A Better Way to Operate: Improving the Performance of Synthetic Ropes for Conductor Line Stringing

Abstract

This case study examines the practices of a major utility company in sourcing and maintaining synthetic ropes for pulling hard line conductor cables. Synthetic ropes made with high-modulus polyethylene (HMPE) fiber, such as Honeywell Spectra® fiber, offer the strength of comparable steel rope at one-seventh of the weight. When designed and maintained with the end use in mind, HMPE ropes enable faster, more efficient and safer operations.

Introduction

There are more than 160,000 miles of electrical transmission lines located throughout the United States today. This electrical grid infrastructure continues to expand, and existing infrastructure is maintained and replaced by electric utility companies all over the country in order to continually provide reliable service to the millions of households and businesses dependent upon electrical power.

The largest public power company, the Tennessee Valley Authority (TVA), is responsible for providing and maintaining reliable energy service to more than 9 million people in seven states. Created in 1933, TVA sells more than 171 billion kilowatt hours of power each year.

As an industry leader, TVA prides itself on providing a safe working environment for its employees and the communities in which they work. TVA began using high-modulus polyethylene (HMPE) fiber ropes six years ago to pull hard line conductor cables, as they were safe, reliable and cost-effective. Recently, the company's field operations began to lose confidence in the braided 12-strand HMPE ropes they use after experiencing inexplicable and untimely rope failures. This prompted TVA to review its overall pulling line operations in order to ensure employees could do their jobs in the safest way possible.

The benefits of using synthetic pulling lines made of HMPE gel-spun fiber, such as Honeywell Spectra® fiber, is well documented in the utility industry. The key benefit of an HMPE fiber rope is it is approximately seven times lighter than steel wire rope, with comparable strength. The weight savings allows operators to eliminate much of the weight on their rigs, making the equipment and rope easier to maneuver and position in difficult environments. The rope's light weight also allows the crews to avoid overweight permitting by saving a significant amount of weight on their trucks. The use of HMPE fiber ropes enables faster, more efficient and safer operations. This case study will examine the lifecycle and use of HMPE pulling ropes at TVA, which helped the company identify a better rope design and a more standardized approach to managing its rope inventory.

A Review of Current Operating Procedures

TVA began to review its current field operating procedures and best practices with Yale Cordage to identify opportunities for improvement. Major findings of this initial review included:

Validation that HMPE Ropes are Safe and Easy to Use

The operating crews preferred working with HMPE fiber ropes because of the ease in handling. HMPE fiber ropes also increased safety due to their low dielectric characteristics, allowing the crews to handle the ropes near live conductor cables in a safer fashion.

No Current Product Standardization

TVA used a variety of ropes with different original breaking strengths. These ropes were from different rope manufacturers, who utilized different HMPE fiber suppliers.

No Proof Testing of New Ropes

Purchasing and in-field specifications for the ropes were based on published specifications from the rope manufacturers. There were no requirements for proof break testing to validate the original breaking strength.

Standard Practice of Using Rope to Breaking Point

Typically, ropes were put into service and utilized until breakage occurred. Whether a rope would return to service following a break was determined by a simple visual or field break test using a dynamometer. Crews did their best to ensure performance safety, but there was no documented, scientific data to support the determination of whether rope was safe for continued use. Although this approach was more comprehensive than some, it did not result in the dependability TVA sought.

Ropes Subject to High Level of Abrasion

The braided ropes were subject to heavy abrasion from being dragged through the mud and rock during initial hookup, along with the normal wear and tear experienced during pulling operations.

No Rope Monitoring/Tracking Program

TVA was not tracking its rope inventory. Once purchased, ropes were put directly onto machines, and sometimes changed to other machines depending on needs in the field. The ropes did not have serial numbers, so there was no way to chart their service time in the field, the number of jobs they performed, what machines the ropes had been used on, or the loads the ropes were subjected to.

Break Testing and Failure Analysis

The next step by the combined team was to record the residual breaking strengths of the current ropes in operation to know how abrasion and operating wear was affecting the ropes' performance. Fifteen rope

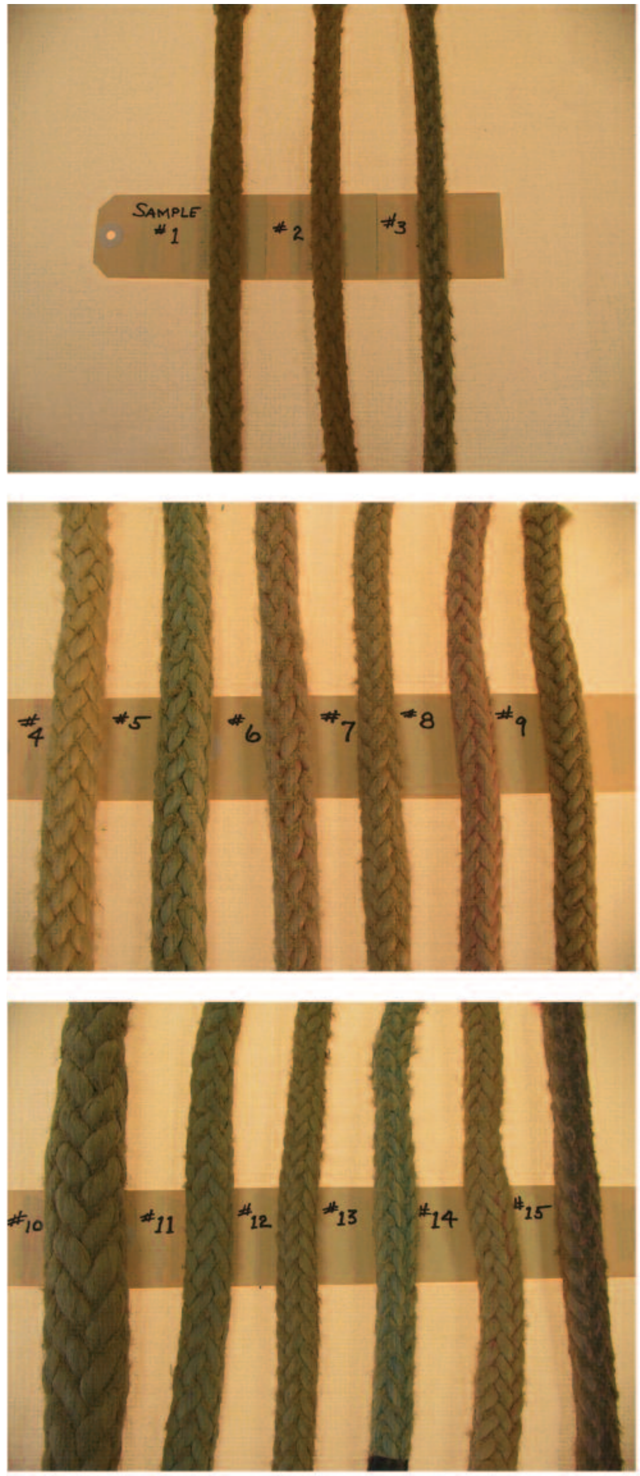


Figure 1a: 12-strand HMPE ropes tested for residual breaking strength (results in Figure 1b).

Residual Break Testing: 12-Strand Ropes

Rope Sample Number	Measured Diameter from Field	Measured Linear Density from Field	Measured Breaking Strength from Field	Estimated Original Linear Density	Estimated Original Breaking Strength	Percentage of Original Breaking Strength Retained
	Inches	Pounds/100 Feet	Pounds	Pounds/100 Feet	Force Pounds	
1	0.51	6.0	13,734	10.2	52,800	26%
2	0.51	6.2	12,789	10.2	52,800	24%
3	0.49	5.8	18,304	10.2	52,800	35%
4	0.69	9.7	13,465	13.3	64,600	21%
5	0.66	9.5	18,389	13.3	64,400	29%
6	0.64	9.6	17,004	13.3	64,400	26%
7	0.56	6.9	10,020	10.2	52,800	19%
8	0.58	6.7	7,763	10.2	52,800	15%
9	0.64	8.9	6,514	13.3	64,400	10%
10	0.99	22.2	27,889	31.9	131,000	21%
11	0.57	6.4	9,249	10.2	52,800	18%
12	0.57	7.4	7,503	10.2	52,800	14%
13	0.56	6.6	7,765	10.2	52,800	15%
14	0.61	7.2	6,377	10.2	52,800	12%
15	0.68	9.7	18,088	13.3	64,400	28%

Figure 1b: Results of residual break tests of 12-strand HMPE ropes.

samples were collected and residual break testing was conducted. Results of this testing can be found in Figures 1a and 1b.

The testing showed extreme degradation, with up to an 88 percent loss in the rated breaking strength of the 12-strand HMPE braided ropes. Most of these ropes were in operation for less than two years, including some that were only six months old.

Sub-ropes from these samples were also sent to Honeywell, the manufacturer of Spectra fiber, to perform additional failure analysis on the sub-ropes and individual fibers. Analysis from Honeywell's lab confirmed the root cause of the strength loss, which appeared to be abrasion wear. A review of the sub-ropes showed evidence of high compressive forces being exerted on the ropes, resulting in stiffening.

Damage due to wear and abrasion of the fibers was visible on the outside surface of the ropes, and since all of the sub-ropes were exposed to the rope surface along the length of the braid, external damage was observed in all of the sub-ropes examined. Tensile testing of 20 individual yarns from the examined sub-ropes confirmed that abrasion damage was also evident at the yarn level. Honeywell also found internal sub-rope damage from contaminants, such as sand. Consequently, all sub-ropes examined showed reduced breaking strength either from external abrasion, internal abrasion or both, as seen in Figure 2.

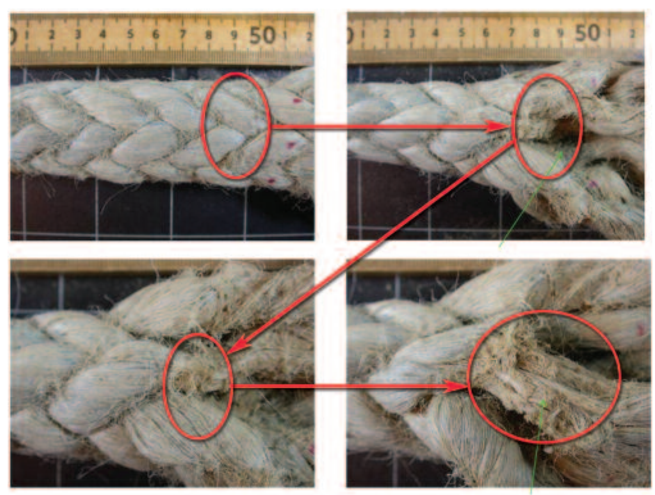


Figure 2: Example of abrasion seen in 12-strand HMPE ropes.

A Case for a Better Design

With internal and external abrasion identified as leading factors in the degradation of the ropes' breaking strength in the field, TVA began investigating alternative rope designs and constructions to determine if a better option was available. TVA chose Unitrex™ XS rope construction, made by Yale Cordage, which offers a variety of benefits over traditional ropes:

- Increased safety
- High abrasion resistance
- Lower weight
- Torque-free design
- Limited stretch

A diagram of this construction can be seen in Figure 3:

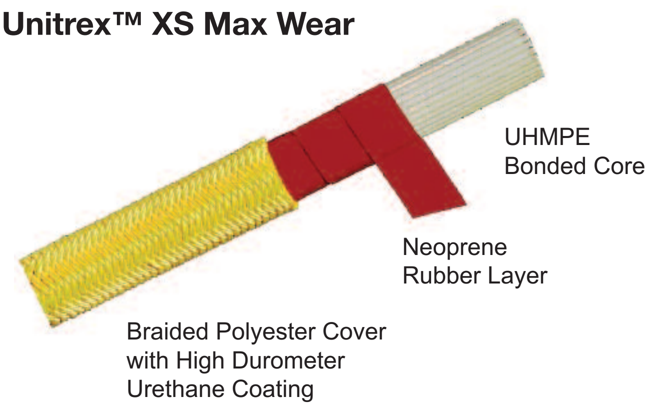


Figure 3

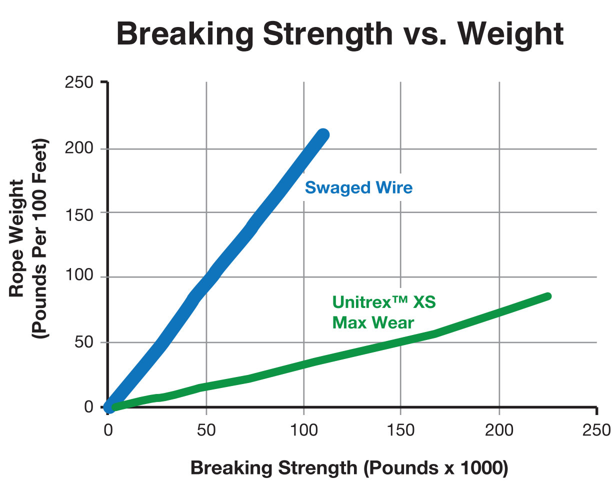


Figure 4

A New Way to Operate

The next step in TVA's analysis was to establish a new way of managing synthetic pulling line assets, and to document if the Unitrex XS design would show better retained strength in the field versus the current ropes. Five spools of Unitrex XS cable were purchased and put on trial in the field. Along with testing the cable in the field, the following operational changes were made:

Product Standardization

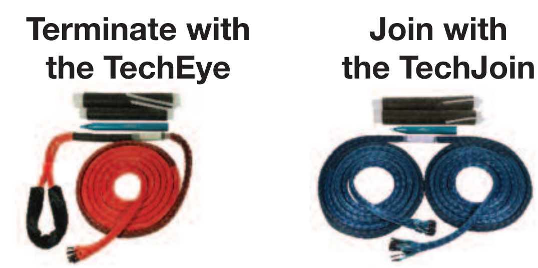
Four spools contained 15,000 feet of three-quarter-inch Unitrex XS, and one spool contained 15,000 feet of seven-eighths-inch Unitrex XS cable. All Unitrex XS cables utilized Honeywell Spectra fiber as the core HMPE fiber strength member. All ropes were manufactured at Yale's North Carolina facility and installed directly onto TVA equipment.

Rope Tracking

All cables were marked with a serial number and assigned to specific pulling units, eliminating the uncertainty of how long each rope had been in service and allowing TVA to track and record work history.

Rope Testing

The cables were inspected and sampled at prearranged intervals, with a section of each Unitrex cable cut out and tested for residual breaking strength at each inspection. Based on the break test results, TVA could assess if the rope should be retired from service, as well as start building a database to estimate the life expectancy of the Unitrex XS cable in its operating environments.



Shown: 940TechEye10 *Shown: 940TechJoin20*

Kits include fid and 3M Cold Shrink™ required for assembly.
Black shading marks the installation target zone for cable ends.

Figure 5

Standardization and Development of Repair Procedures

Unitrex XS cables damaged in the field were identified during routine inspections, and a field repair kit was developed to allow the damaged cable to be repaired onsite. Yale's TechEyes and TechJoins repair kits, seen in Figure 5, were supplied to field personnel who were trained on how to use them properly. Sources of damage to the cables were sought, found and repaired.

The results of this project can be found in Figure 6a. As the results show, all spools of the Unitrex XS cable lost less than two percent of the original breaking strength after two years in service, and no rope breaks have been experienced. This compares to the 50-88 percent strength loss of the standard braided design previously utilized, and the routine breaking of the ropes during each pull in, which is shown in Figure 6b.

Inspection and Recertification

It was decided that an ongoing program of inspection and recertification was required for all of TVA's stringing equipment. Under this program, Yale works directly with TVA personnel to remove all the rope from a stringing machine and inspect it for damage. This has been done at Yale's Salisbury, North Carolina facility, which has large spooling equipment. Periodically, samples are taken from the rope and tested for residual break strength, damaged sections are repaired and new rope is added to restore the rope to its original length, as needed. Simultaneously, the rope ends are swapped so that the inside and outside of the stringing line are used in service.

Residual Break Testing: Unitrex Ropes

Unitrex Sample Number	Rope Construction	Minimum Listed Catalog Strength	Original Tested Strength	Measured Breaking Strength at 2 Years in Service	Percentage of Original Breaking Strength Retained at 2 Years in Service
		Pounds	Pounds	Pounds	%
1	Unitrex 3/4"	66,150	71,186	69,930	98%
2	Unitrex 3/4"	66,150	70,993	69,830	98%
3	Unitrex 3/4"	66,150	71,525	70,586	99%
4	Unitrex 3/4"	66,150	71,341	70,438	99%
5	Unitrex 7/8"	90,000	100,444	99,870	99%

Figure 6a

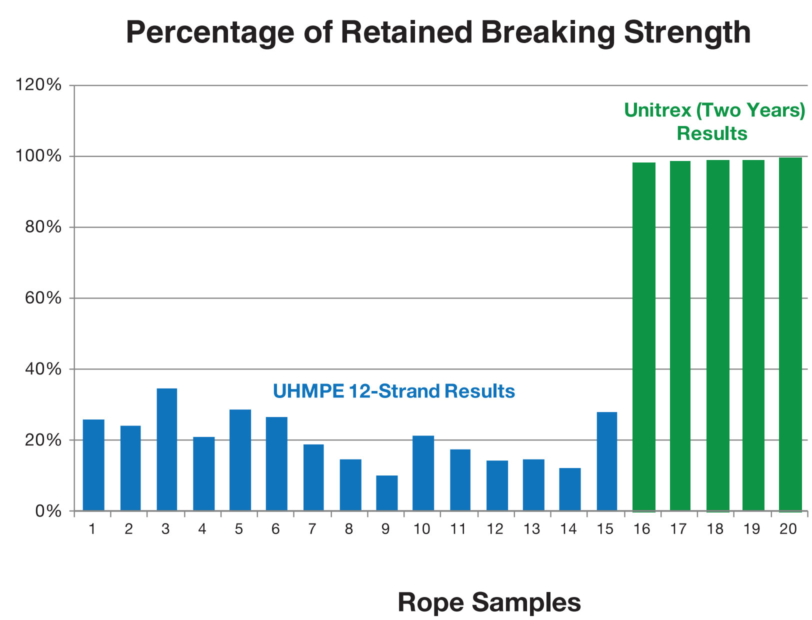


Figure 6b: Comparison of results between 12-strand HMPE ropes and Unitrex XS.

Conclusion

The performance over the past two years of the Unitrex XS cable has given TVA the confidence to expand its use within TVA's field operations. However, a two-year sample set is only the beginning, as additional work and time is needed to develop an operating value model to track Unitrex's lifetime performance. The model could potentially consist of documenting efficiency gains as a result of the rope not breaking, reductions in recordable health, safety and environmental incidents, increases in cable operating life, overall reductions in operating costs and establishment of rope retirement criteria.

Additional considerations by TVA include the opportunity to reduce the cable diameter and operating safety factor, based on the high strength retention of greater than 98 percent of the ropes in their operating environments. This would result in reducing cable costs and weight, or may potentially allow TVA to place more cable footage on its pulling reels, giving them the ability to perform longer pulls. Finally, amortization schedules could possibly be extended versus conventional synthetic rope designs as a result of the documented longer life span of the Unitrex XS cable.

Authors:

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TVA: William King – Manager, Transmission Line Construction

About Yale Cordage: Yale Cordage is a specialty rope manufacturer based in Saco, Maine, that designs application-specific ropes for a variety of industrial and recreational uses. An innovator in rope manufacturing for more than 60 years, Yale was the first to introduce ropes based on aramid, high-modulus polyethylene (HMPE), and liquid crystal polymer technology. For more information on Yale Cordage, please visit www.yalecordage.com.

About TVA: TVA, a corporation owned by the U.S. government, provides electricity for business customers and distribution utilities that serve 9 million people in parts of seven southeastern states at prices below the national average. TVA, which receives no taxpayer money and makes no profits, also provides flood control, navigation, and land management for the Tennessee River system and assists utilities and state and local governments with economic development.

About Honeywell: Honeywell (www.honeywell.com) is a Fortune 100 diversified technology and manufacturing leader, serving customers worldwide with aerospace products and services; control technologies for buildings, homes and industry; automotive products; turbochargers; and performance materials. Based in Morris Township, N.J., Honeywell's shares are traded on the New York, London, and Chicago Stock Exchanges. For more news and information on Honeywell, please visit www.honeywellnow.com.