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MÜNCHEN 1981
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BOOK 28

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GENERAL RECOMMENDATIONS FOR THE MANUFACTURER'S LUBRICATION AND THE RE-LUBRICATION OF STEEL WIRE ROPES USED IN ROPEWAY INSTALLATIONS FOR PASSENGERS

**Compiled between September 2011 and October 2013
by the O.I.T.A.F. Work-Committee No II**

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FOREWORD

Considering the many years that have elapsed since the last publication of the “Recommendations for the initial lubrication and the re-lubrication of steel wire ropes used in ropeway installations” (Books 4 and 21) in 2010 the International Organization for Transportation by Rope, O.I.T.A.F., has decided to rewrite the document. The working group’s proposal to combine both recommendations in one book (new book 28) has been approved by the Management Committee.

The final version of these recommendation is the result of cooperative work, discussions and contributions made by delegates appointed by representatives of rope and ropeway manufacturers, operators including a survey supported by 176 operators from Austria, France, Germany, Italy and Switzerland, supervisory authorities, control bodies, universities and independent consultants from the following countries: Austria, France, Germany, Italy, Switzerland and USA.

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INTRODUCTION

These recommendations concern the initial manufacturer's lubrication of steel wire ropes used in ropeways for passenger transportation as well as to the re-lubrication of the same ropes during their operation.

It is directed to ropeway operators, to rope and ropeway manufacturers as well as to manufacturers of rope lubricants.

The recommendations are based on the following preconditions

- The rope manufacturer must ensure that the lubricant used is designed and declared for use on ropeway ropes by its manufacturer
- The rope manufacturer must ensure that the lubricant used allows a quantitative assessment of the amount applied
- The rope manufacturer must ensure that the lubricant applied is homogeneously distributed along around and throughout the rope
- The ropeway operator must ensure that the re-lubricant used fully complies with the recommendations of the rope manufacturer, thereby ensuring compatibility of the manufacturing lubricant and the re-lubricant.
- The manufacturer of the manufacturing lubricant and/or re-lubricant must ensure that the lubricant does not adversely affect the wires (e.g. corrosion) or the plastic materials in use.
- The manufacturer of the lubricant must carry out the necessary tests by the appointed and approved institutions, in order to prove that the product fulfils the specific requirements for use in the field of ropeways in particular for human transportation (See Chapter 3. Potential Hazards).

1 TECHNICAL CONSIDERATIONS

1.1 Basics of steel wire rope lubrication

A steel wire rope needs to be lubricated in order to prolong its useful service life including reducing the rate of development of the numbers of broken wires. This is important in order to avoid unscheduled interruptions.

This goal can be reached, both by increasing the corrosion protection, and by reducing the coefficient of friction between the wires and the strands.

It is important to underline however that although there is no limit for corrosion protection, it should not be concluded that there is also no limitation regarding the reduction of friction. It has to be kept in mind that a rope whose inner friction is theoretically zero loses one of its most important properties which is, that a broken wire is able to carry the full load again, in a certain distance from the break.

Thus it is obvious that the importance and necessity of corrosion protective becomes more important the more corrosive the environment is e.g.:

- salty air
- higher temperature and/or humidity
- corrosive industrial emissions

as well as the importance of a lubricant increases the higher the number of fatigue cycles is e.g.:

- higher speed
- more operating hours per day
- more operating days per year
- shorter systems

It is therefore obvious that any generalization regarding the lubricant applied during rope manufacture, as well as the use of any re-lubricant during operation, which does not specifically take into account the context of each system, including for example:

- the climatic conditions
- the environment
- the operation mode
- the expected rope useful service life

can potentially lead to operational and finally to economic issues. Under certain conditions, such an omission might even lead to safety issues!

Investigations which have been carried out in the past have shown that:

- The flexion of a steel wire rope around sheaves (forced bending / high local pressure between the wires) causes fretting and the fretting scars act as the initial crack which finally develops into a wire break.
- The presence of a lubricant acting as a “third body” between the two metallic surfaces in contact reduces the occurrence of fretting, therefore reducing the occurrence of wire breaks due to fatigue.

The results of numerous investigations which have been carried out both in laboratories and in real operations can be summarized as follows:

- As a rule most manufacturing lubricants in use cannot withstand repeated high pressure between the wires for the duration of the entire rope service life, in particular when the rope is subject to repeated bending, because the lubricant gradually loses its ability to lubricate effectively and continuously the elements of the rope such as the wires, the strands and the core. (Fig. 1).

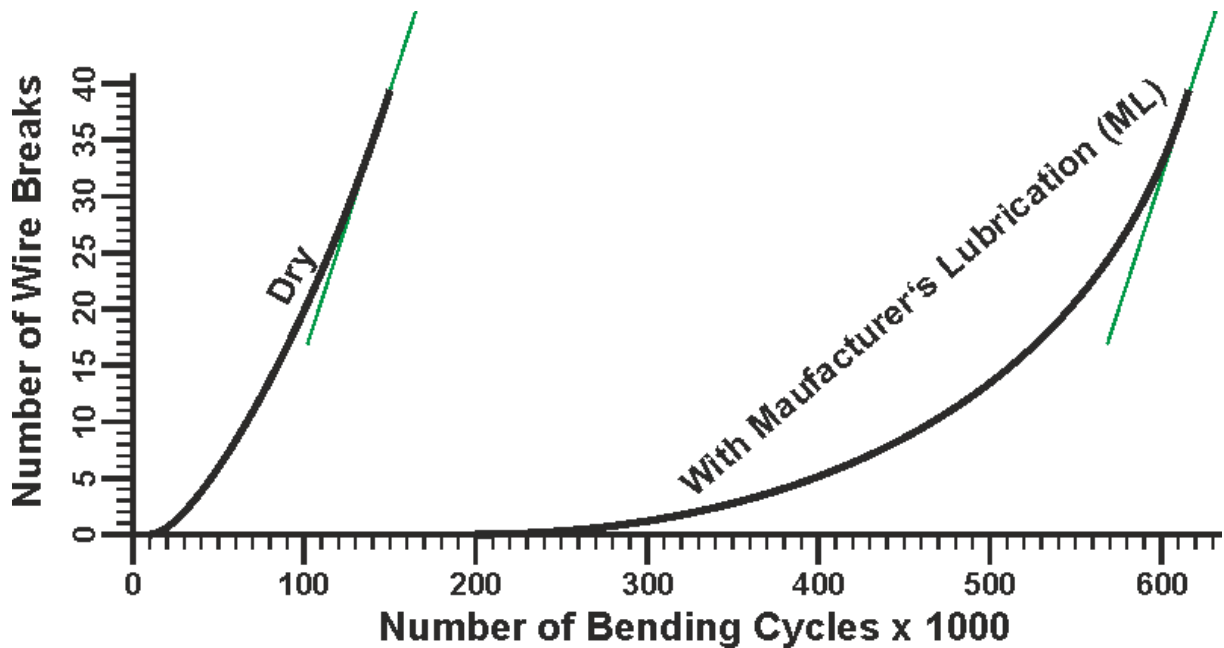


Figure 1: Comparison between a “dry” and a “lubricated” rope when fatigued under forced bending and under heavy working conditions. The number of wire breaks are referenced to a specific rope length. It is evident that:

- The number of wire breaks grows significantly faster in the case of a rope without any lubrication, than in the case of one with an effective manufacturing lubrication.
- The final gradient of the development of the number of wire breaks (the green line) is the “same” for both the dry and the rope lubricated during manufacturing if no re-lubrication is performed. This indicates that the exclusive dependence on the manufacturer’s lubricant, in most cases, does not guarantee its effective action as a “third body” throughout the whole service life.

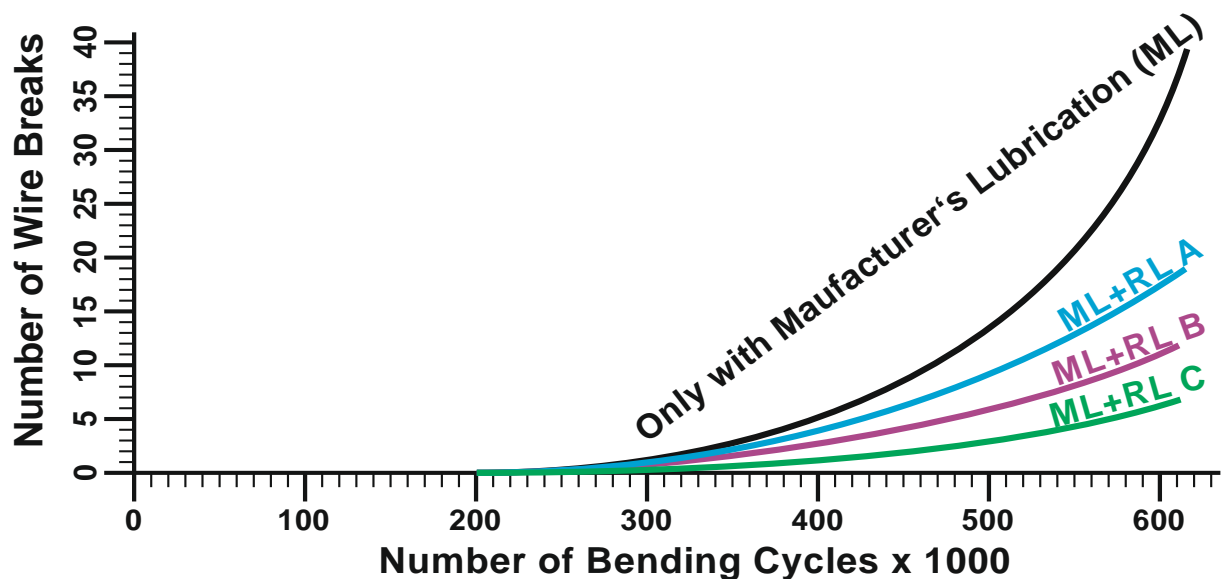


Figure 2: Comparison between a rope with only the manufacturer’s lubrication and one which has been re-lubricated during operation. It is evident that:

- As a rule re-lubrication elongates the service life of a rope
- Depending on the actual re-lubricant used the improvement in service life can be significantly different.

The above results have been obtained through numerous test, carried out on samples taken from the same rope, which have been lubricated with different lubricants. For further details see "Effects of fretting fatigue on flexed locked coil ropes, Fretting Fatigue" ESIS 18 (Edited by R.B. Water) 1994, Mechanical Engineering publications, London, pp. 283-294

As a result of the above facts it should be stated that:

- An important requirement for the manufacturer's lubricant is its ability to re-penetrate between the contact surfaces of the wires after a reduction of the load during the working cycles (e.g. when a rope is straightening again after bending).
- Service life re-lubrication should be applied at a rope bending point in order to make sure that the wires are moving relatively to each other and therefore helping the re-lubricant to penetrate inside the rope or the strand (See Chapter 2.2 Instructions how to re-lubricate).

The requirements for the lubrication properties as well as the corrosion protection properties of a lubricant are determined by the existing constraints in respect of

- the rope itself
- the ropeway facility and
- the operation of the ropeway

1.2 Constraints with respect to the Rope

The following requirements need to be fulfilled by the lubricant:

- *Workability*

The lubricant must be workable during the rope making process. Dripping point, flammability, viscosity and resistance to pressure under rope making conditions are the most important criteria during initial lubrication.

Upon re-lubrication the lubricant should be easily applicable, should not cause any toxic or narcotic emissions, and its availability should be guaranteed at all service locations (Transportability; Keyword: Transportation and Storage of Hazardous Materials).

- *Adhesive Power (Tackiness)*

Once applied, the lubricant should continue to adhere to the wire surface, but at the same time it is also desirable that it can be wiped off during rope making to enable easy removal of surplus lubricant. Since these requirements contradict each other, it is necessary to find a compromise.

- *Resistance to pressure*

Resistance to high pressure is an essential property of a lubricant. In order to fulfill its role as a third body between the friction partners (wires, strands, and steel core where applicable as for tension ropes), the lubricant should be able to withstand operating pressures.

- *Flow-Back Ability*

If the lubricant should be displaced as the result of pressure that is too high, it should be capable of flowing back between the contact surfaces after pressure reduction and during relative movement between wires. This is particularly important as it has proved to be scarcely possible to develop a lubricant for locations within a rope which experience intensive pressure, that is capable of withstanding the pressure during the rope's entire service life.

- *Preventing stress corrosion cracking*
Care should be taken that the lubricant used prevents the occurrence of stress corrosion cracking (cracking assisted by chemical processes).
- *Corrosion protection*
The need of corrosion protection of the lubricant depends, on one hand, on the kind of wire material used (coated or bright) and, on the other hand, on the respective environment. While it can be assumed that the wire materials used are well-known, the environment (humidity, pollution, salty air etc.) however, should be scrutinized in each specific case.
- *Compatibility with polymers used*
Since many different kinds of polymer are used as key components of ropes, the compatibility of the lubricant with such polymers must be ensured.
- *Comments regarding the amount of lubricant in for different rope types*
 - All locked coil ropes must be fully lubricated during manufacturing
 - The amount of lubricant introduced to a strand must be controlled during the stranding process
 - Stranded ropes usually should not be lubricated during the closing process of the rope
 - The core can be lubricated

1.3 Constraints with respect to the ropeway facility

The following criteria are of significant importance in respect of the ropeway facility:

- *The Coefficient of Friction*
The principal of function of the great majority of rope facilities is reliant on the friction between the rope and the driving sheave as well as the rope and the clamp. For this reason the coefficient of friction is the first and most important limiting requirement which the material combination under the influence of the lubricant should under all circumstances fulfil; not only the functionality, but even the safety of the facility during operation, depends on this parameter (See Chapter 3. Potential Hazards).

In case of systems using track rope brakes, care shall be taken, that neither the initial lubricant nor the re-lubricant adversely affects the braking function (See Chapter 3. Potential Hazards).

In the case of systems using „Chapeau de Gendarme“ special care should be taken during re-lubrication; the manufacturer of the system or a competent person should be consulted.
- *Compatibility with Polymers in Use*
The compatibility of the lubricant with the linings of sheaves and line rollers should be ensured. Especially with re-lubricants that essentially consist of a base substance dispersed in a solvent, it is important that not only the base substance fulfils the compatibility requirements (chemical stability, swelling, adhesion etc.), but also, and particularly, the solvent must meet this requirement (See Chapter 3. Potential Hazards).

1.4 Constraints with respect to the operation

The following requirements are to be taken into account in respect of ropeway operation.

- *Viscosity & Adherence*

Both the viscosity and the adherence of the lubricant should be chosen so as to avoid the removal of the lubricant from the rope, as well as to avoid soiling the facility by the lubricant over the whole temperature range, as well as for the whole speed range of the facility (See Chapter 3. Potential Hazards)

- *UV-Resistance*

When it comes to ropeway ropes, the UV- resistance of the lubricant is of particular importance, since the ropes are almost exclusively employed at higher altitudes where ultraviolet-radiation is more intense than in lower areas.

- *Resistance to the "Techno-Climate"*

Resistance to substances encountered in the atmospheric environment is also gaining more and more importance. This is especially the case for facilities operated near industrial or populated areas with higher air pollution.

- *Stability towards Time and Temperature*

Ropes used in ropeway applications remain in service for a relatively long time. For this reason, the lubricants used must not suffer from decomposition over the service period, nor should the continual changing of temperature (within the permitted range) negatively affect the quality of the lubricant.

- *Viscosity Reduction as a Result of Temperature and Dampness*

Certain climatic conditions such as a sudden rise in temperature occurring simultaneously with a rise in humidity should not lead to an excessive reduction of the viscosity (See Chapter 3. Potential Hazards).

1.5 Further requirements

Two more points must be underlined:

- *The unity of basic lubrication and re-lubrication*

The lubrication of the core, manufacturing lubrication of strands and rope, and finally the re-lubrication must be compatible.

- *Product Consistency*

The complexity of the technical demands on the lubricant, and not least the fact that many of those are contradictory, make their fulfilment very difficult. For this reason, once an optimal solution has been achieved it should be treated as a valuable, but sensitive balance. Any change in the lubricant formulation can destroy this balance and thereby the quality of the result. In this context, both the rope manufacturer (referring to the initial lubricant) as well as the ropeway operator (referring to the service life lubricant) have to ensure that the manufacturer of the specific lubricant really takes care that the products remains consistent. Eventually changes of the lubricant formulation necessitated by legal, technical and not least economic reasons should be carried out with particular care, and only after consulting the rope maker and the ropeway operator.

2 RE-LUBRICATION (RL)

2.1 Preamble

- Follow the maintenance manual of the rope manufacturer
- Only cleaned ropes should be lubricated
 - It is highly recommended that the rope is cleaned at regular intervals, in particular during the first year of operation, when most soiling is to be expected!! Depending on the rope type (locked coil or stranded rope) and the manufacturer's lubricant used, brushes, textile or polymer wipes, soft wire strand etc. can be used.
 - The rope cleaning should be carried out during dry and preferably cold weather conditions.
 - During the cleaning procedure care should be taken to avoid any mechanical damage to the rope surface. In particular, where steel brushes are used, care should be taken to avoid that the rotational direction of the brushes is perpendicular to the direction of the strands.
 - In general the use of any solvent or other chemical liquid should be strictly avoided.
 - If the rope is not cleaned for a long period of time, a thorough cleaning by means of the usual methods may no longer be possible. In this case it is advisable to consult the rope manufacturer.

2.2 How to re-lubricate

- The whole rope length has to be re-lubricated.
- The re-lubricant should penetrate inside the rope in order to reduce friction between the wires.
- In order to ensure the re-lubricant penetrates inside the rope it should be applied just at a rope bending point. It is necessary to ensure that the rope surface is "wet" with the lubricant at the bending point (See Figure 3). Care should be taken that the re-lubrication takes place as far away as possible from the drive in order to avoid any issues with the coefficient of friction between the bull wheel and the rope.

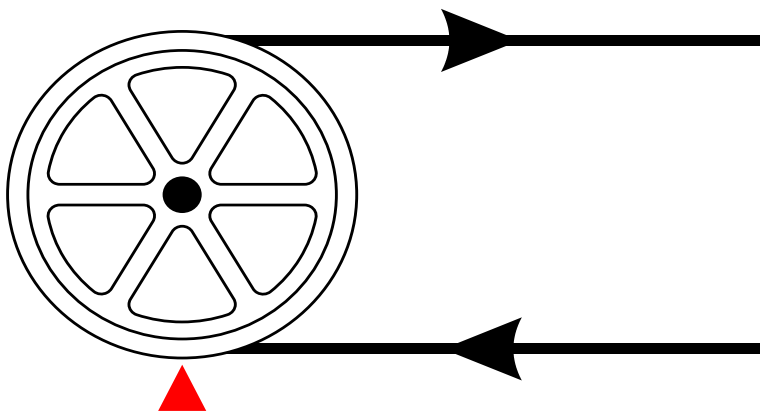


Figure 3: The re-lubrication should take place at a rope bending point.

- When a standing rope (e.g. track rope) has to be re-lubricated it is advisable to apply the re-lubricant just in front of the carrier-rollers (in the travelling direction).
- If an excessive amount of the re-lubricant is applied, care should be taken that the surplus amount is removed, making sure that the rope surface remains visible.
- The quantity has to be determined by experience. For the typical amount please consult the following table. In case of a lack of information always start with smaller amounts.

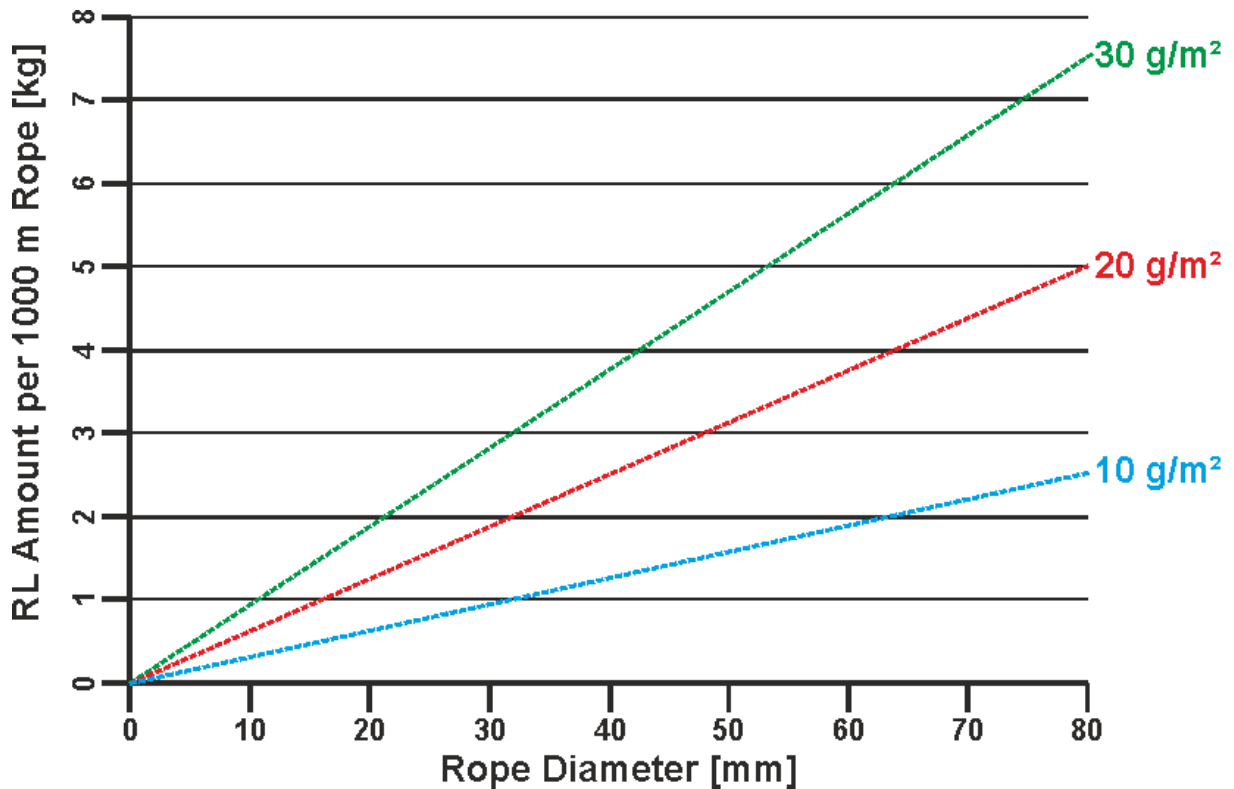


Fig. 4: Plot indicating the amount of re-lubricant in kg/1000 m rope, depending on the rope diameter and the required amount in g/m² of outer surface.

- The re-lubrication should be carried out under dry conditions and after cleaning. The minimum application temperature should be chosen according to the re-lubricant used, with the aim of reducing the evaporation time of the solvent (if present).
- In order to optimize the result specific devices (sprayer, drop oiler etc) and procedures (manual application, automatic device etc.) appropriate to the specific system and its operation may be necessary.
- The chosen method of application should ensure that the rope surface at the point of bending is covered with a thin layer of lubricant. This can be achieved by means of spray, drop-oiler, and a brush or a felt etc. It is recommended that surplus re-lubricant is removed by means of a wiper after the bending point where the rope is straight.

2.3 Frequency

- Whole rope: the re-lubrication interval should be established taking into consideration the operation frequency (number of bending cycles) and the environment.
- In general this interval should not be longer than one year.
- It is recommended that re-lubricating is maintained once the process has been started.
- Specific rope parts:
 - Splice: Only the tucks and the tucked tail ends of a long splice should be intensively re-lubricated at least monthly after each regular visual inspection.
 - Track Rope / Roller-chain: It is recommended that the rope area flexed over a roller chain be lubricated on a frequent basis, preferably continuously. If no continuous lubrication device has been installed, it is recommended that the flexed rope area is re-lubricated during operation at least monthly after the regular inspection.
 - Track Rope / Bollards: Care should be taken to ensure that the rope part wrapped around the bollard remains inspectable and is always covered with lubricant in order to avoid corrosion.
 - Track Rope / Saddle: It is recommended that the rope area flexed over a saddle shall be re-lubricated on a frequent basis. In particular those two track rope areas at both ends of the saddle, which are exposed to alternating bending, shall be re-lubricated for example monthly.
 - Tensioning rope: It is recommended that the flexed rope area shall be re-lubricated at least monthly after the regular inspection.

2.4 General Remarks

- It is strongly recommended that up-to-date record of every re-lubrication process shall be kept. It should include: date, name of the responsible person, type and quantity of the applied re-lubricant, weather conditions, the application method and elapsed time before operation of the system recommences.
- The operator should monitor any potential issues which may arise as a result of a re-lubrication before resuming passenger service. Therefore it is recommended that the system is double-checked (in particular rollers, sheaves, tongues of clamps as well as any potential change in behaviour regarding the necessary friction etc.) and if necessary either to take immediate measures and/or to adapt the re-lubrication procedure for the future in accordance with observations.
- The saddles of a track rope have to be re-lubricated by means of a specific grease in order to avoid high friction between the rope and the saddle. The applied products and the re-lubrication intervals need to comply with the recommendations of the ropeway manufacturer.
- The safety instructions and the environmental precautions as described in the technical data sheet of the re-lubricant used have to be followed precisely!
- It is recommended that a visual inspection is performed after the cleaning and before re-lubricating the rope.

3 POTENTIAL HAZARDS

Caution! If for whatever reason the lubricant used (manufacturer's or re-lubricant) is not properly chosen and/or is wrongly applied the following hazards can occur:

- *Coefficient of friction*

The re-lubricant can adversely affect the coefficient of friction and this can result in significant issues and not least dangerous situations for the ropeway system.

Therefore the re-lubrication of a haulage and a carrying/haulage rope needs to comply with the requirements of the code for the minimum allowed coefficient of friction (See EN 12385 part 8 Annex A.2.1 "*Coefficient of friction*: The value for coefficient of friction shall be $> 0,22$ at $20\text{ }^{\circ}\text{C}$; it shall be determined in accordance with DIN 21258").

Even when using a re-lubricant which complies with the above standard it is important to take care that the applied amount does not exceed the amount given by the rope manufacturer. It has been found that an excessive amount of re-lubricant can significantly reduce the coefficient of friction.

The re-lubricant used on a track rope should not adversely affect any carrier rope brake. For example it shall not contain any solid lubricant.

- *Non-compatibility with polymers in use*

Where the re-lubricant in use is not compatible with the polymers and/or rubber in use (both, those in the rope itself as well as those used in the system) this will finally lead to a rapid degradation of these materials when in contact with the lubricant.

Therefore only a lubricant which has passed all the necessary compatibility tests should be used (See EN 12385 part 8 Annex A.2.2 "*Swelling of sheave lining material*: When fully submerged in rope lubricant over a period of 14 days at a temperature equivalent to the lowest temperature above $20\text{ }^{\circ}\text{C}$ at which immersion can take place, the change in volume of the lining material specimen shall not exceed 20%. The reduction in hardness shall not exceed 10° Shore A. The method used shall be in accordance with DIN 53521").

- *Viscosity & adherence or/ and excessive amount*

Where the re-lubricant in use changes its viscosity when in operation within the expected conditions (temperature and humidity) this would lead:

- to soiling the facility and the passengers as well as to building up material on the sheave and roller lining
- to causing the grip tongues to stick onto the sheaves and, in extreme cases, subsequent to break.

Therefore care should be taken to ensure that the range of temperature and humidity of the environment where the system operates is well within the range of temperature and humidity for which the lubricant has been specified.

4 CONCLUDING REMARKS

- Use of an appropriate manufacturer's lubricant as well as a suitable re-lubricant during operation significantly increases the rope lifetime.
- This current recommendation gives technical background information and tips for the typical procedures (cleaning, re-lubricating). It also identifies potential hazards resulting from misuse.
- It is important to underline that where there is any uncertainty the rope manufacturer needs to be contacted.

5 GLOSSARY

Manufacturer's Lubrication

Lubrication which is applied to the rope during its manufacture.

Re-Lubrication

Lubrication which is applied during operation. Depending on the function of the rope or the rope part which is being re-lubricated, re-lubrication can take place continuously or at specific times.

Useful Service Life of a Rope

Time period during which the rope complies with the demands of the applicable standards

Fretting

Fretting refers to wear, and sometimes corrosion damage at the boundaries of contacting metallic surfaces. This damage is typically induced under high load and in the presence of repeated relative surface motion, as induced for example by the relative movement of the wires and strands during rope bending.

Stress Corrosion Cracking

Stress corrosion cracking is the accelerated growth of a crack when assisted by chemical (corrosive) processes.