

# Steel Wire Ropes for Traction Elevators: Part Three

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## Learning Objectives

After reading this article, you should:

- ◆ Realize that ropes should be stored dry, frost free, dust free and protected against condensate.
- ◆ Understand that opposite bending, horizontally running, lateral deflection and uneven tension levels reduce the service life of elevator ropes.
- ◆ Learn that wire ropes settle after installation and, in so doing, do not have a constant elasticity modulus.
- ◆ Realize that elevator ropes should be re-lubricated after a certain number of journeys.
- ◆ Understand that elevator ropes are discarded due to wire breakage, wear, diameter reduction or corrosion.
- ◆ Learn that when changing the elevator ropes, the groove profiles of unhardened traction sheaves should always be re-measured.

## Elevator Ropes in Operation

### Storage

Elevator ropes are made up of bright wires that are unprotected against corrosion. In order to achieve slip-free operation in the elevator, they are given a relatively minimal coat of lubricant. Consequently, over extended periods of storage prior to installation, ropes should be protected against corrosion. Ideally, they should be stored in a dry, frost-free and dust-free environment. Contact with cement dust or sand should be avoided, in

particular. When covering ropes for their protection, care must be taken to ensure adequate ventilation in order to prevent condensation. For instance, storage where temperature conditions fluctuate should be avoided.

### Unrolling for Mounting

The ground rules for rope mounting must be observed without fail. By removing rope from the side via the reel coupling or from the coil strap, it is uncoiled or coiled, depending on the direction of lay. This twisting action brings about a change in the rope structure that cannot be corrected. In the case of ropes with steel cores, this type of forced rotation creates uneven strand lengths. The result is an uneven distribution of load in the rope bundle and the emergence of strands that have been extended beyond their normal length (Figure 23).

### Kink Formation and How It Can Be Remedied

Carelessness (during, for example, unrolling) can cause internal torsion (twist) in the rope. This, in effect, turns the rope into a braid that can only be remedied by its end being turned. Violent rotation at the braid itself or pulling on the rope will nearly always culminate in the formation of a kink. The resulting damage makes the rope unusable, and it must be replaced (Figure 24).

### Untwisting

Where long lengths are involved, a rope can untwist under its own weight when hanging freely in the shaft without having been secured against rotation. The same effect occurs if the rope is pulled upward using a thin auxiliary rope. Lang-lay

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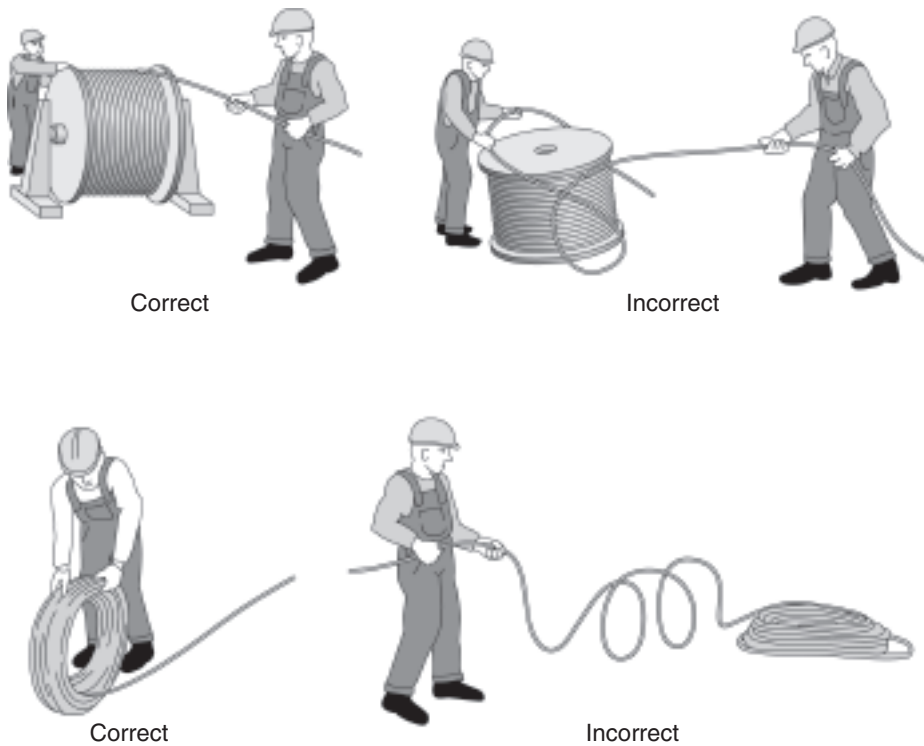


Figure 23

ropes, ropes with steel-wire cores and (in particular) double parallel ropes are especially susceptible in this context. They react extremely sensitively if commissioned when in this condition. The loosened rope is incapable of absorbing loads evenly distributed over all the rope elements as intended by the design, and can be destroyed as early as the first load cycles. Consequently, this type of rope is supplied with a marking line that makes incorrect rotation easily recognizable and provides a way of realigning ropes during installation.

**Hidden Dangers Inherent to Rope Installation**

Sharp concrete or steel edges represent a major hazard for ropes. If they are drawn over this type of edge under load (and, in some cases, the intrinsic weight of the rope can be sufficient), they will sustain permanent damage. This type of damage is evident in the rope when in an unloaded condition. It will show a corkscrew-like deformation that, when under load, is almost impossible to detect. To avoid this hazard, rollers

(or at least rounded wooden beams) should be used for rope deflection.

Sandy or dusty surfaces are highly damaging for ropes. The lubricant on the surface of the rope sticks to the loose dirt particles and forms a rough layer, which damages both the rope and sheaves during operation. This effect can also compromise smooth running, as large dirt particles can cause the ropes to run unevenly off deflection and traction sheaves, resulting in rope vibrations.

Some forms of damage caused by unsuitable installation methods only become evident after a relatively short period of operation. The ropes demonstrate horizontal wear lines in parallel formation in certain areas, while other parts of the rope are almost intact. One cause for this phenomenon is the use of an unsuitable fixture for tensioning the ropes: for example, in order to measure the weight of the car or counterweight. The resulting rope deformation (and, in certain circumstances, additional kinking) result in local damage in the form of wire break nests, rendering the rope open to immediate replacement.

**How Drive Arrangement Affects Ropes**

Let's assume that the elevator drive system is arranged as shown in Figure 25 for a variety of reasons. The reduced space requirement comes at a price: the ropes are bent in opposite directions, which severely compromises rope service life.

Another problem inherent in this arrangement is brought about by its horizontally running ropes, which have a tendency to vibrate. The energy of this vibration is concentrated at the point at which the ropes run onto the sheaves, increasing the internal mechanical tensions in the rope. This additional stress results in premature fatigue of the wires, culminating in wire breakage. The vibrations occurring in the horizontal area of the rope following deflection produce vertical vibration of the car and counterweight, creating an obvious detrimental effect on ride comfort.

In the case of elevators with a 2:1 suspension, the individual deflection sheaves are rotated by up to 90°. Depending on the construction and the resulting deflection points, the ropes may have a tendency to vibrate and impact each other. This type of impact does not necessarily result in a reduction of service life, but it does create perceptible noise to passengers in the elevator car. Another problem encountered by ropes is lateral deflection when running over a sheave.



Figure 24

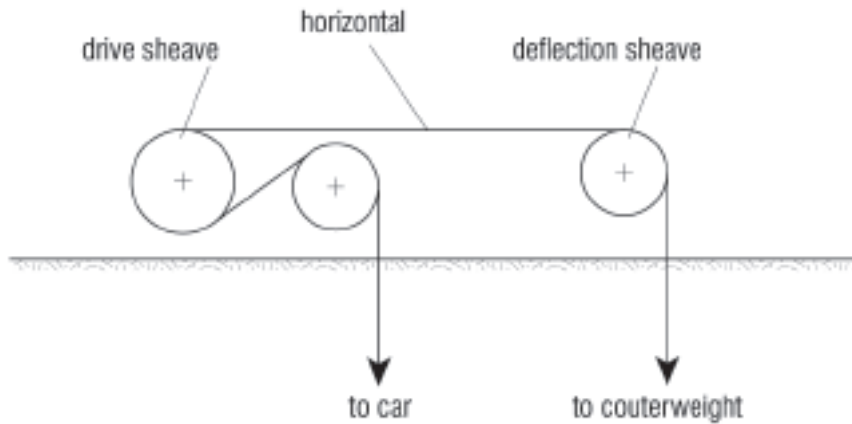


Figure 25: The laterally positioned machine

The ropes do not make central contact with the deflection sheaves, but are slightly offset. Depending on properties of the grooves such as aperture angle and surface roughness, this causes the ropes to rotate. The possible reaction of the rope to this phenomenon is influenced by its structure (Lang lay or regular lay). Under unfavorable circumstances, a Lang-lay rope can become untwisted, whereby the strands also offer no resistance to the rotation. In the worst-case scenario, a regular-lay rope can be untwisted to the point where the wires in the outer cores block this rotation process. Although, comparatively speaking, this is the less critical of the two situations, it should also be avoided.

When using ropes with a steel core, assessment of the external torque must be carried out in a similar way. A rope with an independent wire-rope core (IWRC) will always work against torque effect, either by means of the inner or outer section. In the case of parallel-laid, full-steel rope cores (PWRC) under unfavorable circumstances, the rope bundle can be permanently destroyed, resulting in strands emerging from the inner section of the rope. Once again, this risk highlights the urgent necessity for securing ropes against rotation in an elevator installation at the end termination points.

### Lateral Arrangement of the Traction Drive

Positioning the machine laterally at the bottom results in more pronounced rope deflection than is the case with the machine positioned above. Due to the extreme rope length, more frequent shortening may be anticipated. The high number of sheaves required exerts a negative impact on service life. According to EN 81-1, all sheaves traveled over by the same section of rope that also runs over the traction sheave count.

Positioning the machine laterally at the top reduces the necessary rope length as compared to that of a bottom-positioned machine. This benefit is countered by the fact that with this drive arrangement, all the sheaves must be taken into account when calculating anticipated service life. In installations entailing particularly "angular" rope guidance with a correspondingly high number of sheaves, deficiencies can arise in terms of traction. Although this does not bring about uncontrolled car movement, it does cause occasional slip of the traction sheave under the rope.

### How Rope Tension Affects Elevator Ropes

When designing and calculating elevators, the assumption is made that all the ropes proportionally transfer the same tensile force. In practice, this hardly ever happens. Deviating relative rope tensile forces



Figure 26: Rope Tensile Force measurement

are practically unavoidable. In installations involving great shaft heights, the frequently deployed method of pulling or pushing on the rope is no longer adequate. Newly developed rope tension measuring devices that offer a method of adjusting the rope tensile force to an even level can provide assistance. Uneven tension levels bring about different degrees of contact pressure on the grooves of the traction sheave, resulting in corresponding differences in rope slippage. In some cases, this brings about uneven wear in the grooves and ropes. Consequently, all ropes should be tested for even load after an initial operation phase. This inspection should be carried out after four to six weeks. In some cases, delaying this inspection has resulted in premature wear of ropes and/or sheaves (Figure 26).

### Rope Vibration

Rope vibration brings about noise in the elevator and a possible reduction of service life. Transversal rope vibration for a vibrating wire can be approximately calculated using the following formula:

$$f[\text{Hz}] = \frac{n}{2 * l} * \sqrt{\frac{F}{q}}$$

- $f$  = vibration frequency
- $n = 1, \dots$  basic vibration
- $n = 2, 3, \dots$  (for harmonics)
- $l$  = length (m)
- $F$  = rope force (N)
- $q$  = weight per meter of rope (kg/m)

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This type of transversal rope vibration (as described in the context of drive-position-related issues) is caused by factors such as horizontal rope alignment or deflected rope paths. Conversely, vibrations in the direction of the rope axis are caused by stick-slip rope movements on the traction sheave, caused in turn by pitch errors generated by the drive system or the motor. The interaction between the rope and groove geometry when the rope runs off the traction sheave can also bring about vibrations.

**Elimination/Reduction**

Initially, installation should be inspected to ascertain the condition of rope lubrication and equal tensions on the ropes, and corrected if required. Another check refers to measurement of the running diameter of the rope in the traction and deflection sheaves. Slight eccentricity (ovalization) can result in an intrinsic vibration from the ropes when combined with any unfavorable deviation in the grooves. The loss of ride comfort this causes will be clearly noticed.

A vibrating system can be “retuned” using certain measures, such as selecting a higher weight per meter or changing rope rigidity. Replacing an 8 X 19 construction with fiber core with 6 X 19 ropes with fiber core has often proved a successful remedy for this problem.

**Rope Elongation**

Rope elongation is one of the most frequently misunderstood terms and the cause of much confusion. This is because there is no existing unequivocal elasticity module for ropes that can predict the elongation of the rope over its complete service life. In addition, the question of rope elongation can arise in connection with elevators for different reasons, such as:

- ◆ Rope shortening in connection with initial elongation
- ◆ Adjustment work while loading and unloading the car to ensure floor leveling between the car and landing entrance

- ◆ Vibration of the car or counterweight in the context of acceleration/deceleration
- ◆ The elongation behavior encountered with even identical rope constructions is largely dependent on the competence of the manufacturer and can vary tremendously.

**E Modulus**

The modulus of rope elasticity (E modulus) is frequently the subject of inquiry. Its determination begins with the measurement process performed on new ropes. In it, ropes are subjected to continuously increasing loads that reach up to 10% of its minimum breaking force. At the same time, the degree of elongation is recorded. The result of this loading process is the first curve shown in Figure 27. After releasing the load on

the rope to the starting value, 10 loading cycles are generally executed, at up to 50% of the  $F_{min}$  with a subsequent release of the load (right-hand section of Figure 27). The purpose of these loading cycles is to settle the ropes, and they are not recorded.

The pitch of the curves between two load points is frequently determined as the E modulus. A comparison between ordinary- and Lang-lay ropes is provided in Figure 28. The significantly higher elongation of the Lang-lay construction is clear. This is particularly noteworthy when considering the fitting of this rope in the case of extreme shaft heights/rope lengths. The smallest elongation is provided by steel ropes as shown in Figure 29 in comparison to an 8-strand fiber-core rope.

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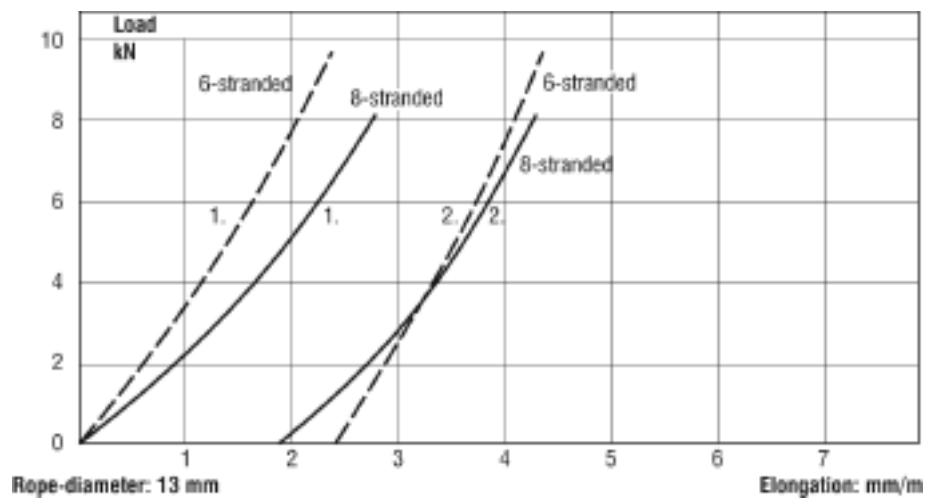


Figure 27

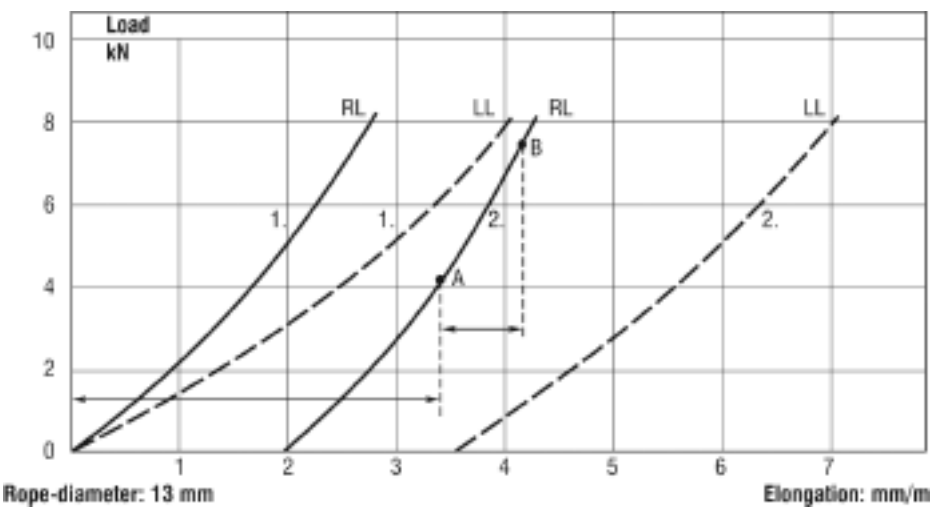


Figure 28

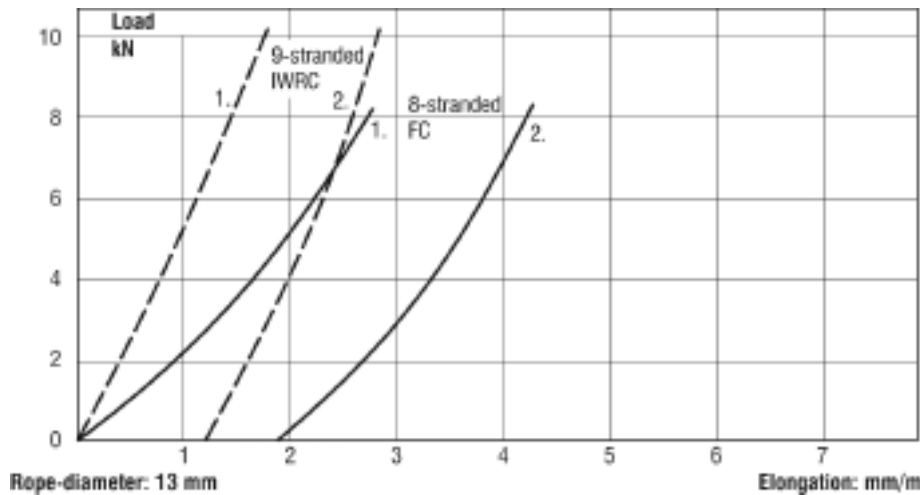


Figure 29

In Tables 1-3, two measurements are entered for comparison. These relate to a six-strand and an eight-strand rope, respectively, with fiber cores. The higher metallic cross-section of the six-strand rope clearly results in lower elongation under the same load conditions. The final load, once again at 10% of the minimum breaking force, is fully documented the same way as the first curve. This is shown in the right section of the diagram. The smallest elongation is provided by full-steel ropes, illustrated in the final diagram in comparison to an eight-strand fiber-core rope. The breakdown in Table 5 is a recommendation based on empirical values and intended as an aid in selection of the most suitable rope configuration.

Table 1: Traction Elevators					
Rope Length	Rope Configuration			With High Comfort Expectation	Complex Rope Guidance
	Frequency of Use				
	Low	Medium	High		
Up to 40 m	A	C	C	D	E
Up to 100 m	C	D	E	E	E
Greater than 100 m	D	E	E	E	E

General requirements: precisely metered lubrication due to traction drive, narrow rope diameter tolerance and strength of outer wires in lower range of tolerance field

**Shortening Ropes after Installation**

The horizontal distance between the two measurement curves is explained by the so-called initial elongation of ropes. This is an irreversible process. In an elevator, this elongation is the reason for the necessity to shorten ropes following installation.

A distinction must be made dependent on rope construction. A class 6 X 19 rope with fiber core has a slightly lower permanent elongation (0.45-0.75%) than a class 8 X 19 rope with fiber core (0.55-1.0%). In the case of IWRC, this value depends on the re-

spective rope structure and generally lies between 0.15% and 0.35%.

This type of universally applicable guide is subject to the proviso of a "normal" loading of the rope. It is almost impossible for the rope manufacturer to predict beyond this guide, as this can only be determined from the operation of the elevator installation. The elongation behavior of ropes depends on the load range in which they are operated. Where extreme lifting heights are involved, the intrinsic weight of the rope also has a role to play.

**Table 2: Roped Hydraulic Elevators**

For Service Life and Maintenance	Rope Configuration		
	Frequency of Use		
	Low	Medium	High
Good Solution	F	F	G
Better Solution	-	G	J

General requirements: well but not liberally lubricated, higher nominal wire strengths possible (as high breaking force is particularly desirable in this case) and rope diameter tolerance for non-elevator ropes = -0 +5%

**Table 3: Tensioned Balance Ropes**

Rope Diameter	Rope Construction
Up to 24 mm	K
Greater than 24 mm	L

General requirements: well (but not liberally) lubricated, no high breaking force required (with total breaking force of balance ropes smaller than that of suspension ropes), rope diameter tolerance for non-elevator ropes, fiber core (due to rotation tendency of balance ropes), fiber core made from synthetic material (as ropes with fiber core made from natural fiber react to high levels of humidity with a change of length), and not regular-lay ropes

**Table 4: Ropes for Overspeed Controllers (Governor Ropes)**

Required Rope Grade	Rope Construction		
	Normal	High	Very High
Rope Construction	M	N	P

Requirements: precisely metered minimal lubrication; galvanized with synthetic fiber core for humid conditions:

**Spring Deflection of the Car under Load**

The pitch of the curves depends on the relevant E modulus of the ropes. Elongation is then only dependent upon the load. This characteristic of ropes, termed elastic elongation, provides a measure for the frequency of readjustment following car loading and unloading. The competence of the rope manufacturer is tested by these two characteristic values. A high degree of permanent elongation generally gives rise to the need for several (costly) rope-shortening processes.

"Direct" connection of the car to the traction sheave using ropes that demonstrate minimal elongation under load is mostly synonymous with a high level of ride comfort. The transition from an 8 X 19 rope with

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**Table 5: Stability of Rope Constructions for the Individual Rope Configurations of Tables 1-4**

Rope Construction	Corresponding Special Drako Elevator Rope	Benefits	Drawbacks	Recommended Rope Configuration				
				Rope Grade				
				1370 / 1370/ 1570	1370/ 1770	1570 / 1570/ 1770	1770	1960
Six-strand with fiber core	6 X 19 Seale + FC	Insensitive to mounting; price	With increasing diameter, rigid to very rigid; also see 6 X 19 Warrington	–	–	M	N	–
	6 X 19 Warrington + FC	Compared to eight-strand ropes, greater breaking forces; for semi-circular grooves, service-life improvement over 6 X 19 Seale	Sometimes causes vibrations and heavy groove wear when used with V grooves and undercut grooves.	–	A	A M	F N	P
	6 X 25 Filler + FC 180 B*)	The fiber core makes the balance rope less susceptible to the frequent occurrence of rope rotation due to the relatively weak rope tension.	With full-steel upper ropes, more or thicker balance ropes are required for weight compensation.	K	–	K	–	–
	6 X 36 Warrington-Seale + FC 180 B*)			L	–	L	–	–
Eight-strand with fiber core	8 X 19 Seale + FC or 8 X 19 Warrington + FC or 8 X 21 Filler + FC	Universal rope for normal elevators; insensitive to mounting; adjusts to slightly worn grooves; medium price range	Low breaking force; more rope elongation due to larger fiber core; consequently faster rope diameter reduction than with 6 X 19 and full-steel ropes.	–	C	C	–	–
	8 X 25 Filler + FC 200 B*	See 180 B.	Lower weight per meter than 180 B	K	–	–	–	–
Six-strand with steel core	6 X 19 Seale or 6 X 19 Warrington + IWRC	Only for governor ropes with higher breaking force requirement	Higher price than 6 X 19 + FC	–	–	P	–	P
	DRAKO STX	Suspension rope with high breaking force (d 6 mm)	Higher price than 8 X 19 + FC	–	–	–	–	D/E
Full-steel rope; eight-strand with steel-wire core	DRAKO 250 T	High breaking force; more liberal greasing; lower elongation; fewer rope shortening processes	Higher price than 8 X 19 + FC	–	–	D P	–	–
	DRAKO 210 TF	High breaking force; easily increased transversal elasticity		–	–	D	–	–
	DRAKO 250 H	Increased breaking force; low rope elongation; fewer rope-shortening processes; less-frequent re-lubrication	Higher price than 6 X 19 + FC	–	–	–	G	–
Full-steel rope; nine-strand with steel-wire core	DRAKO 300 T	High breaking force; low rope elongation; very good service life	Higher price than DRAKO 250 T	–	–	E P	–	–
	DRAKO 300 H	Increased breaking force; otherwise, see DRAKO 300	Higher price than T.DRAKO 250 H	–	–	–	J	–
Special group of full-steel ropes in double-parallel design		Extremely high breaking forces; in some cases, very high bending strength in laboratory testing	Extremely careful installation is required for rope lengths as short as 40 m	No general recommendation is possible, as suitability is strictly manufacturer dependent.**)				

\*) Special weight compensating ropes for elevators, for exclusive use as tensioned balance ropes

\*\*) The longer the period for which this type of rope construction has proven successful in the market, the more likely it is to demonstrate good suitability through application type C.

fiber-core construction to a rope with a steel-wire core reduces elastic rope elongation by approximately 50% if the other installation parameters are kept constant. This notable difference is primarily the result of the different E modulus, and secondarily of the far larger metallic rope cross-section with steel core.

When considering spring deflection of the car, it should also be borne in mind that the elasticity of the car frame and compression of the springs exert an additional influence.

Note that should the elongation behavior of ropes be contrary to experience gained in application, a check should be performed of whether this could be due to an installation error – in this case, untwisting of the rope. Rope end terminations that have not been secured against rotation can also be the cause of untwisted ropes. In particular, ropes with steel-wire cores demonstrated substantially higher elastic elongation when untwisted, as the outer strands were loosened and the load increasingly suspended only on the steel core.

The rumored practice of “improving” the elongation behavior of ropes by simply twisting them (even if they are flawlessly installed) is highly inadvisable and should not be used. Although it can actually reduce rope elongation, this practice can also drastically reduce rope life.

### **Rope Re-Lubrication**

Elevator ropes are lubricated during manufacture in order to prevent corrosion and abrasion. However, only enough lubricant to ensure that the elevator operates with sufficient traction and without slippage should be applied. As lubricants also tend to bind dust and abraded particles, however, this initial lubrication is hardly ever sufficient to be effective over the entire service life of the rope. It is, consequently, advisable to occasionally re-lubricate elevator

ropes. As long as wiping a finger over the rope shows a faint smudge, there is no need for lubrication.

### **Applicable Criteria**

It is not possible to provide any definitive statement in respect of re-lubrication intervals, as they depend on:

- ◆ The frequency of elevator use
- ◆ The environment (temperature, presence of dust, etc.)
- ◆ The sheave material and sheave wear: hardened traction sheaves require more re-lubrication, as no graphite is released from the sheave as a result of wear.
- ◆ Slippage between the rope and sheave

### **Methods**

Re-lubrication using fluid lubricants can be carried out using a can of lubricant and a paintbrush or decorator's roller. Lubricant spray should only be used for short ropes. In any case, only very minimal quantities should be applied, after which the elevator should execute several complete round trips, while attention is paid to the slip behavior. Afterward, additional lubricant can be added if necessary.

If there is any doubt whether the rope still has adequate traction after re-lubrication, carry out a complete round trip before and after re-lubricating: take the car completely up, make a joint chalk mark across the rope and elevator, then take the car completely down and back up again; there should be no major offset between the chalk marks.

Permanent lubrication devices can cause problems when used continuously and with installations in which there is little lift-system traction in reserve.

### **Lubricant Properties**

Lubricants should not be too low in viscosity but have sufficient penetrative capability to get inside the rope. The most suitable lubricants are rope lubricants diluted with solvent.

Using them with caution (including good ventilation) and avoiding excessive application (as a solvent that has not quite evaporated compromises traction) is the ideal combination.

In some countries, re-lubrication agents containing solvent are prohibited for occupational safety reasons. Hydraulic oils or worm-gear oils are unsuitable. Lubricants with particle content (such as molybdenum sulphide or Teflon® particles) are also unsuitable for traction elevators, as these agents can reduce the friction between rope and groove to a high degree.

Ropes for roped hydraulic elevators and compensating ropes should be more heavily lubricated. This type of rope may only be re-lubricated with suitable lubricating grease, as in this application, the precise amount of lubricant is not as critical as it is with traction sheave ropes. Generally speaking, however, customary lubricating oils for traction sheave ropes would also be used in these applications.

### **Lubricants for Unusual Elevator Installations**

For humidity in the shaft, no special precautions need be taken, only more frequent checks. If applicable, use galvanized ropes.

In outdoor elevator installations, apart from installations in extremely dry climates, use galvanized elevator ropes. The basic lubrication provided when the ropes are manufactured should not be normal rope lubricant (which can be washed away by water) in this case, but a water-resistant medium. Special types of lubricant exist for this purpose. Re-lubrication, essential for galvanized ropes, should be performed without fail using lubricants containing solvents. These should be applied during cooler weather (as the solvent should not evaporate as quickly) and after extended dry periods. Continued

For installations operating in high- or low-temperature environments, remember that no special measures are required for temperatures ranging between 0°C and 50°C. Where temperatures are constantly between 40°C and 50°C, the condition of the lubrication should be checked at more frequent intervals, as the lubricant becomes less viscous and is, consequently, used up faster. The lubrication effect is also less pronounced.

**Lubricant in the Fiber Core**

Requests are sometimes made for the fiber core, during manufacture, to be provided with a lubricant that will last for the lifetime of the rope. It would be an easy matter for a rope manufacturer to inject a generous helping of grease (for instance, 25%) into the fiber core. However, far from the desired effect of providing gradually metered lifetime lubrication, the excess grease would seep out within just weeks of fitting the rope. However, the main reason for carefully limiting the grease content of the fiber core becomes evident upon studying Figure 30, which illustrates the cross-section of a new, unloaded 8 X 19 Seale. The outer strands are supported on the fiber core; the rope diameter is consequently determined by the volume on the inside of the rope (fibers and grease).

As the life of an elevator rope is closely linked to its effective rope diameter, it is essential for the fiber core to maintain its volume for as long as possible. Consequently, re-

lubrication should be performed from the outside in such a way that lubricant also penetrates the fiber core.

**Degreasing Over-Lubricated Elevator Ropes**

One possible cause of excessive rope slippage on the sheave can be over-lubrication. Under no circumstances should an attempt be made to wash ropes using cleaning agents or solvents. The solvent penetrates the rope and draws a greater amount of lubricant toward the outside. The method of external degreasing was developed over 30 years ago and has been very successful in solving problems. It uses very fine, neutral-reacting, powdery quartz flour.

This powder can be ordered as Florideal and applied by forming a funnel shape with gloved hands, filling them with the powder and slowly dusting the ropes in a downward direction from the traction sheave, with the machine positioned at the top. The powder absorbs the oil/grease. The dried mass then crumbles away. Brush away the remains of the powder/grease mixture using a wire brush. The sheaves should also be cleaned, possibly using solvent.

**When to Discard Elevator Ropes**

Elevator ropes are normally discarded due to wire breakage, wear and diameter reduction. However, other discarding criteria such as corrosion or excessive elongation can also take effect.

**How Many Wire Breaks Are Admissible?**

The number and distribution of externally visible wire breaks are the most important criteria when it comes to detecting when an elevator rope should be discarded. This is quantified by a count of the maximum number of visible wire breaks over a reference length of the rope. According to ISO 4344,<sup>[3]</sup> the maximum number of wire breaks over one length of lay must be determined separately, for all outer strands and

the two most heavily damaged outer strands, and should also be evaluated separately. For six- and eight-strand elevator ropes with fiber cores, ISO 4344 provides an indication of the maximum admissible wire breaks.

For all other elevator ropes, reference is made to the specifications of the relevant rope manufacturer. Taking the number of wire breaks at discard as a reference, it is then possible to determine whether the rope should be discarded immediately, more intensively monitored or continue to be monitored normally (Table 6). To avoid strand breakages and consequential damage, the maximum admissible number of wire breaks must also be examined in accordance with ISO 4344 relative to the crown of a strand.

In old installations in compliance with TRA 102,<sup>[22]</sup> elevator ropes are classified, monitored and discarded under the highest gear drive group of DIN 15020<sup>[23]</sup>/ISO 4309.<sup>[24]</sup> If the outer wires demonstrate heavy signs of abrasion, they are likely to break at these points and in relatively quick succession. If wire breaks are evenly distributed, the residual service life can be estimated relatively easily.

The European Rope Standard EN 12385 Part 3<sup>[25]</sup> refers to ISO 4344 for elevator ropes in this context. In non-European countries, the relevant national regulations apply to determining when a rope should be discarded. The number of wire breaks can sometimes fail as a discard criterion under certain circumstances: wire breaks due to external wear only occur when the sheaves (in particular, the traction sheaves) in a rope drive system are made of gray cast iron or steel. If only plastic sheaves are used, the safety directive for elevators “Plastic Rope Sheaves” must be observed, as here, under certain circumstances, inner wire breaks can occur instead.

*Continued*



Figure 30: Support of the outer strands on the fiber core



**Table 6: Discard Criteria**

Criteria	Discard or examination within the time span prescribed by an expert			Immediate discard		
	Rope grade 6 x 19	Rope grade 8 x 19	Rope grade 9 x 19	Rope grade 6 x 19	Rope grade 8 x 19	Rope grade 9 x 19
Average number of wire breaks among outer strands	More than 12 per length of lay	More than 15 per length of lay	More than 17 per length of lay	More than 24 per length of lay	More than 30 per length of lay	More than 34 per length of lay
Number of wire breaks, predominately in one or two strands	More than 6 per length of lay	More than 8 per length of lay	More than 9 per length of lay	More than 8 per length of lay	More than 10 per length of lay	More than 11 per length of lay
Number of wire breaks adjacent to another in outer strand	4	4	4	More than 4	More than 4	More than 4
Intermediate wire break	1 per length of lay	1 per length of lay	1 per length of lay	More than 1 per length of lay	More than 1 per length of lay	More than 1 per length of lay

Discard criteria for single-layer ropes with fiber cores, according to visible wire breaks

**Rope Discarding Due to Reduction in Wire Diameter**

Due to external and internal wire wear, over long service periods, a continuous diameter reduction can take place in elevator ropes. In ropes with fiber core, this effect is exacerbated by the drying out and abrasion of the fiber core.

With a diameter reduction of 6% relative to the nominal diameter (for example, when a 13-mm rope reduces to 12.2 mm), the elevator rope should be discarded immediately, as:

- ◆ There is a risk of sudden rope breakage, e.g., due to inner wire breakage at the contact points between strands.
- ◆ The traction calculation is based on the fact that the rope fits precisely into the groove. Consequently, the projected traction is no longer provided if the elevator ropes are too thin.
- ◆ Driving grooves abraded by ropes that are too thin are consequently too narrow for new ropes, which are then inevitably damaged.

**Internal Corrosion in Strand Gaps**

If there is evidence of abraded red particles exuding from the rope strand gaps, the rope diameter

should be checked in the affected sections for reduction in diameter. In the case of diameter reductions of less than 4% relative to the nominal diameter, further reduction can be slowed by re-lubrication. Suspected causes for the formation of what is commonly known as “rouging” or “red dust” are insufficient lubrication, incorrect re-lubrication and a damp or aggressive shaft atmosphere.

Where a diameter is reduced by more than 6% relative to the nominal diameter, generally speaking, a rope change is necessary. In this case, the suspected cause for corrosion formation is excessive friction between the outer strands. Normally, the outer strands rest on the rope core, and friction between the outer strands is minimal. However, if the diameter of the rope core reduces due to rope wear, the outer strands begin to mutually support each other, with the result of greater friction between them. The abraded particles produced by this process are not metallically bright, but red-brown in color (fretting corrosion). This abrasion process is known as “rope bleeding.”<sup>[26]</sup> The risk lies in the possible resulting inner wire

breaks, which only become visible after load relief and extreme rope bending (Figures 33 and 34). The long wire break ends are characteristic of this phenomenon.

**Traction Sheaves Groove Shapes**

A distinction is drawn between shaped grooves (V-grooves or U-grooves with undercut) and round grooves. The groove shape exerts not only a significant effect on traction, but also on rope service life. The grooves can become worn with operation and must be subjected to a special inspection when exchanging ropes. New ropes (perhaps those at the upper end of diameter tolerance) will respond to worn and excessively small grooves with a shortened service life. The reason for this is excessive Hertz pressure when a rope with a nominal diameter of 13 mm impacts on a worn groove with a diameter of, for example, 12.7 mm.

Another damaging influence on rope service life is a groove worn to an uneven depth, particularly in drive systems with double wrap. The ropes run at different speeds in grooves with different heights. Because of the difference in height between

*Continued*



Figure 32: Inner wire breaks are visible when stretched.



Figure 33: Inner wire breaks are visible when bent.

the grooves, a slack condition occurs in some of the ropes, which causes excessive slip, indicated in some cases by an audible creaking. In this case, the rope sections between the traction sheave and secondary sheave of the double wrap can be exposed to extremely high “strain tension.”

When changing the rope, the groove profiles of unhardened traction sheaves should always be re-measured. The measurement gauges for the grooves should always be graduated in 1/10-mm steps. It is important that a new rope is not fitted into a groove that has worn to suit the existing ropes, and replacement of the traction sheave should be considered in the following reasons:

- ◆ Evidence of excessive traction caused by the traction-sheave grooves being machined by the reduced diameter of the rope. (For example, the lift car can be lifted upward after the counterweight has been buffered.)
- ◆ Ignoring wear in the traction sheave grooves will seriously reduce the service life of the new ropes.
- ◆ The ropes in question have a fiber or steel core, as steel-core ropes will not adapt to a worn groove profile. Never change only the traction sheave; always change both ropes and sheave to obtain the required service life.

### Re-Machining

During elevator maintenance, it is frequently found that while a sheave may have worked without problems for 10-15 years with its original rope set, after re-machining (re-cutting or re-grooving) and fitting it with new ropes, wear or rope imprints occur at a far faster rate. This was proved as long as 25 years ago by a major car manufacturer with around 700 elevator installations on its plants. It proved that 60% of such sheaves had to be exchanged again after only a year in operation.

### Unhardened Traction Sheaves

The material used to make traction sheaves cannot be easily determined without detailed metallographic examination. However, the hardness of the traction sheave can be measured. Long-term studies have shown that for a sheave with a hardness of up to 180 Brinell hardness (HB), signs of rope impressions or higher levels of groove wear occur. With a groove hardness of 180-195 HB, the probability of this kind of damage occurring is reduced. With increasing groove hardness (to above 200 HB, or better still, over 210 HB), this type of damage pattern becomes highly unlikely.

For GG 25 gray cast iron, the hardness limit achievable using modern foundry methods is around 230 HB. The hardness test should only be executed on the machined surfaces of the casting and by preparing the top layer of the machined surface to any paint or surface imperfections, or the measured results will be incorrect. Pressure produced by the test process must be sufficient to ensure that this prepared surface is penetrated.

Spherical graphite cast iron GGG 60 demonstrates better material characteristics than GG 25, but is also more costly. Experience and analyses gained from expert consultation demonstrate that not only the hardness of the groove, but also the alloy component (such as copper) determine resistance to wear. Wear

characteristics are also influenced by the formation and distribution of the graphite particles in the cast iron. The fact that the sheaves are no longer stored prior to utilization, but machined and mounted immediately after casting can also have a detrimental effect on the material properties.

### Hardened Sheaves

The hardening of V-grooves has been performed in Europe since 1967. Hardened, undercut U-grooves have been a familiar feature since 1978. When using hardened rope grooves, it should be noted that:

- ◆ The profile of the different grooves and groove depth must be correctly matched. If the groove is hardened, the rope is no longer able to help correct the groove.
- ◆ The edges of the undercut must be well rounded; otherwise, two deep wear lines will appear in the ropes.
- ◆ In hardened V-grooves, no dual-tensile ropes with “soft” outer wires may be used – only ropes made of wires with nominal tensile strengths of 1570 and 1770 N/mm<sup>2</sup>.
- ◆ The ropes must be re-lubricated.
- ◆ Ropes that reduce too much in diameter will run onto the edges of the undercut, resulting in insufficient traction.

### Plastic in Traction Sheaves

A plastic or plastic-lined traction sheave (which can radically increase

*Continued*

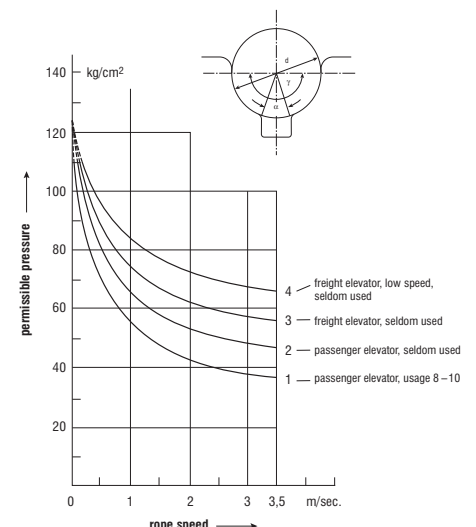


Figure 34: Upper limit of contact pressure in elevator traction grooves

traction) is a practically unknown phenomenon in Europe. It is important to bear in mind that when used with steel wire ropes, determination of the discard age by externally visible wire breaks can be impeded. However, it is also true to say that this material is in use in other countries for sheaves.

While TRA 003 and EN 81/1986 still stipulate a binding requirement for gray cast-iron or steel traction sheaves, specifying a coefficient friction of  $\mu = 0.09$ , in EN 81-1/1998, the required coefficient of friction is specified relative to the nominal speed of the installation. As the standard gives recommendations in this area, if evidence of compliance in terms of safety can be proved, it leaves the door open for the use of alternative traction-sheave materials.

### Contact Pressure

As an important influence on the service life of the rope and traction sheave, too little attention is paid by elevator constructors to contact pressure occurring between them. By adjusting contact pressure (for example, to the frequency of use), it is possible to exert an instrumental influence on load and, consequently, the service life of the rope. However, in EN 81-1/1998, there is no mention of the contact-pressure calculation featured in the previous version of

the standard. From the point of view of the rope manufacturer, this is a major omission. Contact pressure is "indirectly" included in the calculation of the safety factor in accordance with Annex N of EN 81-1. Although focus has correctly been placed on a minimum rope service life, the standard neglects to include an explicit verification of contact pressure. It is possible to state that a configuration in compliance with EN 81-1/1998 permits significantly higher contact pressure than was admissible according to EN 81-1/1986. The fundamental correlation between contact pressure and serviceability was established as far back as the standard reference work on traction published in 1927.<sup>[30]</sup>

### Regulations

Rope manufacturers only have the opportunity to see machine rooms if the rope service life is shorter than the operator has anticipated. In many cases, it becomes evident that although the design has been performing in accordance with EN 81-1 (where a safe minimum service life has been calculated), this should not be confused with an elevator balanced to achieve maximum economic efficiency. It is frequent that the parameters that determine the service life of a rope are maximized to their limits, which in turn brings about a corresponding reduction of

service life. To increase user satisfaction, there should be better communication between partners at the pre-planning stage of the design to determine the expectations on service life. This should increase awareness of the fact that a long service life is associated with costs.

### Deflection and Diversion Sheaves

Deflection and diversion sheaves should be made of the same high-grade cast iron as traction sheaves. The grooves of deflection and diversion sheaves rarely wear to such a degree that new ropes could be damaged as a result. Despite this, however, the grooves of the deflection and diversion sheaves should be included in the inspection when changing ropes. The frequently voiced opinion that a sheave with a minimal wrap angle is consequently exposed to minimal stress is a misconception. Contact pressure (in other words, the force per millimeter of wrap length) is just as great as if the sheave had a wrap angle of, for instance, 180°. Here, too, the degree of contact pressure determines the extent of sheave and rope wear. According to elevator manufacturers, the use of universal sheaves for a range of rope diameters has not proven successful. Deflection sheaves can be made of plastic, such as polyamide. Their use is regulated in Germany by the Safety Guidelines for Lifts SR plastic sheaves.<sup>[31]</sup> There is no concern regarding the use of plastic sheaves in conjunction with a steel or gray cast-iron sheave. The discard age of the ropes can be determined by symptoms such as externally visible wire breaks, which are results of running over cast-iron traction sheaves.

### Groove Wear Due to Rope Impressions

If rope impressions (braid formation) (Figure 35) occur as a form of groove wear evenly in all grooves and is highly pronounced, then the sheaves probably have an insufficient hardness level.

*Continued*



Figure 35: Rope impressions in the grooves of a traction sheave

However, if the sheave hardness is proven to be correct, other circumstances can result in rope impressions. These include:

- ◆ Uneven rope tension levels
- ◆ Dry ropes (lack of re-lubrication)
- ◆ Excessively worn grooves, e.g., ropes have been changed without the worn traction sheave being replaced.

In each instance, the quality of the cast iron is the most important factor. It is highly likely that a correlation exists between this form of groove wear and rope elasticity. Imprints of this type in the groove must have been filed out by a twisting movement of the rope as it runs over the sheave. Evidence has shown that elevators fitted with eight-strand ropes with a fiber core made of polypropylene result in a higher number of cases in which rope impressions have been discovered in grooves. Conversely, ropes with steel-wire cores (i.e., ropes with a substantially reduced elongation behavior) are very seldom found responsible for rope impressions in grooves, provided the sheave has sufficient hardness. Where traction sheaves of inferior cast-iron quality and hardness are used, it is possible to avoid excessive groove wear by selecting a “non-hard” rope. In this type of rope, the outer wires of its outer strands comprise wires of a relatively low wire tensile strength – around 1180-1370 N/mm<sup>2</sup>.

#### Bibliography:

- [1] EN 10016, Non-Alloy Steel Rods for Drawing and/or Cold Rolling
- [2] EN 12385 – Part 5 (2003), Steel Wire Ropes – Safety Part 5: Stranded Ropes for Lifts
- [3] ISO 4344 (published 2004), Steel Wire Ropes for Lifts – Minimum Requirements
- [4] DIN 50150, Conversion Table for Vickers Hardness, Brinell Hardness, Rockwell Hardness and Tensile Strength, December 1976, Beuth Verlag GmbH, Berlin
- [5] EN 81-1/1998, Safety Rules for the Construction and Installation of Lifts – Part 1: Electric Lifts
- [6] TRA 003, Technical Rules for Elevators – Calculation of Traction Sheaves, September 1981, Verein der Technischen Überwachungsvereine e. V., Essen

- [7] DIN EN 81, Safety Rules for the Construction and Installation of Lifts – Particular Applications for Passenger and Goods Passenger Lifts Part 1: Electric Lifts, October 1986
- [8] EN 12385 – Part 1 (published 2003), Steel Wire Ropes. Safety – Part 1: General Requirements
- [9] ASME A17.1 Safety Code for Elevators and Escalators. The American Society of Mechanical Engineers, New York
- [10] EN 13411 – Part 4 (2002), Terminations for Steel Wire Ropes. Safety – Part 4: Metal and Resin Sockets.
- [11] DIN 3093, Wrought Aluminium Alloy Ferrules; Parts 1 and 2, December 1988, Beuth Verlag GmbH, Berlin
- [12] EN 13411 – Part 3 (2003), Terminations for Steel Wire Ropes. Safety – Part 3: Ferrules and Ferrule-Securing
- [14] EN 13411 – Part 1 (2002), Terminations for Steel Wire Ropes. Safety – Part 1: Thimbles for Steel Wire Rope Slings
- [15] DIN 15315, Wire Rope Grips for Elevators, May 1983, Beuth Verlag GmbH, Berlin
- [16] EN 13411 – Part 7 (2004), Terminations for Steel Wire Ropes. Safety – Part 7: Symmetric Wedge Socket
- [17] DIN 1142, Wire Rope Grips for Rope Terminations, January 1982, Beuth Verlag GmbH, Berlin
- [18] EN 13411 – Part 5 (2003), Terminations for Steel Wire Ropes. Safety – Part 5: U-bolt Wire Rope Grips
- [19] EN 13411 – Part 6 (2003), Terminations for Steel Wire Ropes. Safety – Part 6: Asymmetric Wedge Socket
- [20] Czitary, E., Seilschwebebahnen [Cable pulleys], Springer Verlag, Vienna, 1951
- [21] Wyss, Th., Stahldrahtseile der Transport- und Förderanlagen (Steel Wire Ropes in Transport and Conveyor Systems) Schweizer Druck- und Verlagshaus AG, Zürich 1956
- [22] TRA 102, Technische Regeln für Aufzüge – Prüfung von Aufzugsanlagen, (Technical Rules Governing Lifts – Inspection of Lift Systems) April 1981, Verein der Technischen Überwachungsvereine e. V., Essen
- [23] DIN 15020, Principles Relating to Rope Drives Sheet 2, Monitoring of Rope Installations, April 1974, Beuth Verlag GmbH, Berlin
- [24] ISO 4309, Wire Ropes for Lifting Appliances – Code of Practice for Examination and Discard, 1990
- [25] EN 12385 – 3 (2003), Steel Wire Ropes – Safety – Part 3: Information for Use and Maintenance
- [26] *Wire Rope Users Manual*, American Iron and Steel Institute, Washington
- [27] Babel, H., Metallische und nichtmetallische Futterwerkstoffe für Aufzugsseile (Metallic and Non-Metallic Filler Materials for Elevator Sheaves), Dissertation University of Karlsruhe, 1979
- [28] Hafenbautechnische Gesellschaft e. V., Hinweis für den Einsatz von Seiltrieben mit Kunststoff-Seilrollen in Kranen, fördern und heben 33 (1983) (Notes on the Use of Rope Traction Systems with Plastic Sheaves in Cranes, Transport and Lifting), No. 1, p. 33
- [29] DIN 15063, Lifting Appliances; Sheaves, Technical Conditions, see explanations on 5.4 December 1977, Beuth Verlag GmbH, Berlin

- [30] Hymans, F./Hellbronn, A. V., Der neuzeitliche Aufzug mit Treibscheibenantrieb (The Modern Lift with Traction Drive), Springer Verlag
- [31] SR Kunststoffrollen, Sicherheitstechnische Richtlinien für Aufzüge – Seilrollen aus Kunststoff (SR Plastic Sheaves, Safety Guidelines for Lifts – Plastic Sheaves), December 1984, Carl Heymanns Verlag KG, Köln, Berlin
- [32] Molchow, Michael, Stahlseile und neuartige Tragmittel (Steel Ropes and New Means of Suspension), *Lift Report* 27. Year of publication (2001), Volume 5, p. 6-12

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Use the below learning-reinforcement questions to study for the Continuing Education Assessment Exam available online at [www.elevatorbooks.com](http://www.elevatorbooks.com) or on page 145 of this issue.

- ◆ How should ropes be unrolled for mounting?
- ◆ Why do ropes untwist?
- ◆ How does the drive arrangement affect the rope?
- ◆ Can rope vibration be eliminated or reduced?
- ◆ Which types of rope elongation are to distinguish?
- ◆ How is the elasticity modulus of ropes defined?
- ◆ What criteria are applicable to rope relubrication?
- ◆ How many wire breaks are admissible?
- ◆ What should be done in case of internal corrosion development in the strand gaps?
- ◆ What is a hardened traction sheave?



## ELEVATOR WORLD Continuing Education Assessment Examination Questions

### Instructions:

- ◆ Read the article **“Steel Wire Ropes for Traction Elevators: Part 3”** (page 95) and study the learning-reinforcement questions.
- ◆ To receive **one hour (0.1 CEU)** of continuing-education credit, answer the assessment examination questions found below online at [www.elevatorbooks.com](http://www.elevatorbooks.com) or fill out the ELEVATOR WORLD Continuing Education Reporting Form found overleaf and submit by mail with payment.
- ◆ Approved for Continuing Education by **NAEC for CET® and CAT® and NAESAI for QEI.**

1. How should ropes ideally be stored?
  - a. Dry.
  - b. Frost free.
  - c. Dust free.
  - d. Protected against condensate.
  - e. All of the above.
2. Which is **not** a “hidden danger” inherent in rope installation?
  - a. Concrete or steel edges.
  - b. A glass shaft.
  - c. Sandy surfaces.
  - d. Dusty surfaces.
3. Which does **not** reduce the service life of elevator ropes?
  - a. Opposite bending.
  - b. Horizontally running.
  - c. Lateral deflection.
  - d. Car with mirrors.
4. Rope vibration frequency does **not** depend on:
  - a. Rope length.
  - b. Rope force.
  - c. Rope weight per meter.
  - d. Rope grade.
5. What’s the elasticity module of an elevator rope?
  - a. About 210 N/mm<sup>2</sup>.
  - b. About 135 N/mm<sup>2</sup>.
  - c. It is not constant and depends on the rope force.
  - d. 1570 N/mm<sup>2</sup>.
  - e. 1770 N/mm<sup>2</sup>.
6. Which rope construction has the smallest degree of elongation?
  - a. Regular lay, full steel.
  - b. Lang lay, full steel.
  - c. Regular lay, fiber core.
  - d. Lang lay, fiber core.
7. Which method of re-lubrication is **not** recommended for elevator ropes?
  - a. A can of lubricant and a paintbrush.
  - b. Using lubricant spray.
  - c. Moving the rope through a dipping bath.
  - d. Using a can of lubricant and a roller.
8. What is **not** an indication that elevator ropes must be discarded?
  - a. Wire breakage.
  - b. They have been installed for more than a year.
  - c. They have reduced diameters.
  - d. They have corrosion.
9. Which is **not** a groove shape that a traction sheave can have?
  - a. Round groove.
  - b. V-groove.
  - c. U-groove with undercut.
  - d. TT-groove.
10. Which circumstances can result in the occurrence of rope impressions?
  - a. Uneven rope lengths.
  - b. Dryness and excessively worn grooves.
  - c. Round grooves.
  - d. Over-lubricated ropes.

## ELEVATOR WORLD Continuing Education Reporting Form



Article title: **“Steel Wire Ropes for Traction Elevators: Part 3”** (EW, September 2009, page 95).

Continuing-education credit: This article will earn you **one contact hour (0.1 CEU)** of elevator-industry continuing-education credit.

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