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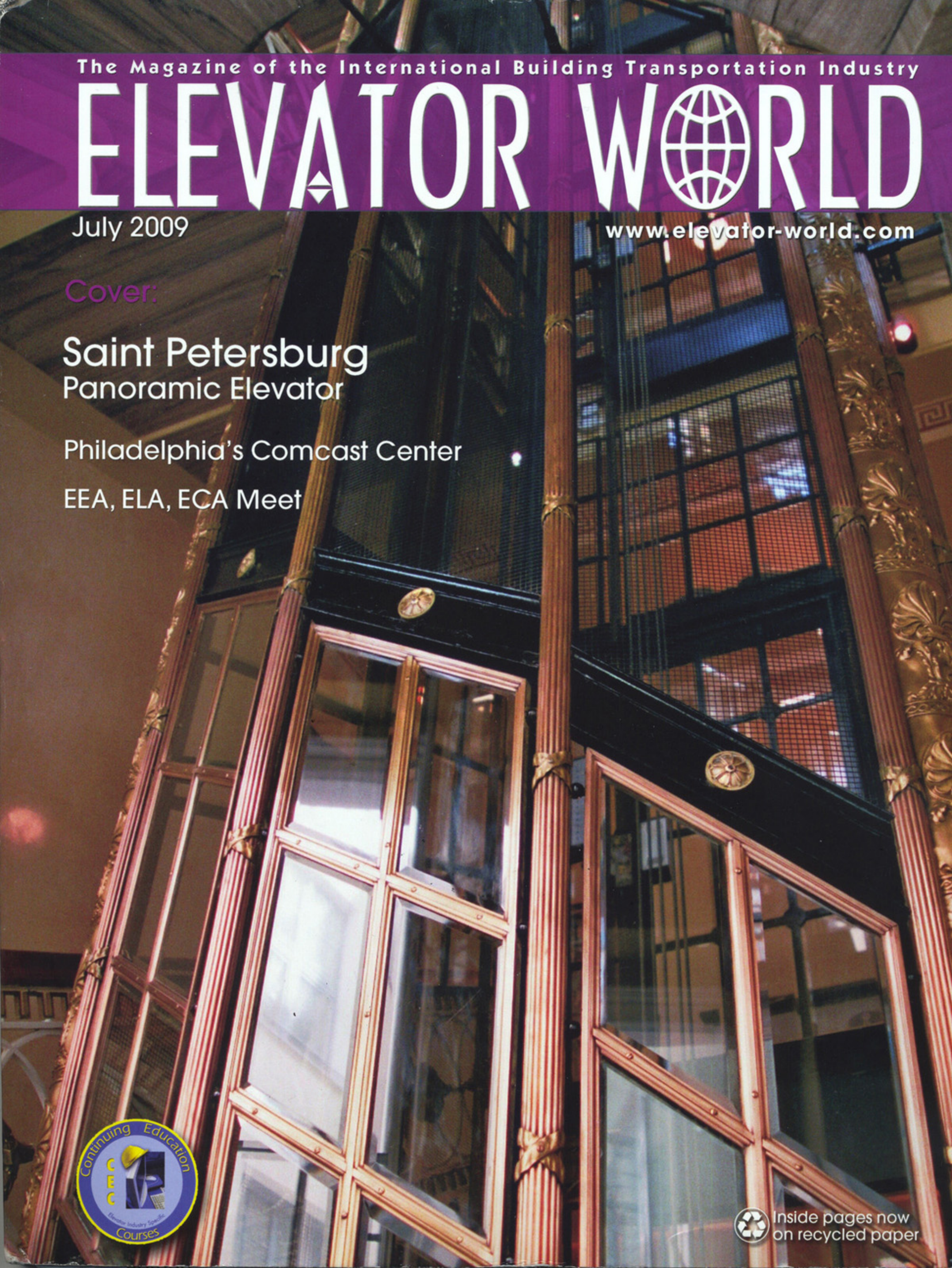

Cover:

Saint Petersburg
Panoramic Elevator

Philadelphia's Comcast Center

EEA, ELA, ECA Meet

Inside pages now on recycled paper

Focus on Wire Rope

The Impact of Worn Sheave Grooves on Rope Life Expectancy

by Kevin Heling, Rick Perry and Martin Rhiner

The Red Herring

Every good mystery story employs certain dramatic devices used to increase intrigue and interest. One of the most common is the "red herring," used to throw the reader off the track of the true villain through the skillful use of misdirection. At first, the red herring appears to be the obvious answer to solving the case. Yet once it is properly placed with all the other clues and you take the time to evaluate all the evidence from a different perspective, a far different picture develops. So, in order to correctly untangle a perplexing story, the true sleuth must look beyond the red herrings (or the seemingly obvious evidence) and critically examine the case to find the right answer.

One would try to follow the same process to solve a mystery in real life, as well. But what if you had to solve a case where the victim appeared equally as guilty as the suspect? Would you consider only the facts? Or would you wind up being influenced by witnesses who could be biased, or simply misinformed? It's possible that you could end up spending all your time sleuthing (collecting evidence) and only be left with puzzling observations that implicate – but do not lead – to a solution. Indeed, you may come up with no concrete solution to the mystery at all.

A Mystery

For about the last decade, elevator rope manufacturers have heard one claim repeated so often that some may have accepted it as truth: "In comparison to the good old days, modern hoist ropes are simply not as good as they once were." This comment has been said despite the fact that over the years, manufacturers have implemented newer, more advanced manufacturing processes, sophisticated designs and more rigid and exacting quality controls. Despite these facts, elevator professionals point to statistics showing a rise in the volume of installation shutdowns, as maintenance professionals are forced to hurriedly take systems offline and spend hours performing expensive repairs.

Sometimes professionals repeat anecdotal stories of poor unfortunates who tried their best to re-rope elevators with hoist ropes matching the previous ones in every particular (even going as far to use the same manufacturer as before). Yet, despite their best efforts, they found to their dismay that the recently replaced selections lasted only a fraction as long as they expected. Obviously, something is going on, but what? The mystery of the premature death of hoist ropes requires some examination.

One can hardly blame industry professionals for hearing these tales and not swiftly coming to the conclusion that the ropes are clearly the culprits. After all, every maintenance professional is aware of the importance of selecting the right rope for the job, keeping an eye on rope alignment, handling the rope correctly during installation, properly lubricating the ropes and equalizing rope tensions; these are obvious basics to the industry, and some rope manufacturers provide loads of

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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 the editorial contributions of Hugh O'Donnell of Hugh O'Donnell Metallurgical Enterprises in Longmeadow, Massachusetts, and other industry professionals for their support and advice during the preparation and editing of this article.

printed instructional materials showing how it is properly done. So when maintenance professionals go onsite and hear complaints of "rope chatter" or vibration in an installation and see signs of heavy throw-off of lubricant, buildup of deposits of metal filings, evidence of heavy crown wear and vastly shortened rope life, they naturally jump to one conclusion – the ropes are at fault. But is this fact, or have hoist ropes become the red herring of this mystery? We have seen that field-test examinations and the use of the Brugg Rope Life Predictor (RLP) can show that at worst, hoist ropes are mere accomplices in this mystery. The calculations and evidence show that there are other suspects with equal (if not greater) impact in this story, as well.

Back Story

First, no hoist-rope manufacturer would ever suggest that it would be impossible for a manufacturing flaw to find its way into a particular rope. Naturally, there is a chance that a particular rope could be made from flawed materials, be assembled improperly, escape detection during extensive nondestructive mechanical testing and avoid being discovered by trained personnel whose very jobs depend on catching minute quality-control mistakes. However, when soberly evaluated, the chances of this happening are so low that even the most reckless Las Vegas gambler would be wary of betting on it.

So why don't rope manufacturers present these facts in a more forceful way, and in so doing, totally nip these rumors of a loss of rope quality? Why have they allowed this myth to continue? We can only guess. One reason could be that, despite the facts, most rope manufacturers have found it easier to not confront these claims head on, mistakenly believing that by confronting the matter, they would give credence to the rumor. Another reason may be that some less forthright competitors have found it useful over the years to use these rumors to their advantage. We cannot discount the possibility that some manufacturers may have considered it less costly to go along with the story than to invest the real time, effort and funds required to educate the truth. There's no sure way of knowing if any of these reasons are the true cause. One thing, however, is certain: the manufacturers' *laissez faire* approach toward addressing the myth only served to buttress the rumor and lend it credence.

The strongest potential reason for saying nothing about the matter at all was simply smart business. Rope manufacturers have been loath to bring up the fact that surrounding machinery components, if improperly made, misaligned or not maintained, could well have a potentially enormous impact on the problem of shortened rope expectancy, as well. One can hardly expect a rope manufacturer to blame another manufacturer of elevator components of being complicit in a far larger problem, especially since this link was difficult to show conclusively. It would be bad for business.

Related to (or because of) today's demand for machine-room-less (MRL) designs and the need for modern elevators to handle more repetitions, and accelerate and decelerate far faster than ever before, it is no longer in anyone's real interest to turn a blind eye to the deeper, less-obvious but equally destructive reasons for rope failure any longer. Such silence profits no one – especially elevator maintenance professionals, who, if they simply continue to do business as usual, will eventually find themselves losing both profits and business. Indeed, we believe that severely shortened rope life will become an even greater problem if we don't look beyond the red herring of this mystery and toward other possibilities.

Background on the Next Suspect: Sheaves

An elevator hoisting system is an interconnected group of machinery that balances and counterbalances mass and gravity in order to vertically convey passengers in the cabin. Though consisting of many pieces, including the car, counterweight, motor, a drive system, safety devices, a compensation method, rails, buffers, a governor system and more, most would agree that sheaves and hoist ropes are its primary components. They may not be attractive, but without sheaves and a hoist method (ropes or belts), you don't have an elevator; you have a box sitting in a hoistway.

More than simply heavy, grooved cylinders, sheaves are manufactured to meet specific measures of Brinell hardness (HB) (a test invented in 1900 by Dr. Johan August Brinell of Sweden to determine the hardness of forgings and castings too coarse for Rockwell or Vickers testing). Manufactured in a foundry, the hardness of a casting may be increased by either heat treating rope grooves or alloying. A heat-treated sheave is carefully heated then cooled at controlled temperatures. This hardening of the rope grooves of the sheave has little or no effect on the core hardness of the casting.

A more common method in the elevator industry for increasing sheave hardness is called alloying. Here, the actual composition of the iron in a sheave casting is altered through the introduction of other elements. Though more expensive, this process is expected to create a uniform hardness throughout the entire cross section.

Friction sheaves are normally made of GG25 to GG30 gray cast iron with various alloying additions. They are rarely offered in GGG 50-60 modular cast iron. Generally, the hardness of a sheave is 200-270 HB. Such hardness is required to endure both sufficient service life and dimensional stability of the rope grooves in heavy-duty sheaves.

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Another important aspect of sheave hardness, according to Hugh O'Donnell, a metallurgical consulting engineer to the elevator industry, is that while the measured Brinell hardness of a sheave casting is a good foundation, the final microstructure of the iron in the sheave casting is most important to the life performance of the sheave in the elevator hoisting system. While one can have and measure the right Brinell hardness on a sheave, if the sheave blank was not controlled in the cooling rate and time ("shakeout"), the resulting microstructure of the surface metal of the casting will be less than optimal. Poor microstructure will result in uneven wear of the sheave during use (friction). A sheave with uneven wear creates another major impact on the elevator hoisting system, with a direct impact on the observed performance of the ropes.

The sheave side of the story has also been affected by the industry-wide move toward MRL elevator designs and the overarching need to compact elevator machinery as much as any other elevator component. Indeed, today's sheaves are almost half the size of those used only two decades ago. While this greatly helps to minimize the amount of space occupied by an installation and greatly lowers the cost, smaller sheaves create higher radial pressures on hoist ropes. Their reduced size also means that they have far less surface-bearing area, which generates higher load-bearing pressures on the ropes. They also offer less surface contact area, which negatively impacts ropes' traction. To compensate for this lack of surface contact area, manufacturers developed sheaves featuring undercut U- and V-grooves, effectively creating other challenges such as increasing the groove pressure. Still, even after 150 years, if Elisha Otis were to look at today's sheaves, he'd no doubt be able to recognize them. Nevertheless, with respect to diligence, we must make sheaves a suspect in our mystery. Let's take a look at some of the evidence, especially in regards to the subject of unequal sheave groove depths.

Evidence of Variable Sheave Groove Depths

We were recently called to evaluate the elevator system of a high-rise building in the eastern U.S. Table 1 provides some relevant system-specific information on this installation.

An examination of six hoist ropes in a bank of six high-rise elevators showed alarming evidence of advanced, severe rope crown wear after only 18 months of service (1.2-1.4 million elevator starts). The old ropes were removed and rope diameter measurements carefully taken from the area where maximum crown wear was most evident. As you can see from our readings in Table 2, the initial 11/16-in. (17.5-mm) rope has been gouged and worn significantly.

Naturally, a rope's diameter gets smaller as the rope, carrying a load, wears over time. And if those ropes are tensioned equally (we recommend a maximum of ±10%), then both rope diameters and the sheave grooves should wear at the same rate. Clearly, the ropes were wearing unequally; therefore, we thought it would be beneficial to examine the amount of wear on the sheave, particularly in the grooves.

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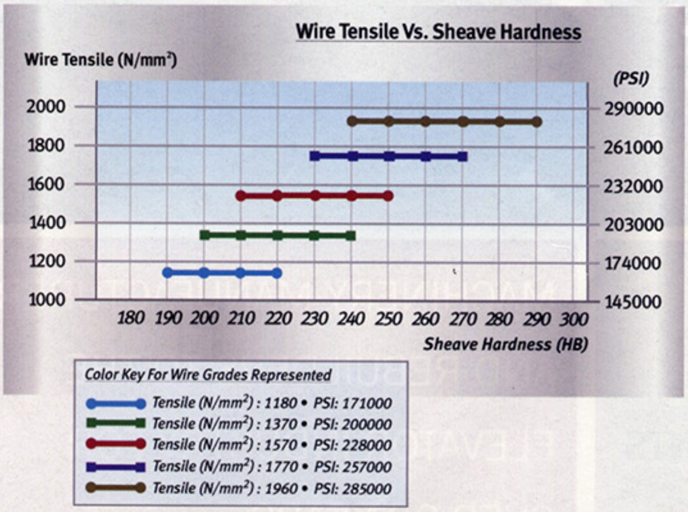

Figure 1: The relationship between Brinell hardness (HB) of sheaves and the tensile strength of wire

Date of Installation	1963
Car Weight	5300
Capacity	3000 lbs
Speed	1000 ft/min
Type of Wrap	Double
Groove Profile	U
Type of Suspension	1:1
Number of Ropes	6
Rope Diameter	11/16 in.
Type of Rope	8x19 RRL Dual Tensile, Sisal Core
Shackles Used	Babbit

Table 1

Diameter Of Old Ropes *(No Load)*

Measurements taken from most worn section

1	2	3	4	5	6	Average	Nominal Rope Dia.	Discard Rope Dia.	Units
16.85	17.02	17.00	16.62	16.98	16.95	16.90	17.5	16.27	mm
0.6634	0.6701	0.6693	0.6543	0.6685	0.6673	0.6655	0.6875	0.6406	in.

Table 2

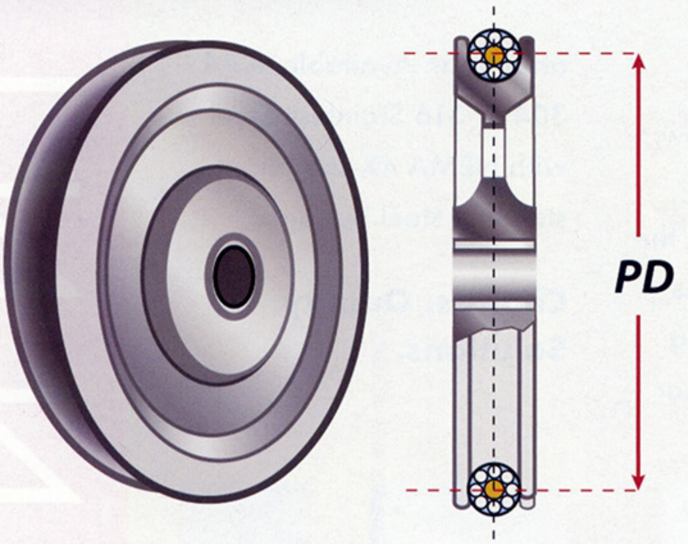

Figure 2: The layout of a typical single groove of an elevator sheave (PD = pitch diameter)

To ascertain the amount of variation in groove depths of the drive sheave, we measured the distance from the top of each rope to a fixed point. Any difference in height is evidence of a variation in groove depth, and this difference translates into different pitch diameters (the contact point between the rope and groove), which means that each rope travels a different linear distance than the one next to it. This creates rope wear and a situation in which the grooves wear at different rates, too. In this installation (with measurements based upon a 42-inch pitch diameter) the difference in groove-depth variation was quite high (0.032 in.).

Admittedly, this difference appears insignificant. However, when one considers how such a discrepancy can affect pitch diameter circumference, which has a direct bearing on the actual distance of how far a rope will travel, one can better understand its true bearing on our case. For instance, if one takes the difference between the highest and lowest point of pitch diameters (based on a highest pitch diameter of 42 inches), one can use the following formula to derive the difference in circumference of the two grooves:

$\pi(42 - 41.94) = 0.1885$ in.

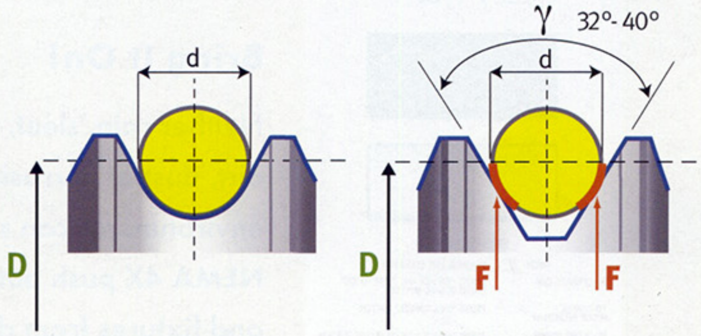

Figure 3: These representations of a (l-r) round (or U-) groove and V-groove, when combined with Figure 2, illustrate how pitch diameter is defined. The 32° V-groove drawing also details sources of friction within the sheave over a rope's lifetime.

Difference In Linear Travel
(Due to Differences in Groove Depth)

	Largest	Smallest	Unit
Pitch Diameter	42.000	41.942	inch
Circumference	131.947	131.765	inch
Circumference	10.996	10.980	feet
Rise	500.000	500.000	feet
No. Revolutions of Drive Sheave	45.473	45.473	rev.
Linear Distance Travelled	500.00	499.310	feet
Difference in Linear Distance		**8.286**	**inch**

Table 4: This table more clearly defines how even a minor discrepancy in pitch diameter can affect the distance a rope may travel.

Such a rope, situated in a lower groove, carries less load, has lower friction and will slide in the groove to equalize the length. As this action is repeated thousands of times, it leads to accelerated groove wear and pronounced crown wear – situations that are virtually impossible to correct through the equalization of rope tensions, or even through changing the ropes. The reality is that it is impossible to equalize the tensions (load), as this would require relatively equal rope lengths in the rope set. This cannot be achieved if the drive-sheave grooves have a noticeable pitch variation.

Crown Wear: Exhibit A

Though we suspect every maintenance professional has run into cases of noticeable crown wear, many still

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Variation In Groove Depth

Groove number from left to right, double wrap drive sheave													
1	2	3	4	5	6	7	8	9	10	11	12	Difference	Units
11.88	11.52	11.77	11.56	11.53	11.60	11.68	11.66	12.27	11.46	11.85	11.71	0.81	mm
0.4677	0.4535	0.4634	0.4551	0.4539	0.4567	0.4598	0.4591	0.4831	0.4512	0.4665	0.4610	0.032	in.

Table 3

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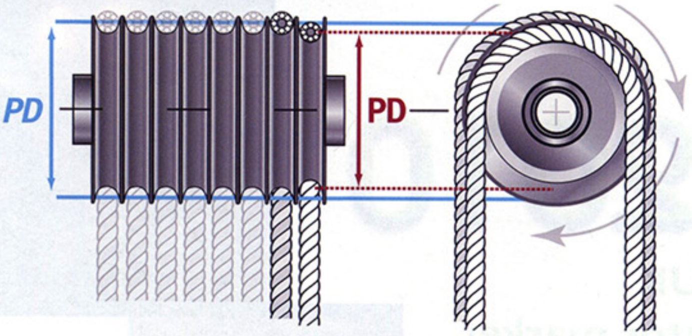

Figure 4: The blue line represents the correct pitch diameter, while the red line reveals a variation in groove depth, which equates into a difference in pitch diameter. Despite the fact that both ropes are moving at the same speed, the discrepancies in groove depth mean that the ropes do not move the same distances. This condition must lead to excessive rope wear, loss of performance and further sheave-groove degradation.

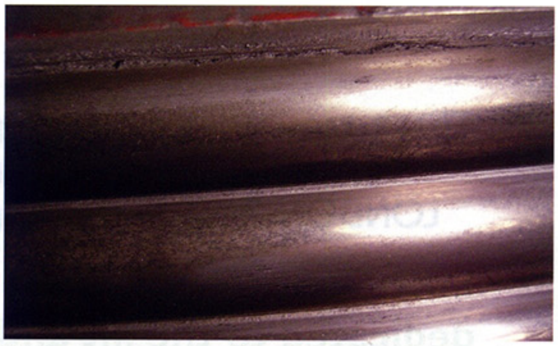

Figure 5: This close-up of one of the worn grooves shows evidence of light pitting due to years of service. In this case, small metal parts or shavings, (filings) have become removed from the groove itself. The presence of filings within an installation is some cause for concern and could be an indication that the hoist ropes need replacement and that sheave re-grooving is required. A pitted surface, if left unaddressed, can greatly affect the rope surface and lead to dramatically shortened rope life expectancy.

perceive this as an indication of a problem or weakness inherent in the ropes themselves. In this case, however, perception is not reality. Failure to accept facts (due to either obstinacy or indifference) radically decreases rope life, means increased materials costs and labor expenses (due to having to frequently re-rope the installation) and either expensive re-grooving of the sheave or total sheave replacement.

In its simplest sense, crown wear is a sign of an obvious mismatch between groove depth and rope diameter. Over time, ropes naturally stretch and become smaller in diameter due to the impact of both the load stresses placed upon them and friction. This means that the rope's diameter will become slightly narrower than the groove itself and eventually begin to wear into the groove.

This is not evidence supporting the old argument that today's ropes are too "hard" for the sheaves, or even proof of "soft" sheaves themselves. Not only are arguments of this sort absurd, they are insulting to both sheave and rope manufacturers. This makes it sound as if rope manufacturers have the temperament of bullies, finding it in their best interests to create materials innately stronger or more durable than what sheave makers can ever hope to match. It also makes sheave manufacturers look as if they are helpless, technologically wayward victims who have no option but to stand by and have their products compromised by hoist ropes like a warm knife on butter.

This is, of course, nonsense. HB testing and controlled quality processes make it possible for both rope and sheave manufacturers to ascertain metal hardness with precision and be able to match each other's capabilities efficiently and within a fairly broad and comfortable range of compatibility. Arguing over matters such as the relative hardness of a sheave versus that of a hoist rope is almost irrelevant, in our opinion. We take the position that a good rope maker should not be compelled or coerced into producing ropes outside of the industry and code standard ranges from 1,370 N/mm^2 to 1,570 N/mm^2 and 1770 N/mm^2 for extra high strength applica-

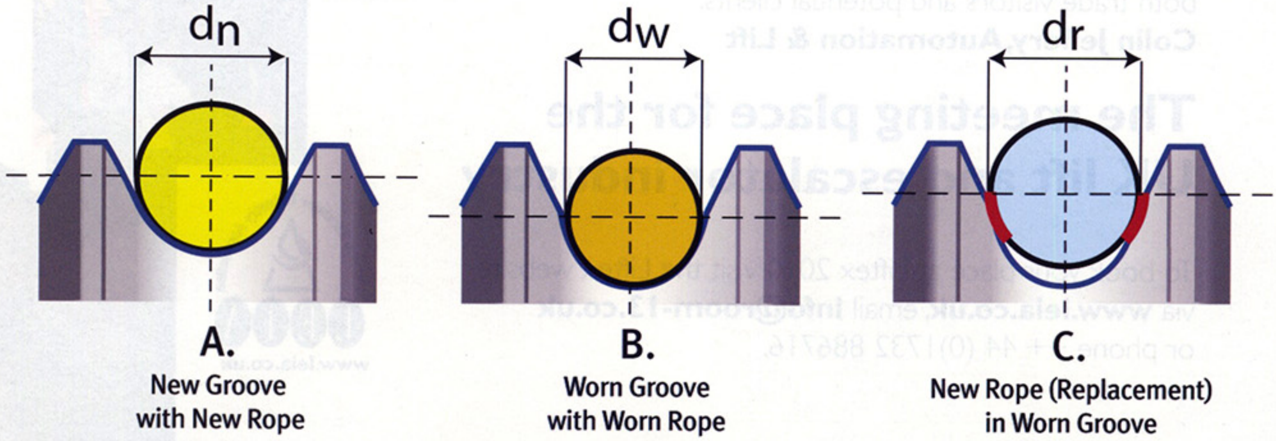

Figure 6: The evolution of crown wear starts as a rope naturally loses diameter over time and settles lower into a groove, creating a newer, smaller channel. The figure at right shows how simply replacing a rope leads to surface abrasion, (crown wear) and continues the cycle of rope/groove degradation. The red area in the far right indicates pinch points in the groove.

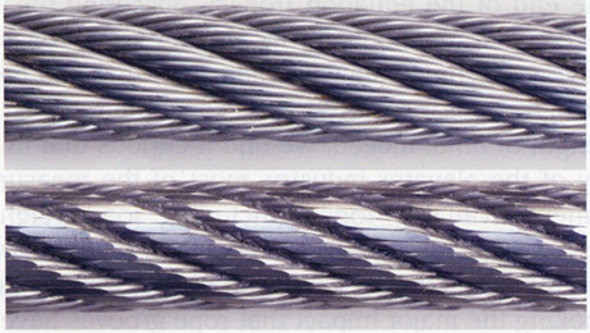

Figure 7: The excessive crown wear shown in the bottom sample of an 11/16-in., 8 X 19, RRL rope (taken from a double-wrap drive sheave) is easily visible in this close-up. Notice the polishing or abrasion of the individual outer wires themselves.

tions. Producing ropes with lower-tensile outer wires definitely creates a reduction and significant compromise in the life and durability of the ropes and sheaves, the key working parts of the elevator hoisting system. Even further, a safety issue may arise if ultimate breaking loads are threatened or compromised by this practice.

The reality of the situation is simple and unavoidable: hoist ropes (even pre-stretched ones) become smaller in diameter due to the natural strains and stresses that comes from continuous elevator usage. And the impact of those ropes upon the sheaves (and then the sheaves upon the ropes) can only be ameliorated through regular, effective, vigilant maintenance. Unfortunately, however, a fair number of industry professionals choose to merely replace the worn ropes without addressing the important underlying problem of unequal groove depths. Consequently, any newly applied rope ("A" in Figure 6) placed within the previously damaged groove will be pulled into a narrower channel ("B" in Figure 6), causing the rope's outer wires to become pinched, its cross section distorted and the outer strands to show very aggressive signs of abrasion ("C" in Figure 6). Remember that the different elongations of the rope created by the unequal loading of car and counterweight must be accommodated as the rope moves over the drive sheave. This rope "creepage" causes wear on both ropes and sheave.

A Rule Of Thumb Approach To Understanding Rope Life*

Sets of Hoist Ropes	*Bending Cycles (Estimated)*
New Installation: Original Set	16,000,000
1st Replacement Set	8,000,000
2nd Replacement Set	4,000,000
3rd Replacement Set	2,000,000
4th Replacement Set	1,000,000

Table 5: * = system wear and degradation with no parts replacement or maintenance other than changing ropes

Figure 8: A complete set of ropes showing dramatic, heavy crown wear

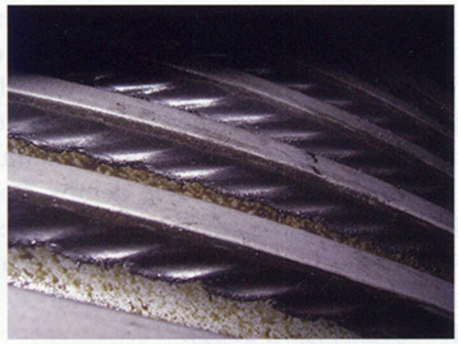

Figure 9: The rope imprints and patterns visible in this close-up of the surface of a secondary sheave is evidence of the impact of simply replacing ropes but not re-machining the grooves or replacing worn sheaves. This, in turn, leads to following generations of progressively and multiplicatively shortened rope life, no matter what rope is selected in the future.

The source behind the quantities of filings that professionals find around the machine at many installations is this constant rubbing from the ropes having to move about in sheaves with unequal groove depths. The filings are minute remnants of the rope wires and the sheaves as they have been pulverized by the aforementioned constant sliding action.

Some may argue that we are overstating the problem, but one needs only look at Tables 5 and 6 as they illustrate how successive generations of ropes placed on sheaves with unequal groove depths can have their life

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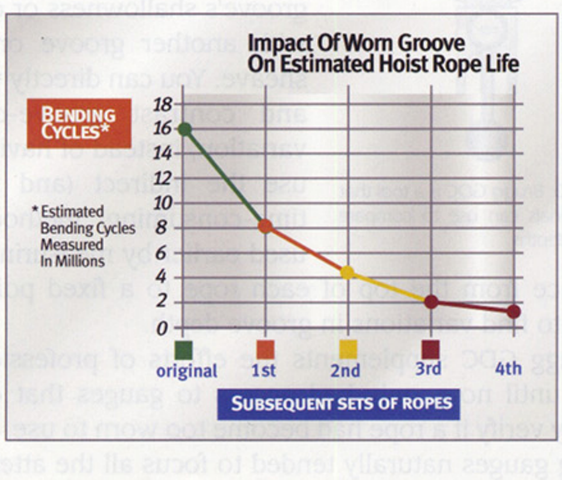

Table 6

expectancies negatively impacted in an inversely exponential manner. This is objective evidence, not subjective hearsay, detailing how progressive rope generations could wear out in a few short years or even months, instead of the rope lasting years, as many would like to expect.

Looking behind the Obvious

Nothing we have said on this topic is dramatically new. Until now, the only palliative rope manufacturers could offer have been instructions on rope installation, better maintenance procedures and general admonitions to professionals to lubricate their ropes regularly or equalize rope tensions.

Certainly, these are helpful guidelines, as these factors can and will contribute to even more dramatic reductions in rope life. However, until recently, it was difficult to simply, objectively and empirically show how hoist ropes can be destructively impacted by the effect of multiple key variables, including variable groove depths. Fortunately, this has changed with the recent codified presentation of Brugg RLP, based upon the work of Dr. Klaus Feyrer in his book *Wire Ropes: Tension, Endurance, Reliablity* (ELEVATOR WORLD, April 2009).

RLP permits a professional to quickly and easily ascertain which rope works best in a prospective installation, how that choice will impact budget outlays for maintenance over time, then accurately calculate how many cycles that rope could safely reach before it will have to be replaced. With RLP, the user can manipulate key system variables and create scenarios to better understand their impact upon rope longevity.

Additionally, Brugg has created a unique groove-depth comparator (GDC) device. Able to be used with a variety of common rope sizes (including 5/8-in. (16.0-mm) and 1/2-in. (12.7-mm) ropes, the device directly and accurately measures groove depth and then compares a particular groove's shallowness or depth with another groove on the sheave. You can directly verify and contrast groove-depth variation, instead of having to use the indirect (and more time-consuming) method we used earlier by measuring the distance from the top of each rope to a fixed point in order to find variations in groove depth.

Figure 10: Brugg GDC is a tool that professionals can use to compare groove depths.

Brugg GDC supplements the efforts of professionals who, until now, only had access to gauges that could merely verify if a rope had become too worn to use. Measuring gauges naturally tended to focus all the attention on one end of the equation (ropes), obscuring the fact that one could not simply throw another set of ropes on a sheave (sometimes many decades old) that had never been re-grooved or replaced and expect them to last for any length of time. Indeed, we find it curious that in the history of the elevator industry, most of the measuring equipment available today (including load-weighing devices and tension-equalization devices) tends to focus only on ropes and their potential problems, while entirely overlooking the major impact that rope grooves have on rope longevity.

Why Is There a Mystery at All?

Naturally, this begs a question: Why did industry professionals simply assume that any evidence of rope failure was apparent proof that the ropes themselves were the major cause of breakdowns, or that rope design and manufacture were flawed? Why has the industry, despite white papers in the trade publication, numerous educational seminars and years of face-to-face meetings with rope manufacturers, tended to largely overlook the contribution that sheaves have to the problem, and (more specifically) be blind to the consequences that sheave groove-depth variation has upon the rise in incidents in elevator breakdowns? Perhaps it is for no other reason that until RLP, it was too expensive for many to perform the complex analyses it took to see the whole picture. Or, perhaps, it was simply due to a lack of communication between sheave manufacturers and rope providers and an inability to move beyond past recriminations. But this does not begin to explain why industry professionals have tended to accept ropes as the "red herring" and not question the matter further. Unfortunately, this is the real world, and there are some other overarching reasons.

Cost

Today, for many, cost is the overriding factor when it comes to making decisions on how to best maintain both old and new elevator installations. And, since (arguably) very few maintenance professionals can count on possessing long-term contracts with building owners anymore, they must economize where they can and maximize their productivity as much as possible. While this does not mean that professionals give any less care to maintaining installations, it does lead to a natural inclination for some to not look too deeply for potential problems. It is a rare professional who looks forward to going to a building owner (who has neither the time nor the inclination to listen to theories on what could happen) to try to convince him or her to spend more money than had ever anticipated on an installation that may be many decades old. When confronted with the choice of spending thousands by simply hanging a new set of ropes, or of spending tens of thousands more replacing or re-grooving

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the sheave, the building owner actually has very little choice. While the building manager may consider this to be simply a case of being budget conscious or cost effective, we see it as failing to see the big picture and consider the total cost. At the very least, it is a bandage solution that will cost more in the long term. If one looks at the statistics of how many times elevators are re-roped, versus how many times the sheaves are re-grooved, it may be easy to assume incorrectly that (once again) ropes are unequal to the challenge of today's elevators.

Understandable or Realistic Indifference

Today's elevator maintenance professionals are well-trained, reliable experts whose job is to address problems as quickly and as profitably as they can for their companies. While they are well versed in procedure, sometimes they lack an overall understanding of how all the mechanical parts of an installation interact together and affect each other. So, seeing ropes with crown wear and finding sheaves that bear imprints, they logically see ropes as the ultimate culprit.

While this situation may be alleviated somewhat through the efforts of trade publications providing continuing-education articles for their readers, it takes an active effort by professionals to keep up with new trends, products and findings in the elevator industry. This is not easy, and, to be frank, can be boring at best. If industry professionals feel their time and interest will only be rewarded by tightened maintenance budgets and labor cuts, they have limited incentive to learn. Therefore, it is easier to go on believing in the old ideas regarding ropes, instead of knowing any better. Indifference may not be bliss, but it requires less effort and seemingly less sacrifice.

Distrust

In any audience, there will always be some who will not believe technical articles and discount personal demonstrations provided by rope manufacturing representatives as simply biased presentation. This is understandable. Both sheave and rope manufacturers may have not cooperated together to address the matter. Though Brugg cannot accept full responsibility for a standing problem, we as a rope manufacturer must admit a certain element of culpability. This was a mistake. So, both sides should not be surprised when consumers, presented with solid technical data, would review the results skeptically and with a little suspicion.

Who Is Guilty?

In the long run, any failure to recognize the truth means everyone's guilty. As we have shown, the evidence against hoist ropes being unable to withstand modern stresses or handle today's modern elevators is open to some interpretation. In fact, a mere surface examination (without examining sheave groove depth) of ropes with crown wear could (and has) lead to the incorrect assumption that the ropes are the culprit.

In the final analysis, this may not be a case of being able to identify a single suspect behind diminished hoist-rope life. Instead, this may be a situation where multiple suspects, all acting together, had a role to play. Choosing to blame ropes, or automatically changing them with no consideration made to important factors like sheave groove condition, continues a pattern that leads to failure and increased long-term cost. It is time for professionals to look beyond the red herring and do a little more sleuthing.

For those who have invested their valuable time and managed to read this far, we remind you that there is more than a handful of other hoisting-system impacts that will reduce the life of a set of ropes (and notably, we have seen examples of ropes lasting less than two years). This has been studied and documented, and there is agreement that some problems may not be associated at all with the manufacturing quality of the ropes. These include:

- Installations with unusually high rates of usage exemplify that with steel-wire ropes, the number of bending cycles leads to wear and fatigue. Timeframes in these cases are less relevant.
- Much higher radial and bending pressures related to smaller mass in systems (working now at the lower end of code-allowed D:d ratios) have a big impact on rope wear.
- Increased loading of the individual ropes in the system – again because of cost, working at the lower end of load safety factors
- Higher acceleration and deceleration to deliver the "service" customers are demanding (which usually means fewer elevators or "under elevatoring" and a further contribution to high usage rates)
- More aggressive groove profiles (undercut U- and V-grooves) are needed to increase traction with fewer hoist ropes (moving closer to minimum safety factors) and less rope to sheave contact area (using a smaller D:d ratio).
- Cost, time and competitive pressures potentially reducing the quality of some components (such as sheave castings)
- Time and cost pressures during installation – shortcuts are taken (i.e., failing to tension ropes/equalize the load)
- Less than optimal performance of maintenance and service activities (i.e., lubrication, monitoring bearing wear, etc.)

A little bit of effect from each of these factors or a bigger effect from a couple of factors will yield a dramatic effect on rope life and performance.