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Evaluation of Field-Applied Lubricants to Increase Wire Rope Life

By Jack E. Fraley, Grant L. Anderson, and Paul F. Sands

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

°F	degree Fahrenheit	in	inch
ft	foot		

EVALUATION OF FIELD-APPLIED LUBRICANTS TO INCREASE WIRE ROPE LIFE

By Jack E. Fraley,[1] Grant L. Anderson,[2] and Paul F. Sands[3]

ABSTRACT

Poor lubrication reduces the life of wire hoist ropes when they are used in corrosive environments. Although lubricants are added to ropes during the manufacturing process, these lubricants can deteriorate during use, and it is often necessary to add more lubricant to both the interior and exterior of the rope while it is in service. The U.S. Bureau of Mines evaluated the effectiveness of synthetic lubricants, using electromagnetic nondestructive testing (NDT) to measure deterioration in ropes while they were in service. For nonpressurized lubricant applications, synthetic lubricants appear superior to petroleum-based lubricants in their ability to penetrate to the interior of a rope. Therefore, the synthetics offer better wear and corrosion protection.

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INTRODUCTION

As part of its program to enhance mine safety, the U.S. Bureau of Mines evaluated many wire ropes that had been removed from service to determine the effects of lubricants on the inhibition of corrosion, wear, and fatigue. Evaluations involved tensile tests, visual inspections of disassembled ropes, and microscopic examinations of individual wire failures. Also, tests were run comparing the strengths of ropes having different amounts of corrosion. The results show that, in the United States, corrosion and wear are the predominant mechanisms leading to rope failure and that corrosion often occurs in the interior of a rope. A petroleum-based lubricant, commonly called the layup lubricant because it is poured onto the wires as they are being layed into a wire rope, is introduced during manufacturing. This lubricant can become dry, can be washed away by water, or can otherwise be depleted or contaminated during the service life of a rope. Therefore, corrosion is generally associated with loss of the layup lubricant. However, if the interior of a rope can be adequately lubricated by introducing new lubricant while it is in service, corrosion and wear can be reduced or even stopped.

Wire ropes are complex structures, as shown in figure 1. The wires are tightly wound, making it difficult for a lubricant to reach the rope interior unless an expensive pressure system is used. Some layup or other petroleum-based lubricant that is added while a rope is in service may thicken or even harden through use, resulting in a surface barrier that prevents new lubricant from penetrating to the rope interior. Because of this, lubricating the interior of a rope by simply applying the lubricant on the surface requires special lubricants or procedures.

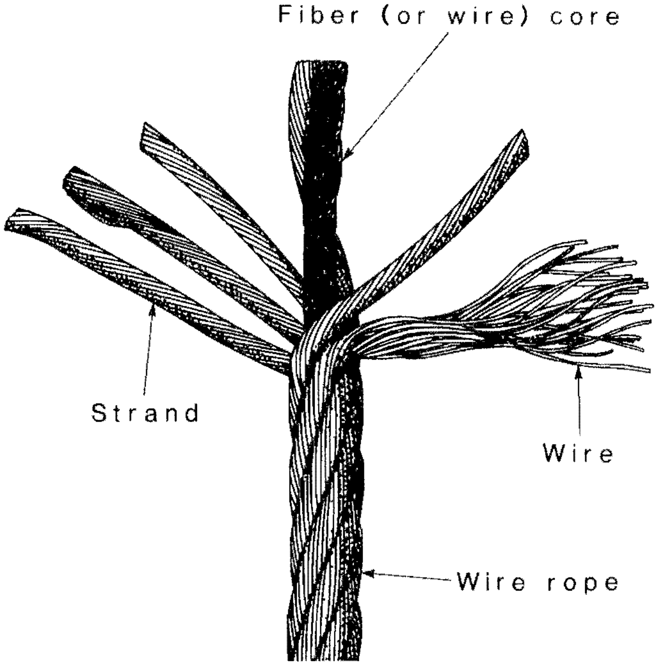

Figure 1.–Typical construction of fiber-cored, right lang lay wire rope.

Many different lubricants have been proposed, but their effectiveness has been difficult to evaluate. Although there are standard laboratory tests, neither high wire-to-wire loads nor the temperatures and corrosive conditions found in shaft environments can be adequately simulated in a laboratory. Furthermore, most laboratory tests are destructive, which does not allow sequential testing of the same rope to define a trend.

The only method that can be used to evaluate the condition of the interior of the rope without destroying it requires electromagnetic nondestructive testing (NDT). Even though NDT cannot yet be used to measure the strength remaining in a rope, the extent of wear, corrosion, and broken wires can be compared over time.

Voluminous commercial NDT records are available from different mines where different lubricants were used. In some cases, the type of lubricant was changed during the service life of the rope, and in other instances, different ropes in the same shaft were treated with different lubricants. These data provided the information used in this evaluation of the ability of different lubricants to extend the life of a rope or to reverse a trend in deterioration.

The NDT technique provides a record of change in the magnetic response of a rope to broken wires and to changes in the area of metallic cross section. These changes are recorded as an inked trace on a strip chart. The traces must be interpreted, but the relationships upon which the interpretation depends are not yet clearly understood. For this reason, interpretation requires a trained, professional NDT inspector.

To inspect a rope using an electromagnetic NDT instrument, the rope is magnetically saturated and passed through a magnetic sensor head that reads changes in magnetic field. The total magnetic flux is a function of the metallic cross section, and the flux changes as the area in the cross section changes. Broken wires or other local faults (LF) in a rope disrupt the field, causing distinguishable irregularities in the trace. In this manner, metal loss in the cross section (known as loss in metallic area, or LMA) from wear or corrosion and LF caused by broken wires or other discontinuities can be detected.

A typical NDT instrument system is illustrated in figure 2. It includes a sensor head that envelopes the rope and a recorder for making the ink trace.

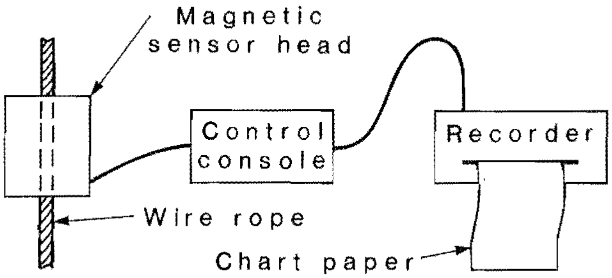

Figure 2.–Diagram of typical NDT facility.

Examples of LMA and LF traces are shown in figure 3. The traces shown in figure 3*A* are from a rope in good condition, and the traces in figure 3*B* are from a rope that has deteriorated. To measure the percentage of LMA, that part of the rope containing the most metal is first located on the LMA trace (upper traces on both strip charts). The largest flux represents the most area, and a horizontal reference line drawn at this point is defined as 0% LMA. The maximum loss of metal from wear and corrosion is determined by measuring the distance from the 0% LMA reference line to the lowest point on the LMA trace. This low point, which indicates the area of greatest deterioration, can occur anywhere along a rope. The maximum LMA in figure 3*B* is 10.5%.

Sharp discontinuities in the LF trace (lower traces on both strip charts) show the presence of broken wires, corrosion pitting, or nicking from internal wear. Corrosion products, pitting, and other results of corrosion disrupt the magnetic flux and increase the amplitude of the LF trace. The larger the amplitude, the more corrosion. Wear alone, however, does not generally increase LF amplitude. Corrosion and wear can be distinguished by comparing the LF trace to the LMA trace. Both corrosion and wear have caused a loss in metallic cross section on the LMA trace in figure 3*B*. The LF trace in figure 3*B* is an example of a trace that indicates corrosion.

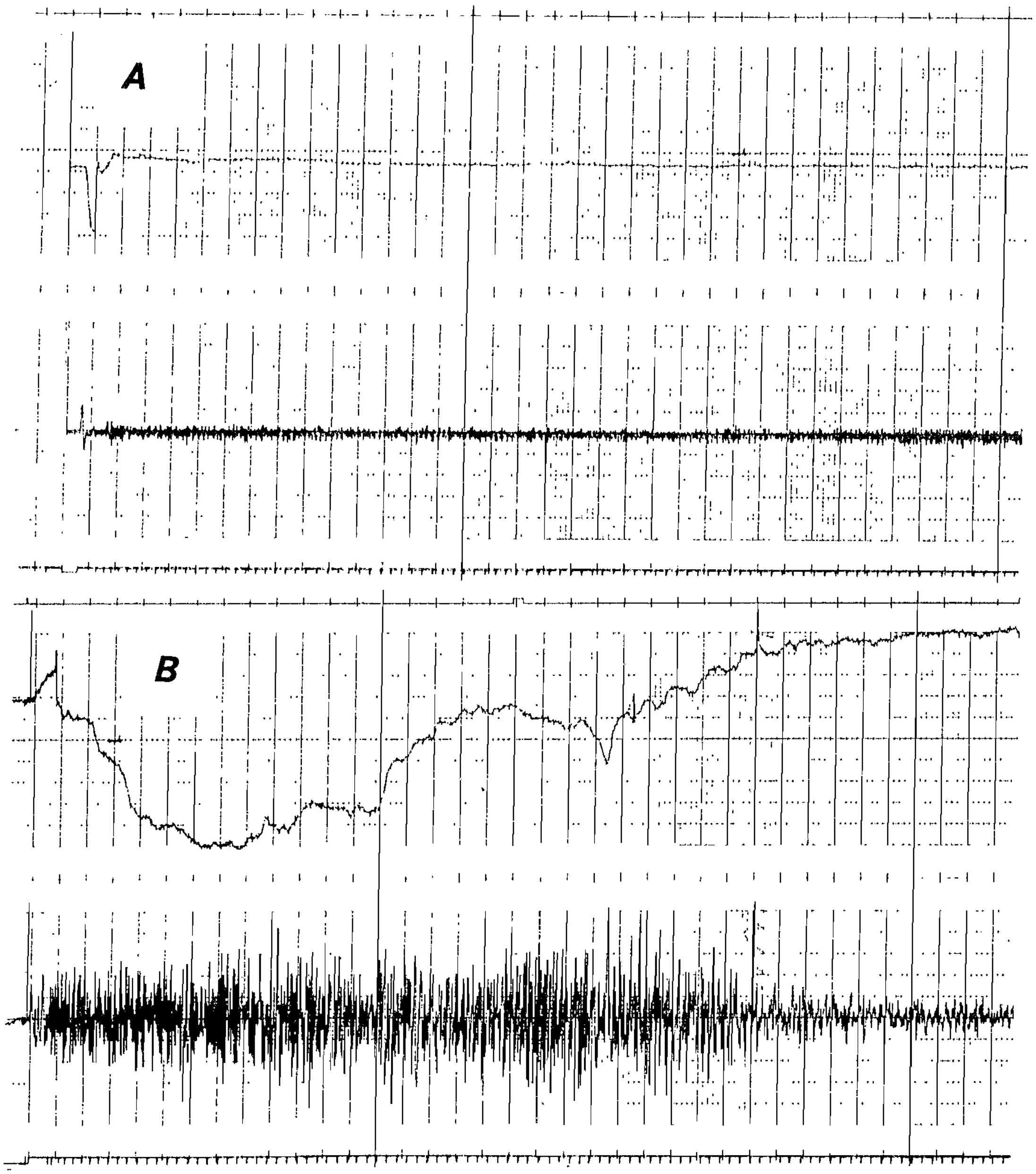

Figure 3.–Strip charts showing LMA (upper trace) and LF (lower trace) for ropes in good condition (*A*) and poor condition (*B*).

ACKNOWLEDGMENTS

Thanks are given to David Hall of Halkin Services, Inc., Denver, CO, who obtained permission from six mines to allow the Bureau to use their NDT data on in-service ropes.

INVESTIGATION PROCEDURE

Electromagnetic NDT records from six different mines were chosen because the environments and hoisting conditions in these mines cover a wide range of conditions and because there was continuity in the mine testing programs. The six mines include a salt mine, coal mine, silver-lead-zinc mine, trona mine, silver mine, and molybdenum mine. The strip charts for mine 3 (the silver-lead-zinc mine) are included in this report to explain how traces are analyzed. Interpretations of the traces were made in collaboration with a professional electromagnetic NDT inspector.

The ropes evaluated during this study were lubricated while in service. Some lubricants were so thick they were applied with a brush, while thin, synthetic, penetrating-type lubricants were applied by either dripping or spraying. Application was either periodic or continual.

The performance of different lubricants was evaluated by comparing the amounts and rates of deterioration in the rope as defined by LMA, corrosion, and broken wires. The lubricants are described only as either petroleum-based or synthetic, and differences in manufacturers or the lubricants themselves within each of these two groups were not considered.

Eleven different ropes were studied at the six mines. Ropes from mines 1 and 2 illustrate the wide variation in rates of rope deterioration that can occur when no lubricant is added to a rope while it is in service. In mine 2, the rope lasted for many years, while in mine 1, the rope lasted for only months, even though it had been galvanized for added protection. In mines 3 and 6, ropes that had been lubricated with a petroleum-based lubricant were compared with ropes in the same installations that had been lubricated with a synthetic lubricant. In mines 4 and 5, ropes that had been treated with a petroleum-based lubricant were subsequently treated with a synthetic lubricant. In all cases, the ropes came from the manufacturer with petroleum-based layup lubricant having been added to the rope interior as the rope was fabricated.

RESULTS

MINE 1

Mine 1 is a salt mine that uses a four-rope, tower-mounted friction hoist, as shown in figure 4. Humidity is around 80%, and temperatures range from 30° to 90° F. This mine was chosen for the study because the corrosive nature of salt would provide a "worst case" scenario. Dripping water keeps the ropes wet at all times, which worsens the corrosive effects of the salt.

The rope studied was a 6 by 27, flattened strand, left lang lay rope, 1 in. in diameter and 1,500 ft long. It had been galvanized for corrosion protection. Table 1 shows that LMA was negligible over the first 9 months, but reached 1.3% by 15 months. This loss increased to 3.8% after 21 months. Therefore, the average monthly loss nearly doubled, from 0.22% (9 to 15 months) to 0.41% (15 to 21 months). The amplitude of the LF traces also increased, indicating an increase in corrosion. Apparently the galvanizing and the original lubricant forestalled corrosion for a year. The subsequent increase in rate of deterioration coincided with a deterioration of the galvanized coating, the lubricant, or both. The data emphasize that, in very corrosive conditions, even a seemingly well-protected rope can deteriorate quickly if lubricant is not added during service.

Table 1.–LMA in galvanized rope without lubrication while in service, mine 1

Time from initial test, months	LMA, %	Rate of loss, %/mo
Initial test	Neg.	Neg.
3	Neg.	Neg.
9	Neg.	Neg.
15	1.3	0.22
21	3.8	.41

Neg. Negligible

MINE 2

Mine 2 is a coal mine using a four-rope, ground-mounted friction hoist with a cage and counterweight. The shaft is free of running water but is very humid. Typical temperatures are around 60° F. The ropes are 6 by 27, right lang lay, 1.5 in. in diameter, and 1,200 ft long. One of the ropes had only a 1.5% metal loss after a full 10 years of service. Two tests made 6 months apart confirmed this low rate of deterioration. Loss was apparently

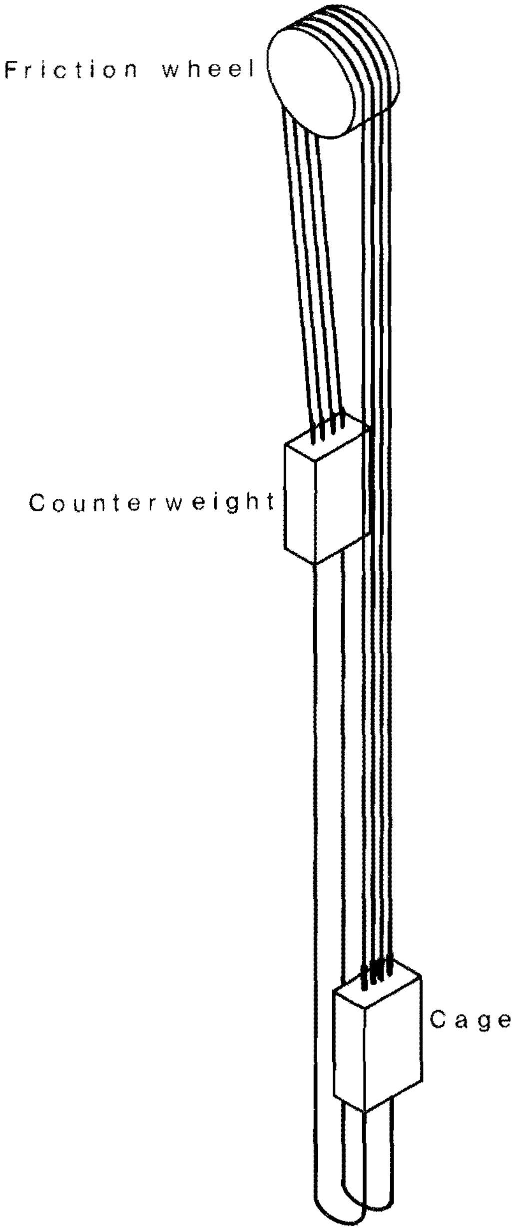

Figure 4.–Typical friction hoist.

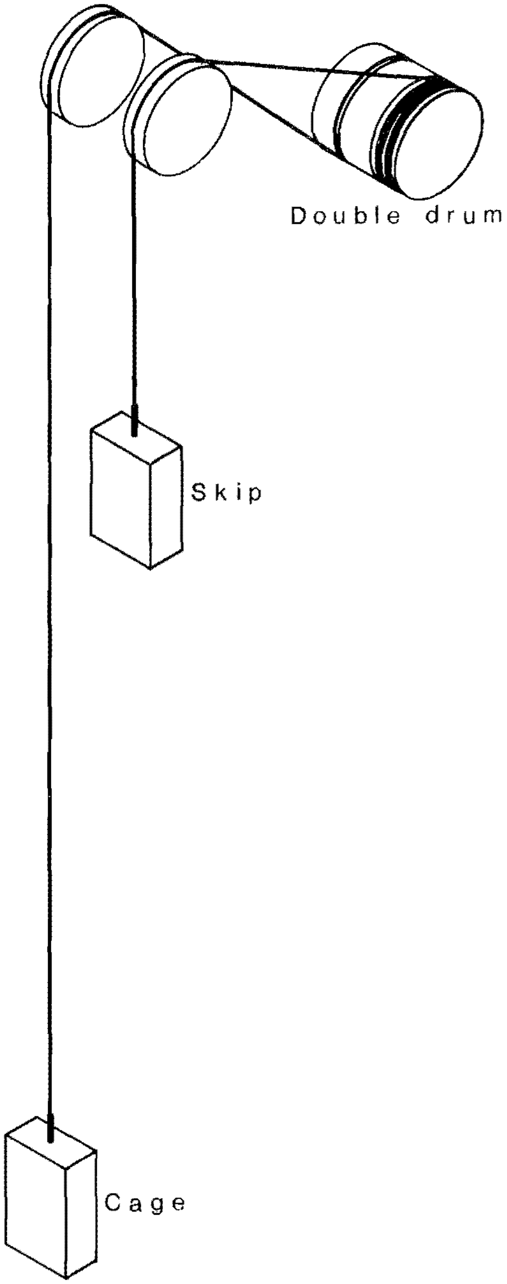

Figure 5.–Typical skip hoist.

from wear at the head sheave or on the drum because there was no corrosion. This extremely low rate of deterioration occurred even though the rope was not lubricated at all while it was in service and had only the layup lubricant that was added during its manufacture. In this case, the layup lubricant was enough to protect the rope for 11 years. The rope was retired shortly after the nondestructive tests because of a few broken wires and some external wear. The new rope was tested to determine its rate of deterioration. Two tests run 18 months apart showed no metal loss.

The experience with this installation shows that if conditions are favorable, ropes having only a layup lubricant can operate for long periods of time without corroding or wearing.

MINE 3

Mine 3 is a silver-lead-zinc mine. The shaft is wet, hot, and humid, and the water is acidic. The humidity and temperature increase with depth, and the temperature at the bottom is about 90° F. A double-drum hoist lifts a material skip and a man cage, as shown in figure 5. Both ropes were lubricated with petroleum-based lubricants and replaced, and the new ropes were lubricated with a synthetic lubricant. Although the synthetic lubricant provided reduced deterioration, wear on one rope was more pronounced than on the other. The NDT traces from this mine are included (figs. 6-10) in this report to explain the procedure used in evaluating lubricants with NDT.

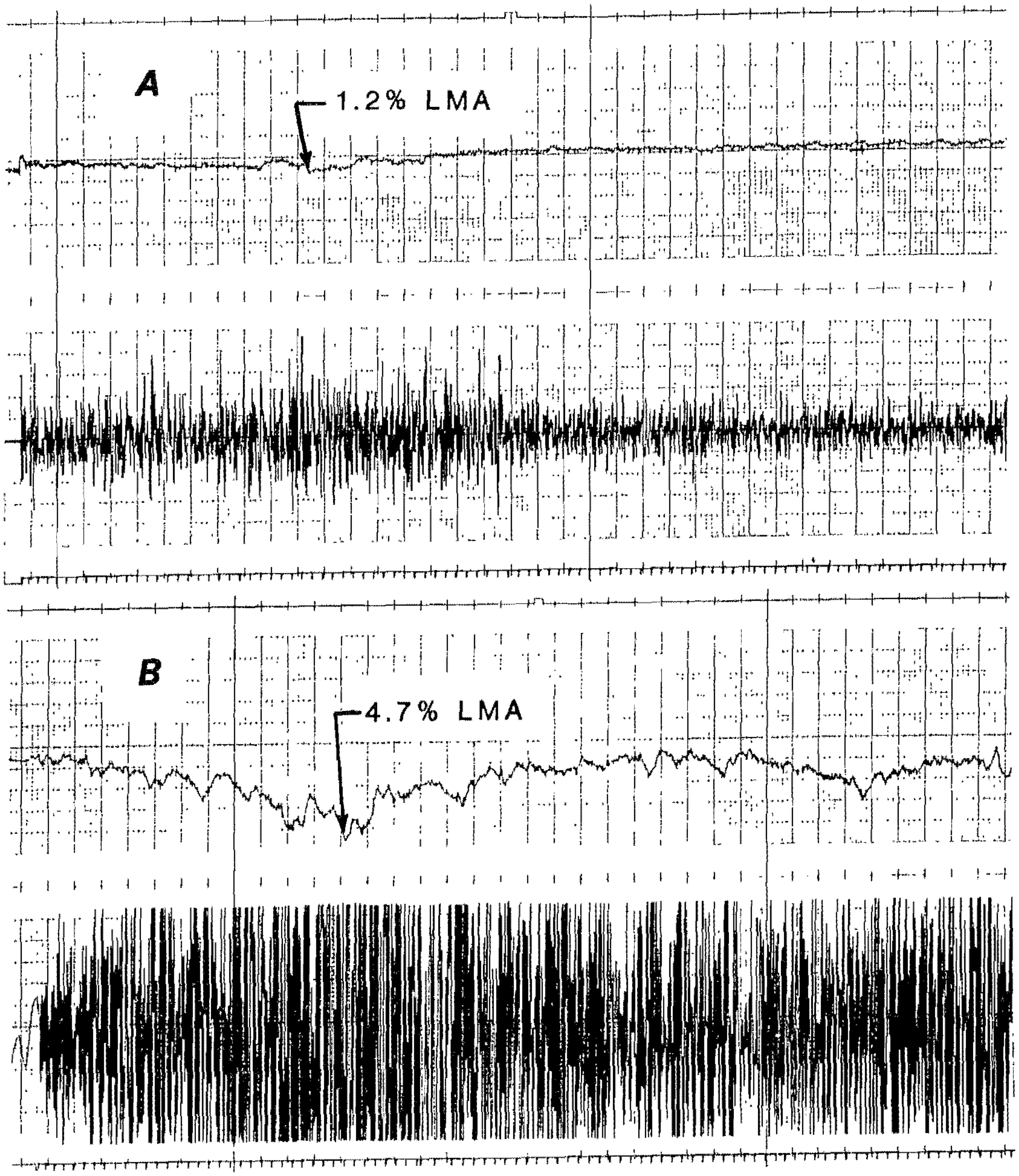

Figure 6.–Strip charts showing internal corrosion, man cage rope, mine 3. *A*, Initial test; *B*, after 6 months.

Man Cage

The man cage hoist ropes were 6 by 30, style G, flattened strand, right lang lay rope, 1 in. in diameter and 1,170 ft long. Two ropes were compared, each lubricated with different lubricants in the field. The first rope was lubricated with a thick, petroleum-based lubricant. The rope was replaced with a new rope after the original rope began to deteriorate rapidly. The new rope was lubricated with a synthetic lubricant.

Figure 6 shows the LMA and LF traces from two nondestructive tests run 6 months apart on the first rope. The increasing deterioration over this 6-month period is clearly shown by the increased amplitude of both traces. The amplitude and short cycles of the LF trace indicate internal corrosion; the increase in amplitude in the second test shows a significant increase in corrosion. At the time of the first test, 1.2% of the cross-sectional area had already been lost; over the next 6 months, this loss increased another 3.5%, for a total loss of 4.7%, and a threefold increase in the rate of deterioration. The increased deterioration led to the rope's being replaced with a new rope, which was lubricated in the field with a synthetic lubricant. The results of the first NDT, shown in figure 7, reveal several broken wires and one missing wire. The LF trace does not indicate metal loss from corrosion because there is not a general loss of metallic cross section. The missing wire is indicated by the two long LF lines and the corresponding dip in the LMA trace where the missing wire decreased the metal area in that part of the rope.

A second test on the same rope was made about 6 months later, and the results are shown in figure 8. The broken ends of the wires have separated, as illustrated by the longer vertical line of the LF trace. There is no increase in the number of broken wires because the number of longer LF lines remains the same. The LMA and internal corrosion are minimal.

A third test was done about 18 months later. Figure 9 shows that the ends of the broken wires have separated further, but there is still no appreciable internal corrosion; that is, not all of the LF traces are higher. Furthermore, the LMA trace indicates little overall loss of metal from the rope. The small dips represent localized reductions in cross-sectional area caused by the gaps between the ends of the broken wires. The gaps have increased, but there is no evidence of new breaks and the amplitude of the LF trace again reflects no increase in corrosion.

The only known difference between these two man cage ropes was the difference in the type of lubricant used. The rate of deterioration in the rope lubricated with the synthetic lubricant was distinctly less than the rate in the rope lubricated with the petroleum-based lubricant. The results, summarized in table 2, show that the rope lubricated with the petroleum-based lubricant lost 0.58% per month of its cross-sectional area over 6 months of service. The rope that replaced it was lubricated in the field with a synthetic lubricant and showed minimal deterioration after 2 years of service.

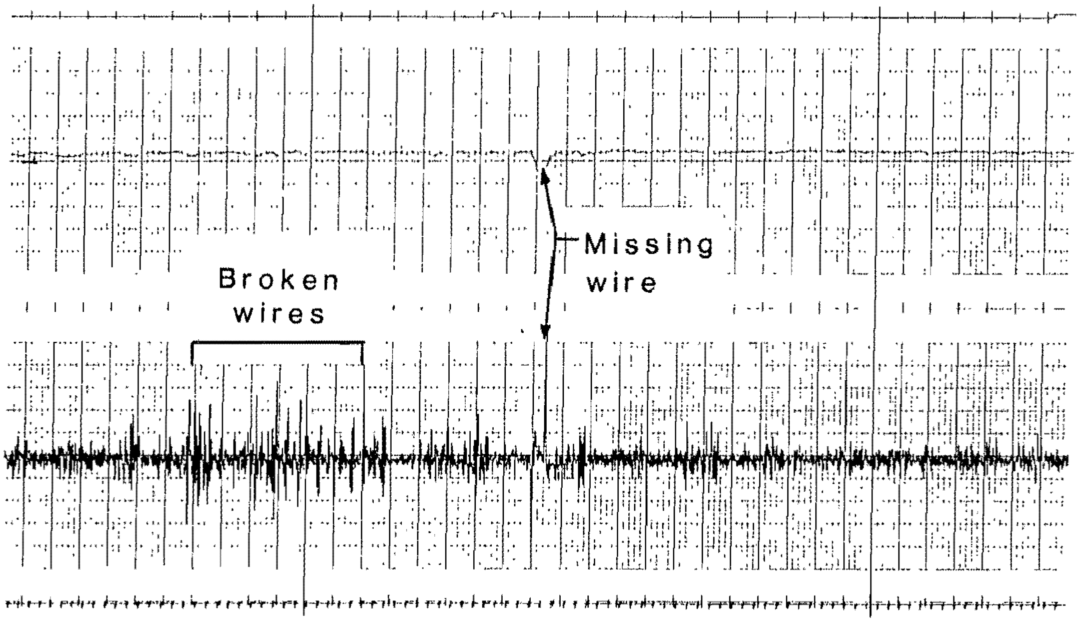

Figure 7.–Strip chart showing broken and missing wires, man cage rope, mine 3.

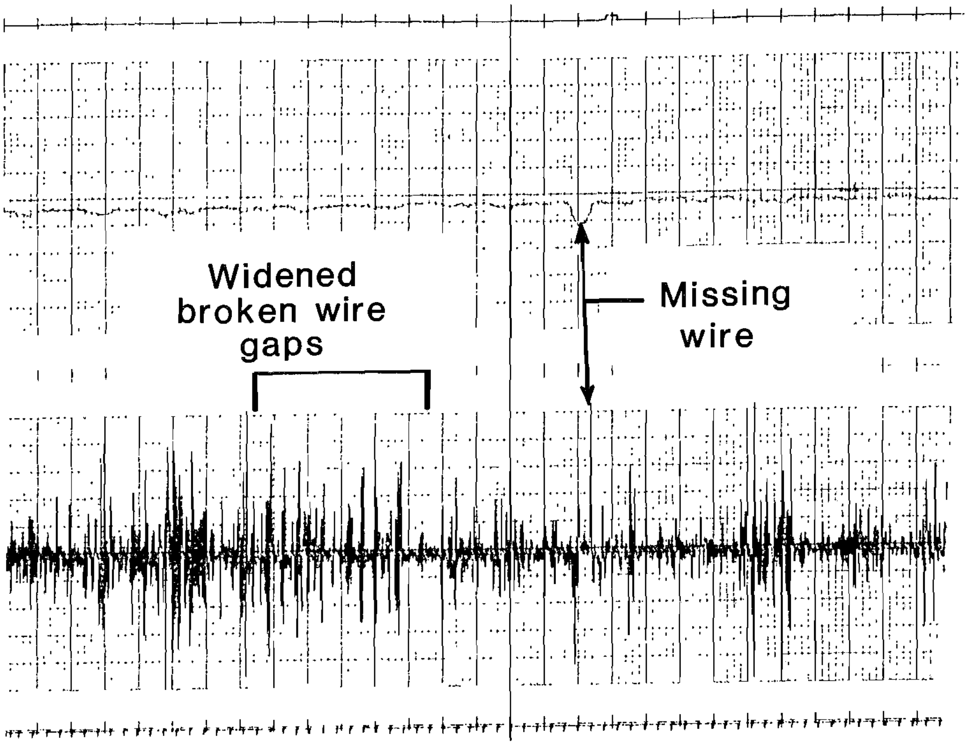

Figure 8.–Strip chart showing gaps where broken wires (fig. 7) have separated, man cage rope, mine 3.

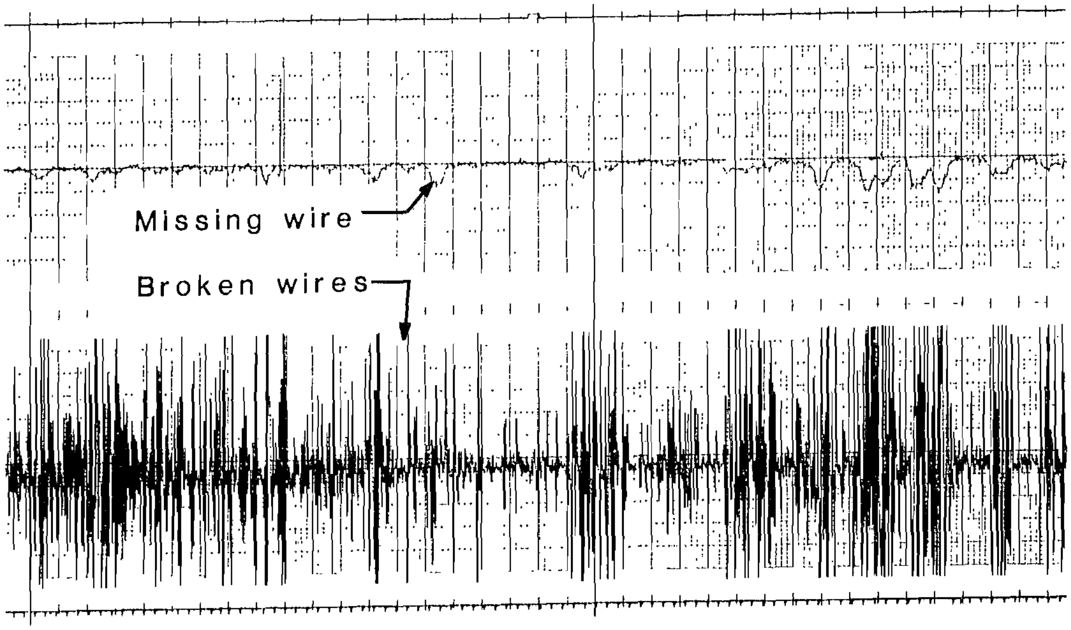

Figure 9.–Strip chart showing further separation of broken wires, man cage rope, mine 3.

Table 2.–LMA using petroleum-based and synthetic lubricants, mine 3

Time from initial tests	LMA, %	Rate of loss, %/month
MAN CAGE ROPES		
Old rope, petroleum-based:		
Initial test	1.2	NAp
6 months from initial tests . . .	4.7	0.58
New rope, synthetic:		
Initial test	Neg.	NAp
6 months from initial tests . . .	Neg.	Neg.
24 months from initial tests . .	Neg.	Neg.
SKIP HOIST ROPES		
Old rope, petroleum-based:		
Initial test	0.4	NAp
6 months from initial tests . . .	1.0	0.1
New rope, synthetic:		
18 months from initial tests . .	Neg.	Neg.

NAp Not applicable.
Neg. Negligible.

Skip Hoist

The skip hoist rope was of a different construction than the man cage rope. Because it was used during shaft sinking and for production hoisting, a rotation-resistant rope was chosen by mine personnel. The rope was 1 in. in diameter and 1,170 ft long. It was lubricated with a petroleum-based lubricant similar to that used on the man cage rope. Figure 10 shows the results of two nondestructive tests made 6 months apart. Even though the man cage and skip hoist ropes were in the same shaft, were lubricated with the same lubricant, and were tested at the same time, the skip hoist rope showed far less deterioration than the man cage rope.

The first test showed a maximum LMA of about 0.4%, while the second test showed a maximum loss of 1.0%. This equates to a loss of only a 0.1% per month. Both LF traces have little vertical amplitude, which indicates no internal corrosion. The small LMA in the skip hoist rope as compared with that in the man cage rope is not understood, but is thought to be the result of better lubrication. The more open construction of the rotation-resistant skip hoist rope allowed easier penetration of lubricant to the rope interior than did the flattened strand construction of the man cage rope.

Even though there was little loss of cross section, the rope still had to be replaced because of scuffing, which broke some of the outside wires. This did not appear to be related to lubrication. However, the new rope was lubricated with a synthetic lubricant. The data, summarized in table 2, show that the synthetic lubricant provided better protection than the petroleum-based lubricant, even under conditions where the performance of the petroleum-based lubricant appeared to be satisfactory.

MINE 4

Mine 4 is a trona mine. A ground-mounted friction hoist lifts a cage having a counterweight and a tail rope. Both the conveyance and counterweight ends of the rope were first lubricated with petroleum-based lubricant and then with a synthetic lubricant. This arrested deterioration, which had been accelerating.

The friction hoist used four ropes. The rope chosen for investigation was the one closest to a shaft water leak and was a 6 by 27 fiber-cored, flattened strand, left lang lay rope, 1-1/4 in. in diameter and 1,500 ft long. The alkaline water running down the walls of the lower portion of the shaft is corrosive. Because of these conditions, management chose a galvanized rope. The location of the leak was such that only the counterweight end of the rope came near it; thus, the counterweight end was subjected to the most corrosive environment.

Both the conveyance and the counterweight sections were NDT-tested periodically. Table 3 shows that LMA at the conveyance end was negligible after 6 months. Twelve months later, deterioration was evident and the lubricant was then changed from a petroleum-based to a synthetic type. The next test, at 24 months, showed LMA of 3.2% in spite of the application of synthetic lubricant. The amplitude of the LF trace showed that metal loss was caused by internal corrosion. However, the loss increased to only 3.6% after 31 months and to 4.2% after 55 months. This equates to a decreased rate of LMA of 0.18% per month between 6 and 24 months, to 0.06% per month between 24 and 31 months, and to only 0.03% per month between 31 and 55 months. The gradual nature of the decrease in metal after application of the synthetic lubricant presumably reflects the time required for the synthetic lubricant to penetrate through the existing lubricant.

Table 3.–LMA using petroleum-based and synthetic lubricants, mine 4.

Rope and lubricant	Time from initial tests, months	LMA, %	Rate of loss, %/month
Conveyance end:			
Petroleum-based . . .	6	Neg.	Neg.
Synthetic[1]	18	NAp	NAp
Do.	24	3.2	0.18
Do.	31	3.6	.06
Do.	55	4.2	.03
Counterweight end:			
Petroleum-based . . .	18	NAp	NAp
Synthetic[1]	24	6.3	.26
Do.	55	8.7	.08

NAp Not applicable.
Neg. Negligible.
[1] Lubricant changed from petroleum-based to synthetic.

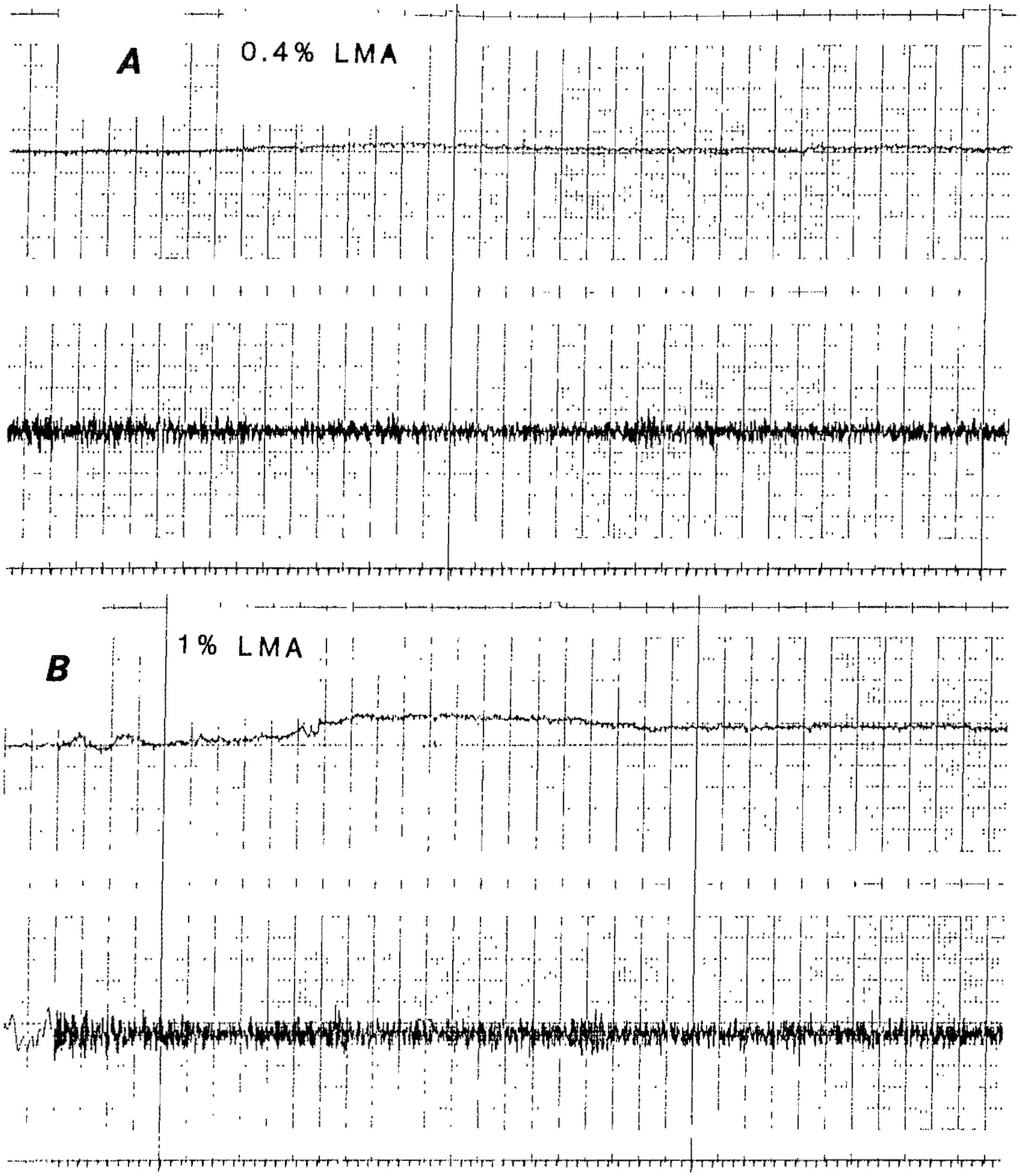

Figure 10.–Strip charts showing little LMA and LF, skip hoist rope, mine 3. *A*, Initial test; *B*, after 6 months.

Table 3 also shows that the counterweight end of the rope, while lubricated with a petroleum-based lubricant, lost 6.3% of its cross section or 0.26% per month over the first 24 months. The lubricant on this rope was also changed to a synthetic type 18 months after rope installation, and the average LMA dropped to only 0.08% per month between 24 and 55 months of service.

A comparison between the counterweight and the conveyance ends of the rope shows that the counterweight end lost nearly twice as much metal (6.3%) as the conveyance end (3.2%) after 24 months of service. Presumably this occurred because the conveyance end was closer to the water leak. Furthermore, between 24 and 55 months of service, even though both ends were lubricated with the same synthetic lubricant, the counterweight end had a rate of loss per month about three times higher, that is, 0.08 versus 0.03. Even though 0.08 is still a low rate of metal loss, the relatively higher rate may indicate that while synthetic lubricants penetrate rope, they may not completely displace water or neutralize corrosive agents even when applied in large quantities.

Figure 11 compares plots of rates of LMA following use of the two different lubricant types. The curves show an initial period of stability followed by an increasing and then a decreasing rate of LMA. The initial stability results from the use of galvanized rope as well as the protection provided by the layup lubricant. After the lubricant was washed away and the galvanizing coating wore off, the LMA rapidly increased because of increased internal corrosion. Time was required for the synthetic lubricant, which was applied first at 18 months, to penetrate into the rope. This is shown by the gradual decrease in rate of metal loss.

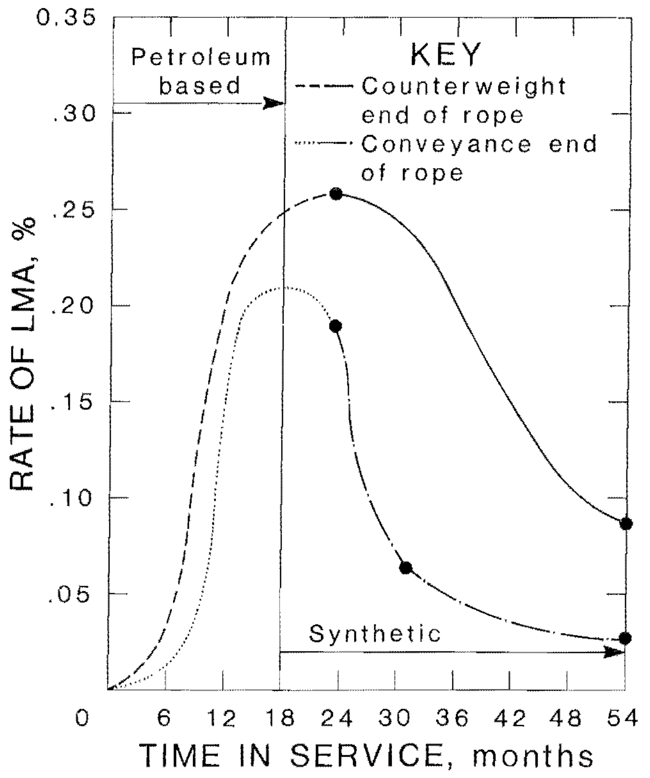

Figure 11.–Reduction in rate of LMA after changing from petroleum-based to synthetic lubricant, mine 4. Rate of LMA before 18 months is inferred.

MINE 5

Mine 5 is a silver mine that uses a double-drum hoist. The shaft drips water and the humidity is high. The rope was 6 by 21, fiber-cored, right lang lay, 1-3/8 in. in diameter, and 2,400 ft long. From the time of installation in 1978 to 1984, the rope was lubricated with a petroleum-based lubricant. Because the rope was periodically cut off just above the skip where corrosion was greatest, the advantage of a synthetic lubricant could be shown by testing different sections after first using a petroleum-based and then a synthetic lubricant.

Rates of deterioration were measured over three different periods: one while lubricating with the petroleum-based lubricant and two after changing to the synthetic lubricant. Because of the high rate of deterioration, the section of the rope above the skip was periodically removed and the rope reterminated. This moved less deteriorated rope from above down to the skip. Therefore, it was not possible to retest the worst section of the rope periodically. The situation, however, allowed testing of different lubricants under the same conditions.

Table 4 shows that changing from a petroleum-based lubricant to a synthetic lubricant reduced the rate of LMA. Tests were run at the beginning and end of one 6-month period while the rope was being lubricated in service with a petroleum-based lubricant. At the beginning, LMA was 4%, and 6 months later it was 5.4%. Both readings were taken near the skip. This equates to a monthly rate of loss of 0.23%. The amplitudes of the LF trace showed that damage from corrosion had increased over the 6 months. The rope was then cut off and reterminated at the skip, which moved rope from above the cutoff point to directly above the skip.

Table 4.–LMA using petroleum-based and synthetic lubricants, mine 5.

Lubricant type	Time from initial test, month	LMA, %	Rate of loss, %/month
Petroleum-based . . .	([1])	4	NAP
Do.	[2]6	5.4	0.23
Synthetic[3]	12	1.6	NM
Do.	[2]24	5.1	.29
Do.	30	2.2	NM
Do.	36	2.5	.05

NAp Not applicable.
NM Not measured.
[1] Initial test.
[2] Following this test, the section of rope above the skip was removed.
[3] Lubricant change from petroleum-based to synthetic.

The lubricant was then changed to a synthetic type. Nondestructive tests were run 12 and 24 months after the initial test, with losses being 1.6% and 5.1%, respectively. This equates to a rate of 0.29% per month, a rate slightly higher than when using the petroleum-based lubricant. A greater amplitude on the LF traces showed that again corrosion was in part responsible for the 5.1% loss.

The rope was reterminated a second time and tested 6 and 12 months after the retermination (30 and 36 months after the initial test). This equates to 24 and 30 months after the synthetic lubricant was first applied. The LMA was 2.2% after the first test and 2.5% 6 months later, equaling a rate of loss of only 0.05% per month over this period. The amplitude of the LF trace did not increase either, indicating that internal corrosion had slowed or stopped. The synthetic lubricant had reduced the rate of metal loss from an average of about 0.29% per month to a negligible 0.05% per month. Because the rate of metal loss between 30 and 36 months was greatly reduced, it was assumed that the synthetic lubricant had not yet penetrated the old lubricant and into the rope.

MINE 6

Mine 6 is a molybdenum mine. The shaft is wet and acidic, the humidity is over 50%, and temperatures range from 0° to 90° F. The ropes investigated were on a double-drum waste hoist and were 6 by 27, flattened strand, fiber-cored, right lang lay, 1-3/8 in. in diameter, and 1,150 ft long. Table 5 compares results from two different ropes used in the same shaft.

Table 5.–LMA using petroleum-based and synthetic lubricants, mine 6.

Rope and lubricant	Time in service, months	LMA, %	Rate of loss, %/month
Old rope, petroleum-based	19	11	0.58
New rope, synthetic	2	.7	.35
	15	2.8	.16
	27	3.7	.07
	34	3.8	.01

The first rope, lubricated during service with a petroleum-based lubricant, had to be replaced after only 19 months of service because it lost 11% of its cross section. This equates to 0.58% LMA per month. The rope was then replaced with a new rope that was lubricated in the field with a synthetic lubricant. The new rope lost 0.35% per month over the first 2 months, but the monthly rate dropped to 0.16% between 2 and 15 months and to 0.07% per month from 15 to 27 months. It dropped further yet to 0.01% per month between 27 to 34 months. Figure 12 summarizes the results. Even after nearly twice the accepted service life, the rope lubricated with the synthetic lubricant had only about one-third the metal loss of the rope lubricated with the petroleum based lubricant.

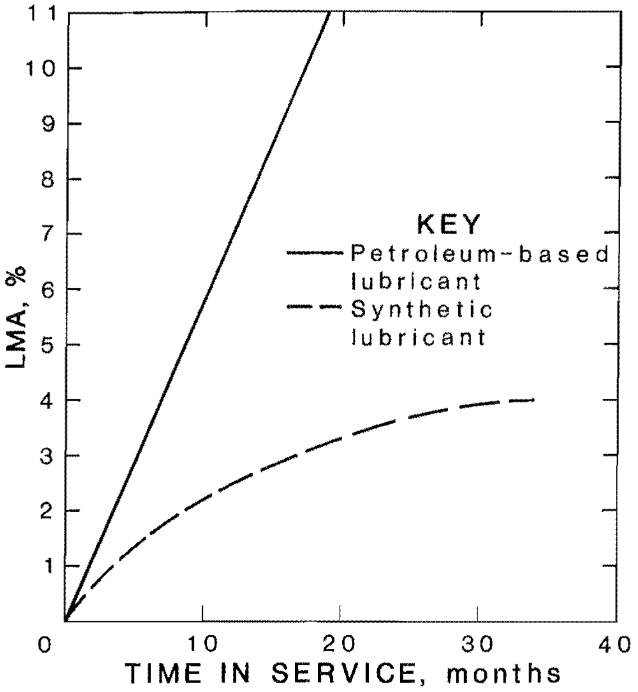

Figure 12.–Reduction of LMA using synthetic lubricant on double-drum hoist, mine 6.

LF CORROSION FACTOR

Because corrosion is shown by the amplitude of the LF trace, a method was developed to quantify corrosion using trace amplitude. The number of chart squares intersected by the LF trace are counted. The greater the amplitude of the trace and the more oscillations per unit of length, the greater the degree of corrosion and the greater the number of squares intersected by the trace. The newly proposed term, LF corrosion factor, has been defined as the percentage of total LF strip chart squares intersected by the LF trace. The corrosion factor includes broken wires, but their contribution is small. LF corrosion factors were measured for the second rope studied at mine 6, and the increase of corrosion with time was plotted (fig. 13).

The relationship between the LF corrosion factor and the actual amount of corrosion or loss of strength has not yet been determined. Also, quantitative measures of the LF corrosion factor are difficult because variations in the sensitivity setting of the NDT instrument cause variations in the LF corrosion factor without an actual change in corrosion. Therefore, accurate sensitivity settings are essential. A computer program may be required to count squares before the method can be simplified and standardized enough to receive wide use.

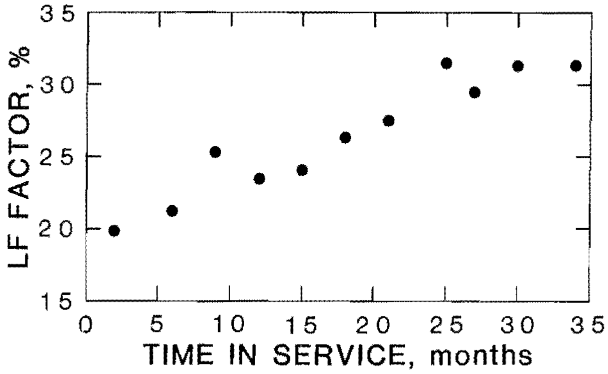

Figure 13.–LF corrosion factor versus age of rope.

PRESSURE LUBRICATION

Even though synthetic lubricants appear to be superior to petroleum-based lubricants when dripped, sprayed, or brushed on, some installations require special lubricant properties that synthetics do not have. Fortunately, pressure systems have been developed that can force petroleum-based lubricants into rope interiors. However, these systems often entail costly equipment and operating procedures. Although such pressure lubricators are not the subject of this investigation, their existence is noted because they offer an alternative to the use of synthetics. New equipment designs are being introduced by industry, but tests have not yet been completed.

SUMMARY AND CONCLUSIONS

The results show that not only can thin lubricants penetrate a rope, they can penetrate an existing thick lubricant that has hardened on the surface, even though full penetration through a hardened lubricant may require many months because the heavy lubricant must be broken down first. Synthetic lubricants have few advantages if the petroleum-based lubricant added during manufacture remains effective. Some improvement was noted in every case in which the synthetic lubricant was used, even in mines where temperatures varied over a wide range. It was not clear whether or not the penetrating lubricants completely replaced or otherwise neutralized some water solutions.

Electromagnetic NDT is the only method available for evaluating the condition of the interior of a rope. Rates of deterioration can be obtained by comparing LMA periodically over the life of a rope. NDT also differentiates between internal corrosion and internal wear by comparing the LMA and LF traces. Therefore, NDT methods can be used to compare the effectiveness of different lubricants. Studying NDT results from field tests is more realistic as well as less expensive and time-consuming than a controlled research program.

In an attempt to quantify the amount of corrosion in a rope, the percentage of the total number of strip chart squares intersected by the LF trace was determined. This LF corrosion factor can be used to determine the extent to which LMA results from internal corrosion as opposed to wear.

Under dry and noncorrosive conditions, the layup lubricant was seen to provide adequate protection for over 10 years. Some ropes can achieve long service lives without any field-applied lubricant. However, in most cases, rope service life can be increased through applying a penetrating lubricant.