Understanding Traction Hoist Ropes in Today's Elevator Installations

Continuing Discussion on Perceptions of What Might Be Wrong with the Ropes

by Rick Perry, Martin Rhiner and Kevin Heling

Learning Objectives

After reading this article, you should have learned about:

- Factors that can adversely affect hoist-rope life
- Why lubricating and tensioning hoist ropes are necessary processes
- As elevator machines age, hoist-rope life expectancy goes down and why

Over recent years, industry professionals have begun to acknowledge that increased reports of elevator breakdowns connected to rope wear or rope failure are more than a simple sign of inherent rope manufacturing or design deficiencies. Many are now coming to see hoist rope "failure" as the result of a combination of factors that more properly have their source in the initial installation phase of a project or are points that are overlooked during routine maintenance. Indeed, many professionals are also even coming to the opinion that a key contributing cause behind "early" hoist rope failure is potentially related to some industry calculations that do not consider how newer, faster accelerating and decelerating elevators are placing far greater strains on older, long-established rope selections (such as standard 8 X 19 sisal varieties) – strains that those ropes were not originally created to handle.

Newer building designs, which place a premium in using every bit of floor space profitably, have helped spur the rise of machine-room-less system designs and the move towards installing fewer elevators in some commercial buildings. While a boon to building planners and architects, this move to do more with less requires the use of smaller components, correspondingly aggressive sheave groove profiles, greatly increased elevator start cycles, tighter bend radii for ropes and the use of sheaves requiring multiple angles of deflection. This places far greater stresses and demands upon the ropes and ancillary equipment. Lastly, elevators themselves have evolved from being used sporadically in facilities to functioning nearly continuously due to increased demand and the result of changing societal factors. This increased usage has meant that professionals have had to cease measuring rope longevity as simply how long (time frame only) they've been in use on an elevator to instead gauging how many starts the rope in the installation has delivered. In short and most significantly, all these factors can and have combined to create installation environments that have moved from being somewhat unfriendly, to ones that are decidedly hostile to hoist ropes themselves. This is the current reality.

This reality does not mean one should simply see hoist rope performance as being trapped in a constantly decreasing spiral and make no effort to address the situation. Instead, evidence shows that by paying attention to various factors, implementing and assuring some certain preventative measures, and through the use of forethought and

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Value: 1 contact hour

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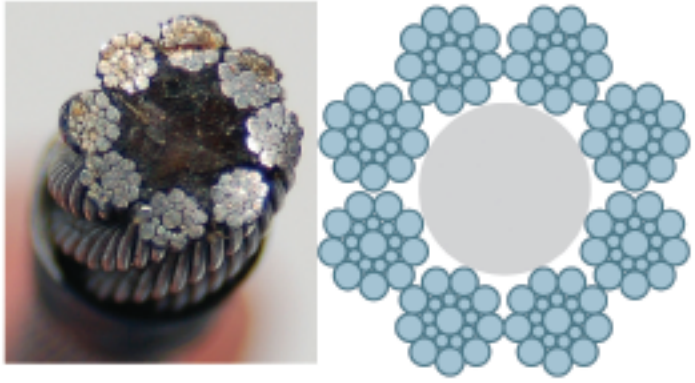
good planning, professionals can instead see hoist rope performance levels that at least equal, if not surpass, what they have become accustomed to seeing.

Let us be clear. Hoist ropes are designed to higher standards, are tested far more rigorously, use materials of a higher quality and are manufactured to a degree of sophistication that would have been unimaginable in the past. Unfortunately, this still does not mean that they cannot fail; any moving machine part can. Forward thinking, problem-solving state-of-the-art manufacturers can and will perform in-depth, post mortem, forensic analyses of returned samples and even go to those installations where a failure occurred in order to verify results. The analysis of current elevator designs and the desire to create ropes that better meet the vastly increased demands in current installations have led manufacturers to offer a whole new generation of hoist ropes that address these needs. So rather than blindly blaming the ropes solely for the rise in reported incidents of elevator breakdowns, we feel it would better profit professionals to consider other factors that have an equal (if not greater) impact on rope performance in today's brave new world of elevators.

First, the Facts

Hoist ropes are not merely a random wrapped grab bag of stranded wires. They are precisely engineered, surprisingly complex objects made of soft steel offering a number of moving parts. Take for instance an 8 X 19 Seale hoist rope: it has 152 separate moving parts (eight strands, 19 wires per strand). In addition to being crafted to be both strong and durable, elevator ropes must be designed to be flexible as well. Normally, these are mutually exclusive goals. Rarely is any item created to provide strength required to be able to bend with the same level of proficiency as well – normally, higher strength means rigidity.



Overhead of Brugg Sisal Core 8 X 19 rope with construction diagram

Ropes do not work in isolation. They are required to be able to work efficiently in unison with other ropes and surrounding machinery. So wire and strand elements inside a rope must be able to flex, bend and readjust as it is pulled over the sheave (or sheaves) and then straightened again. It's hardly surprising that a rope shows wear, or even that a strand will break (even steel has its own inherent limits). Instead, one should be amazed they perform as well as they do in an inherently destructive environment.

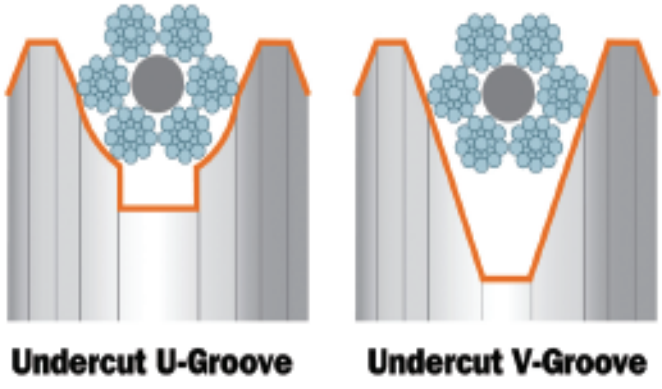
To the trained eye, a hoist rope can serve as a valuable messenger to alert you to upcoming problems and help you better diagnose them. So, in fact, creating an indestructible hoist rope (though being quite a feat of engineering) would actually be a disastrous development, because it would make them useless as a guide in helping you diagnose the root cause behind even larger potential problems. Replacing sheaves and surrounding equipment can be an expensive proposition – hoist ropes are far less so.

It's Not Rocket Science: It's Hoist Rope

If you truly want to improve the performance of your hoist ropes, there are some simple facts you should consider that are basic to professionals but still bear repeating.

Think Hard about What You're Aiming for

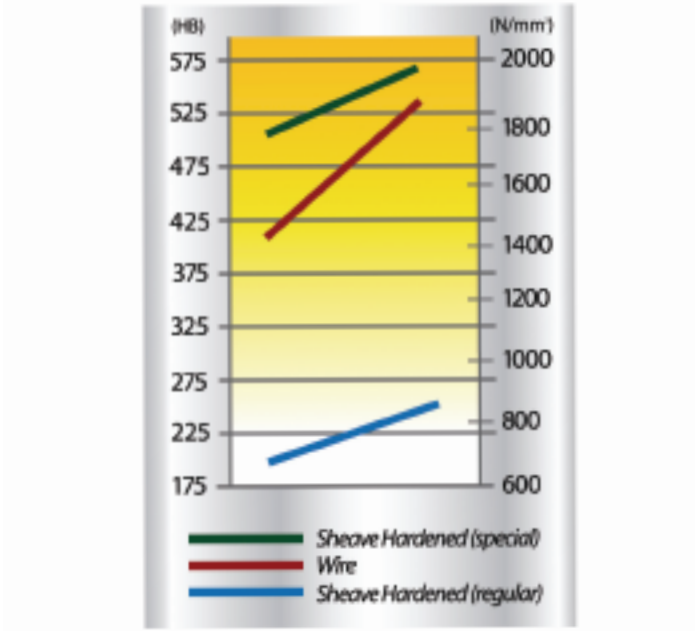
As any good craftsman will tell you, "Measure twice, cut once." In other words, a little bit of planning and consideration can save you time and money. For instance, have you considered what an installation's normal yearly stops and starts will be? If you're expecting more than 200,000 per year (which has become more and more the industry standard), then you may need to use something other than standard sisal cores made of naturally imperfect natural sisal. Perhaps you need a parallel steel or mixed core variety.



Undercut U- and V-groove profiles. The kind of groove configuration is an important factor in the choice of a hoist rope.

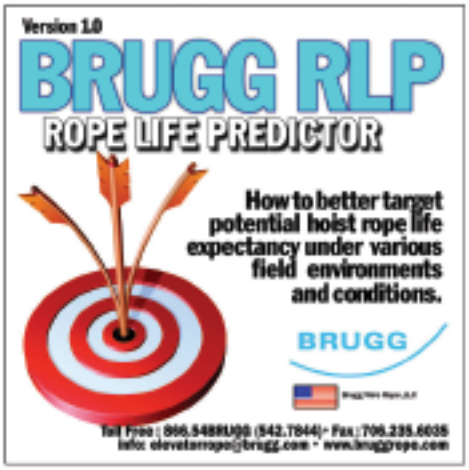
Check whether the ropes will have to deal with aggressive sheave groove configurations; how many and how close are the deflector sheaves. Consider the Brinell Hardness of the drive sheave to be used, and factor in wire tensile grades and groove pressure combinations as a part of your thinking process. Consider using sheave liners when using lang-lay rope and *never* substitute

six-strand ropes for eight, or eight for six-strand without written approval from the equipment manufacturer. This is an issue critical to both system design safety and proper function that supersedes availability considerations.



The Brinell hardness of your drive sheave is an important factor that needs to be considered when deciding upon the proper hoist rope.

Choose Quality Rope – This Means the Right Rope Maker and the Right Rope Type for Your Application



Brugg RLP is a prognostic calculation program based on the seminal work of Professor K. Feyrer and his research team at the University of Stuttgart. The calculation method takes a variety of environments and field conditions into account, and offers a forecast of the potential life expectancy of your rope selection against the basics of your system design.

Certainly a variety of factors need to be considered during the design of any installation, but using price as the ultimate criterion for any decision is a strategy that is doomed to failure. First and foremost, gauge if the manufacturer chosen is a proven, experienced source for hoist rope with strong design, materials and with production process controls in place. Become familiar with what goes into the core (it is the foundation of any hoist rope), and you should examine its design and understand the limits and strengths of each design offered and select accordingly. Lastly, you should review whether a manufacturer's process controls lay length, helix and torsion, and how the rope components (wires and strands) are actually assembled. Remember that each manufacturer's rope is inherently different from another in design and composition. So it is unwise to use ropes from two different rope producers on the same elevator.

$$\lg N = b_0 + \left(b_1 + b_4 \cdot \lg \frac{D}{d}\right) \cdot \left(\lg \frac{S d_0^2}{d^2 S_0} - 0.4 \cdot \lg \frac{R_0}{1770}\right) + b_2 \cdot \lg \frac{D}{d} + b_3 \cdot \lg \frac{d}{d_0} + \frac{1}{b_5 + \lg \frac{l}{d}}$$

The number of expected bending cycles (rope life) a rope must face is a key piece of information that must be considered prior to any rope selection. Formulas already exist to make this task much easier to perform. Ask your hoist-rope manufacturer to assist you.

Choose a Rope that Fits Your Needs, Rather than Hoping that Available Standard Rope Will Fit the Situation

It goes without saying that you should choose a hoist rope that meets the potential needs of your particular system, and don't make your selection based solely on simple convenience. If you'd like assistance in doing calculations, why not consult with the personnel at a state-of-the-art manufacturer for their recommendation on the proper rope to use? After all, it's their job to keep up with all the alternatives available. Why not benefit from their free experience and expertise?

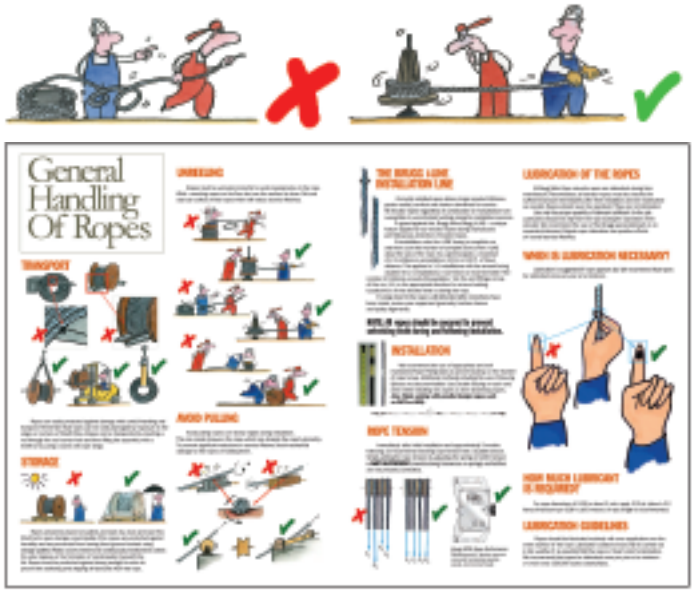
Actually, selecting the right rope for the right situation sounds easy, but all too often professionals fail to anticipate the various factors that a particular rope will face in a certain environment. For instance the decision to use a standard 8 X 19 sisal core rope, instead of a more robust rope design – eight or nine strands with either a parallel or nonparallel design results in a huge percentage of the installation downtimes that occur today. For years, standard sisal served adequately and has been the economical choice (one might even say the standard choice) of the entire industry. But the very design that has been standard 8 X 19's strength is running into real problems with today's higher performance and high use elevators. Obviously an eight-strand sisal core rope is less round and less stable than an nine-strand rope (such as Brugg DP9, HRS, and its new MCX and SCX series of rope) and thus will conform to some degree to a worn groove, forcing the rope to become more ovoid in shape. This can lead to real problems such as increased friction between individual strands, accelerated wire and strand fatigue, and, in a number of instances, lubricant being squeezed out of the core (which further compromises the ropes ongoing performance).

Continued

If you foresee that a particular installation will require rapid accelerations, decelerations and nearly continuous use, you should at the very least consider using a more robust eight-strand rope. Indeed, if you are concerned that a rope may face aggressive handling during installation (or that during the installation process, the rope could be forced somewhat open) or that an installation's age or condition may make it more likely that the deflector sheaves may have fleet angle, it would pay for you to consider non-parallel (Point-Contact) designs of rope such as Brugg's MCX/SCX 8 and 9 series. The mixed cores (MCX-series, made of fibers and steel strands) create a higher breaking strength when compared to sisal ropes of the same diameter. In addition, elongation is reduced and fatigue bending performance is significantly improved.

In a real, rope life-expectancy case study, Brugg staff recently found that the same system using 8 X 19 sisal core rope is expected to deliver just over 470,000 bending cycles, and if Brugg HRS rope (double-parallel, mixed core rope with nine strands) is used, the prediction model can estimate the installation/system will deliver about 975,000 bending cycles – a life expectancy improvement of 100 percent (or double the life). Brugg, or some other rope professionals, can perform this same life expectancy comparison with your challenging installation or system for you and estimate the improvement expected when considering the use of high performance ropes over the 8 X 19 sisal core rope. Such calculations, based on Prof. Feyrer's research, are calculated with 95% certainty that 10% of the ropes reach the maximum number of wire breaks (discard criteria).

Do the Legwork. It Will Pay in the Long Run.



There's no mystery to good installation technique. To avoid problems, consult the manufacturer's materials in your shipment.

As we all know, oversights occur, and finding that someone has installed the wrong rope on a machine does happen. To lessen this possibility, first check the crosshead plate to ascertain the correct rope you'll need on a piece of vintage equipment. In addition, check with the building manager or owner to determine if a unit has been structurally modified. If this has occurred, or if you find that weights have been added or removed from the unit, you need to recalculate load factors. Yes, we agree, it's a hassle, but a little bit of extra work at the beginning may bring to your attention that you need to recalculate your loads, or perhaps even install a completely different rope construction or one bearing a higher breaking strength.

It's Not Indestructible: Be Careful with It

We've already noted that hoist rope is a highly crafted, precision item. If you follow the previous steps suggested you've already made quite an investment in time and effort to choose what you need. So take the time to take care of your hoist rope by using the proper handling procedures provided by that manufacturer in your shipment. Remember: quality manufacturers distinguish themselves by offering you all the information you'll need during this critical phase. So if your manufacturer doesn't offer instructions or written recommendations, you may wish to reconsider if this is a source you should be using for hoist ropes at all. Installation is not the time to blindly trust to luck or experience – consequences of ignorance, or indifference during this phase could be very expensive.

Never leave ropes uncovered on the site as they can be easily damaged by exposure to the elements (precipitation or excessive heat) or to the edges of forklift forks. When transporting hoist ropes, remember to insert a rod through the reel center hole and then lift the entire assembly with a forklift or use a crane with rope slings. To reduce the buildup of dirt and dust on ropes (which can reduce service lifetimes) unreel them on a clean surface and take precautions to avoid kinking. At all costs, avoid pulling ropes over sharp edges as this damages the ropes (which can create torque on the rope), change its geometry and shorten its life.

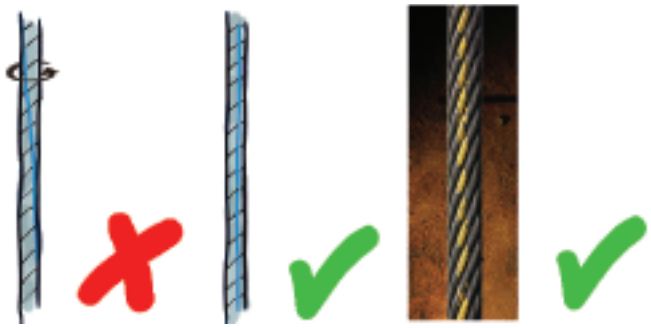
A variety of diagnostic equipment, from the simple measuring gauge to complex devices such as Brugg RPM (with the user CD), exists for the professional today.

Find and Use the Right Tools

In today's industry, there are far more tools than ever before that you can use to handle problems or questions that may have been avoided or failed to be used due to cost or expediency. There is no reason why consultants, elevator mechanics or inspectors should not avail themselves of some of the state-of-the-art equipment available today that simply and accurately measures the total weight of an elevator car and the counterweight, measures tension or diameter of ropes, or calculates the total suspended mass of a car to verify sheave loads. They're accurate, necessary and increase performance. Simply choose one that fits your handling needs – buy it and then use. Don't be shortsighted.

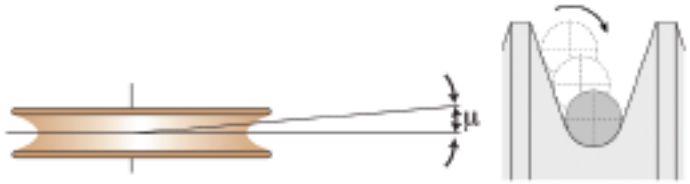
In addition to actual diagnostic tools, Brugg even offers a prognostic program to help you accurately gauge how long a particular rope, handling a certain number of cycles, used in one of a variety of environments, will actually last in any installation. Brugg's Rope Life Predictor (RLP) CD contains a series of automatic computations where you simply enter your data and follow the instructions, and the formulas automatically provide the answers that remove the guesswork from choosing the right rope. If you haven't looked into the various advanced tools available to the industry professional today, you should.

Pay Close Attention to Installation Basics.



By using the i-Line feature, you can easily detect if ropes are twisted and review other important details around the installation.

Never twist ropes open or allow it to twist open by "hanging it out" – use the i-Line. This simple feature makes it easy to detect when ropes are twisted and helps you review equipment geometries, and traction sheave and pulley alignments. End terminations have a critical impact on rope life. So take the time to ensure you've followed procedures correctly through the correct application of rope pulling grips or reeving splices (use double seizing on each end when installing new ropes or shortening ropes and triple seizing with parallel design ropes).



Monitor your fleet angles (the angle of a rope as it leaves one sheave and connects with another), as too wide an angle can result in premature wear of the rope. A 4% fleet angle will reduce rope life by 30%.

Check the alignment of drive and deflector sheaves or, if new ropes are to be installed on existing sheaves, check for unequal groove depths, which could lead to the replacement of the sheave itself. Naturally, should you have any questions on installation, simply call the manufacturer as they have many printed instructional pieces available for your use.

Lubrication and Tensioning

Choose any approved lube applicator that is efficient and easy to use in order to ensure proper lubrication during maintenance. Above all, select a lubricant that is OEM approved.

All too often, installers simply place ropes in an installation and never consider the topic of lubrication. True, most hoist ropes come from manufacturers already lubricated, but that does not address conditions the ropes may have encountered during transport, as they sat on the site awaiting hanging or during the installation process. For instance, strong exposure to heat can cause the softening of lubricants from the rope or new construction sites can be dusty environments where temperatures can fluctuate dramatically – thereafter, more lubricant must be applied. For rope diameters of 0.39 to about 1 inch, we recommend an application of 0.35 pint (about >0.2 liters) of lubricant per 328 feet (100 meters) of rope length. Remember, where moisture is an issue, select a lubricant that performs the valuable function of being able to displace water. There are several available on the market, and they can definitely make a difference in performance.

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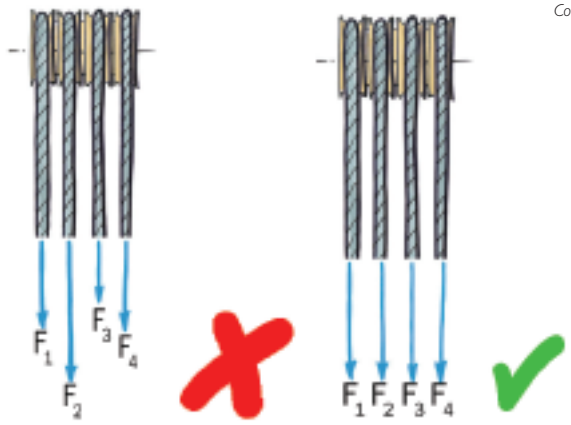
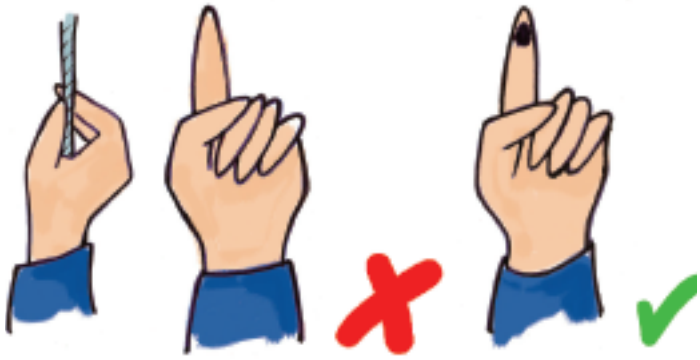


Failing to equalize hoist-rope tensions is one of the major causes of rope wear and overall system performance degradation.

In addition, installers frequently overlook properly equalizing rope tensions and sometimes gauge tensioning by "plucking" the rope or merely eyeballing it. This is inherently inaccurate and destructive, and since various tensioning devices are available in the market today, totally unnecessary. By all means, finish the job right and equalize rope tensions – aim for tension equalization within ±10% at the time of installation, after a take-up and at regular intervals in between.

Maintenance: The Make or Break of Rope Life Expectancy

We understand that some in the industry have been, shall we say, a little less than perfect in performing certain maintenance chores. We know this is not due to purposeful neglect, but is to some degree a complex and understandable reaction to the high labor costs that come from using highly trained professionals to perform tasks correctly. Time and inconvenience follows shutting elevators down in order to perform superior maintenance, and the acquisition of maintenance contracts that must be performed at the lowest possible cost by maintenance professionals in order to see any profitability will hardly win kudos from irate building owners. We understand the trend. Needless to say, rope makers find it worrisome. Especially since the advantages of performing proper maintenance offers such strong evidence of significantly increasing the expected rope life.



If it's bone dry, your ropes are going to die young. Take the time to lubricate every 250,000 cycles or once a year (preferably in the spring).

Again, lubricate your ropes. We recommend you lubricate ropes every 250,000 starts or at least once a year, preferably in the spring. The lubricant you use should be compatible with the original one (homogeneous solution). It should offer good penetration capability, with a friction coefficient of μ 0.09 (-) (material pair steel/cast iron), and very good adhesion. We also suggest you use a lubricant with an ISO grade of 10, a Viscosity Index (ASTM D-2270) of no lower than 80, with a viscosity at 104°/40°C CST/SUS (ASTM-D445/D2270 of 10/59. A failure to adequately lubricate can reduce the life of the rope by up to 50% and increase sheave wear.

As we mentioned, during the installation phase it is critical that you keep rope tensions equalized to within ±10% throughout a rope's lifetime (we have found research studies that indicate that a 15% difference in tensions between ropes has a huge impact on wear). Infrequent, poorly performed or neglected tension equalizations can negatively impact a rope's life expectancy by up to 50% and cause damage to other components in the installation. High tensions on ropes lead to rapid wear on outer wires and sheave grooves. Low tensions can make ropes slide through the sheave grooves and create wear on ropes and sheaves, too. Either way, badly tensioned ropes mean trouble for you.

Keep an Eye on the Surrounding Components such as:

◆ Sheaves

Worn sheaves will wear ropes, which will wear on sheaves, setting up a cycle of destruction for both. Replacing or regrooving sheaves may be necessary to prevent this. Check groove profiles annually to verify the fit between ropes and the sheave. A proper fit means good traction. Without good traction, you're either sacrificing rope life or sheave wear or both. Take the time to perform a quick check and measure whether all the ropes sitting in their sheave grooves are at equal height.

◆ Bearings

Worn bearings can lead to the creation of odd fleet angles and result in additional motion, leading to an increase in rope tensions and pressures placed on ropes. For instance, too wide a fleet angle and the rope will scrub up against the flanges of a sheave groove and result in additional wear. An angle of as little as 4° will reduce the life of a rope by as much as 33%.

◆ The System Environment

If an elevator is operating in an arid or dusty environment, naturally this is going to impact the frequency of lubrication. In addition, any indication of humidity or air-conditioning venting onto the ropes, extreme dirt and cement dust, or evidence of wildly fluctuating temperature changes in a hoistway or machine room is worth immediate investigation. Pay attention to any obstructions or impediments that may hinder equipment performance or make contact with the ropes as well. Keep an eye out for increased (or increasing) car motion resistance as this is a possible sign of bad rollers or guides. In addition, note any excessive car vibrations as this may be caused by either electrical (drive systems) or mechanical problems in system operations.

Records: How Hard Can It Be?

This is the simplest, yet most overlooked factor for increasing rope performance. We beg you to track the number of starts wherever possible. This not only establishes

a true life expectancy benchmark for a rope, but it is a major advantage in planning for a re-roping event. It is practically impossible to estimate rope expectancy, diagnose the cause behind problems, or even verify if any changes have been made to the facility in general if you have to work in a data vacuum. Rigorously record any environmental events that may have affected the system. If you don't take records now – start. If you do keep records, make sure they are easily available to those who will work in an installation in the future. It's common courtesy, and it makes good sense.

Reality Check

Despite all the innovations manufacturers provide to handle the challenges in today's industry, the toughest thing we have to confront are unrealistic expectations among professionals. Every day, state-of-the-art manufacturers have to address the challenges presented by constantly evolving elevator designs with newer more advanced offerings. As they cannot rely on pat answers, neither can you. This means your level of industry knowledge must advance as well. Whenever possible, take the time to speak with your elevator manufacturer to understand how new ropes, new maintenance developments and advances in technology impact your field and potentially your own future as well.

One other thought to bear in mind: Never expect a second, third or later generation rope to return any vintage installation to the state of efficiency it offered when it was new and pristine. Nothing can do that. The reason? Cumulative wear on all the parts of an assembled system. In effect, an elevator installation is a self-contained system where how one part works can impact the rest. So this means that some of the factors we mentioned previously may be out of your control. Remember that due to the vast changes in elevator system designs and, despite your best efforts, rope life may be shortened and performance reduced regardless.

We Can Make a Difference

We'll admit that the reality of the previous statement is somewhat sobering. However, while a level of wear is natural, proper maintenance WILL greatly reduce the amount of wear on your system. In addition, it will increase rope life by controlling the multiplicative effects of factors as they combine to impact your system. For instance, we rarely find only one factor to be behind the apparent "early death" of any rope. Instead it's a cumulative and multiplying effect. If you combine a lack of lubrication (-0.50), with unequal tensioning (-0.50), in addition to bad angular pressures (-0.30), you'll find that a rope's life will be reduced to only 7.5% of its original design expectation. These easily verified factors, if left unaddressed, will mean re-roping many times more often than necessary. That means more than merely rope replacement costs to you. For the total cost you will need to factor in labor and possibly other mechanical replacement costs as well.

Ropes do wear out and break, and we'll continue to design and build ropes for newer elevator challenges, as well as constantly refine our processes in quality. That's a promise, and that's our job, but it's time for us all to redress the problem of hoist-rope failure and poor performance by looking at the total picture and teaming up to do everything we can together. Accusations get us nowhere. We're all a part of the problem. Fortunately, we all have a big role in its solution too.

Rick Perry, Martin Rhiner and **Kevin Heling** of Brugg Wire Rope, LLC in Rome, Georgia offer more than 60 years of combined experience in the elevator hoisting industry, with their primary focus being in the area of ropes and cables. The authors gratefully acknowledge the talents of numerous other professionals for their support, advice and critical analysis used in the preparation and final editing of this article.

Learning-Reinforcement Questions

Use the below learning-reinforcement questions to study for the Continuing Education Assessment Exam available online at www.elevatorbooks.com or on page 141 of this issue.

- Rope life expectation: How should it be measured?
- Which part of the hoist rope is the foundation?
- What are some of the things that can reduce rope life?
- How many moving parts does a standard 8 X 19 Seale construction rope have?
- How often should you lubricate ropes? Why?

ELEVATOR WORLD Continuing Education Assessment Examination Questions

Instructions:

- Read the article **"Understanding Traction Hoist Ropes in Today's Elevator Installations"** (page 105) and study the learning-reinforcement questions.
- To receive **one hour** of continuing-education credit, answer the assessment examination questions found below online at www.elevatorbooks.com or fill out the ELEVATOR WORLD Continuing Education Reporting Form found overleaf and submit by mail with payment.
- Approved for Continuing Education by **NAEC for CET and CAT, and NAESAI for QEI**.

1. In an 8 X 19 Seale construction rope, how many wires comprise the moving parts of the rope?
   a. 114.
   b. 133.
   c. 152.
   d. 171.

2. We must be cognizant of the Brinnell hardness of these two elevator-machine components to achieve proper rope life:
   a. Sheave and rope.
   b. Sheave and counterweight.
   c. Sheave and shackles.
   d. Rope and lubricator.

3. On the jobsite, where is the best place to locate the original rope diameter, break strength and number of ropes required for the elevator?
   a. Rope tags.
   b. Machine room (placed within easy view of main sheave).
   c. Crosshead plate.
   d. Elevator log book.

4. How often should elevator hoist ropes be lubricated?
   a. At least once per year.
   b. Every 250,000 cycles.
   c. When the rope is dry.
   d. All of the above.

5. What can prematurely reduce hoist-rope life.
   a. Poor tensioning.
   b. Lack of lubrication.
   c. Bad angular pressures.
   d. Worn sheave grooves.
   e. All of the above.

6. Lack of equal rope tensions can lead to a reduction in hoist rope life by as much as:
   a. 10%.
   b. 25%.
   c. 30%.
   d. 50%.

7. When you install new hoist ropes on an existing machine, you can expect the new rope to always last as long as the last set of ropes.
   a. True.
   b. False.

8. Rope life today should be measured in years of operation.
   a. True.
   b. False.

9. The ultimate goal of elevator-rope manufacturers is to produce an indestructible hoist rope.
   a. True.
   b. False.

10. The core is the foundation of any elevator hoist rope.
    a. True.
    b. False.

Question 5 has been revised for better clarification

ELEVATOR WORLD Continuing Education Reporting Form

Article title: **"Understanding Traction Hoist Ropes in Today's Elevator Installations"** (EW, April 2008, page 105).

Continuing-education credit: This article will earn you **one contact hour** of elevator-industry continuing-education credit.

Directions: Select one answer for each question in the exam. Completely circle the appropriate letter. A minimum score of 80% is required to earn credit. You can also take this test online at website: www.elevatorbooks.com.

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