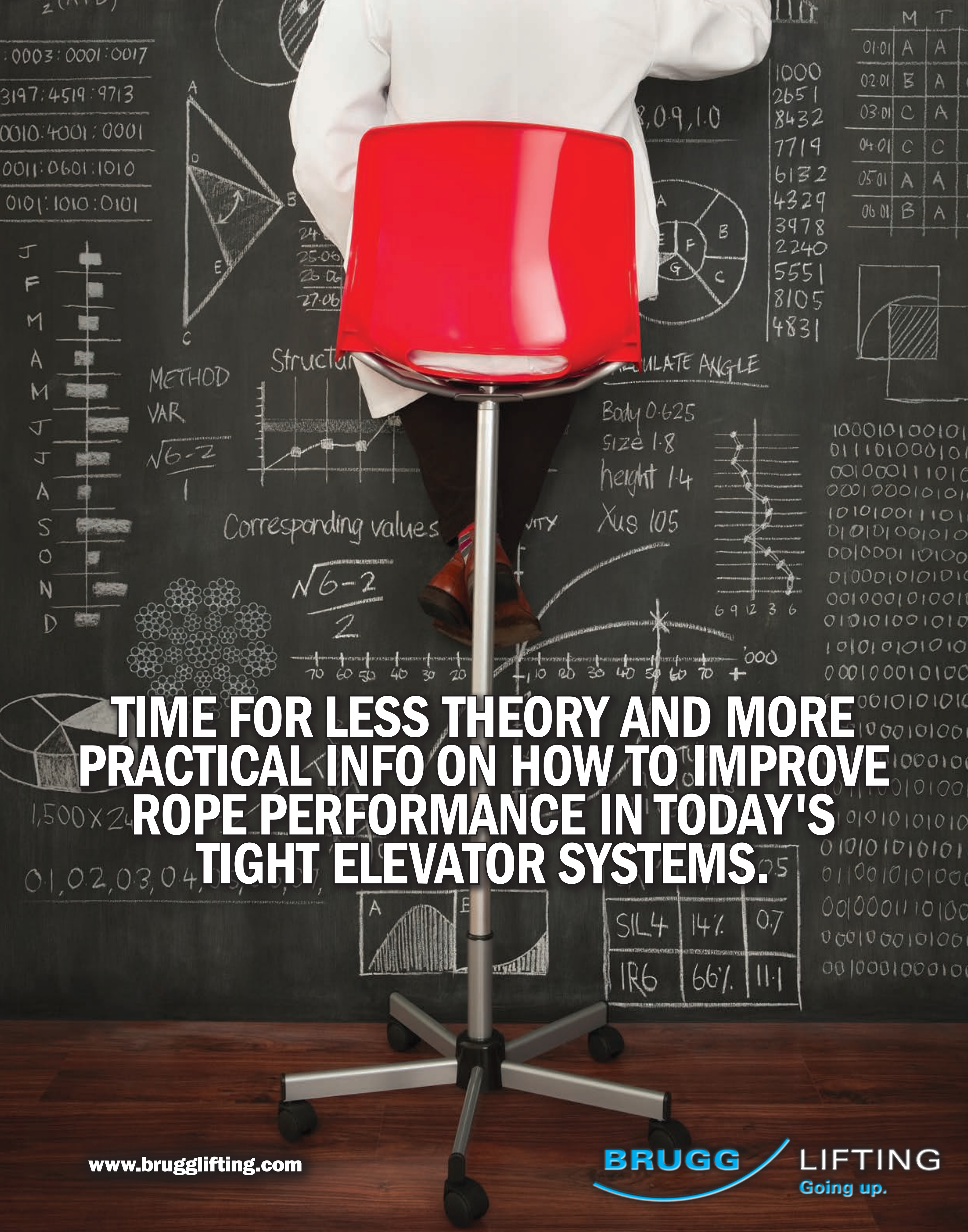

TIME FOR LESS THEORY AND MORE PRACTICAL INFO ON HOW TO IMPROVE ROPE PERFORMANCE IN TODAY'S TIGHT ELEVATOR SYSTEMS.
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Going up.

TO TRULY MAXIMIZE BOTH ROPE PERFORMANCE AND LIFE EXPECTANCY DON'T PUT IT INTO PLACES IT WAS NEVER DESIGNED TO GO.

Industry professionals are finding 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. Hoist rope "failure" is the result of a combination of factors that more properly have their source in either the system design, installation practices, or are points that are overlooked during routine maintenance. Indeed, many professionals are realizing that the key contributing cause behind "early" hoist rope failure is related to calculations that do not consider how newer compact machines and drive sheaves, faster accelerating and decelerating elevators, and highly used systems are placing far greater strains on the traditional rope selections ***(Standard 8 x 19 Sisal ropes)*** — strains that those ropes were never originally created to handle.

Newer building designs, which place a premium on 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 elevators use 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 other hoisting system equipment. Additionally, elevators themselves have evolved from being used sporadically in facilities to functioning nearly continuously because of increased demand and 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 experienced. All of these factors have combined to create installation environments that have moved from being somewhat unfriendly, to ones that are decidedly hostile to hoist ropes themselves. Unfortunately this is the current reality in the industry today.

Don’t Give Up Hope Yet.

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. Evidence shows that by paying attention to various factors, implementing and assuring certain preventative measures, and through the use of forethought and good planning, professionals can instead hope to see 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, tested more rigorously, use materials of a far higher quality and are manufactured with a degree of skill that was not available in the past. Yet this still does not mean that they cannot fail. Moving machine parts can and will. Forward thinking, problem-solving, state-of-the-art manufacturers perform in-depth, post-mortem, forensic analyses on returned samples and even go on-site to installations where a failure occurred in order to verify results. The analysis of current elevator designs and the desire to make ropes that better meet the vastly increased demands of current installations has led progressive manufacturers to offer a 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, professionals would profit better in considering other factors that have an equal ***(if not greater)*** impact on rope performance in today’s new world of elevators.

Now The Facts.

Hoist ropes are not merely a random wrapped bundle of stranded wires. They are precisely engineered, complex objects made of selected steel tensiles featuring a number of moving parts. For example an 8x19 Seale hoist rope has 152 separate moving parts ***(8 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 aims 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, high strength means rigidity.

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 drive sheave (and other sheaves) and then straightened again. It is hardly surprising that a rope shows wear, or even that a strand will break ***(even steel has its limits)***, instead one should be amazed that they perform as well as they do in an inherently destructive environment.

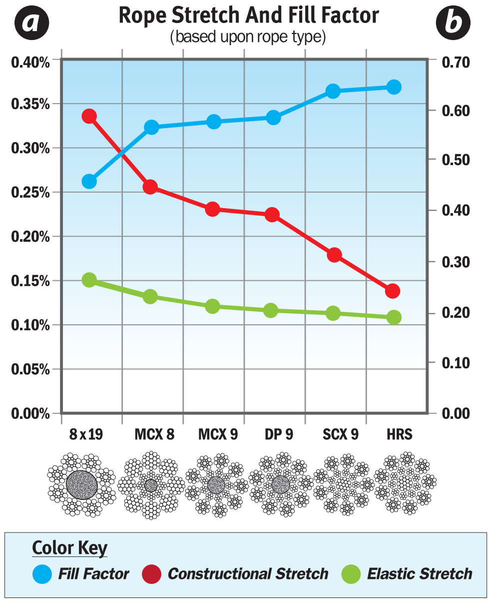
To the trained eye a hoist rope can even serve as a valuable warning to alert you to upcoming problems and help diagnose their underlying cause. So an indestructible hoist rope ***(which would be an impossible feat of engineering)*** would eliminate this benefit for maintenance professionals. In the final analysis, replacing sheaves and surrounding equipment is 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 basic rules you should consider that are familiar to industry professionals but still bear repeating, such as:

Think Hard About What It Is That You Are Aiming For.

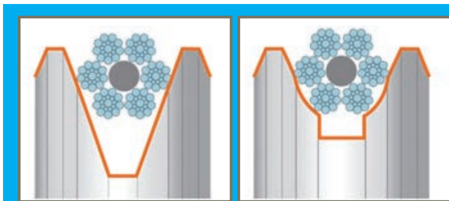
As any good craftsman says,“Measure twice—Cut once.” And with only a little bit of planning you can save both time and money. For instance have you considered what an installation’s normal yearly stops and starts will be? If you are expecting more than 200,000 trips per year ***(an industry standard)*** you may need to use something other than Standard Sisal Core ropes as they are made of naturally imperfect Sisal. There are Point Contact or Parallel Closing designs with Mixed or full



A comparison of hoist rope stretch in inches (shown as axis A) to a rope's Fill Factor (axis B)—which depicts the total amount of metallic area present in a its cross section— shows the deficiencies in Standard 8x19 Sisal Core ropes

Steel Cores. And rounder 9-strand, instead of 8-strand ***(or 6-strand)*** constructions, are readily available in the marketplace today.

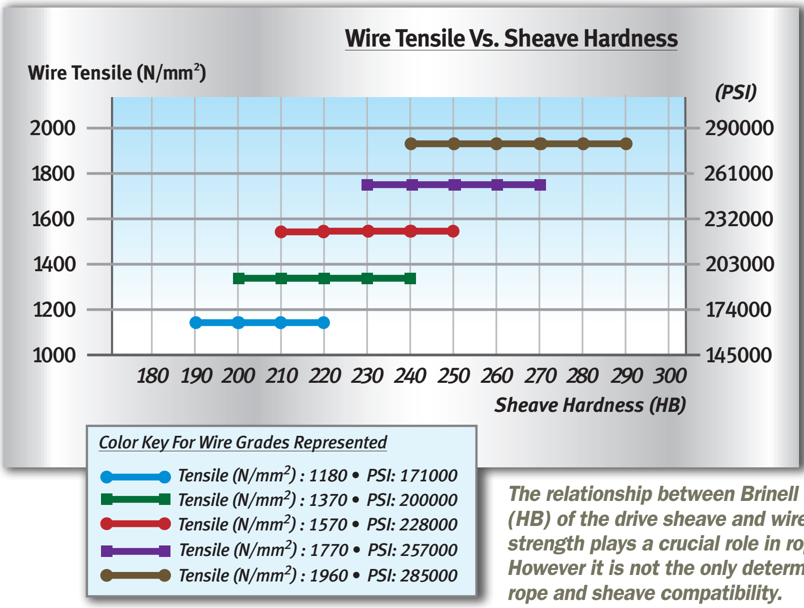
Check whether the ropes must deal with aggressive sheave groove configurations; verify how many and how close the deflector sheaves are; consider the Brinell Hardness of the drive sheave to be used; and factor in wire tensile grades and groove pressure combinations as a part of your thinking process. And there are many issues critical to system design safety and proper function that must be considered too. Required traction is a major application issue.



(Shown left to right — Undercut V-Groove and Undercut U-Groove profiles) The kind of groove configuration you must handle is an important factor in your final choice of a hoist rope.

Choosing quality rope from a quality rope maker is the best road to take.

A variety of factors need to be considered during the design of any installation. And using price as the ultimate basis for any decision is always a mistake. First and foremost, gauge if the manufacturer chosen is a proven, experienced source for hoist rope with strong



The relationship between Brinell Hardness (HB) of the drive sheave and wire tensile strength plays a crucial role in rope life. However it is not the only determinant of rope and sheave compatibility.

design, materials and production process controls in place. Become familiar with what goes into the core — it is the real foundation of any hoist rope — and examine its design and understand the limits and strengths of each design offered and select accordingly. You should review whether a manufacturer strictly controls lay length, helix and torsion, and how the rope components ***(wires and strands***) are assembled. And you must understand that each manufacturer's rope may differ in design and composition.

Don't just make do with any rope — Pick one that best fits the situation.

It goes without saying that you should choose a hoist rope that meets the potential needs of your particular system and not just base your selection simply on convenience. If you need assistance in doing calculations, consult with 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 its working environment. The decision to use a Standard 8 x 19 Sisal core rope instead of a more robust rope design — offering 8 or 9 strands using either a Parallel or Point Contact 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 for the entire industry. But today its very design, which has long been Standard 8 x 19's strength, poses problems for modern higher performance and high use elevators. First, an 8-strand Sisal core rope is less round and less stable than a 9-strand rope ***(such as Brugg DP9, HRS, or our Point Contact MCX9 and SCX9 ropes)*** 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 rope core ***(which further compromises hoist rope performance)***.

Much of the responsibility for shortened rope life can be attributed to the fact that Standard Sisal is a naturally varying fiber incapable of dealing with the increased needs and stresses found in modern elevator designs.

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 8-strand— or even better, a 9-strand rope. Indeed if you are concerned that a rope may face aggressive handling during installation ***(or that during installation the rope could be forced somewhat open)*** or that an installation's age or general condition may make it more likely that the deflector sheaves may have a fleet angle, it would pay to consider Non-Parallel ***(Point-Contact)*** designs such as our MCX/SCX 8 or 9 series. When compared to Standard Sisal ropes of the same diameter, Mixed Core ropes ***(MCX is made of fiber and steel strands)*** offer a far higher load capability, elongation is reduced and fatigue bending performance is greatly enhanced as well.

In one of many rope life expectancy case studies our staff found that the same system using 8 X 19 Sisal Core rope is expected to deliver just over 470,000 bending cycles, however if Brugg HRS rope ***(Double-Parallel, Steel Core rope with 9 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)***. Either Brugg or some other rope professional can perform this same life expectancy comparison with your own challenging system and estimate the amount of improvement you can expect by switching from old-fashioned 8 X 19 Sisal Core ropes to High Performance hoist ropes. Such highly complex calculations, based on Prof. Feyrer's research, calculated with 95% certainty that 10% of the ropes reach the maximum number of wire breaks ***(discard criteria)***.

Do the legwork — It will pay off in the long run.

We all know that mistakes 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 MBL (Minimum Breaking Load) you'll need on a piece of vintage equipment. In addition check with the building manager or owner in order 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 ***WILL*** need to recalculate load factors. It's a hassle but a little bit of extra work at the start will bring to your attention that you may need to recalculate your loads, install a completely different rope construction, or perhaps even use a hoist rope with a higher breaking strength.

It's not indestructible — So be careful with it!

We've already noted that hoist rope is a highly crafted, highly precise machine. And if you follow the previous steps suggested you've already made quite an investment in time and effort to choose what you need. So please take the time to properly care for your hoist rope by using the handling procedures provided by that manufacturer in your shipment. Remember that quality manufacturers distinguish themselves from the rest by offering you all the information you'll need during this critical phase. If your manufacturer doesn't offer specific instructions or written recommendations you may wish to reconsider your source. Installation is not the time to blindly trust to luck or experience —

and the consequences of simple ignorance, or indifference during this phase can be quite expensive indeed.

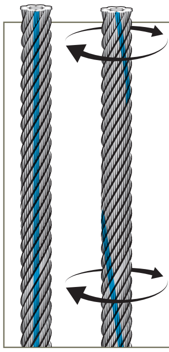
Never leave ropes uncovered on the site as they can be easily damaged by exposure to the elements ***(avoid precipitation or excessive heat)*** or to edges on corners of forklift forks. When transporting hoist ropes remember to insert a rod through the reel center hole and then lift the entire assembly 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 and creates torque on the rope. And torque can change rope geometry and shorten its life.

Make the investment and use the right tools.

In today's industry there are more tools than ever before one can use to handle problems or questions that some consistently fail to confront due to concerns of cost or expediency. There is no reason for any industry consultant, elevator mechanic or inspector to not avail themselves of some of the state-of-the-art equipment available today that assures proper installation. They are necessary. And they increase performance. Choose one that best fits your handling needs and then make a practice of using it in your installation.

To avoid installation problems either consult the manufacturer's informational materials that come in your shipment or can be readily accessed online.

In addition to installation tools Brugg even offers a prognostic program to help you accurately estimate how long a particular rope, handling a certain number of cycles, used in one of a variety of environments will last in an installation. Brugg RLP ***(Rope Life Predictor)*** offers users a series of basic computations where one simply enters the key data online, follows instructions, and the program automatically provides you with the critical answers removing any guesswork from choosing the right rope for your needs. If you haven't looked into the various advanced tools available for today's industry professional— it's time you should.



Brugg provides i-Line, a useful feature applied to hoist rope during manufacture that permits a professional to detect uncontrolled twisting during installation. With i-Line one can determine whether rope corrections are necessary, or if one should instead closely review equipment geometry, traction sheave and pulley alignments.

Pay close attention to the installation basics.

Never twist ropes open—or closed— and use seizing tape, wire or cable bands. And do not allow the rope to twist open by "hanging it out". We provide i-Line so you can detect twisted ropes and review equipment geometries, and traction sheave and pulley alignments. End terminations have a critical impact on rope life. Take time to ensure you have taken advantage of the correct application of Rope Pulling Grips or Reeving Splices. ***And remember to Double Seize rope ends when installing or shortening Fiber Core (NFC) ropes and to Triple Seize Parallel or Point Contact design ropes***.

Always review the alignment of the drive and deflector sheaves. If new ropes are to be installed on existing sheaves look for unequal groove depths because this may indicate the need to replace the sheave itself. If you have any questions on rope installation simply call the manufacturer and avail yourself of the instructional pieces they provide.

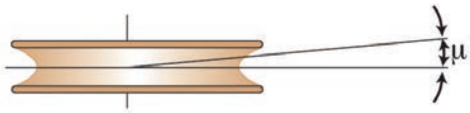
Lubrication and tensioning— Critically important.

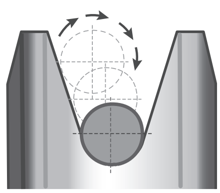
All too often professionals simply install ropes and fail to consider the importance of lubrication. True, most hoist ropes come from manufacturers already lubricated. But that does not address conditions that the ropes may have encountered during transport, as they sat on the site awaiting hanging, or during the installation process. For instance strong exposure to heat can cause the softening of lube within the rope. And construction sites can be dusty environments where temperatures can fluctuate dramatically — so more lubricant must be applied.

For rope diameters of 0.39 to about 1 in. we recommend an application of 0.35 pint ***(about >0.2 liters)*** of lubricant per 328 feet ***(100 meters)*** of rope length. Remember that whenever moisture is an issue on the job site to select a lubricant that is able to displace water. There are several now readily available on the market today and they can definitely make a difference in performance.

Installers frequently overlook properly equalizing rope tensions and sometimes gauge tensioning by "plucking" the rope or merely eyeballing it. **This is inherently inaccurate, destructive and unnecessary**. Especially since various measuring devices, and at least one true tensioning tool ***(Brugg RLE)***, are available to the market today. By all means, finish the job right and equalize hoist rope tensions — aim for tension equalization within ±10% at installation, after you shorten the ropes, and at regular intervals afterwards.

In addition to unequalized rope tensions, and inadequate lubrication technique, unequal sheave groove profiles can lead to crown wear, shortened hoist rope life and overall system performance degradation.

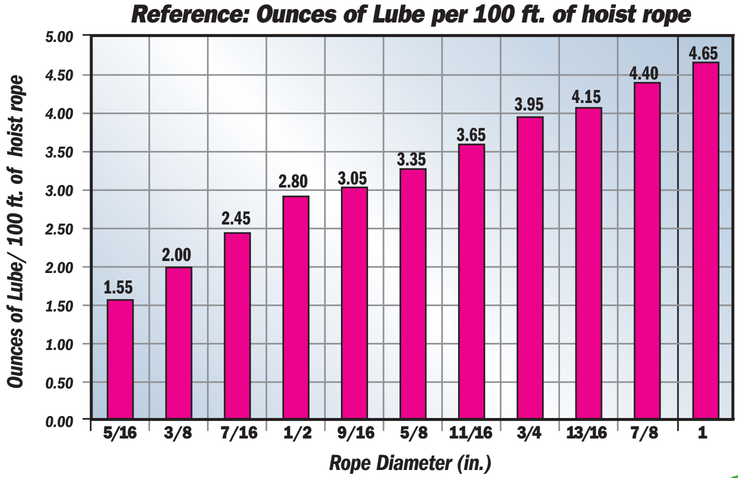


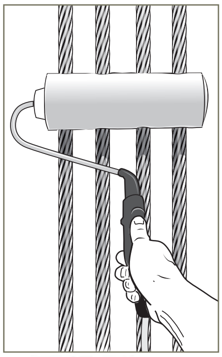


Monitor fleet angles closely (the angle a rope leaves one sheave to connect with another) at too wide an angle can result in premature rope wear. A simple 4° fleet angle reduces hoist rope life by 33 %.

Maintenance— A key factor in extending rope life.

We understand that some in our industry have been, shall we say, a little less than perfect in performing certain maintenance chores. We know this is not due to willful neglect but is an understandable reaction to a variety of factors. There is the cost of using skilled professionals to perform maintenance correctly; the time and inconvenience that results from shutting elevators down in order to perform superior maintenance ***(disruptions that are hardly guaranteed to win cheers from irate building owners)***; and the acquisition of



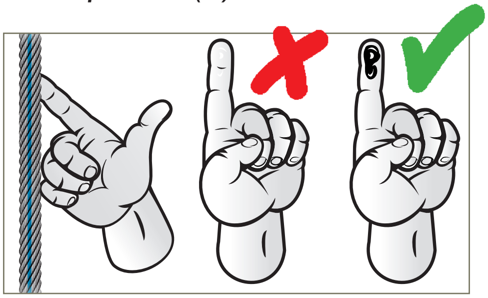


A variety of lube applicators are available to professionals today—the choice is yours. We urge you to select only a lubricant that is OEM approved. If your rope is bone dry to the touch it's going to die. The chart provided offers a simple guide one can use to determine the amount of lubricant to be applied per 100 ft. of rope.

maintenance contracts that must be performed at the lowest possible cost by maintenance professionals in order to see any profitability at all. We certainly understand the trend and needless to say rope makers find it worrisome. Especially since the advantages of performing proper maintenance offers such strong evidence of significantly increasing expected rope life.

Again, lubricate your ropes. Create a schedule and then follow it. Lubricate your ropes every 250,000 cycles ***(starts/trips)*** or at least once a year. The lubricant used should be compatible with the original rope lube ***(lay-up)***. It should offer a good penetration capability, with a friction coefficient of μ 0.09(-) ***(material pair steel/cast iron)***, as well as very good adhesion. We 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 @104°/40°C CST/SUS ***(ASTM-D445/D2270 of 10/59)***.
A failure to adequately lubricate can reduce the life of an elevator rope by up to 50% as well as increase sheave wear.

As mentioned during the installation phase, it is critical that you keep tensions equalized to within ±10 percent throughout a rope's lifetime ***(we have found that only a 15% difference in tensions between ropes has a dramatic negative impact on rope wear)***. Infrequent, poorly performed, or neglected equalizations can negatively impact a rope's life expectancy by up to 50% and cause damage to other installation components. High rope tensions lead to rapid wear on outer wires and sheave grooves. Low rope tensions can make ropes slide through the sheave grooves and also create wear on both ropes and sheaves.



Keep An Eye On Surrounding Key Components Such As:

Sheaves

Brugg GDC (Groove Depth Comparator)

Worn sheaves wear on hoist ropes, which wear on sheaves, setting up an endless cycle of destruction for each. Replacing or re-grooving sheaves is necessary to prevent this. We strongly recommend you check groove profiles before every re-roping to verify the fit between ropes and the sheave. A good fit means good traction — without good traction you are sacrificing hoist rope life, sheave wear or both. Though measuring sheave groove variations was once a time-consuming task to perform, now Brugg GDC ***(Groove Depth Comparator)*** allows professionals to quickly measure and compare sheave groove variations directly within the sheave itself.

Bearings

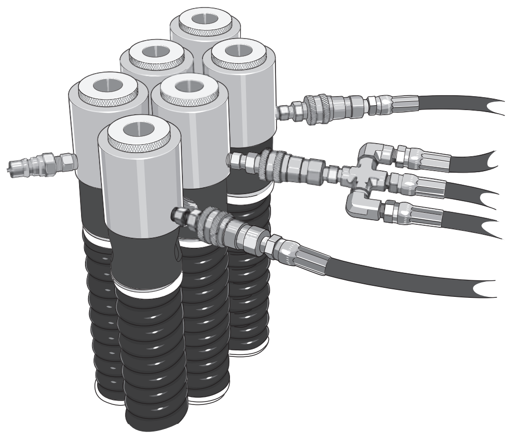
Worn bearings can create fleet angles and result in additional motion leading to an increase in pressures placed on ropes. For instance too wide a fleet angle will cause a hoist rope to scrub up against the flanges of a sheave groove, create torsion, and result in additional hoist rope wear. Remember than a fleet angle of only 4° will reduce the life of an elevator rope by as much as 33%.

The System Environment

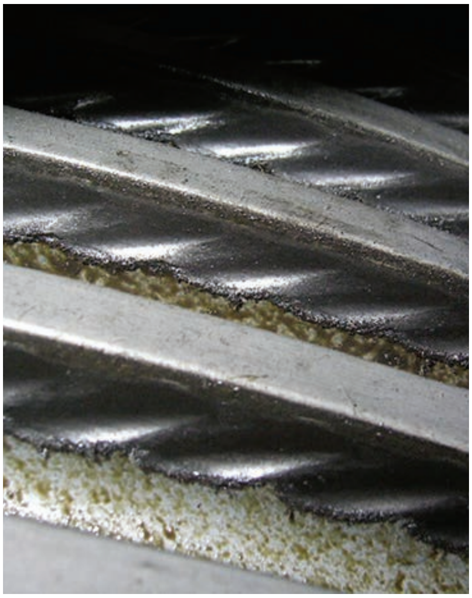
If an elevator is operating in an arid or dusty environment this factor will naturally impact the frequency of lubrication. Additionally, any indication of humidity or A/C venting onto the hoist ropes, extreme dirt and cement dust, or evidence of wildly fluctuating temperature changes in a hoistway or machine room is worth immediate investigation. Be aware of 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 potential indication of bad rollers or guides. Pay attention to any excessive car vibrations as this could be caused by either electrical ***(drive systems)*** or mechanical problems in system operations.

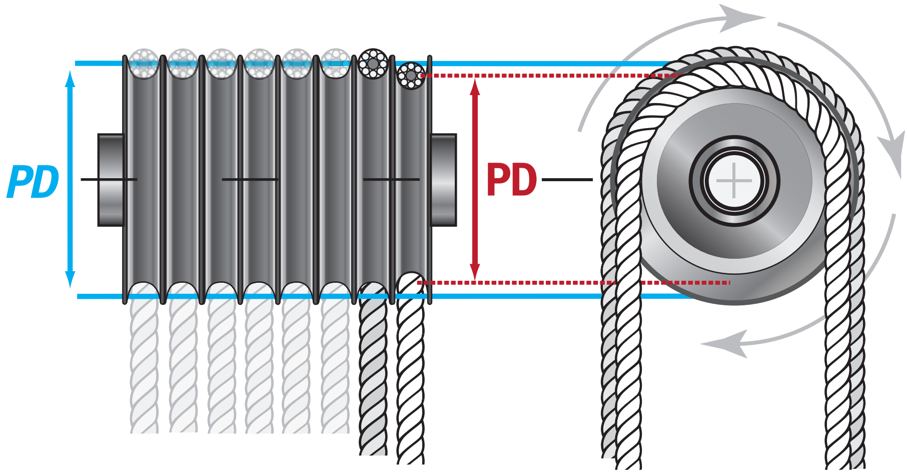
Keep Good Records!

This is the simplest, yet most overlooked factor towards 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 almost impossible to estimate hoist rope life, diagnose the cause behind various problems, or to even verify if any changes have been made to a facility in general if you have to work in a total 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



Brugg RLE (Rope Load Equalizer) makes hoist rope load equalizations easy and accurate. Using basic hydraulic principles, the device turns a job that once took four man hours to perform into a task that one man can now handle in under thirty minutes. Keeping rope load tensions equalized to within ±10 % has never been simpler. This means gains in system performance and extended hoist rope life.





Sheave groove depth variations can create different rope pitch diameters—which can lead to exaggerated rope wear, sheave groove erosion (detailed in photo at left) and loss of performance. The blue line indicates correct pitch diameter, while the red reveals groove depth variation, which equates into a difference in pitch diameter. This means that despite the fact that both ropes are moving at the same speed, they are not traveling equal distances. Simply replacing the ropes will have little effect in improving system performance (instead it will only lead to drastically shortened life for the ropes themselves). A wiser, though expensive, course of action is to have the sheave re-machined or replaced entirely. Fortunately Brugg GDC (Groove Depth Comparator) can easily indicate if a problem exists by measuring groove depth variations within the sheave itself.

they are easily available to those who will work in that installation in the future. It's common courtesy and it makes good sense.

Reality Check.

Despite all the innovations manufacturers provide the toughest challenge 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. They can help you better comprehend how today's newer rope designs, recent maintenance developments and advances in technology will impact your future.

One other thought to bear in mind: Never expect that a second, third, or later, generation of hoist rope can return any vintage installation to the same state of efficiency it possessed as when it was brand new. That is simply impossible due to the cumulative, natural wear on all the parts of an assembled system. An elevator installation is a self-contained, enclosed system where the workings of one part impacts the function of others in a multiplicative manner. This means that some of the previously mentioned factors may be out of your control. Remember that due to the vast changes in elevator system designs and despite even your best efforts, rope life may be shortened and performance reduced regardless.

When You Pay Attention To The Details Everyone Wins.

We admit that the reality of the previous statement is somewhat sobering. However while a certain 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 cumulative and multiplicative effects of various factors as they combine to impact your system. Indeed we rarely find that only one factor is solely behind the apparent early death of a hoist rope.

If you were to combine a lack of lubrication (-0.50), with unequal tensioning (-0.50), in addition to bad angular pressures (-0.30), you would find that a hoist rope's life is reduced to only 7.5% of its original design expectation.

These easily verified factors, if left unaddressed, will mean re-roping many times more than is necessary.
And that means more than merely rope replacement costs. To evaluate the total cost involved you need to factor in labor and potentially other expensive mechanical replacement costs too.

Hoist rope wires do wear out and even break, that's their function. And we'll continue to design and build ropes for newer elevator challenges, as well as constantly refine our processes in quality too. That is more than a promise — that's our job. But the time has come for us all to begin to redress the problem of hoist rope failure and poor performance by taking a good, unprejudiced look at the total picture and working together to handle it. Accusations are fruitless and frankly they get us nowhere.
We all have a role in the problem. Fortunately however, we all have a big part to play in its solution as well.

A Russian nesting doll (called matryoshka) illustrates the idea that rope failure is rarely the result of one single cause. Instead it is the multiplicative impact of a number of factors that are destructive in combination. In order to remedy a problem one has to look beyond the obvious solution to find the true cause (or causes) nestled within.

THE SCIENCE AND ART OF DRIVE SHEAVE ALLOY GRAY CAST IRON.

The interaction between a drive sheave and hoisting ropes to control elevator car motion is actually quite complex, though in the elevator industry we often take this for granted. The most important factors in this interaction include friction, wear rates, rope lubrication, sheave groove profiles, rope tensions and their equalization. From an elevator system performance and maintenance and impact perspective ***(cost and attention)***, the top two concerns are the wear rates ***(lifetimes)*** of both the ropes and the drive sheave.

Here we will deal with a basic outline of the various metallurgical factors that have a profound impact on hoist ropes and drive sheaves. We believe that by following the guidelines and information we offer, and by making a concerted effort to control as many of the critical factors within your ability as you can, your ropes and sheaves will achieve optimum performance and life.

Drive Sheaves

It is absolutely critical to control the chemistry and cooling rate of the drive sheave blank when the casting is poured. Proper controls will provide a sheave casting microstructure that has good wear resistance and acceptable traction characteristics.

Specifically, the casting microstructure should consist of 90-100% fine-grained lamellar pearlite, 0-10% proeutectoid free ferrite, and less than 1% alloy carbides.
To better illustrate this aspect of our story take a look at the photomicrographs we've provided showing acceptable and unacceptable near-groove microstructures. Our first image details an acceptable near-groove microstructure. Photomicrography reveals that there is little free ferrite ***(white)*** present. The image also reveals the total absence of alloy carbides within the near-groove microstructure itself.

The second image details its counterpoint, an unacceptable near-groove microstructure. Highly evident is the visual presence of white grains of free ferrite, flake graphite, and small white dots that indicate particles of alloy carbide. It is absolutely vital to control pearlite and free ferrite in order to optimize sheave groove life and to minimize the sheave groove wear rate.

For those readers who are not metallurgists perhaps we should offer a helpful description of terms. For instance, Pearlite grains consist of alternating layers of ferrite and iron carbide. Ferrite is essentially pure iron and it provides extremely low wear resistance. It is composed of independent grains that are routinely found surrounding the lamellar graphite flakes within the casting.

On the other hand, iron carbide is a very hard compound that offers very high wear resistance. This combination provides good traction — or in elevator industry parlance, good friction — due to the dual combination of soft ferrite and the high wear resistance that comes from the presence of iron carbide. If the presence of free ferrite within the casting is not rigidly specified and controlled during the foundry process then excessive wear can be expected. Indeed this becomes almost certain when the free ferrite is coupled with the lubrication effect that comes from the presence of associated graphite flakes.

Sheave Chemistry

To achieve the required microstructure, we strongly suggest that the following chemistry guidelines, listing elements as a percentage of weight be used.

Note that the Cu, Ni, and Sn percentages are listed as optional rates due to the fact that in a particular foundry they may have determined that they do not need them, or perhaps require a lesser amount than noted to achieve the required microstructure.

Both Cu and Ni aid in the stabilization of Pearlite formation and retention.
Sn minimizes the solid-state diffusion of C atoms, during cooling after casting, from the lamellar iron carbide in pearlite ***(surrounding the flake graphite)***. If you find yourself with flake graphite, surrounded by ferrite, you will have a significant wear problem with the sheave.

C	**(Carbon)**	**2.90 - 3.20**
Si	**(Silicon)**	**1.50 - 2.00**
Mn	**(Manganese)**	**0.70 - 1.00**
S	**(Sulfur)**	**0.10 *(max)***
P	**(Phosphorus)**	**0.15 *(max)***
Mo	**(Molybdenum)**	**0.50 - 0.90**
Cu	**(Copper)**	**1.00 - 2.00 *(optional)***
Cr	**(Chromium)**	**0.10 - 0.25**
Ni	**(Nickel)**	**1.00 - 1.50 *(optional)***
Sn	**(Selenium)**	**0.05 - 0.10 *(optional)***

(Total all others 0.25 max)

Cooling Rate

To minimize C solid-state diffusion from the iron carbide platelets in Pearlite to the flake graphite, it has been found effective to control the time that the casting is in the sand mold. The casting should be removed from the mold and cooled in still air when the poured casting drops to a temperature of approximately 1400°F (760°C). The old-fashioned practice of casting and cooling in river banks, which is commonly done in certain areas of the world, makes this whole process of proper cooling— also called “shakeout”— a very challenging, if not an impossible proposition.

The final and best result for control of chemistry and cooling rate can only be found in a drive sheave casting with a hardness range of HB 210-290, combined with a correct and good microstructure. This, more or less, will be equivalent to class 40 or class 45 iron ***(40,000 psi UTS, 45,000 psi UTS respectively)***. Each casting should be tested for hardness on the outer rim ***(flat side)*** to determine its acceptability for drive sheave use.

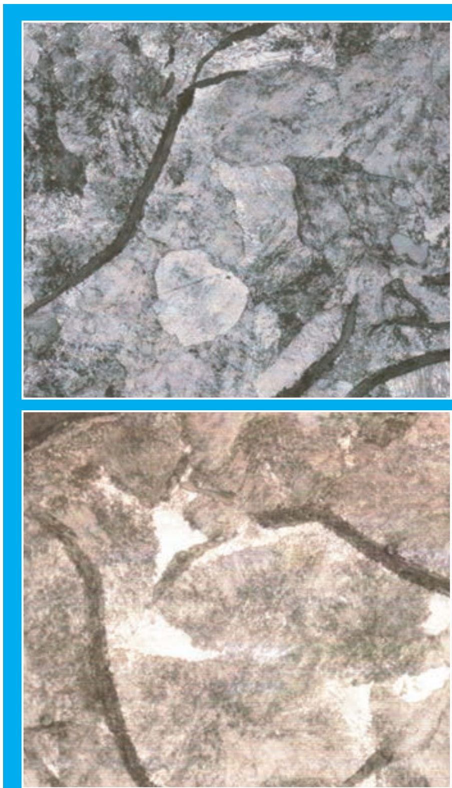
Ropes

Elevator hoist ropes are commonly produced with strand outer wires offering tensile strengths ***(in MPa)*** of 1180, 1370, 1570, and 1770. From an HB standpoint, these tensile values equal 348, 400,444, and 492 respectively. This means that the common wires used are all quite a bit harder than the gray iron bulk hardness. However let’s remember that the iron is a combination of soft ferrite platelets and hard iron carbide platelets ***(Pearlite)***.

Ideally sheave HB and wire grades should be compatible with each other in order to achieve optimum life and performance. And in practice there are comfortable ranges one could target to assure rope tensile and Brinell hardness compatibility.

What is odd is that we still hear concerns from some in the field that today’s ropes are simply too hard for modern sheaves. Let us speak candidly and clearly on this point — it is categorically untrue. If the original metal casting is made correctly, the rope properly matched, installed and maintained, then the very chance of a rope proving to be too hard for a sheave goes to nearly zero.

Keep in mind as well that it is well known that wire bending fatigue resistance is directly related to tensile strength — the lower the tensile strength, the lower the bending fatigue life at a given load. When coupled with the fact that lower tensile wires have lower abrasion resistance it can be readily concluded that, in general, higher tensile wire ropes will have longer lives.



The upper image details an acceptable near-groove microstructure, while the second is clearly unacceptable due to the presence of white grains of free ferrite, flake graphite and particles of alloy carbide. A sheave casting featuring such a microstructure will wear due to the casting itself. Such wear is not an indication that the rope used was too hard.

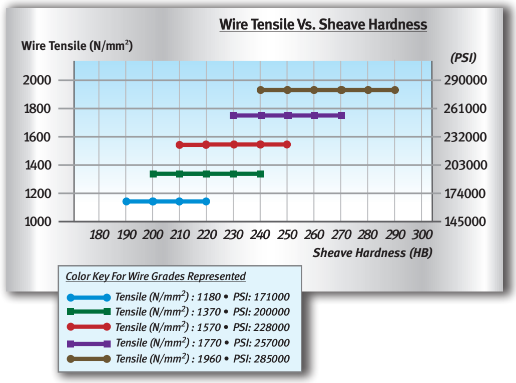
The relative motion between hoist ropes and drive sheave caused by acceleration, deceleration and unequal stretch, side to side, caused by unequal loads, side to side, tends to greatly exacerbate the dual wear problem ***(of both the hoist rope and the sheave)***.

To obtain the maximum amount of life for both ropes and drive sheave we have found the compatibility of these two components to be absolutely critical. We suggest the following guidelines you could follow in order to achieve optimum compatibility.

Wire Tensile Grade (MPa)	***Drive Sheave HB***
1180	**190 - 220**
1370	**200 - 240**
1570	**210 - 250**
1770	**230 - 270**

We have consulted with metallurgical specialists with years of experience in elevator sheaves and ropes and they all say that while achieved HB is a good guide to follow, it can only serve as a mere recommendation, unless you can be certain that the sheave cast cooling process and chemistry were kept fully under control.

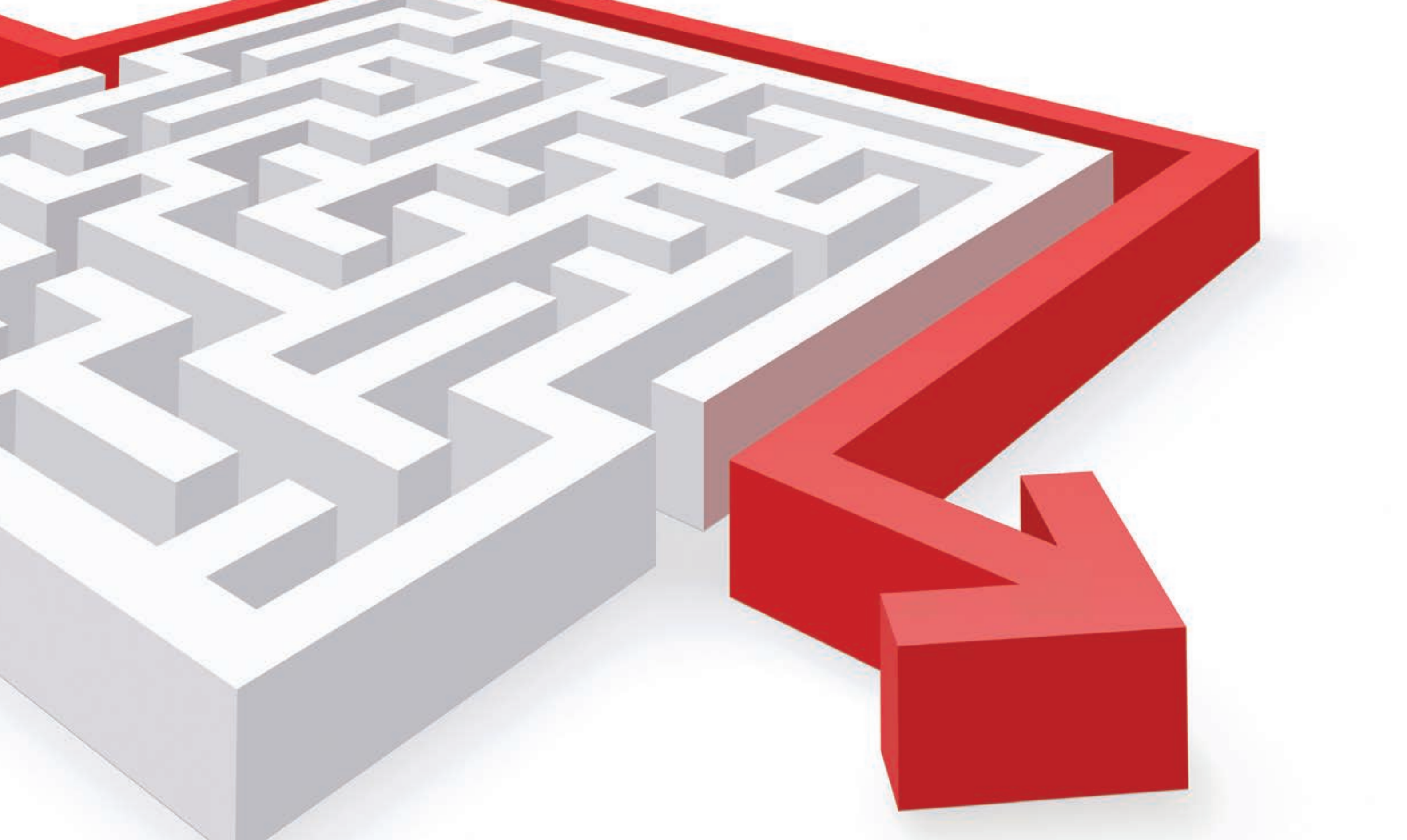
Unfortunately this last point seems to have been missed by many in industry. ***Let us state this again for emphasis, a measured HB that is acceptable does not necessarily guarantee you will have good sheave performance, nor does it mean that the sheave selected will not have a negative impact on rope performance.*** We have heard of situations where a high HB has been achieved and alloy carbide is present, yet this combination has aggressively worn down the hoist ropes.



Often one can determine the compatibility of hoist rope and sheave hardness by matching the Brinell hardness of a sheave to a rope with the appropriate tensile strength. However, this is only one of the many factors one must consider.

In Conclusion

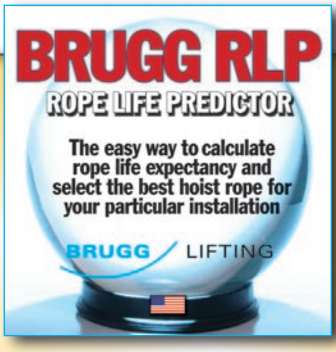
When drive sheave microstructure and hardness are coupled with appropriate and compatible outer wire tensile grade ropes combined optimal rope and sheave life can be achieved. In addition, equalizing rope tensions during installation and periodically afterwards, will serve to help prevent unequal groove wear. We also recommend periodic rope lubrication, at least once per year, to maintain the rope and its core ***(especially for Sisal as lubrication preserves the natural fiber health)***. This will help prevent rope rouging, and maintain the correct traction, or friction relationships, that must exist between hoist ropes and sheave.



MAKING SOME SENSE OF THE MAZE OF SCIENCE BEHIND ROPE LIFE EXPECTANCY.

The Dilemma.

Ever since the introduction of the first modern elevator in the 19th century, elevator professionals have considered how long various installed elevator components can be expected to last. Certainly one area of fascination by many today involves the longevity of one of the elevator's more "active" elements — hoist ropes. As a rope manufacturer we tend to believe that the topic of hoist rope longevity is more than an academic concern. In fact, we think the matter is critical to the well-being of elevator installations in general, and to the profitability of maintenance professionals in particular.



Brugg RLP (Rope Life Predictor) is an online app that allows the user to enter key data and calculate with 95% confidence the number of bending cycles where a maximum of 10% of hoist ropes reach discard criteria.

We know that a fair number of engineers and consultants would be interested to analyze and compare the hardness of the metal present in hoisting components and then attempt to quantify the effect of various wear and fatigue factors on rope longevity. Though tedious and time-consuming, the process of extrapolating rope life expectancy can be accomplished by using mathematical calculations. This level of forethought is relatively complex, expensive and, we think, is not typical. Many who attempt such calculations are daunted by the sheer complexity of the math and consequently choose to accept rough analyses, or life expectancy calculated or derived using less than complete calculations. While better than nothing, decisions based on partial data are inherently flawed and lead to less than accurate, incomplete, or sometimes erroneous conclusions.

Today it is highly evident that the increased requirements and stresses of modern elevator designs impacts working components, especially elevator ropes, in significant and highly varying degrees. Naturally it would be helpful for professionals to have easy access to empirical models featuring a meaningful degree of accuracy. Then when combined with detailed observations on-site of surrounding machinery by experienced industry professionals, such models could greatly assist professionals in their efforts to decide which rope selection is best for a particular installation and could answer questions about how long a particular hoist rope should last.

We know that the lack of a simple, cost-efficient process that permits professionals to mathematically utilize objective key data leads them to choose ropes that neither suit their needs nor meet their own expectations ***(or the building/property owner's expectations)***. We have even found where a simple lack of knowledge in this matter has led some in the industry to rely on flawed anecdotal evidence, or to even base critical product decisions on comparisons in **how long** ***(time referenced only)*** it took for a previous set of hoist ropes to fail. Needless to say this is exactly the wrong course one should follow.

This present state of the industry also fails ***(or resists, due to a limited understanding of cost)*** to consider maintenance issues, such as installation methods, the effects of poor ***(or no)*** load equalization, changing environments within the installation itself, or even the impact of significantly increased elevator usage on hoist ropes ***(more trips on the elevator or more bends in the system)***. These are all real issues that create real headaches for elevator service professionals bidding on new maintenance contracts or for architects and installation designers who have to choose product from among a wide range of rope manufacturers and distributors. All too often the thinking may be focused on topics concerning machine duty, and meeting the applicable codes and standards, while far less time is given to matters such as rope design and the rope's mechanical ability to perform. The fact that a rope meets the minimum standard of the code, which is focused on public safety, has little or no relationship to the endurance or life of that rope in a specific system or application.

The Problem.

For most of its early history the typical elevator experienced few real changes in overall design with respect to hoisting principles. Over the last 30 years greater acceleration and deceleration demands, increased repetitions ***(higher usage)***, closer sheave placements and reverse bends due to building space limitations have greatly impacted elevator designs and machinery. These factors plus the use of much smaller sheaves which consequently require more demanding sheave groove profiles have created astonishingly significant increases in the pressures placed on elevator hoisting ropes. The combination ***(multiplication)*** of several of these factors have created some surprising ***(and really unanticipated)*** results in terms of the life expectancy of hoist ropes in some installations. Some severe instances of very short rope life may even result in a potential legal liability situation for elevator companies ***(as maintenance attention and frequency may not catch such aggressive wear and failure)***. The industry-wide adoption of MRL ***(machine - room-less)*** designs has made the accurate prediction of hoist rope life expectancy far more vital than ever before.

To meet the challenge of more complex elevators many rope manufacturers have already made the move to more advanced constructions. Today's hoist ropes are crafted to meet more exacting tolerances and manufactured using rigid quality controls. Like the elevator itself hoist ropes have evolved. They have gone far beyond yesterday's simple Sisal rope design. It has become essential that hoist rope design be closely matched with the demands of today's elevator system innovations.

It may be that when it comes to determining expected rope life some professionals just don't know how and walk away from the problem. And many have neither the time, nor the real passion, to investigate how various factors now present in today's elevator designs have destructive multiplicative and exponential impacts on the ropes themselves. We believe that this failure to truly grasp the complexity of determining rope life is the basis behind comments that today's rope is simply not as good as it used to be. And while it seems to be that way— objective evidence shows the opposite. Some rationalize their lack of concern over rope life by adopting the lazy attitude that since it's unlikely they will obtain a long-term contract they then need not worry over the matter at all. It's an economic decision and someone else will pay. So why should they care? Other however want to understand why it is that today's better made, more advanced ropes do not seem to last as long as they once did and demand real answers. Questions like these can only be solved by being able to answer one simple question: ***"How long should I expect a hoist rope last on my elevator?"***

Is There Really No Answer To The Question : "How Long Should A Hoist Rope Last"?

Talk to any manufacturer and ask how long the 'average' rope will last and you will be met with a barrage of questions. Some of them will focus solely on the actual elevator system being discussed while others will deal with specific hoist rope design and maintenance issues:

System inputs:

- **car weight**
- **car capacity**
- **% of capacity used**
- **car speed**
- **type of car guide *(i.e. rollers or bushings)***
- **number of hoist ropes**
- **rope diameter**
- **diameter of drive sheave**
- **groove profile of drive sheave**
- **type of wrap *(single or double)***
- **number of deflector sheaves**
- **diameter of deflector sheaves**
- **number of reverse bends in the system**
- **type of suspension *(1:1, 2:1, etc.)***
- **bending length**
- **angular offset between sheaves *(if more than one sheave)***

Rope selection:

- **lay direction of rope**
- **rope design *(i.e. Seale, Warrington, Filler, Fiber Core, IWRC, etc.)***
- **tensile strength of load bearing wires**
- **number of strands**

Rope and system maintenance:

- **degree of rope lubrication *(well-lubricated, some lubrication, dry, etc.)***
- **Environment**
- **New installation, replacement or modernization**

Each of these parameters can and should be considered in order to optimize system performance and maximize rope life. But be aware there could always be system design limitations. And when dealing with an existing system changing many parameters may not be practical. In that case the only course of action may be to substitute other rope designs in an attempt to find an acceptable compromise.

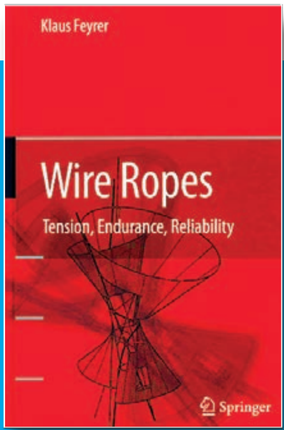
Even after much consideration and research the final answer offered most often by experts is that the life expectancy of any set of hoist ropes depends on the interaction of all these factors together! Small wonder industry professionals are so frustrated. For in reality the seemingly simple question of, "how long should my hoist rope last" is a tremendously difficult one to easily and accurately answer.

Seriously, this is not merely a smokescreen that manufacturers use to stifle discussion on the subject of rope life expectancy. Only after obtaining and inputting all the system data listed previously can any rope maker or industry professional even begin to feel reasonably certain they have enough basic information to make an accurate assessment of rope life expectancy in a specific installation. In addition the calculations are complex, can take time to perform, and the final results can be difficult to interpret. In our experience we have seen cases where the final results have sometimes even been questioned or disregarded entirely.

Of course one can always turn to engineers or consultants for assistance instead of relying upon hoist rope manufacturers to provide the needed analysis. However such a process can prove very expensive, and even their calculations can be found to be lacking or their results will be described as "qualified".

Clearly it is in the best interests of hoist rope manufacturers, consultants, system designers and maintenance professionals — to have a simple, cost-effective, usable way to accurately define and answer concerns about rope life expectancy.

You may wonder why a rope manufacturer would provide a way to help you accurately target rope life expectancy at all. Certainly it would be easier for them to just produce the same familiar Standard Sisal rope choices or simply keep supplying customers replacement rope. We believe that in order to stay alive in the industry today it is necessary for everyone to have access to as much information as possible. It's more than a courtesy in today's business world—it's a necessity.



The Brugg RLP (Rope Life Prediction) application is based upon <u>Wire Ropes: Tension, Endurance, Reliability</u> by Prof. Dr. Klaus Feyrer of the University of Stuttgart.

Only then will we all be able to make meaningful comparisons between rope ***(and other system)*** alternatives. Someone would have to dedicate their life's work to the field and it would demand years of testing and validation to condense this vast work down to the essentials. Finally, it would require someone to combine these calculations together to create a system that professionals could actually use by themselves. This is the very tonic our industry needs to answer the problem of predicting rope life; fortunately that prescription has been filled.

The Answer To The Question: Rope Life Predictor (RLP).

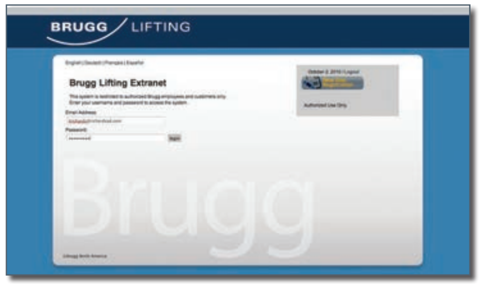
If one man's work can be seen as critical in calculating the life expectancy of ropes under strain and subject to motion, bending, load and tensile forces it is **Professor Dr. Klaus Feyrer**, retired director of the **Institute of Mechanical Handling and Logistics (IFT) at the University of Stuttgart**. Here Feyrer intensively researched the subject and published his research in a variety of articles. Eventually he combined his findings into a single work: **<u>Wire Ropes: Tension, Endurance, Reliability</u>** ***(published by Springer Press)***. Over time he has become the foremost authority in the field of rope technology.

Feyrer's work is comprehensive in scope, with his book serving as a valuable resource that answers all questions concerning rope usage and the lifespan of ropes. That the North American elevator industry as a whole is relatively unaware of his accomplishments can be attributed to the fact that not only does this field receive little notoriety in general, but that almost all of his work was, until recently, only available in German.

Since Feyrer's work used metric, instead of imperial units, it was also more easily suited for immediate use by European engineers as opposed to North American technicians who had to perform the calculations and then convert their findings into the desired imperial measurements. Feyrer's work also demands that those using his calculations must be able to work with complex "higher" mathematics. Unfortunately these factors kept the real potential of Feyrer's work just beyond the reach of those that could best make use of it.

In 2008 Brugg Wire Rope received approval from Dr. Feyrer to present his calculations in a form that would increase their ease of use to a North American marketplace. Brugg RLP ***(Rope Life Predictor)*** is a self-directed program that one can access via the Internet through any browser. Security-protected, the subscriber must use a password to enter a Brugg portal to access the program. There the user may enter key data, complete calculations, adjust variables, contrast scenarios, and then download their results in PDF or Excel format to their own computer. ***(To protect user privacy all data is automatically deleted from RLP after the user logs out.)*** The user can then copy their work and send it to a Brugg representative for validation if desired.

In addition to using Dr. Feyrer's calculations, RLP offers users a simple way to analyze both the short-term and long-term impact in installation, maintenance and reroping costs of a variety of rope designs. The end result is a simple, easily accessible way to analyze which rope best suits an installation and then examine how that rope will impact budgetary outlays over time.



Entering through a secure entry portal, one finds a series of screens to walk you through the process of calculating rope life. In addition to a Cost/Benefit Analysis feature that shows how rope selections and maintenance impact short and long-term budgetary costs, Brugg RLP offers users the ability to quickly review and contrast alternative rope selection scenarios.

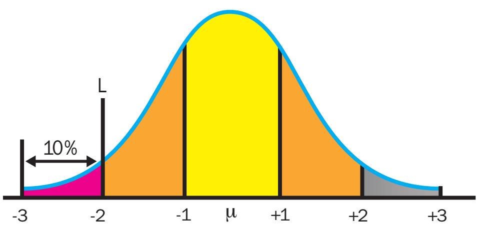
The Basics Behind RLP (Rope Life Predictor).

From Dr. Feyrer's **<u>Wire Ropes: Tension, Endurance, Reliability</u>** one gets a fully rounded view of the forces affecting ropes and a relative understanding how materials react to them. RLP was fashioned by editing, compartmentalizing, and organizing Feyrer's work. The final result is a prognostic program that calculates the discarding number of bending cycles N_{A10} where with 95% certainty not more than 10% of the wire ropes have to be discarded because they have reached the maximum number of wire breaks. This is an objective and measurable criteria, which balances requisite safety with normal and established hoist rope inspection.

RLP's mathematical equations calculate a normal distribution for rope life expectancy (assuming "normal" variations of the working rope within the hoisting system). This means that an early rope replacement (10% level is 2 standard deviations from the mean) can be expected relative to system factors and variation (it is not just the rope itself, even though that is what is seen). Understanding standard deviation shows a potential rope performance opportunity if system factors (materials, installation including proper fitting using i-line, shackling and load equalization and maintenance including load equalization and lubrication) are optimized. It follows that when rope life reaches the mean, the actual result is better by a factor of 2 or more.

There are also certain and important factors such as installation and maintenance techniques that are difficult to empirically judge. The formulas used in RLP are specific for the elevator industry and include the following key and constant factors:

- **All ropes share one common drive sheave**
- **All hoist ropes are tensioned to within 25% from the highest to the lowest (±12.5%)**
- **Rollers are used to guide the car**
- **Rope efficiency due to loss of friction is assumed at 98%**
- **Rope wire tensile strengths and sheave hardness/microstructure are compatible**



RLP gives you a statistically calculated normal distribution of expected hoist rope life.

Once the system parameters are entered and the hoist rope is selected, RLP reasonably shows how certain factors will impact rope life expectancy. The results include:

- **Static load per rope**
- **Dynamic load per rope**
- **D:d ratio**
- **Number of single bends N_{A10}**
- **Number of corrected single bends $N_{A10corr}$ using endurance factors**
- **Number of reverse bends, where applicable**
- **Total number of working cycles to discard ropes**

In addition to Brugg RLP we provide a variety of maintenance equipment and highly detailed informational materials to help professionals maximize system performance and attain the most elevator rope life possible.

The following example shows how the life of hoist ropes increase or decrease by simply changing one parameter. Brugg RLP is a quick, easy and accurate tool to optimize hoist rope performance for a given system and a way to gain an insight in what to expect from your elevator system. The following examples ***(see both A and B)*** show the impact of changing the groove profile, the type of rope, and the number of ropes used in an elevator system, while keeping all other parameters the same.

Example A:

- **Car weight** — **4500 lbs**
- **Car capacity** — **2000 lbs**
- **Car speed** — **400 ft/min**
- **Number of ropes** — **5 or 6**
- **Rope diameter** — **0.500 inches**
- **Drive sheave diameter** — **20 inches**
- **D/d ratio** — **40:1**
- **Bending length** — **40 inches**
- **Roping** — **2:1**
- **Type of wrap** — **Single**
- **Undercut U-Groove** — **105° or 85°**

- **Rope constructions**

  8 x 19 RRL Fiber Core Sisal (FC)

  8 x 25F RRL Independent Wire Rope Core (IWRC)

  8 x 25 RRL Parallel Wire Rope Core (PWRC)

As you can see, merely reducing the amount of undercut by 20°, from 105° to 85°, increases the rope life (number of bending cycles) about 4 times. Feyrer determined an endurance factor of 0.066 for the 105° undercut and 0.260 for the 85° undercut. This means that as the contact area between sheave groove and rope gets smaller, the specific radial force on the rope ***(groove pressure)*** increases. A 0.066 factor means a 93.4% reduction in endurance ***(life)*** tied directly to the groove profile.

The rope life increases approximately 60% when the number of hoist ropes is increased from 5 to 6. The dynamic force on each rope is reduced from 924 lbs ***(set of 5 ropes)*** to 770 lbs ***(set of 6 ropes)***. This directly reduces the specific pressure per point of contact and extends the life of the ropes. Changing 8-strand ropes to

Example A: Summary of calculations

Rope Construction	Undercut	No. of Ropes	Discard No. of Bending Cycles N_{A10}	No. of Ropes	Discard No. of Bending Cycles N_{A10}
8 x 19 RRL FC	105°	5	402,000	6	664,000
8 x 25F RRL IWRC	105°	5	407,000	6	647,000
8 x 25F RRL PWRC	105°	5	757,000	6	1,203,000
8 x 19 RRL FC	85°	5	1,585,000	6	2,616,000
8 x 25F RRL IWRC	85°	5	1,604,000	6	2,549,000
8 x 25F RRL PWRC	85°	5	2,984,000	6	4,742,000

Altering just a few aspects in installation design (namely the degree of undercut and number of ropes required) can make a dramatic impact in the number of bending cycles that a hoist rope can attain. Typically determining which hoist rope is best for an installation is not as obvious as this example.

Example B: Summary of calculations

Rope Construction	Undercut	No. of Ropes	Discard No. of Bending Cycles N_{A10}	No. of Ropes	Discard No. of Bending Cycles N_{A10}
8 x 19 RRL FC	U-Groove	5	719,000	6	1,188,000
8 x 25F RRL IWRC	U-Groove	5	767,000	6	1,219,000
8 x 25F RRL PWRC	U-Groove	5	1,427,000	6	2,267,000

9-strand ropes is another way to lower the specific pressure.

Let us look at the combined effect of these two situations. A four-fold increase in rope life due to a 20° change in undercut multiplied with a 60% improvement by adding one more rope results in an overall impact of about 6.4 times (4x1.6=6.4).

Comparing the 8x19 RRL Fiber Core Sisal (FC) rope with the 105° undercut groove and 5 ropes per set to the 85° undercut groove and 6 ropes per set: 2,616,000/402,000=6.5 times better.
In the extreme case, a comparison of the 8x19 RRL Fiber Core Sisal (FC) rope with the 105° undercut groove and 5 ropes per set to the 8x25 RRL Parallel Wire Rope Core (PWRC) with the 85° undercut groove and 6 ropes per set: 4,742,000/402,000 = 11.7 times better.

Example B:

- **Car weight** — **4500 lbs**
- **Car capacity** — **2000 lbs**
- **Car speed** — **400 ft/min**
- **Number of ropes** — **5 and 6**
- **Rope diameter** — **0.625 inches**
- **Drive sheave diameter** — **25 inches**
- **D/d ratio** — **40 : 1**
- **Bending length** — **50 inch**
- **Roping** — **1 : 1**
- **Type of wrap** — **Double**
- **U-Groove** — **r/d = 0.53**

- **Rope constructions**

  8x19 RRL Fiber Core Sisal (FC)

  8x25F RRL Independent Wire Rope Core (IWRC)

  8x25 RRL Parallel Wire Rope Core (PWRC)

  MCX8, MCX9 or DP9

When a car travels to or from the ground floor the rope section running over the sheaves gets bent 4 times in the same direction ***(4 simple bends)***. Prof. Feyrer uses this symbol to indicate one simple bend. In a double wrap installation the hoist rope gets bent 4 times ***(4 x)***. Therefore the hoist rope sees the following sequence:

1. **Straight between car and drive sheave**
2. **Bent on the drive sheave**
3. **Straight between drive sheave and secondary sheave**
4. **Bent on secondary sheave**
5. **Straight between secondary sheave and drive sheave**
6. **Bent on drive sheave**
7. **Straight between drive sheave and secondary shave**
8. **Bent on secondary sheave**
9. **Straight between secondary sheave and counter weight**

Without regard to the type of rope chosen the number of working cycles N_{A10} is more than doubled. In the above example, the 8x19 RRL Fiber Core Sisal ***(FC)*** rope achieves only 719,000 working cycles compared to the 8x25 RRL Parallel Wire Rope Core ***(PWRC)*** rope, which achieves 1,427,000 working cycles, or about twice the rope life.

As in Example A, hoist rope life increases close to 60% when the number of hoist ropes is increased from 5 to 6. The dynamic force on each rope is reduced from 1,847 lbs ***(set of 5 ropes)*** to 1,540 lbs ***(set of 6 ropes)***.

The combination of a high-performance rope with the addition of one more hoist rope results in an overall impact of about 3 times ***(2x1.6 = 3.2)***. Example B compares these numbers: 2,267,000/ 719,000 = 3.1 times.

Explanations

The discard number of wire breaks is achieved when the number of bending cycles N_{A10} is reached. This number is based on the assumption that the same section of rope is running over the sheave during every trip.
In reality this is not always the case and depends on the usage of the building and may be adjusted accordingly. For instance if only 80% of the trips go to the lobby ***(or ground floor)*** then the actual number of bending cycles is greater and can be calculated by N_{A10}/0.80 to arrive at the installation specific number of working cycles.

The calculations in both examples are based on a 75% capacity for each trip. This number too may be adjusted for installation specific calculations. All factors, formulas and definitions are based on Prof. Feyrer's book. The same approach applies when predicting hoist rope life for different installations including reverse bends, deflector sheaves, etc.

After inputting the required data you can accurately quantify the total number of working bends that a rope may be expected to reach before it must be discarded. As with earlier analyses performed by engineers, consultants or a few select rope manufacturers, a key group of critical factors needs to be considered and understood. Brugg RLP significantly minimizes the amount of complicated information needed to make the calculation. The most important feature of RLP is ease-of-use. After the entry of specific rope data all calculations are performed automatically for you.

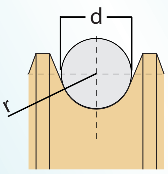
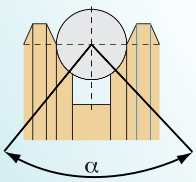
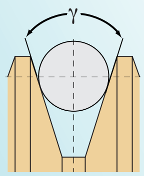
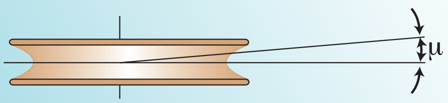
Finally of course we must remember that in all cases sufficient traction must be calculated and achieved through some combination of drive sheave dimension, groove profile and number of ropes used ***(creating friction)***. We have seen cases where this fact is not understood and one result of insufficient traction ***(friction)*** is that the rope can slide too far through the grooves. This has sometimes been misinterpreted as a problem with rope lubrication when it is not.

Why Determining Rope Life Expectancy Should Matter To You.

To accurately forecast how long a rope should perform in a particular installation and then selecting an alternate rope to maximize equipment investment would naturally be of interest to designers of elevator installations. Indeed such a utility would be a tremendous advantage to all who estimate, adjust, and install hoist ropes. Naturally, any meaningful calculation of rope endurance must by necessity account for the quality and frequency of care provided for the hoist ropes themselves ***(which Brugg RLP also considers in its calculations)***. This means that Brugg RLP has great utility for maintenance professionals too. Indeed as Brugg RLP makes clear, these factors are critical to the issue of hoist rope life expectancy itself.

We hope professionals will see this new program as a true source of information and a way to help them overcome an industry bias in the application of hoist ropes. We have become concerned that the industry has become overly content with the old and familiar ***(which is evident in the continued industry-wide use of Standard Sisal Core ropes)*** due mainly to a lack of real

Endurance factors f_N

Rope Lubrication			
-well lubricated		f_{N1}= 1.0	
-without lubrication: (Müller)		f_{N1} = 0.20	
Rope Construction (for round grooves only)	***core***	***8 strands***	***6 strands***
— FIBER CORE	***FC***	f_{N2} = 1.0	f_{N2} = 0.94
— STEEL CORE	***IWRC***	f_{N2} = 1.0	f_{N2} = 0.81
	PWRC	f_{N2} = 1.86	f_{N2} = 1.51
	ESWRC	f_{N2} = 2.05	f_{N2} = 1.66
	EFWRC	f_{N2} = 1.06	f_{N2} = 0.86
Round Groove 	***groove radius r/d*** = 0.53	f_{N3} = 1.0	
	0.55	f_{N3} = 0.79	
	0.60	f_{N3} = 0.66	
	0.70	f_{N3} = 0.54	
	0.80	f_{N3} = 0.51	
	1.00	f_{N3} = 0.48	
Undercut U-Groove 	α = 75°	f_{N3} = 0.40	
	80°	f_{N3} = 0.33	
	85°	f_{N3} = 0.26	
	90°	f_{N3} = 0.20	
	95°	f_{N3} = 0.15	
	100°	f_{N3} = 0.10	
	105°	f_{N3} = 0.066	
V Groove 	γ = 35°	f_{N3} = 0.054	
	36°	f_{N3} = 0.066	
	38°	f_{N3} = 0.095	
	40°	f_{N3} = 0.14	
	42°	f_{N3} = 0.18	
	45°	f_{N3} = 0.25	
Wire Rope Deflection (skew pull) for N_4 	***angle of deflection*** μ = 0°	f_{N4} = 1.0	
	1°	f_{N4} = 0.90	
	2°	f_{N4}= 0.75	
	3°	f_{N4} = 0.70	
	4°	f_{N4} = 0.67	

Sisal Core

Steel Core

Synthetic Core

information on what is now possible. However we believe that when professionals have a better understanding of the many variables that affect hoist rope life, and can see for themselves how using a cheap rope can cost them dearly in multiple re-ropings and labor in the long run, we know they will come to demand more advanced ropes that offer both innovation and provide true cost benefits.

Being able to accurately gauge hoist rope life also permits the entire industry to take another step towards being "greener" with respect to our use of resources ***(where the replacement of ropes is concerned)***. We know that the well-informed buyer, when weighing the difference between a cheaper, less efficient, and less productive rope, versus that of an initially more expensive rope that delivers greater performance, increased life expectancy, and a better return due to reduced maintenance, will choose to make the smarter buy. Building owners and managers should understand this as well.

Longer lasting product means less waste and conserves resources. We believe this is a direction that the entire industry should adopt, and feel it is our job to make this more attractive for all to do. Thus RLP becomes more than a wise choice for those wanting to profit from increased rope life, it is also an essential choice for all who have an interest in preserving our resources for future generations.

Brugg RLP finally makes it possible for everyone to be able to make accurate predictions on rope longevity and better choices in rope selections. And for those who use RLP's Cost/Benefit Analysis function, the program could save them a real fortune in unplanned maintenance, labor and re-roping costs.

Switching from Standard Sisal Core to Steel or Synthetic Core rope designs could solve many problems. Yet even advanced rope constructions will prove deficient if load, usage, environmental and installation design factors are not fully and properly considered.

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