Elevator Hoisting: Maximizing Performance of Ropes in Existing and "Improved" High-Demand Installations

by Kevin Heling, Rick Perry and Martin Rhiner

Learning Objectives
After reading this article, you should be able to:
- ◆ explain why ropes may not last as long as expected.
- ◆ know the factors affecting rope life.
- ◆ evaluate the lifespan of hoist ropes.
- ◆ give an overview of standard maintenance practices of hoist ropes.
- ◆ know the proper means of tensioning hoist ropes and how to check them for equal tension.
- ◆ properly document hoist-rope maintenance procedures.
- ◆ know the best installation practices for hoist ropes.

Elevator ropes (or, more completely, the elevator hoisting system) are frequently misunderstood critical elements in elevator system design and maintenance today. Over time, both elevator hoist-rope manufacturers and the rest of the industry have allowed certain observations in this field to be accepted as fact without challenge or proper communication. Further, a failure to take into account how demanding simple changes in hoisting systems can affect and have affected hoist ropes has contributed to a rise in overall maintenance costs and even more unnecessary confusion. Let's begin by reviewing some of the basics of elevator rope, clarify what to expect, dispel some common misperceptions and provide exposure and technical explanations of the realities of today's elevator hoisting systems.

From the start, let's not think of wire rope as a single, static piece of wire or even steel. It's surprisingly complex and offers a quantity of moving parts. For instance, an 8 X 19 Seale hoist rope has 152 moving parts (eight strands, 19 wires per strand) plus a sisal core. All these parts have to work in unison with both each other and the surrounding elevator components. Although it is a strong, load-bearing component, wire rope is made of moderate-strength steel and is primarily designed to be flexible. The wire and strand components (bundles of wires) must readjust constantly as the rope moves over a sheave and straightens back out. Could we ever make a wire rope that would never wear out or fail? Certainly we can and should believe that anything is possible, but for now we have to understand that this would rob wire rope of most of its true utility to the industry – a control measure related directly to elevator safety. Steel has its limits. Even with all the advantages of sophisticated design and manufacture we use today, we can't overcome the basic fact that hoist rope, just like anything else used in the real world, can and will wear out and need to be replaced.

Value: 1 contact hour

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8 X 19 Right regular lay sisal-core rope

A big question we have heard many times is **Why don't ropes last as long as they used to?** (In the March 2007 issue of ELEVATOR WORLD, Hugh O'Donnell provided a technical summary of proven and "known" rope degradation factors.)

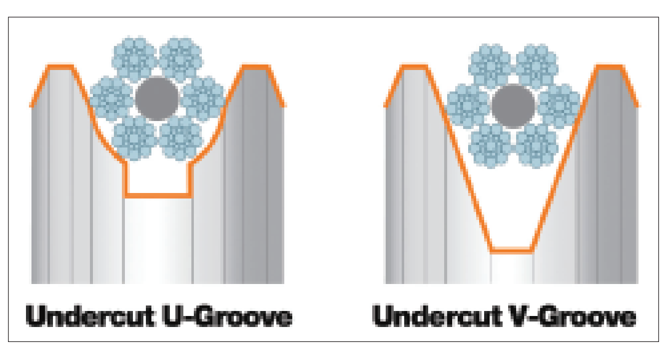
Ropes do not last as long as they used to. There – we have acknowledged it. However, this is not because there was something inherently better in how rope was made in the past compared to how it is made today. Actually, elevator ropes today are as good as, if not better than, those made in the good old days. Some elevator ropes today are manufactured using plastics, die drawing, synthetic and mixed cores, and parallel-lay constructions. Rope manufacturers are under a strong and justified pressure to have their design correct and their manufacturing processes under very tight and strict control. That's progress.

Why is any of this necessary? Why can't manufacturers simply make elevator rope that will last 15 to 20 years like the old ones did? Well, first, it's a challenge to find old classic style elevators that use large drive sheaves (and few if any secondary sheaves) without 2:1 roping or double wrapping and comfortable U-grooves running at slower speeds. Remember those days when there used to be more elevators in a single building? Ah, memories.

Having more elevators in a building is simply not the direction the industry has been going over the last few decades. An elevator shaft takes up valuable rentable space in a building, and elevator manufacturers have been forced to deal with this. Machine-room-less elevators also do not need space for a machine room above the elevator hoistway. Today, elevators are designed to do the same job but use less space and at less cost. The design process of making things smaller may be called "de-massification." Following this de-massification trend (also known as cost reduction), sheaves and machines have gotten smaller, creating tighter bend radii for the ropes. Along with this, sometimes the distance between sheaves has decreased (short recovery for the rope and even more bending), with some sheaves requiring multiple angles of deflection. At the same time, sheave grooving has become much more aggressive in order to achieve the required rope traction needed for increased acceleration and deceleration speeds. The overall numbers of elevator cycles have greatly increased, as well. This is not at all about rope makers wishing to pass the buck to users – this is reality.

What of the perception that ropes manufactured today deliver shorter rope life on vintage equipment? To be fair, in some cases, it *is* true that the ropes are not lasting as long as they did when the equipment was new. However, before we go any further, let's examine how we should evaluate a rope's lifespan. We'll outline a few basic steps we have found useful in increasing rope life in any installation. It seems that everyone just wants to be told how long to expect ropes to last. This cannot be done any more than anyone can tell you how long a set of tires will last on a car. It's not about time, it's about usage; and that usage is significantly affected by system design, environments (some controlled and some not) and maintenance performed (as is the case in the real world).

In any examination of hoist ropes, it might help to remember that rope life does not remain constant. Indeed, the number of starts of an elevator can change dramatically for a variety of reasons, even societal ones. Consider that over recent years, smokers have found it increasingly difficult to find areas in buildings to satisfy their habit due to the designation of certain areas as



U-grooves are usually found on older units.

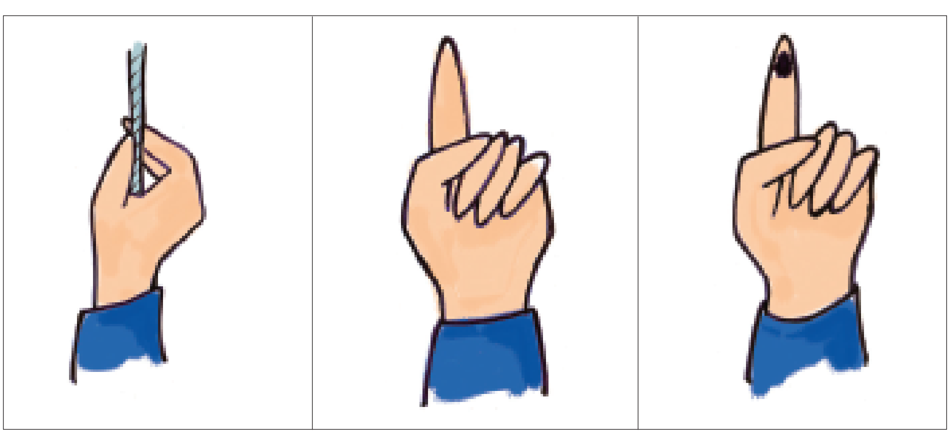
"smoke free." It has been suggested that during this same period, elevator starts have increased by a factor of 3 to 4 times. In order for smokers to find places to conveniently smoke, they may have to use the elevator. We mention this merely to underscore the fact that rope life cannot be considered a simple total of the number of years in service. Instead, rope life must be defined as the number of starts an elevator makes in the life of the hoist ropes instead of the number of years (or time) the rope is on the elevator. We also suggest here that there is some basis to consider ropes on elevators in some of the same ways that tires on cars are considered.

It should come as no surprise that routine maintenance is an important key to increasing the rope life in vintage equipment as well as with the elevator designs of today (where we think maintenance can be even more critical). We begin with an overview of standard maintenance practices that can increase rope life and end with a complete checklist reviewing all installation and maintenance considerations and issues. Knowledge of these "rules" is fundamental training for any elevator maintenance mechanic.

◆ **Lubrication:** This should be done every 250,000 starts or whenever the rope or sheave groove feels dry to the touch.

Lubrication is important for moving steel parts. We all know this. Does it help to point out that university and technical studies (accepted calculations) have determined that failing to lubricate can reduce the life of the rope by over 50%? We think it should, so we say it again. **Failure to lubricate can reduce the life of ropes by over 50%!** Relative to the 250,000-starts guideline, you should also take into account the environment. If the elevator is operating in a very dry, hot and/or dusty environment, put extra consideration into lubrication frequency. Also, an important aspect of re-lubrication is to keep the core of the rope (sisal) healthy. The natural fibers of the core, left to dry out, will absorb moisture and degrade. We also recommend that in new construction situations, where there is inherently extra dust and exposure, the ropes should be lubricated the first time right after the installation is complete. This is also an important consideration for ropes that have a full-steel core or a mixed core (i.e., Brugg HRS or DP-9).

The importance of the lubrication requirement is complicated to a degree by the fact that the friction between the rope and the sheave must be maintained between certain upper and lower limits. Too much lubrication can cause loss of car control; ropes that are too dry (unlubricated) can create excessive traction.



Lubricate every 250,000 starts or if the rope or sheave feels dry to the touch.

Lubricant sample

Applying lubricant

◆ **Tensioning:** We have directly observed in too many cases that tension equalization is either the most overlooked maintenance item today, or the effect of unequal tensions is just not understood or appreciated. The recommendation is that tensions between elevator ropes should be maintained within plus-or-minus 10%. The need for a reliable, fast and easy method of checking rope tensions has been addressed by Brugg with the introduction of the Rope Performance Measurement device/tool.

Rope tensions should be checked and equalized at installation and then, at a minimum, semiannually. As sheaves or ropes wear, or if the

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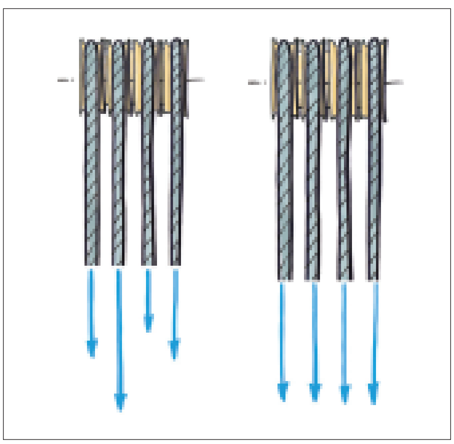
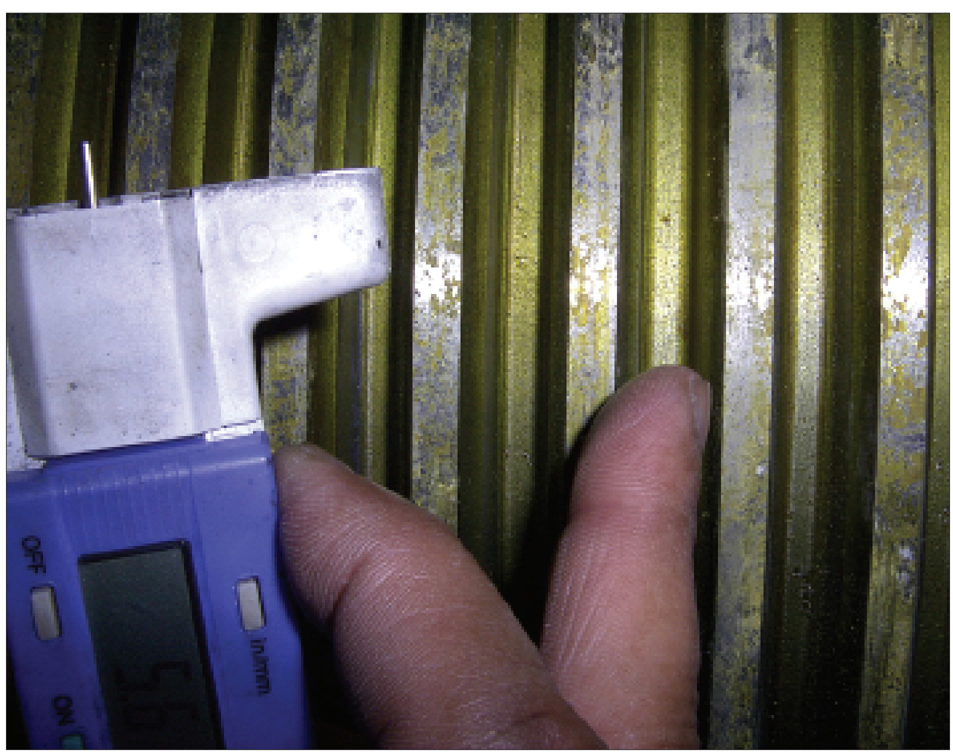
Rope-tension check device

system is particularly aggressive to the ropes, the tension check may be needed more frequently. Technical research on this important factor shows that **the effect of unequal tension is a significant factor on the wear and performance of hoist ropes.**

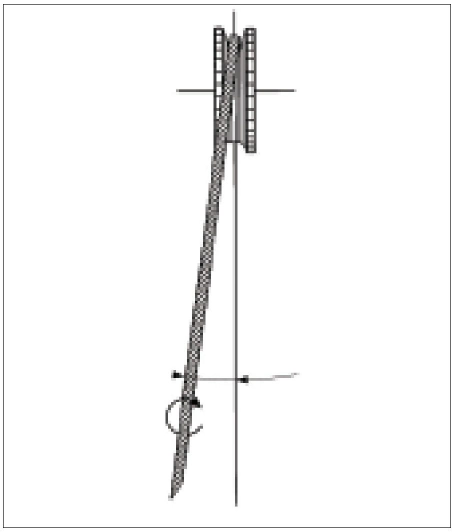

Unequal tension

We have found research studies that show the impact of a 15% difference in tension. When the load factor for the highest tension rope is out of proportion, that particular rope will be impacted dramatically and wear quickly. Conversely, lower-tension ropes may exhibit a sliding action through the sheave groove and wear the rope and the sheave. Costs build. To illustrate the point, think about our comparison to car tires. How many miles will a tire last if it is severely under- or over-inflated? A rope running in sheaves subjected to an unequal load (tension) will give comparable results. If tensions are 50-100% higher on some ropes (which we have commonly observed), this means the groove pressure will be very high, and rapid wear of outer wires and the sheave grooves will occur. Flat spots (either crown wear or mechanical damage), bending and high tension create stress risers leading to early rope failure. The shortcoming of the tire example is that a poorly inflated tire may or may not damage the road (actually, nobody really cares), but if a badly tensioned rope damages another part of the elevator hoisting system (the sheave), you'll care.

- **Sheaves:** An annual check of the groove profile can verify if rope and sheave fit properly. Without proper fit or traction, you are sacrificing the life of the rope or the sheave. Worn sheaves will wear ropes, which can in turn accelerate sheave wear. Either way, long-term maintenance costs will increase. A quick check is to simply observe (or take measurements) whether all ropes sitting in the sheave grooves are at equal height.
- **Bearings:** As equipment ages, bearings wear. This causes sheaves to shift one way or the other, causing the rope to enter the sheave at an angle. Even though proper care is taken at installation to ensure proper sheave alignment, this factor comes into play due to normal system wear. "Fleet angles" will then most definitely cause the rope and sheave to wear improperly and prematurely. **Research has proven that an angle of as little as 4° will reduce the life of a rope by 33%.** This same principle applies to the ropes at installation – ropes must be aligned in travel from one sheave to another. Any angle at installation will automatically cause a reduction in rope life.
- **Rope:** A rule of thumb is that before replacing a rope, you should check the crosshead plate to determine the proper rope for the car. We have seen cases where the wrong rope has been installed. It is also helpful to check with the building manager or



Annual check of groove profile



The rope angle at installation is an important factor in rope life.

owner to determine if the elevator has been modified. In the event that the machine has been modified and weight has been added or removed, you may need to recalculate your loads and perhaps install a different construction or a rope with a higher braking strength. We would like to suggest at this point that the important information on the data plate is the braking-strength information. Use this number for determining the correct tensile ropes to use. The data plate sometimes includes such information as "8 X 19" or "6 X 25" relative to the rope. We suggest that the Ultimate Strength is the important number to meet, and that exceeding it is certainly allowable. We have heard of cases where inspectors have questioned or held up installations because the crosshead data references (8 X 19 rope, for example) and some mixed- or steel-core rope was being used. While it's true that the rope design is different, the important fact is that the ultimate strength of the ropes is higher than that which the data plate requires. We take the position that there are a growing number of installations today where you simply should not or may not want to continue to use the "old standard" sisal-core ropes, unless you can live with the idea of reroping in three or four years. (We have seen cases of high demand/usage where 8 X 19 sisal-core ropes have had to be replaced in as little as one year to 18 months.) Today's elevator designs can (and many should) use eight or 9 strand (outer) constructions with either mixed or Independent Wire Rope Core (IWRC) type cores. With all other factors equal, these constructions will yield two or three times the rope life of a sisal-core rope. There are situations where we now strongly recommend the use of mixed-core (or steel-core) ropes, if you can use them. Drive sheaves with 105° undercut grooves combined with smaller-diameter sheaves (the closer you go to the D:d ratio minimum of 40) combined with operating speeds over 350 fpm and/or yearly starts exceeding 350,000 are systems that will do better if a more robust rope than the 8 X 19 sisal-core design is used.

◆ **Record-keeping:** Documenting all of the services performed on a machine makes diagnosing a problem much easier. By tracking the number of starts an elevator makes (where possible), it will not only establish a rope-life benchmark, but can assist in planning a major maintenance event such as a re-roping. This sounds obvious, but it's surprising how many mechanics overlook this simple step. We have noted on some occasions that although recordkeeping is understood, it is either not available or considered inconvenient to share.

HRS/double-parallel steel-core rope & DP9/mixed-core rope

Results and Expectations: If all of the above steps are taken, rope life on vintage equipment *will* increase. One should never expect that subsequent-generation rope life will ever return to the same levels experienced when the machine was *new*. The wear on all of the parts of an elevator machine over time is cumulative. This cumulative wear impacts the performance and wear of the machine's moving parts – for our discussion, the rope. Because of this cumulative wear, some of the factors above will be out of the mechanic's control and shorten the life of the ropes in the installation. Our biggest point, and we can't emphasize it enough, is that proper maintenance procedures must be implemented to take care of the factors that can be controlled. If this is not done, the negative rope-life factors add up. It is perfectly reasonable to have the interaction of lack of lubrication (-0.50) combined with unequal tension (-0.50) combined with an angular pressure (-0.30). Do the math. You will discover that the rope life will quickly be reduced to only 7.5% (a 92.5% reduction) of its original design expectation. The result will be re-roping two, three and more times than should be necessary. We all know that in this case, the cost also includes the much higher cost of labor.

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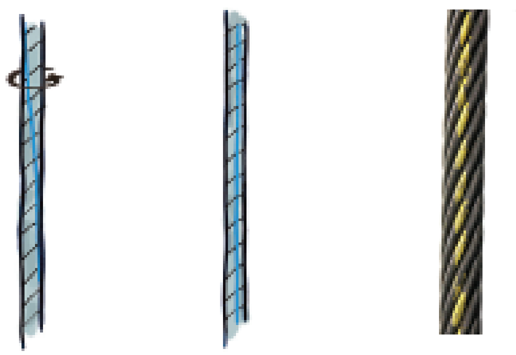
The following checklists are helpful in evaluating an elevator hoisting system:

Application and Design Checklist for Hoist Ropes
1. Expecting higher number than normal yearly starts/stops (over 200,000 per year)
2. Aggressive sheave groove configurations
3. Too many or too close deflector sheaves
4. Wire tensile grade and groove pressure combination
5. Using eight-strand sisal-core ropes instead of IWRC or DP-9 constructions *(More robust rope designs are a potential solution to items one through five.)*
6. Wrong grade of drive sheave cast iron
7. Six-strand rope instead of eight-strand rope. OEMs design elevator systems with specific requirements. Do not substitute six strand for eight strand or eight for six without written approval from the equipment manufacturer. This is not an availability issue – it is a system design issue.
8. Always use lang-lay rope when using sheave liners.
9. Do not use ropes from two different rope producers on the same elevator.
10. Do not use rope from a manufacturer with the design, materials and production processes not adequately controlled.

Installation Checklist for Hoist Ropes
1. Have ropes been twisted during installation handling (open or closing the rope)?



Do not allow ropes to hang out without having them under control.
Such ropes could twist open under their own weight.

2. Tension equalization not performed at installation, after a rope take-up and not repeated as needed
3. Re-roping performed on sheaves that are worn -– installed ropes on sheaves with unequal groove depths
4. Misalignment of drive and deflector sheaves
5. Termination tie-down not performed (isolation of sockets to prevent spinning loose)
6. Missing or broken isolation springs on shackles
7. Rope identification tags missing or incomplete

Maintenance Checklist for Hoist Ropes
1. Failure to lubricate or inadequate lubrication
2. No periodic testing for tension equalization and adjustment of rope
3. Increased (or increasing) car motion resistance – bad rollers or guides, etc.
4. Excessive car vibrations – caused by either electrical (drive systems) or mechanical problems in system operation
5. Hoistway impediments/obstructions making contact with ropes (will cause damage or wear)
6. Extreme dirt, cement dust, etc. contaminates the ropes; also be aware of humidity or A/C venting into the hoistway onto the ropes.
7. Improper shortening (or rope take-up) operation – twisting, tension imbalance, tie-down, etc.

Elevator Ropes – Assumptions, Fiction and Facts

Provided the load on the highest tensioned ropes is not excessive, the opposite effect may occur. The rope with the lighter tension may be sliding through the sheave, creating a sawing or filing action.

Lubricant is being thrown off the ropes because there is something wrong with the ropes. Lubricant is being squeezed out of ropes due to high groove pressure. With aggressive groove profiles (U-undercuts and V-grooves), the pressure contact points on ropes are smaller and more concentrated. In some analyses by Brugg, it has been discovered in some ropes (with as little as one-and-one-half years' use or about 800,000 starts) that half of the factory core lubricant has been squeezed out of the rope. This reduction in core weight/density contributes to early rope fatigue/failure. The lubricant squeezed out collects dust, dirt, metal filings, moisture on its way to the ropes, sheaves and machine-room floor.

Elevator ropes are made of steel; once they are tensioned, they don't need to be re-tensioned. Many things can change in the system. Sisal-core ropes in particular cannot be perfectly uniform and controlled. (Since sisal is a natural fiber, its characteristics can vary.) As ropes wear, they stretch and reduce in diameter. Things don't necessarily change equally. You must periodically check and re-tension ropes. As the system ages and parts wear, the need to re-tension becomes more frequent.

The number of broken wires on a 30-inch-diameter sheave are approximately half that of broken wires on an equally used 25-inch-diameter sheave. It is a fact that a smaller bending radius will accelerate fatigue of wires in wire ropes.

Bearings wear out. Check them.

Lack of lubrication not only prematurely wears the rope, but also wears a deeper profile in sheaves. Dry ropes have been shown to remove up to eight times the sheave surface volume compared to lubricated ropes.

A 2:1 double-wrap system has more bending cycles than ropes on a single-wrap system. The system should allow a minimum of at least three to four lay lengths (for conventional, closed ropes) between sheaves for free recovery space between bends. This increases to 10-12 lay lengths for parallel-lay ropes. Distances less than these standards will have a negative impact on rope life and accelerate the number of fatigue wire breaks.

Kevin Heling, Rick Perry and Martin Rhiner of Brugg Wire Rope, LLC in Rome, Georgia have 60 years of combined experience in the elevator-components industry, with a primary focus on ropes and cables. The authors gratefully acknowledge Hugh O'Donnell of Hugh O'Donnell Metallurgical Enterprises in Longmeadow, Massachusetts and other industry professionals for support and advice during preparation and 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 137 of this issue.

- Name at least five maintenance issues that will affect hoist-rope life.
- What are three installation factors that will quickly reduce rope life?
- What will be the effect of aggressive sheave grooving on hoist ropes?
- During installation, what will be the effect of allowing hoist ropes to hang out without being under control?
- What are the effects of sheave bearing wear on hoist-rope life?

ELEVATOR WORLD Continuing Education Assessment Examination Questions

Instructions:

- Read the article **"Elevator Hoisting: Maximizing Performance of Ropes in Existing and 'Improved' High-Demand Installations."** (page 109) and study the learning-reinforcement questions.
- To receive **one hour** of continuing-education credit, answer the learning-reinforcement questions online at www.elevatorbooks.com or fill out the ELEVATOR WORLD Continuing Education reporting form found overleaf and submit by mail.
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1. Which of the following will have the greatest affect on the reduction of hoist-rope life?
   a. Aggressive sheave grooves.
   b. Smaller sheave diameters.
   c. The number of duty cycles.
   d. All of the above.

2. It has been determined that elevator starts have been increased in recent years by a factor of:
   a. 5.
   b. 3-4.
   c. The number of smokers that there are in the building.
   d. None of the above.

3. Rope life should be defined as a function of elevator:
   a. Miles traveled.
   b. Hoist-rope strands per cable.
   c. Age.
   d. Starts.

4. Ropes should be lubricated:
   a. When rouging becomes noticeable.
   b. Annually.
   c. Every 250,000 starts.
   d. Six months after installation, then annually thereafter.

5. Failure to properly lubricate hoist ropes can reduce their life expectancy by:
   a. 10-20%.
   b. Over 50%.
   c. A very small percentage.
   d. Allowing wear to go unnoticed.

6. Equal tension between hoist ropes should be maintained within:
   a. Plus-or-minus 10%.
   b. The project specification requirements.
   c. ASME A17.1 requirements.
   d. Tolerances as determined by the hoist-machine manufacturer.

7. Hoist-rope tensions should be checked:
   a. Annually.
   b. At each maintenance visit.
   c. When it is noticed that the car ride is rough.
   d. Semiannually.

8. A fleet angle of 4° will:
   a. Not matter.
   b. Never occur.
   c. Reduce rope life by 33%.
   d. Cause a rough car ride.

9. A smaller bending radius will cause ___________ of wires in wire rope.
   a. Accelerated fatigue
   b. Discoloration
   c. Stretch
   d. Shortening

10. How many rope lay lengths should be maintained between sheaves for conventional closed ropes?
    a. One to two
    b. At least five
    c. Three to four
    D. As many as the number of strands in one cable.

ELEVATOR WORLD Continuing Education Reporting Form

Article title: **"Elevator Hoisting: Maximizing Performance of Ropes in Existing and 'Improved' High-Demand Installations."** (EW, August 2007, page 109).

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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