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RE: uPole Fire Rating Testing Report

January 22, 2018

Summary and Conclusion

In response to a request of National Oilwell Varco Ameron Pole Products (NOV APP) from San Diego Gas & Electric for the Fire Rating of uPoles related to wildfire exposure a test protocol was selected and followed based on ASTM E84-16 "Standard Test Method for Burning Characteristics of Building Materials (NFPA 255, ANSI/UL 723 and UBC 8-1). This test is also called the Steiner Tunnel Test. In reality, even up until this time there is no ASTM test protocol specifically applicable to passing wild fire testing of utility and communication poles and structures, so the ASTM E84-16 test was selected because it is a well-known test and it would approximate a passing wild fire in the upper sections of the uPole related to flame spread and smoke generation. Although utility poles are installed vertically, the E84-16 test is done as a horizontal test.

The ASTM E84-16 testing was conducted at the Southwest Research Institute (SwRI) in San Antonio using two AUP24-1/3-11 uPole shafts (each 24 ft. long and nominally 11 inch OD) provided by NOV Fiberglass Systems (NOV FGS) from their Burkburnett, Texas plant where uPoles are manufactured.. Following 19 days of conditioning time to insure dryness, the first test specimen was tested on November 21, 2017 and was exposed to a 10-minute flame exposure on the underside of one end. The second test specimen was tested the next day on November 22, 2017 and was exposed to a 30-minute flame exposure also on the underside of one end. This second 30-minute exposure is considered excessive for a passing wildfire, but this length fire exposure was run as a check data point.

The uPole flame spread indices for both tests came out very positive. An algorithm was used by SwRI to calculate the Flame Spread Fire Index Rating from the test results.

AUP24-1/3-11 uPole 10-minute flame exposure Flame Spread Index = 10 ….**Fire Rating of A**
AUP24-1/3-11 uPole 30-minute flame exposure Flame Spread Index = 10 ….**Fire Rating of A**

These are very positive results. The reason that the 10-minute and 30-minute Flame Spread Indices are the same is that the algorithms are different for the two times of exposure to account for other factors. The ratings fall into A, B and C categories according to the Table Below:

Classification	Flame Spread Index
A	0-25
B	26-75
C	76-200

As a reference, Red Oak has a Flame Spread Index of approximately 100 which would be a Fire Rating of C.

In addition to the Flame Spread exposure, specimens were cut from various sections of the two uPole shafts up the length from the actual high intensity fire impingement region and mechanically tested for

longitudinal (0^0- direction) tension properties, hoop (90^0- direction) tension properties and longitudinal (0^0- direction) compression properties to provide data on the effect on mechanical properties up the uPole due to passing wild-fire exposure. There was some strength drop off in the lower flame impingement regions, but the strength drop off in the wild fire affected zones was not drastic.

SwRI ASTM E84-16 Testing

Figure 1
uPole Ready To Set in E84-16 Test Rig Chamber

Figure 2
uPole Being Set In E84-16 Test Rig Chamber

Figure 3
Refractory Lined Test Chamber Burner End

Figure 4
Insulation Layer Being Placed over uPole

Figure 5 – Burner On

Figure 6 – Watching & Timing Flame Spread

Figure 7 - Fire Tested 24 ft. Long uPole Shaft

Both uPoles came through fire testing as whole lengths. They did not experience fire caused separation of sections. Having said that, fire damage ranged from significant in the end region of the direct flame to virtually none up the length of the uPoles. Because the E84-16 test applies a direct high intensity flame fire load to one end for 10 minutes in the first test and for 30 minutes in the second test, this is significantly more flame energy in the end regions than would be experienced in a normal passing wildfire. To check material property retention after fire exposure material specimens were cut out at the 0-, 3-, 6-, 10- and 23-ft. marks mechanical testing at NOV FGS Burkburnett to provide data on strength retention after fire testing representative of a passing wild fire. The mechanical testing setups and results are summarized in the next section.

Although not necessarily applicable to the E84-16 uPole testing, For the record I included the following statement per the SwRI information in their report*…"This standard should be used to measure and describe the response of materials, products or assemblies to heat and flame under controlled conditions and should not be used to describe of appraise the fire-hazard or fire-risk of materials, products or assemblies under actual fire conditions. However, results of this test may be used as elements of a fire-hazard assessment or fire-risk assessment which takes into account all of the factors which are pertinent to an assessment of the fire hazard or fire risk of a particular end use. The results apply specifically to the specimens tested, in the manner tested, and not to the entire production of these or similar materials, nor to the performance when used in combination with other materials."*

NOV FGS Post Fire Exposure Mechanical Testing

Shaft Section Identification

The fire tested uPole shafts were cut into five sections, approximately 12 inches long each at the 0-. 3-, 6-, 10- and 23-ft. distances from the butt (fire impingement) end of the 24 ft. shaft. The focus of this study is on the 10 minute E84-16 fire test since that is more indicative of a passing wild fire, so this section of this report concentrates on the 10-minute exposure data. The cut sections were labelled as follows:

T1-1 = section cut from the uPole shaft at 0-ft. from the fire impingement end
T1-2 = section cut from the uPole shaft at 3-ft. from the fire impingement end
T1-3 = section cut from the uPole shaft at 6-ft. from the fire impingement end
T1-4 = section cut from the uPole shaft at 10 ft. from the fire impingement end
T1-5 = section cut from the uPole shaft at 23 ft. from the fire impingement end (used as the control)

Figure 8 – Five shaft sections cut from the 10-minute E84-16 fire tested uPole shaft

Longitudinal Tensile Testing (ASTM D638)

Longitudinal (0-degree length-wise) dog-bone specimens were cut from all the shaft sections and mounted and tested in tension per ASTM D638.

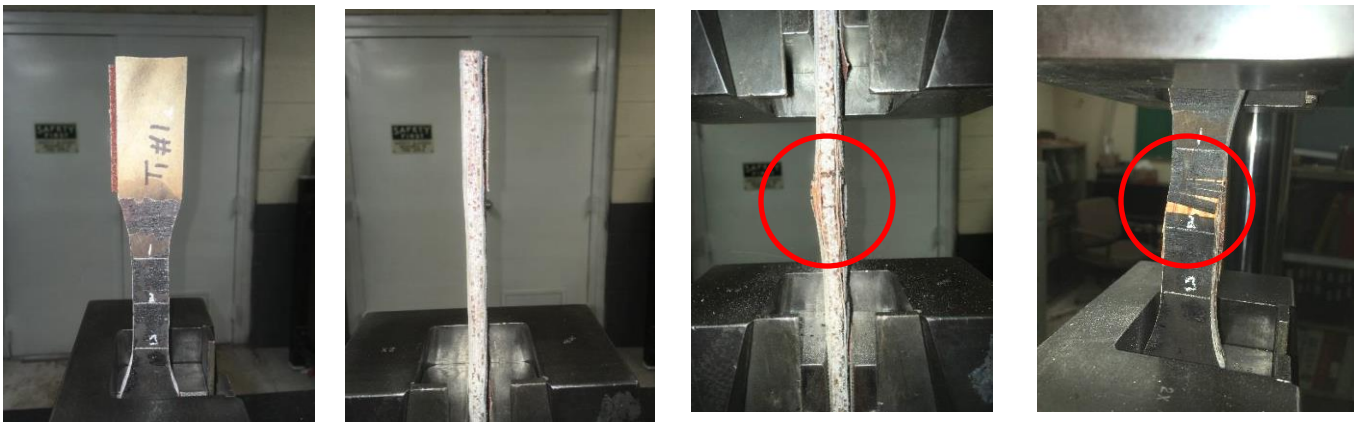

Figure 9 – Typical ASTM D638 uPole Specimen Tensile Test Setup and Mode of Break

Sample	Distance from Flame	Average Axial (0-degree lengthwise) Tensile Strength			
	(ft)	(lb/in of circ.)	% of Control	(psi)	% of Control
Control	23.5	8,633	100%	22069	100%
T1 #1	0.5	8,093	94%	18,948	90%
T1 #2	3.5	6,939	80%	17,214	82%
T1 #3A	6.5	6,944	80%	17,576	89%
T1 #3B	6.5	6,697	78%	17,881	85%
T1 #4A	10.5	8,829	102%	21,573	103%
T1 #4B	10.5	9,274	107%	23,024	110%
T1 #5A	23.5	8,285	96%	19,725	94%
T1 #5B	23.5	8,649	10%	20,065	96%

The above table of test values indicates that the there was some, but not major strength drop off in the region in the vicinity of the flame impingement, and that the flame effects on structural tensile strength did not essentially reduce the strength in the higher regions.

Longitudinal Compression Testing (ASTM D695)

Short longitudinal (length-wise) straight specimens were cut from all the shaft sections and mounted and tested in compression per ASTM D695.

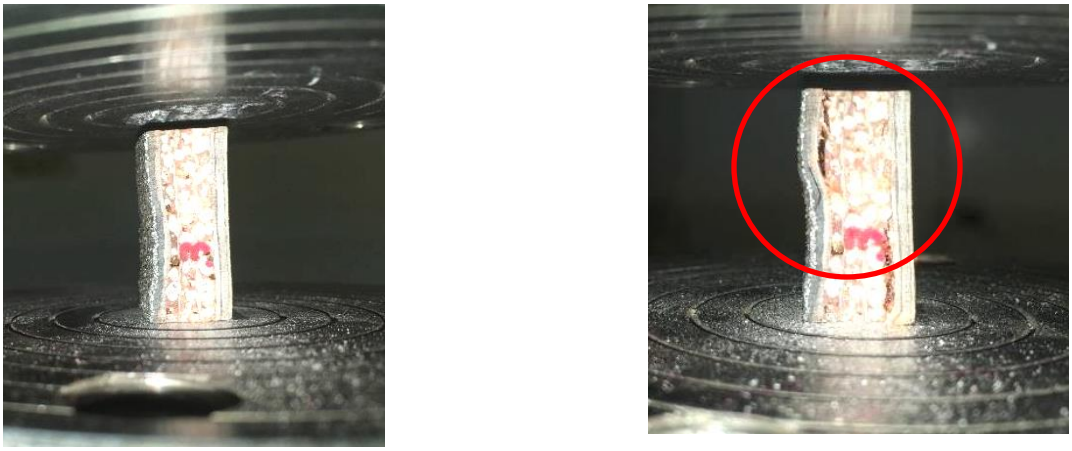

Figure 10 – Typical ASTM D695 uPole Specimen Compression Test Setup and Mode of Break

Sample	Distance from Flame	Average Axial (0-degree lengthwise) Comprehensive Strength			
	(ft)	(lb/in of circ.)	% of Control	(psi)	% of Control
Control	23.5	7,907	100%	19,596	100%
T1 #2	3.5	6,391	81%	14,449	74%
T1 #4C	10.5	9,934	126%	24,857	127%
T1 #4D	10.5	6,560	83%	17,074	87%
T1 #5C	23.5	7,947	101%	19,553	100%
T1 #5D	23.5	7,541	95%	18,010	92%

As in the tensile coupon testing, the above table of compression specimen test values indicates that the there was about a 26%, strength drop off in the region in the vicinity of the flame impingement, which but in the higher regions the flame effects on structural tensile strength did not essentially reduce the compression strength.

Hoop (90-degree) Tension Testing (ASTM D2290)

Ring specimens were cut from the shaft sections and tested in hoop tension with a standard split ring device per ASTM D2290.

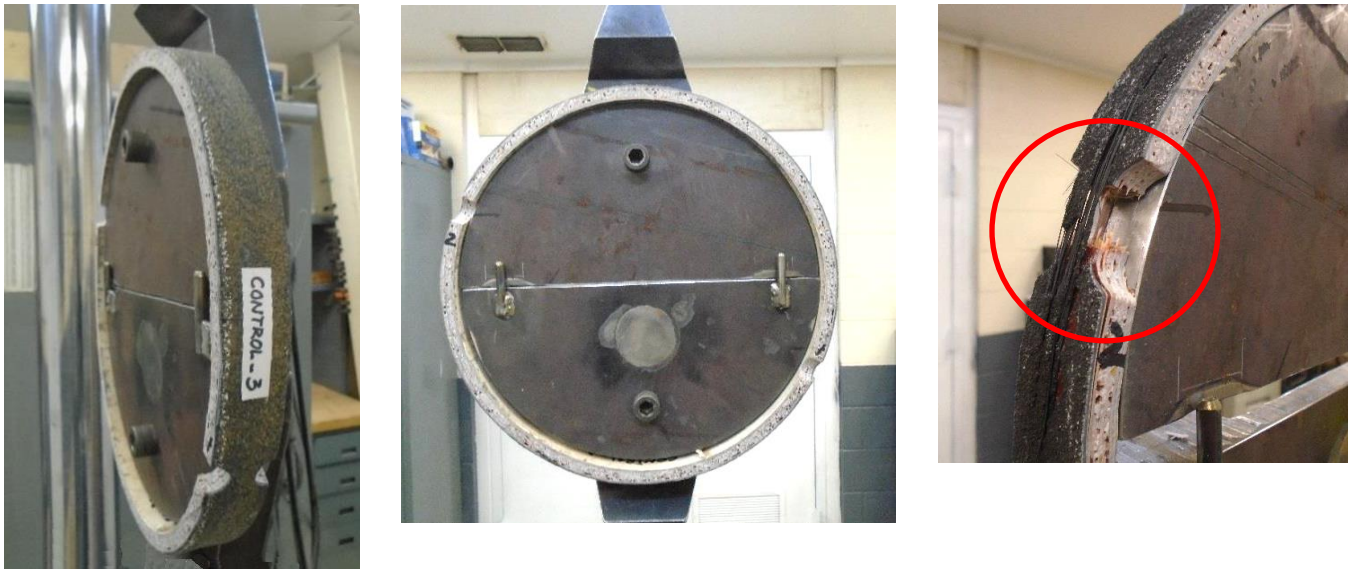

Figure 11 – Typical ASTM D2290 uPole Specimen Split Ring Hoop (90-degree) Tensile Test Setup and Mode of Break

Sample	Distance from Flame	Average Hoop (90-degree) Tensile Strength			
	(ft)	(lb/in of circ.)	% of Control	(psi)	% of Control
Control	23.5	6,166	100%	14,477	100%
T1 #1	0.5	4,420	72%	11,099	77%
T1 #2	3.5	5,692	92%	13,600	94%
T1 #3A	6.5	4,218	68%	10,323	71%

The above table of test values indicates that the there again was some strength drop off in the vicinity of the flame impingement. There was more variation in retained structural properties in the fire impingement zone with this test procedure, but the flame effects on structural tensile strength did not essentially reduce the strength in the higher regions of which the Control Sample specimen was cut..

Respectfully, Dr. James W. Davidson