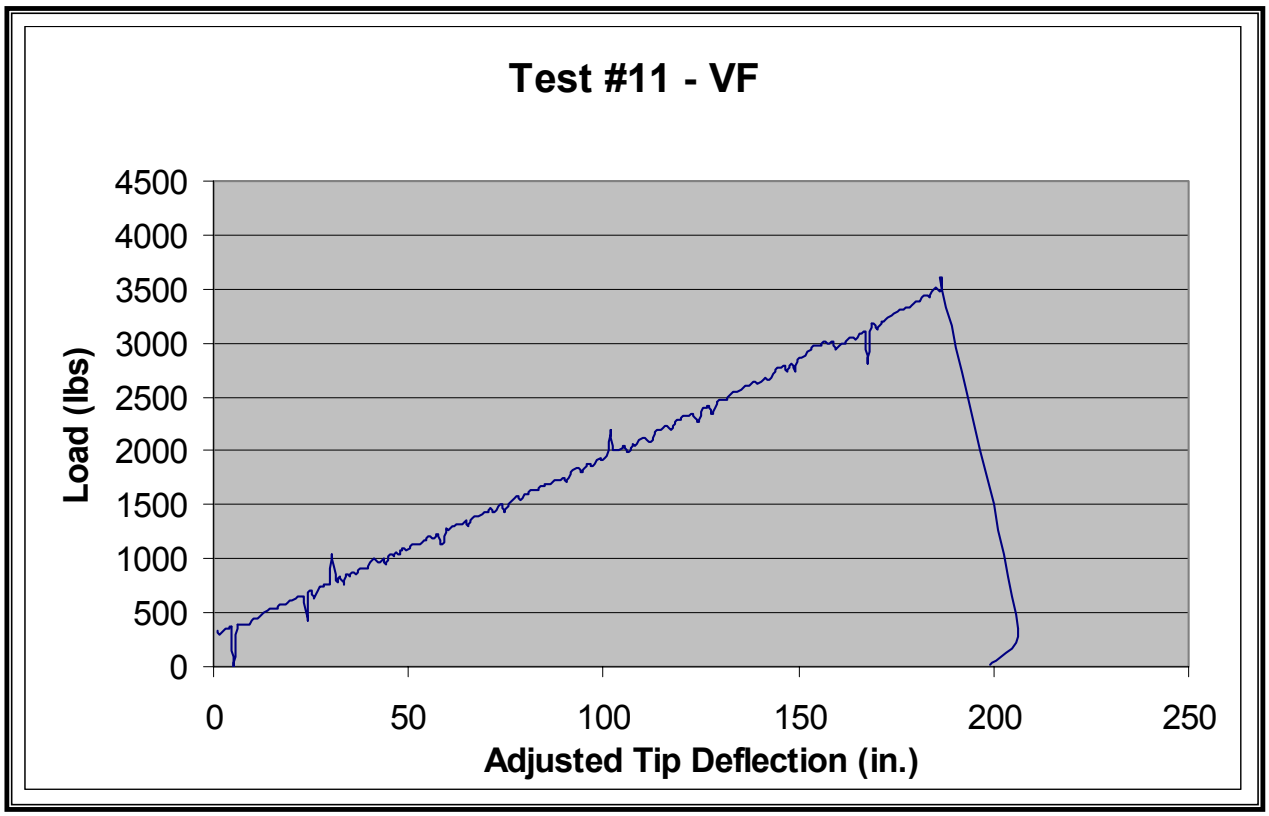
Actual Pole Length	80.08	(ft)
Distance- Butt to G.L.	10.08	(ft)
Distance Tip to Load Point	1.98	(ft)
Distance G.L. to Failure Point	6.50	(ft)
G.L. Diameter (flat-to-flat)	21.06	(in)
Diameter @ Failure Point (flat-to-flat)	20.01	(in)
Maximum Load @ Failure	3612	(lbs)
Distance Tip to Defl. Pt. 1	30.75	(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.)

Strongwell
FRP Pole
Destructive Bending Tests

Sheet No. 14
Date 1-May-03
Time 17:10

Static Bending Test

Test No. 11A **Length** 60 **Flat** V

C= Constant, V= Variable

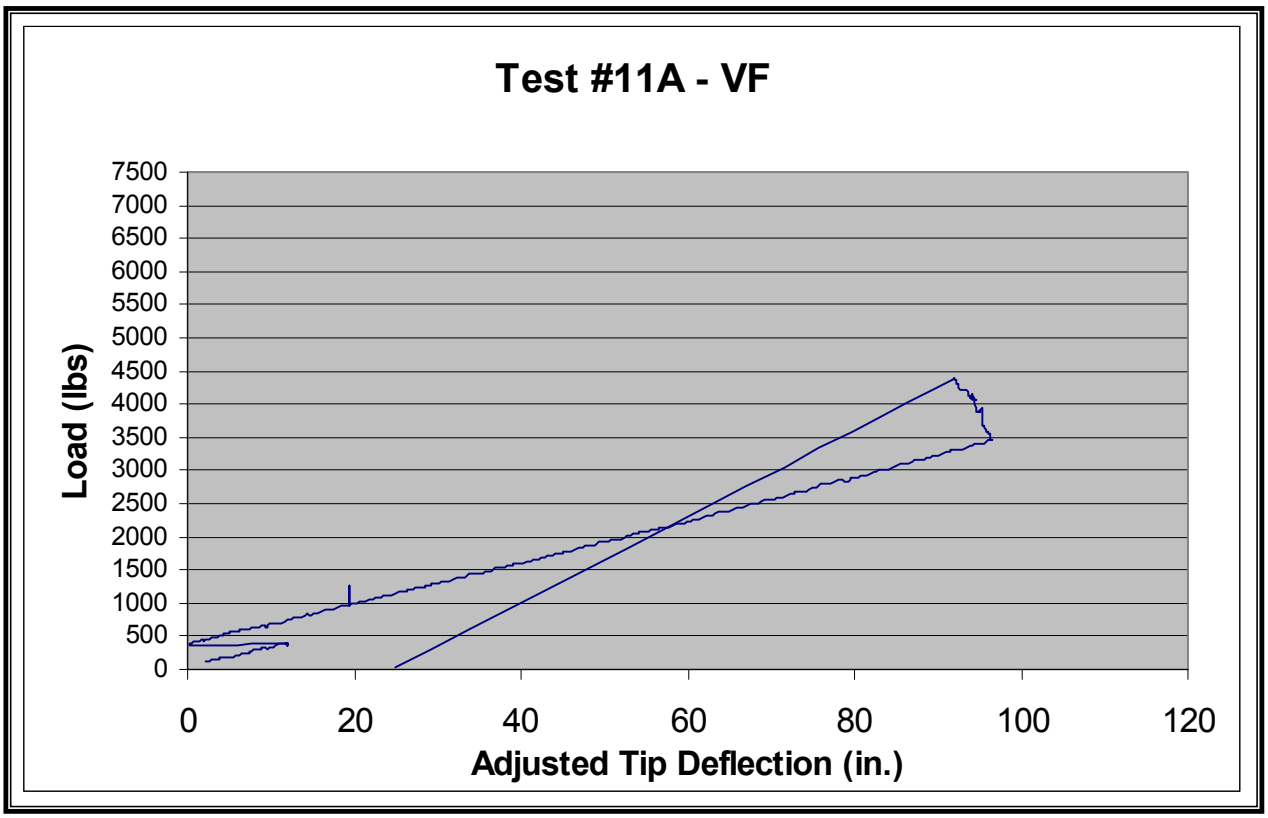
Actual Pole Length	58.04	(ft)
Distance- Butt to G.L.	7.71	(ft)
Distance Tip to Load Point	2.42	(ft)
Distance G.L. to Failure Point	1.00	(ft)
G.L. Diameter (flat-to-flat)	17.90	(in)
Diameter @ Failure Point (flat-to-flat)	17.74	(in)
Maximum Load @ Failure	4408	(lbs)
Distance Tip to Defl. Pt. 1	35.00	(in)
Distance between Butt Defl Pts 2 & 3	69.25	(in)
Adjusted Horizontal Deflection @ 2812# *Deflection Point 1*	77.20	(in)

Defl. Pt.	Defl. (in)
1	92.21
2	0.72
3	1.11

Results	Moment (ft-lbs)	S (in3)	Stress (psi)
@ GL	211,187	86.62	29,258
@ Break	206,779	85.02	29,186

Location	Diameter (f-f)
Tip	9.79
GL	17.90
Break	17.74
Butt	19.15

Comments: Pole #10
Buckling Failure


Test #11A - VF
Load (lbs)
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
20
40
60
80
100
120
Adjusted Tip Deflection (in.)

Strongwell
FRP Pole
Destructive Bending Tests

Sheet No. 16
Date 2-May-03
Time 15:05

Static Bending Test

Test No. 12B **Length** 50 **Flat** V

C= Constant, V= Variable

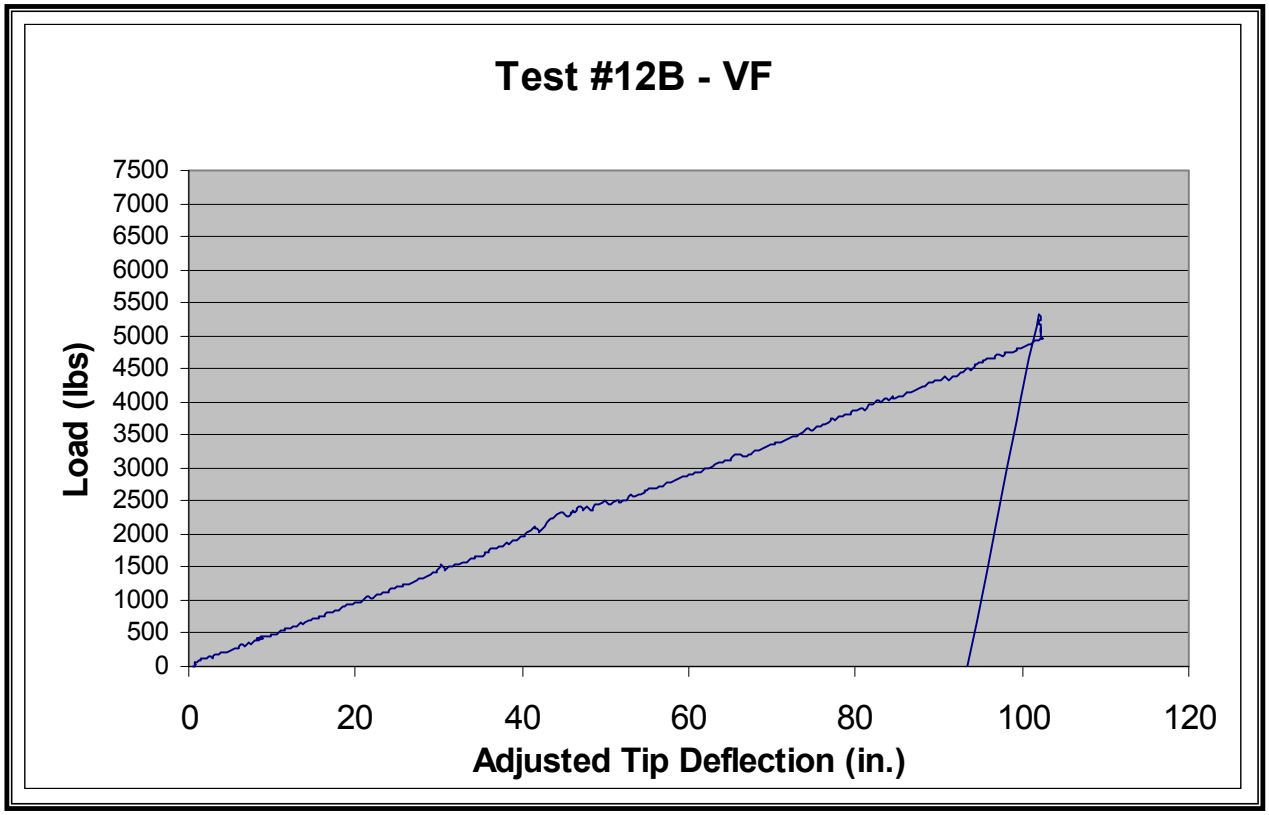
Actual Pole Length	50.00	(ft)
Distance- Butt to G.L.	10.25	(ft)
Distance Tip to Load Point	2.67	(ft)
Distance G.L. to Failure Point	1.33	(ft)
G.L. Diameter (flat-to-flat)	16.20	(in)
Diameter @ Failure Point (flat-to-flat)	15.98	(in)
Maximum Load @ Failure	5324	(lbs)
Distance Tip to Defl. Pt. 1	38.00	(in)
Distance between Butt Defl Pts 2 & 3	95.50	(in)
Adjusted Horizontal Deflection @ 2812# *Deflection Point 1*	55.73	(in)

Defl. Pt.	Defl. (in)
1	61.43
2	0.60
3	0.64

Results	Moment (ft-lbs)	S (in3)	Stress (psi)
@ GL	197,414	70.43	33,636
@ Break	190,333	68.48	33,352

Location	Diameter (f-f)
Tip	9.79
GL	16.20
Break	15.98
Butt	17.85

Comments: Pole #12
Buckling Failure


Test #12B - VF
Load (lbs)
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
20
40
60
80
100
120
Adjusted Tip Deflection (in.)

Strongwell
FRP Pole
Destructive Bending Tests

Sheet No. 17
Date .5-May-03
Time 10:00

Static Bending Test

Test No. 11B **Length** 40 **Flat** V
C= Constant, V= Variable

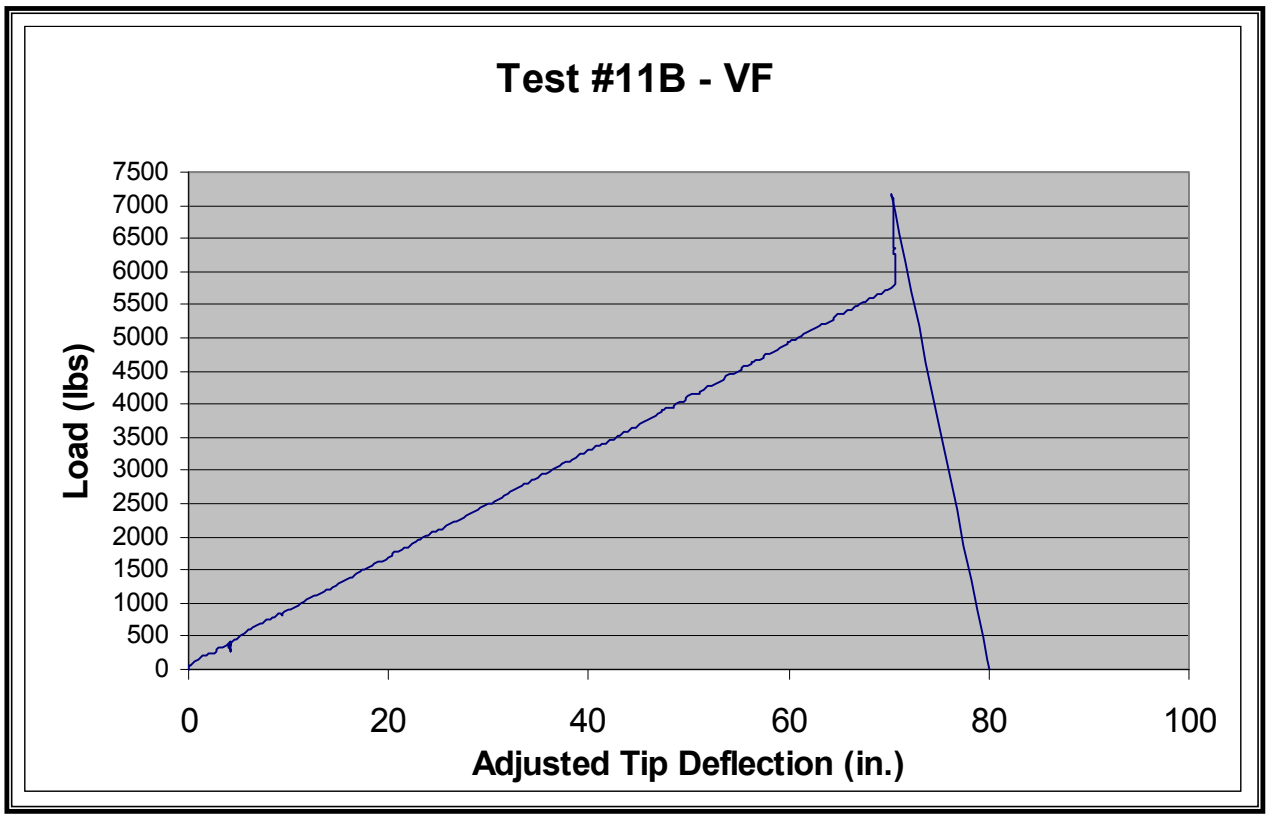
Actual Pole Length	40.50	(ft)
Distance- Butt to G.L.	10.00	(ft)
Distance Tip to Load Point	2.42	(ft)
Distance G.L. to Failure Point	2.00	(ft)
G.L. Diameter (flat-to-flat)	14.71	(in)
Diameter @ Failure Point (flat-to-flat)	14.38	(in)
Maximum Load @ Failure	7160	(lbs)
Distance Tip to Defl. Pt. 1	35.00	(in)
Distance between Butt Defl Pts 2 & 3	96.00	(in)
Adjusted Horizontal Deflection @ 2812# *Deflection Point 1*	34.22	(in)

Defl. Pt.	Defl. (in)
1	37.60
2	0.20
3	0.78

Results	Moment (ft-lbs)	S (in3)	Stress (psi)
@ GL	201,053	57.17	42,203
@ Break	186,733	54.39	41,201

Location	Diameter (f-f)
Tip	9.79
GL	14.71
Break	14.38
Butt	16.32

Comments: Pole #10
Bucking Failure


Test #11B - VF
Load (lbs)
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
20
40
60
80
100
Adjusted Tip Deflection (in.)

APPENDIX B – TEST PHOTOGRAPHS

Test Setup			Test Setup
Test Setup			Test Setup
Pole Failure			Pole Failure