SAFETY IN MINES RESEARCH ADVISORY COMMITTEE

SIMRAC

DRAFT FINAL REPORT

Title: DETERIORATION OF MINE WINDER ROPES

AUTHOR/S: GFK Hecker, EJ Wainwright, C Heydenrych

RESEARCH AGENCY : Materials Science and Technology

Project No: GAP 439

Date: JULY 1998

Executive Summary

The objective of the research project was to determine how winder design parameters affect the safe working life of a rope operating of drum winders with the view to refine requirements in the code of practice for the performance, operation, maintenance and testing of such winders. The major part of the work was the inspection of ropes on selected winders to establish the progress of rope deterioration.

Unfortunately, the only set of ropes that was discarded during the period under review was not made available for subsequent investigation. After consultation with the GAP Engineering Advisory Group, the amount budgeted for this investigation was allocated for tests to obtain discard criteria for non-spin ropes with outer broken wires.

The work was a continuation of work done during 1996 and it is continued during 1998. The report therefore mainly describes the results obtained during 1997.

The tests to obtain discard criteria for non-spin ropes with outer broken wires have suggested that a ribbon strand non spin rope should be discarded when the area of the broken outer wires exceeds eight per cent.

Tests on discarded triangular strand ropes have shown that the discard criteria for such rope constructions are suitable. It is recommended, however, that reductions in rope diameter be measured rather than comparing the rope diameter with the nominal diameter.

Tests on discarded non-spin rope specimens have led to a recommendation for a stricter discard criterion that should be applied until a proper set of discard criteria is found.

Table of Contents

1 Introduction

A SIMRAC sponsored project entitled *Deterioration and discard of mine winder ropes* commenced during 1996. Although it was known at the outset of the project that it would not be completed within one year, it was agreed that it should be divided into one-year contracts. Likewise, although this is the final report on the 1997 project GAP439, the work is continuing during 1998 (GAP501).

As an introduction to the rope deterioration study, a few concepts need to be clarified. Figure 1.1 shows how the statutory safety margin is defined as the difference between the minimum allowable rope strength and the maximum allowable rope force. It also shows how the true safety margin can be determined as the difference between the actual rope strength and the maximum total (static plus dynamic) rope force.

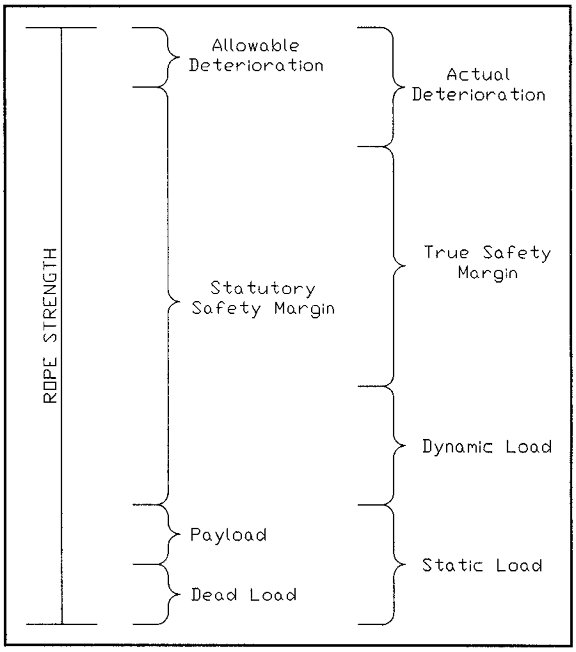


Fig. 1.1: Rope force components

When a new approach towards formulating safety regulations was motivated, the concept of the true safety margin was developed. It was shown that its value would be acceptable if

- the peak dynamic loads would be limited by designing the winder brakes appropriately, and
- the actual deterioration would be kept within acceptable limits by timely rope discard.

Two codes of practice were drafted to deal with the above two requirements:

- **Draft:** *Code of Practice for the Performance, Operation, Testing and Maintenance of Drum Winders relating to Rope Safety*
- **SABS 0293: 1996 South African Standard:** *Code of practice: Condition assessment of steel wire ropes on mine winders**

The requirements in the first code of practice are not only aimed at limiting peak dynamic rope forces but also at limiting the rate of rope deterioration so that unexpected rope deterioration will not occur. This rope deterioration study is aimed at determining how winder design parameters affect rope life.

The purpose of the rope deterioration study was to verify the requirements in the first of the above two codes of practice and, if necessary, to refine these requirements.

The discard criteria for triangular strand ropes in the second code of practice have been shown to be acceptable, as far as could be established from discarded ropes. The discard criteria for non-spin ropes, however, still needs refinement. This forms the second section of this report.

Due to funds being available for laboratory tests and these funds not being needed for the rope deterioration study, some tests were done to determine discard criteria for non-spin ropes. The

* Named the "RCA code of practice" in the remainder of the document

results of the tests are aimed at refining the requirements in the second of the above two codes of practice.

2 Rope deterioration study

2.1 Project requirements

When the project was planned, team members E J Wainwright, M N van Zyl and G F K Hecker discussed the study requirements with T C Kuun. The main conclusions from these discussions were:

- The RCA code of practice must be implemented before any valid conclusions can be drawn from rope lives obtained on winders. To achieve this, ropes must be inspected and discarded properly, i.e. according to the requirements in the code of practice.
- A further factor which greatly influences rope deterioration is rope maintenance. Procedures such as timely pulling in of back ends, breaking back of broken wires etc. must be followed so that poor lives are attributed to poor maintenance and to the winder.
- The influence of rope quality on rope life was not known. Whenever a rope was discarded, it needed to be established whether the rope had deteriorated normally for the specific winder or whether there was an inherent weakness that resulted in a discard criterion being met.

As mentioned in the introduction, the forces acting in a rope are the sum of the static and dynamic loads. These can be calculated by taking the dynamic properties of the rope, the masses and the dynamic performance of the winder into account.

To study the deterioration of the rope, however, the stresses acting in the wires need to be established. There are bending stresses in the wires due to the rope being wound onto the drum and over the sheave. Secondary bending stresses occur when a rope with a given construction is loaded in virtually any direction (axial, bending, lateral compression and torsion). There are also contact stresses between the wires as well as between wires and winder drums and sheaves. The major contributing factor towards deterioration of triangular strand ropes operating on drum winders are contact stresses that flatten the outer wires.

The fatiguing mechanisms of drum winder ropes was considered be one or a combination of the following:

- The wear and plastic deformation (sometimes collectively referred to as plastic wear) that flatten the outer wires of all drum winder ropes with usage and make the rope wires more susceptible to crack initiation.
- The bending of a rope over the sheave and on the drum generate bending stresses that increase the load range. Broken wires that are produced lower the tension-tension fatigue resistance of the rope.
- The repeated contact stresses experienced by the rope when coiled onto the drum produce broken wires.

To get to the bottom of rope deterioration, it is therefore important to have a thorough understanding of the stresses that act in the wires so that the damage accumulation of the wires can be evaluated. Unfortunately the overall project was not accepted as proposed and only the work entailing the field observations and tests on discarded ropes were approved.

2.2 Winder selection

At the outset of the project, field observations continued on the winders that were selected for the studies done under GAP324:

Winder	Study object
St. Helena No. 4 shaft	Longest rope life
Hartebeestfontein No. 4 shaft	Wear
East Driefontein No. 2 shaft	Broken wires
West Driefontein No. 4 shaft	Wear and broken wires

The winder at St Helena No.4 shaft was selected for reference purposes because it has the longest rope life.

A rope on a rock winder is normally wound onto the winding drum when the skip contains rock and unwound when the skip is empty. When unwinding, therefore, the rope experiences a reduction in tensile force as it leaves the drum. As a result, the strain reduces and there is a certain amount of *back-slip*. Plastic and abrasive rope wear is attributed to this slipping action. To obtain a different set of reference conditions, a winder with a counterweight was chosen. The static force in the rope that suspends the counterweight is constant and the load variations are only due to acceleration, deceleration and oscillations produced by winder and shaft characteristics.

To obtain more field data, a winder at Premier No.1 shaft was chosen. The shaft is relatively shallow and the winders are busy. The ropes therefore accumulate cycles faster than on most other winders. The following table shows the winders that were added to those selected for field observation:

Winder	Study object
Premier No. 1 shaft	Busy winder
West Driefontein No. 7 shaft	Zero static load range on counterweight rope

2.3 Rope histories

This chapter provides a summary of the data obtained from the mines' rope record books. Appendix A provides more details and also shows rope test histories.

2.3.1 Rope lives

Figures 2.3.1 to 2.3.5 show the rope lives (in cycles) that were recorded on the selected winders. Where rope lives were available, the average number of cycles per day is shown for each set of ropes. The life (in days) is shown elsewhere.

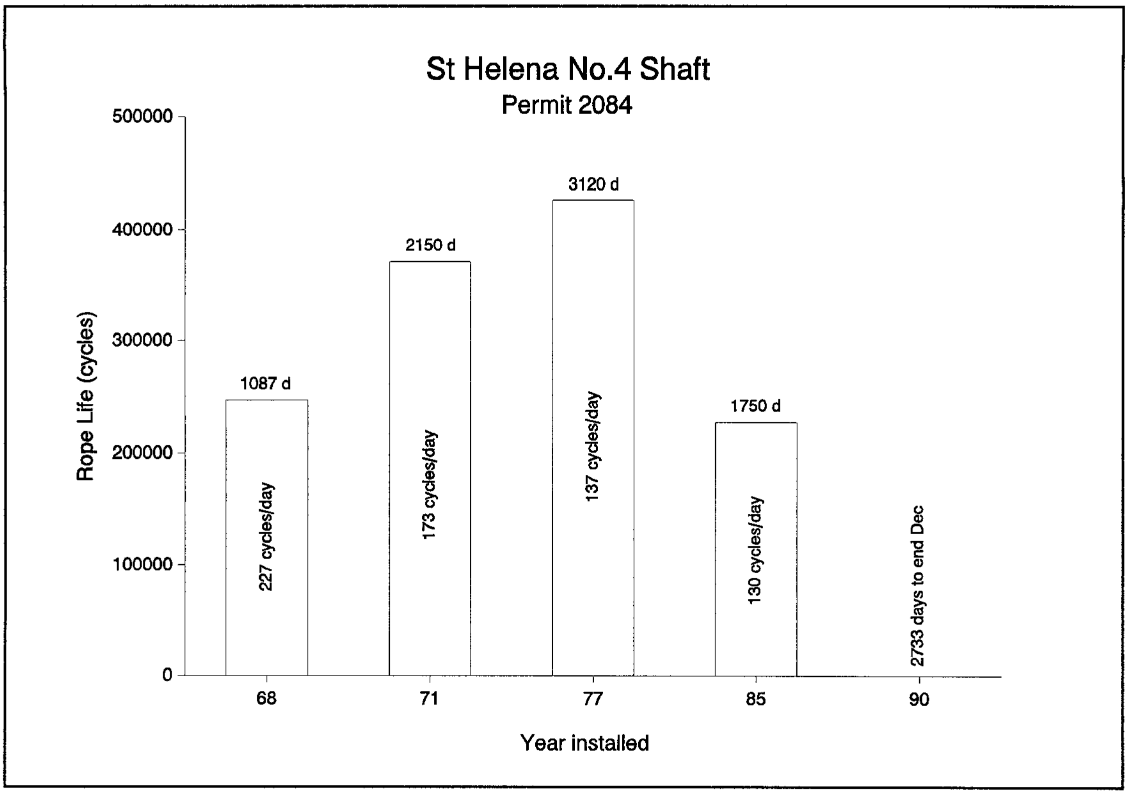


Fig. 2.3.1: ***Rope lives obtained at St. Helena No.4 shaft***

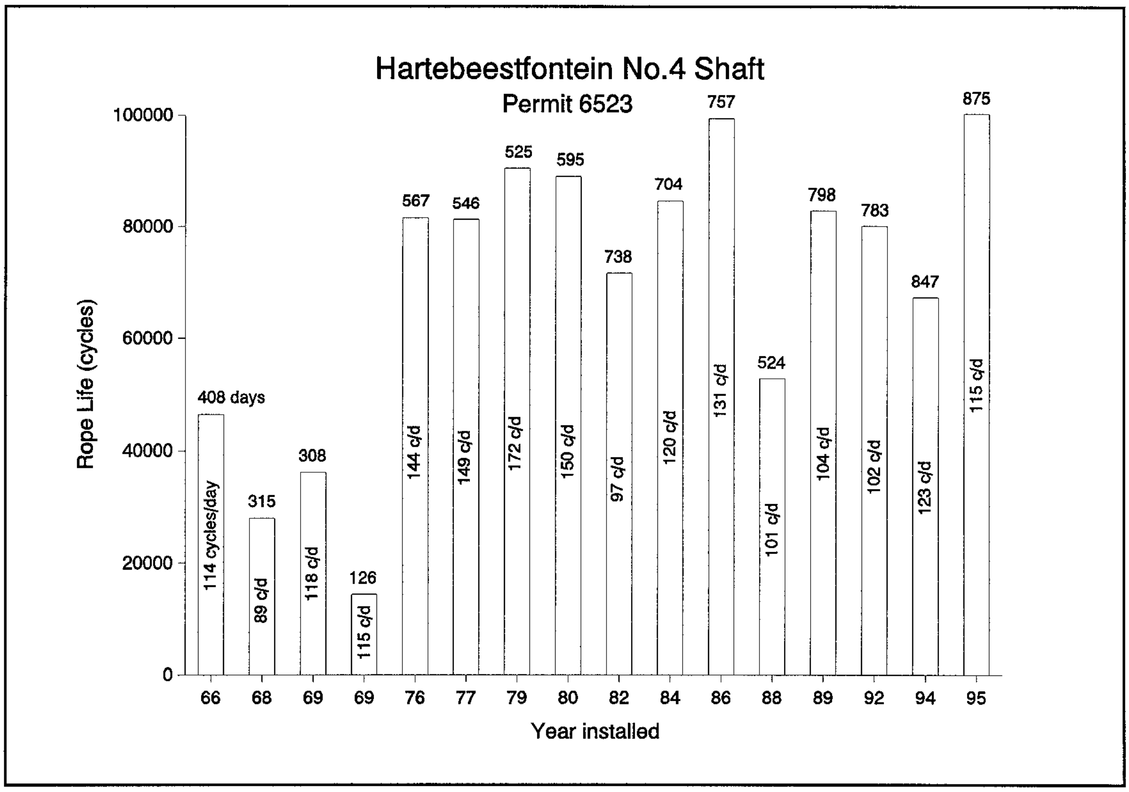


Fig. 2.3.2: ***Rope lives obtained at Hartebeestfontein No. 4 shaft***

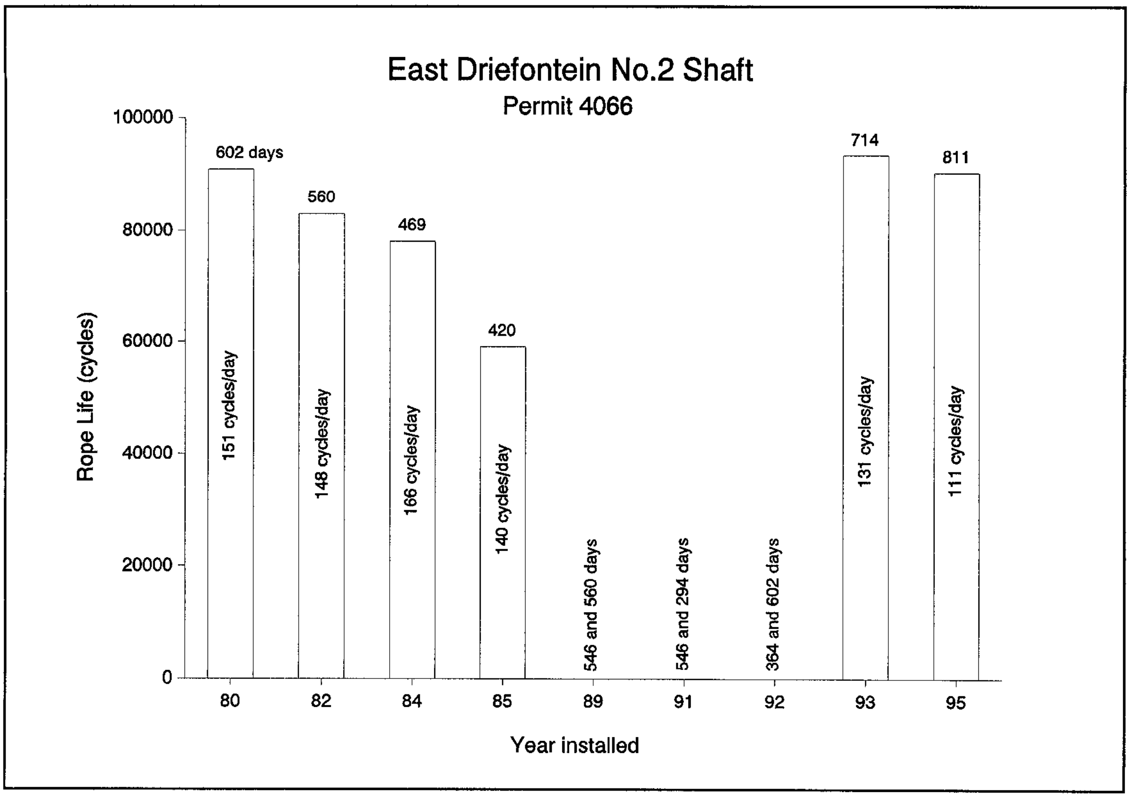


Fig. 2.3.3: Rope lives obtained at East Driefontein No. 2 shaft

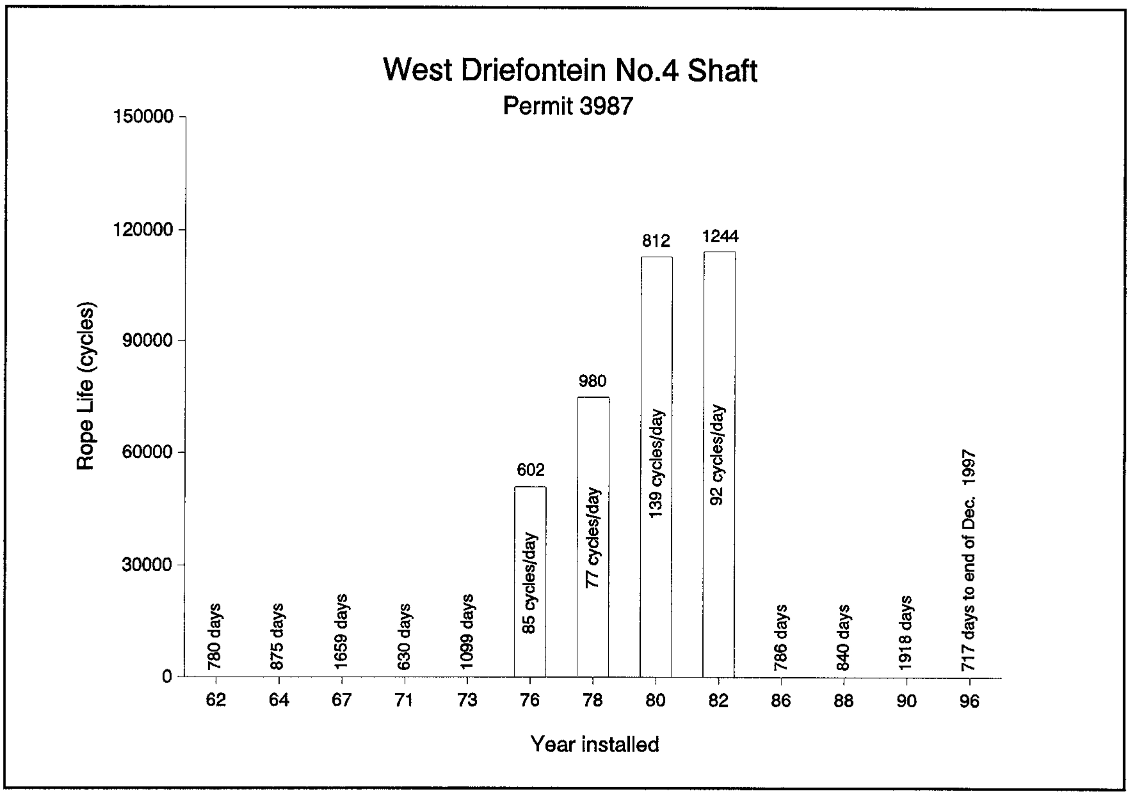


Fig. 2.3.4: Rope lives obtained at West Driefontein No. 4 shaft

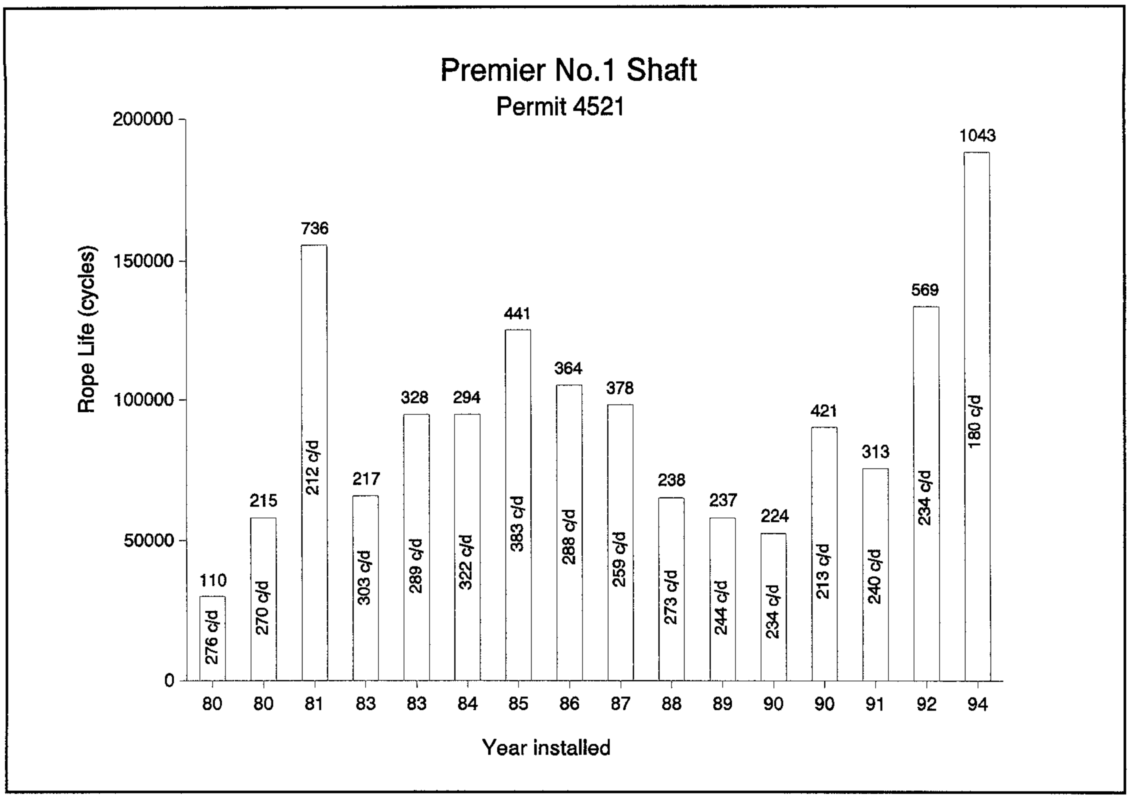


Fig. 2.3.5: ***Rope lives obtained at Premier No. 1 shaft***

During a statistical analysis of rope lives obtained on various winders, two of the rope lives obtained on St. Helena No. 4 shaft (see Fig. 2.3.1) were not included because it was not believed that such long rope lives could be obtained. The lives have been verified, however, and the mathematical model developed during the statistical analysis predicted that such lives could indeed be expected.

Unfortunately not all the lives of the ropes operating on East Driefontein No.2 shaft have been obtained (see Fig. 2.3.3). (Note: The rope life in days is known, but the cycles could not be established).

The rope lives obtained on West Driefontein No. 4 shaft are also incomplete. The four values shown (see Fig. 2.3.4) are those obtained during the gathering of data for the statistical analysis. It is interesting to note that there seems to be a steady increase in rope lives. When the latest values are also obtained it will be interesting to study this trend.

Appendix A lists the records on the ropes that were available by the end of 1997.

2.4 Field observations

This section presents a brief overview of the results of measurements made during the site visits. Appendix B provides a comprehensive list of all the results and has been prepared for future reference.

During the field observations, the following was recorded:

- Condition of the sheaves
- Latest entries into the rope record book
- Rope inspections at the front end and back end of each rope as well as where there were indications of rope deterioration that could possibly lead to the rope being discarded.

At each rope inspection position, the following was recorded:

- Diameter (measured by means of a diameter tape)
- Lay length
- Ovality (diameter measurements across opposing strands by means of a vernier)
- Moulds of the rope surface
- Photographs

The moulds made of the rope surface were processed off site as follows:

- Close the mould where it was split when removed from the rope on site
- Pour plaster of paris into the mould, eliminating enclosed bubbles as far as possible by vibrating the mould
- Section the plastercast at at least two places
- Place the section surfaces on a scanner to obtain a computer image of the section surface
- Analyse the scanned image to obtain the endpoints of wear surfaces on the outer wires.

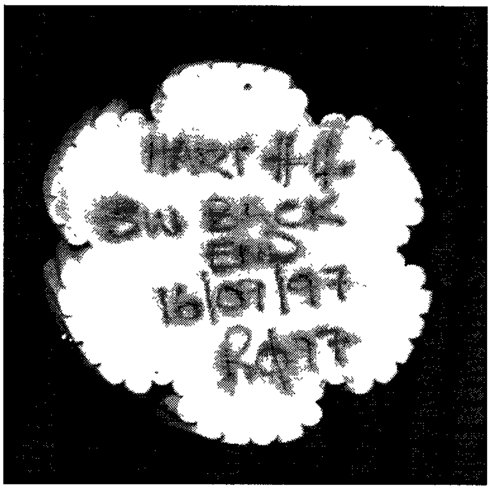


Fig. 2.1: ***Scanned cross section of a rope plastercast***

Figure 2.1 shows a scanned image of the cross section of a plastercast made from a rope mould. To analyse such a cross section, special software was developed. This software provides for the following steps:

- Put the requested image on the display
- Allow the user to indicate the beginning and end of the wear surface of each wire
- Store a results file that contains the calibrated wear length of each wire

Figure 2.2 highlights the endpoints of the wear surface on a few of the wires shown in Fig. 2.1:

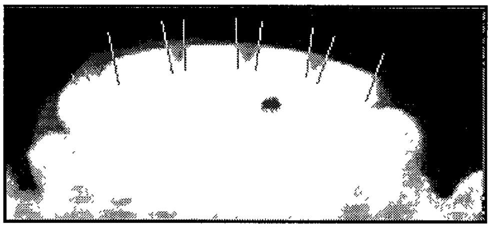


Fig. 2.2: ***Detail of Fig. 2.1 showing the endpoints of wire wear lengths***

The results files were then analysed to produce the number of worn outer wires and the total wear length of each cross section. The tables in Appendix B show the wear lengths (each an average of two analyses) and the figures in Appendix B indicate the wear lengths expressed as a percentage of the nominal rope circumference.

At least two rope plastercast cross sections were analysed for every mould made. This was done to establish the repeatability of the method of analysis. Although the number of worn wires can vary from one cross section to the next, the total wear length was consistent to within a few percent. This indicates the fact that there is more wire wear where there are fewer exposed wires.

2.5 Discussion

The main objective of the project was to relate rope service lives to winder design parameters. The method was to observe the progression of rope deterioration on the selected winders and then to analyse the ropes when they were finally discarded.

During the course of the project, only one set of ropes was discarded, namely that at East Driefontein No. 2 shaft. The ropes were not discarded because their condition had deteriorated, but because they had become too short. This was very unfortunate, because it effectively led to a null result in the research work on that winder. Furthermore the ropes were not made available for a post-mortem study so that a final analysis could not be made.

Viewing the rope lives obtained on this winder (see Fig.2.3.3) shows that the first rope life obtained after the period in which the cycles was not recorded was longer than the longest rope life obtained previously. Because the set of ropes investigated during this research project was not kept in service until it had deteriorated to such an extent that it needed to be discarded, it is to be expected that it, too, could have had a record life (in terms of cycles).

The SIMRAC contract report on project GAP324 describes how front ends and back ends were cut on this winder. The care with which these operations were done as well as the extensive maintenance that was done on the drums suggests that mine personnel are doing whatever possible to ensure good rope lives.

The records of the destructive tests on the ropes operating on the Premier winder, shown in Fig. A.7 exclude one test result: Specimens that were cut for tests on 1997-07-28. The results of the test on the specimen from compartment 3 gave a large reduction in breaking strength. This poor result could be ascribed to damage to the rope or to fatigue of the rope where it entered the resin socket. Further samples were cut on 1997-08-17 and the breaking strength was 12%

higher! Whatever the reason for this loss in strength, it should be considered when reviewing the *Code of Practice for the Performance, Operation, Testing and Maintenance of Drum Winders relating to Rope Safety*. For reference purposes, the results of the poor test are shown in Appendix C.

When viewing the results of the six monthly tests shown in Appendix A and those of the site measurements given in Appendix B, the following can be observed regarding the wear of the ropes:

- The deterioration of the outer wires can, to some extent, be evaluated from the loss in outer wire diameter as measured during the six-monthly front end tests.
- The wear of the front end of a rope is an indication of the wear that occurred when that portion of the rope was passing over the sheave. The worn section only becomes the front end after one or more front end cuttings.
- When the rope wear is expressed as the length of the worn area divided by the rope circumference, it seems as though this value increases rapidly at the beginning of the rope life to between twenty and thirty per cent. Later the wear increases slowly and does not seem to exceed forty per cent except at a few sections.

The rope lives obtained on the various winders (see section 2.3) seems to have improved during the last rope sets. All the rope lives obtained at Hartebeestfontein No.4 shaft have exceeded those reported during the statistical analysis[1], and it is not known whether subsequently ropes have indeed been discarded because of wear (the reason why this winder was selected for the study in the first place). The improved rope lives could be ascribed to the new rope designs that were done during metrication.

2.6 Recommendations

Fuchs[2] has made a few interesting observations regarding rope deterioration. These are limited to research on ropes operating on Koepe winders. It is recommended, however, to investigate some of these observations with the view to possibly apply them to drum winder ropes:

- Rope performance should be studied by close scrutiny of discarded ropes. When a rope has been discarded, the sections that are to be investigated are to be placed into a test machine. The tension and rotation of the rope should then be adjusted until the same tensile force and lay length are obtained when the rope was still in service. The specimen should then be encased in resin. The specimen can now be cut so that cross sections can be inspected for structural rope deformation and wear patterns that can suggest improved rope designs.
- Extensive fatigue tests done in Germany and elsewhere have shown that the S-N curves* of ropes and wires, when plotted on a log-log scale, are parallel. The vertical distance between the curves is attributed to the incalculable stresses that wires endure when they are formed into a rope. A detailed assessment of these stresses should lead to accurate fatigue predictions. To use such a method for drum winder ropes, however, the S-N curves of worn wires have to be established and the number of tests required may be prohibitively large.
- Special forms of damage can be assessed by micrography. It is believed that these forms of damage do not, however, apply to this study of rope deterioration.

---

* Curves showing the life of a component in number of load cycles (N) and the load amplitude (S)

When investigating the above, it must be kept in mind that ropes operating on drum winders experience significant changes to their surface in the form of plastic and abrasive wear. These changes are expected to lead to changed fatigue behaviour - a phenomenon not investigated when studying the deterioration of Koepe winder ropes.

If a winder could be made available for a sufficient length of time, it would be interesting to obtain a wear profile for the entire length of a rope. Since the preparation of rope moulds is a time consuming exercise, it is expected that thirty samples would take a whole day. It would be valuable to obtain such a wear profile of a set of ropes just before it is discarded.

An attempt should be made to determine the criteria according to which ropes were discarded that were in operation after the data collection for the statistical analysis.

The dynamic behaviour of those winders not reported on in the GAP324 report should be evaluated.

In order to ascertain why a rope deteriorates locally to such an extent that the rope has to be discarded, the following is recommended:

- Locate the exact position of the deteriorated rope section when it is on the drum and inspect the drum carefully to obtain an explanation for the deterioration.
- Investigate the susceptibility of a deteriorated rope to fatigue damage of outer wires.
- Study the stresses in rope wires on new and used ropes to establish whether the stresses alone lead to broken wires or whether the wires in deteriorated sections experience higher stresses than elsewhere.

Note: The above recommendations are being followed in the continuation of the rope deterioration study (GAP501).

3 Cut wire tests on non-spin ropes

An unused section of 46mm, 15 strand ribbon construction non-spin rope was donated by Western Areas, South Deep Project. The rope was used for cut wire rope tests to obtain a relationship between loss in rope area due to broken wires and loss in rope strength with the view to recommend discard criteria for non spin ropes with broken outer wires.

3.1 Sample preparation

The rope was cut into 3,25m test pieces. The normal preparation procedure was followed in preparation of the tensile test specimens. After installing the test specimen in a test machine, the specified number of outer wires were cut, using a spike and an angle grinder. Care was taken not to damage adjacent wires during the cutting process. For this test series, only asymmetrically distributed broken wires were simulated. The rope sample was then cycled with 500 load cycles between 5% and 25% of the new rope breaking force. After this a destructive test was conducted on the rope sample.

3.2 Test results

Figure 3.2.1 shows the test results in the form of a graph of loss in breaking force plotted against the area of the cut wires.

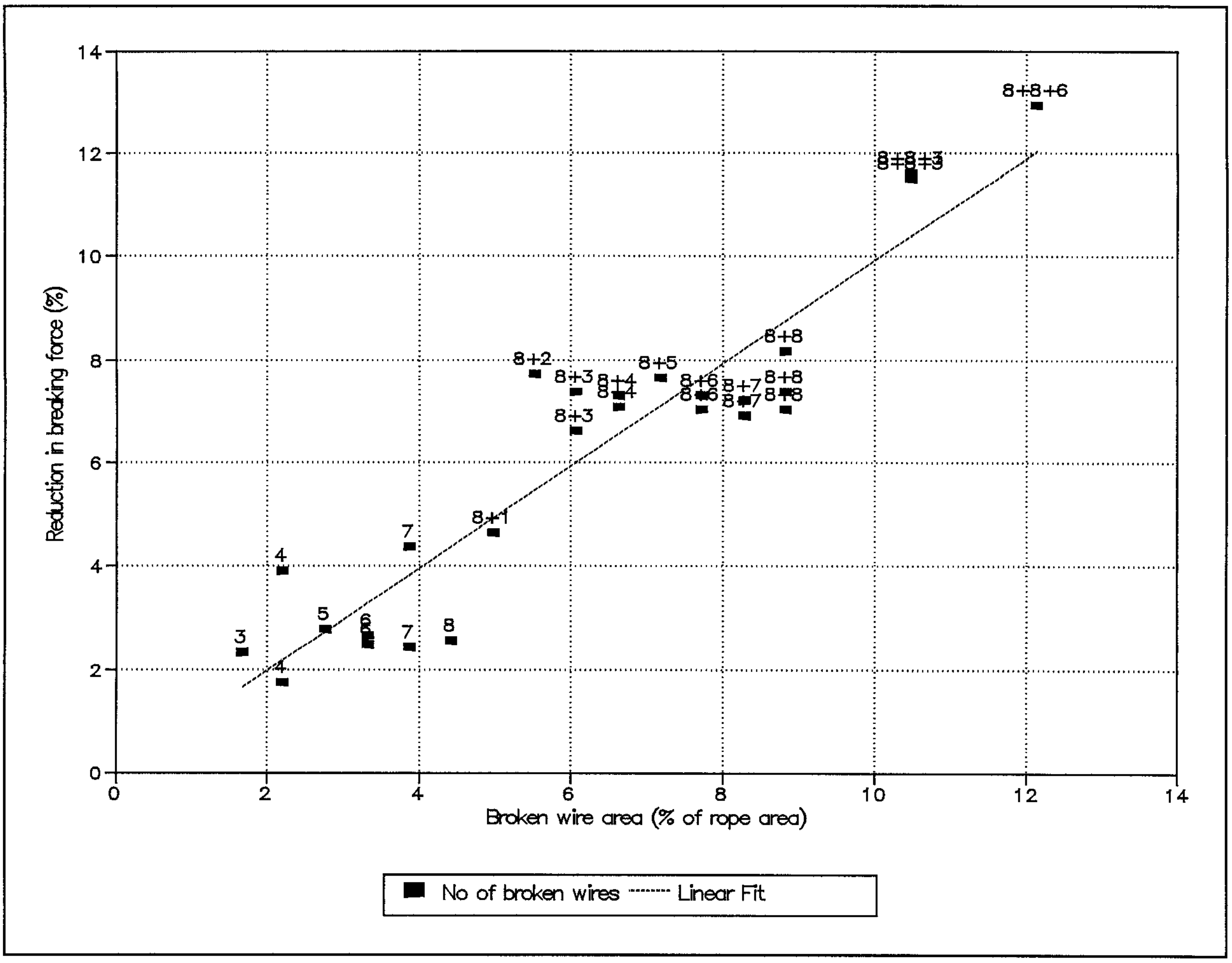


Fig. 3.2.1: ***Results of cut wire tests***

The label with each result shows the number of wires cut in each strand, ranging from three wires cut in a single strand to eight wires in each of two adjacent strands plus six in the third adjacent strand. Note that eight cut wires in one indicate that all the wires were cut in that strand.

Figure 3.2.1 displays a step-wise increase in loss in breaking force with the number of strands in which wires were cut. This may be because broken wires affect the strength of a strand with a relatively small effect of the number of broken wires in the strand. On the other hand the number of tests may be too few to interpret this step-like appearance at all. To investigate this further, different cut wire distributions should be tested.

3.3 Analysis of the test results

Figure 3.2.1 shows a straight line fit of the test results that was calculated as

$$\frac{\delta BF}{BF} = 0{,}99\frac{\delta A}{A}$$

where δBF = loss in breaking force
BF = breaking force
δA = broken wire area
A = rope area

In other words, the loss in rope strength is (to within one per cent) equal to the loss in area due to broken outer wires. This is similar to previous results from cut wire tests done on triangular strand and round strand ropes, except that, in the previous results there was an exponential increase in the loss in breaking force after the initial linear section.

The loss in strength, as calculated by the regression equation, is shown in the following table for discard criteria ranging from 6 to 10 per cent as well as the probability of various losses in rope strength at discard:

Area loss δA (%)	Strength loss δBF (%)	Probability (%) of loss in strength		
		<3%	>10%	>12%
6	5,9	0,3	<0,1	
7	6,9	<0,1	0,2	
8	7,9		2,8	<0,1
9	8,9		16,0	0,2
10	9,9		46,8	2,8

These probabilities were calculated based on normal (Gaussian) distribution of deviations of the test results from the regression equation.

3.4 Conclusions

From the calculated distribution, a discard criterion of eight per cent may be chosen. Based on the test results, this discard criterion will ensure that 97 per cent of non-spin ropes will be discarded at a reduction of breaking strength between 3 and 10 per cent with only a 2,8 per cent probability that strength losses of more than the allowable 10 per cent will occur while less than 0,1 per cent of ropes will be discarded at a strength loss of more than 12 per cent.

This conclusion is based on a limited set of results. The following must be kept in mind:

- **The tests were only done on a non-spin ribbon construction. Other non-spin rope constructions may respond differently to broken wires.**
- **The discard criterion only applies to broken outer wires of the rope.**

A discard criterion to be used in the RCA code of practice should therefore be selected with circumspection.

3.5 Discussion and recommendations

The test results depicted in Fig. 3.2.1 differ noticeably from results of similar tests done on triangular strand ropes. The term *asymmetric distribution of broken wires* has been defined as a situation where more than half of the broken wires occur in one or two adjacent strands. The loss in strength of triangular strand ropes is larger with asymmetrically distributed broken wires than with broken wires distributed uniformly around the circumference of the rope. The test results obtained during this investigation, however, seem to indicate that the response of non-spin ropes may be different.

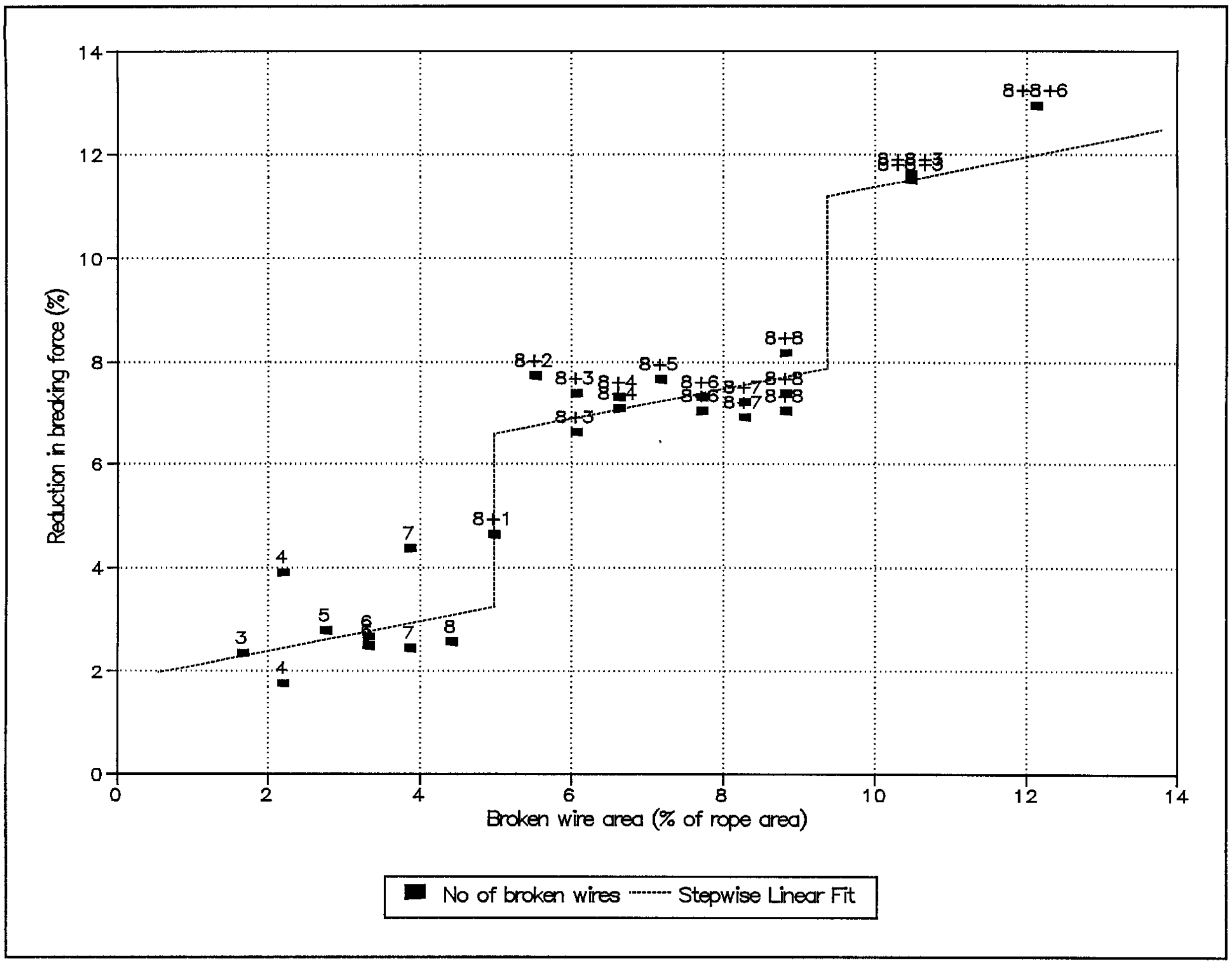


Fig. 3.5.1: Results of cut wire tests with step-wise linear fit of the results

Figure 3.5.1 shows a step-wise linear fit to the data depicted in Fig. 3.2.1. The linear fit is of the form

$$\frac{\delta BF}{BF} = 1{,}81 + 0{,}29\frac{\delta A}{A} + 4{,}616 N_{brstr}$$

where $\frac{\delta BF}{BF}$ = loss in breaking force [%]

$\frac{\delta A}{A}$ = broken wire area [%] not included in N_{bstr}

N_{brstr} = number of outer strands with all wires broken

To put this equation into words: There is nearly a five per cent loss in the rope strength for each outer strand that contains broken wires and a small additional loss in strength that depends on the actual number of broken wires. This equation is merely given for the sake of completeness. Without further information, it should **not** be interpreted with the view of recommending changes in the discard criteria. It does, however, show that the trend of these results is that rope strength suffers more if the broken wires are evenly distributed.

These results were not anticipated at the outset of the test series. When viewing the results obtained at this stage, one would immediately like to compare the effect of a 4+4+4 and a 3+3+3+3 broken wire distribution with the results obtained from the 8+4 distribution.

It is strongly recommended that further tests be done to study the effect of broken wire distribution on rope strength.

As a start, tests with the following cut wire distributions are recommended:

Distributions with 12 cut wires:
4+4+4
3+3+3+3
4+0+4+0+4
2+2+2+2+2+2
3+0+3+0+3+0+3
1+2+1+2+1+2+1+2

Distributions with 15 cut wires:
5+5+5
4+4+3+4
3+3+3+3+3
5+0+5+0+5
3+2+3+2+3+2
2+2+2+2+1+2+2+2

The above combinations will give a set of 24 results if two tests are done with each distribution. These results will have to be analysed and evaluated critically before any further tests are done.

4 Tests on discarded ropes

Discarded ropes were collected and tested to determine their strength so that their actual strength could be compared to the condition as assessed by the rope inspectors. The purpose of these tests was to determine the aptness of rope discard criteria and, if applicable, to recommend refinement of the discard criteria.

For each rope sample tested, a discard factor was calculated according to the RCA code of practice. Graphs of loss in breaking strength vs discard factor were plotted for triangular strand ropes and for non-spin rope samples.

4.1 Test on a kinked specimen

A kinked specimen was submitted for test. The rope had remained in service for two weeks after the kink had occurred. When tested, the breaking strength was reduced by 2,7 per cent.

Although the reduction in breaking strength may seem small, it is not recommended to change the discard criteria that specify that any kinked rope should be discarded. A kinked rope may probably still have most of its original strength, but it will experience a very high rate of deterioration and may soon become dangerous to use.

4.2 Test on a corroded specimen

One specimen was obtained from a rope that was discarded on the basis of corrosion alone. A discard factor of "above one" was indicated by the rope inspector on the basis of loss in diameter and area loss indicated by the magnetic test instrument. During the laboratory test it was noted that the degree of corrosion fell into the category *"considerable"* and *"more than slight"* is reason for discard. The discard factor calculations could not be checked, but the loss in diameter alone was 1,3 times the allowable loss. The sample submitted for test had a reduction in strength of 15,4 per cent.

4.3 Test on discarded triangular strand and round strand rope specimens

A total of eighteen discarded rope samples of triangular strand and round strand construction was received. Fifteen ropes were discarded due to normal deterioration and three due to localised damage.

4.3.1 Test results

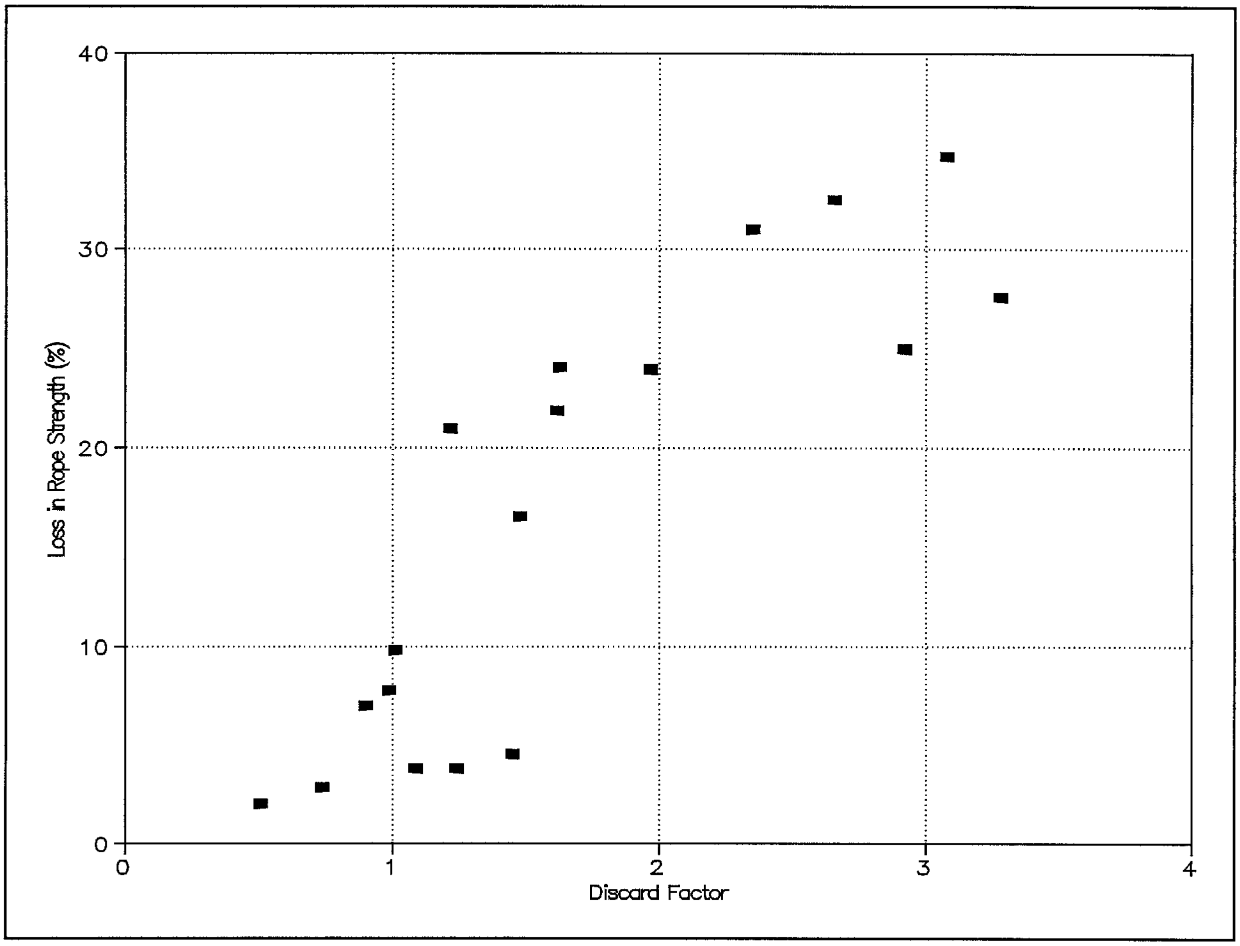


Fig. 4.3.1: Loss in breaking strength of discarded triangular and round strand specimens

Figure 4.3.1 shows the results of the tests done on discarded triangular strand and round strand rope specimens. The figure depicts the reduction in rope strength, as determined by a tensile test, plotted against the discard factor. Appendix D shows how the discard factors were calculated.

4.3.2 Discussion of the results

The results shown in Fig. 4.3.1 indicate that the discard criteria for triangular strand and round strand rope in the RCA code of practice achieve what is intended: A rope that is discarded according to the discard criteria ($DF \leq 1$) will not have a loss in strength of more (or much more) than ten per cent. They also show that ropes are sometimes still discarded too late, namely with a discard factor of much more than one. Such cases include:

- Deterioration of a rope on dead turns on the drum (which are not regularly inspected),
- mechanical damage to a rope,
- seven weeks' normal deterioration,
- deterioration after the engineer was cautioned that rapid deterioration may soon set in,
- a bad section of rope that was assessed after damage was identified during the monthly inspection (this assessment took place 14 weeks after the previous one during which no extraordinary deterioration was reported).

A very disconcerting result was the fact that many discard factor calculations were wrong. In one case a rope was discarded because a discard factor of 1,2 was calculated while a proper calculation led to a discard factor of 0,74. The discarded specimen had a strength of 97,2 % of the new rope strength. The rope was therefore discarded prematurely. In many cases, Mattek staff also made errors in the discard factor calculations. These were only rectified after a thorough check of all the results. The errors are attributed to

- using wrong wire diameters in the calculations,
- inability to distinguish between *symmetric* and *asymmetric* broken wire distributions, and
- interpretation of the term *uniformly distributed wear.*

In many cases the inspectors' reports did not show calculation details and it was therefore not possible to identify where the calculation errors originated.

The RCA code of practice is vague with respect to calculating the change in rope diameter. It states that "*the loss in rope diameter shall not exceed X % of the nominal diameter of the rope*" where X depends on the different wear distributions and rope constructions. It does not, however, define "*loss in rope diameter*". Rope inspectors generally interpret this as the difference between the nominal diameter and the measured diameter, and this is in accordance with the relevant SIMRAC training module*. Such an interpretation has already led to a negative discard factor because the measured rope diameter was larger than the nominal rope diameter. When a rope is suspended in the shaft, its diameter is smallest at the back end. The said interpretation of loss in rope diameter can then lead to a discard factor of more than 0,4 in the case of a brand new rope.

4.3.3 Recommendations

Based on the results of the tests, no recommendations are made to change the discard criteria in the code of practice. On the basis of other observations, however, the following recommendations are made:

---

* Kuun, T.C. *Practical aspects of rope inspection* Project No. GAP 054, October 1995

- **Greater care must be taken in calculating discard factors. If necessary, rope inspectors should receive additional training.**
- **Changes in rope diameter should be calculated as the difference between the actual rope diameter when the rope was new and the actual diameter when the rope is being inspected.**

The second recommendation may need some more investigation. Firstly, it is impractical to measure the rope diameter along the entire length of the rope when it is new. The new rope diameter should rather be calculated by interpolation of the diameters measured at the front end and at the back end during the first assessment of the rope. The new rope diameter can then be calculated as

$$D_{new} = D_f - \frac{z}{t}(D_f - D_b)$$

where D_{new} = new rope diameter at depth z
D_f = new rope diameter at front end
D_b = new rope diameter at back end
t = total suspended rope length

Secondly, the discarded rope tests done so far should, where possible, be re-evaluated to assess whether the changes in rope diameter thus calculated give appropriate discard criteria. This will be a difficult task because in very few cases are measurements of the first assessment available (according to section 6.2 of the code of practice).

4.4 Test on discarded non-spin rope specimens

A total of 31 discarded non-spin rope samples was tested. These samples, however, originated from only three discarded ropes, two of which were of the same construction and originated from the same winder. It must be noted, therefore, that only a very limited amount of information can be gained from these tests.

4.4.1 Test results

A discard factor was calculated for each specimen tested. Because the results of the tests described in section 3 were not available initially, the discard factor was based on the criteria in the code of practice. At present, the only discard criterion in the code of practice applicable to non-spin ropes (and it applies to all ropes) is "*The number of visible broken wires in a single strand shall not exceed 40 % of the total number of outer wires in the strand*". Already a problem arose with counting broken wires: Mattek staff initially counted all wire breaks and therefore recorded more broken wires in one strand than the total number of wires in that strand. This problem is addressed in section 6.2.4 of the SIMRAC training module mentioned on p.19. Unfortunately the mistake was only realised after the tests had been completed and the only correction that could be made was to assume that a wire would only break once in one lay length and to limit the number of broken wires to all the wires in a strand.

Another mistake made by Mattek staff was to measure the rope diameter with a vernier. This is the standard for measuring the rope diameter for statutory front end tests. The code of practice, however, prescribes that *the diameter measurement result at a given location in the rope shall be the smallest of a series of measurements taken at 10 mm intervals along the length of the location*. This is clearly not possible with the vernier that has approximately 200 mm wide jaws.

The discard factor was then calculated on the basis of allowable diameter loss and on the ratio between the counted broken wires and the allowable 40 % in one strand. Figure 4.4.1 shows the test results with the discard factor analysed in this way.

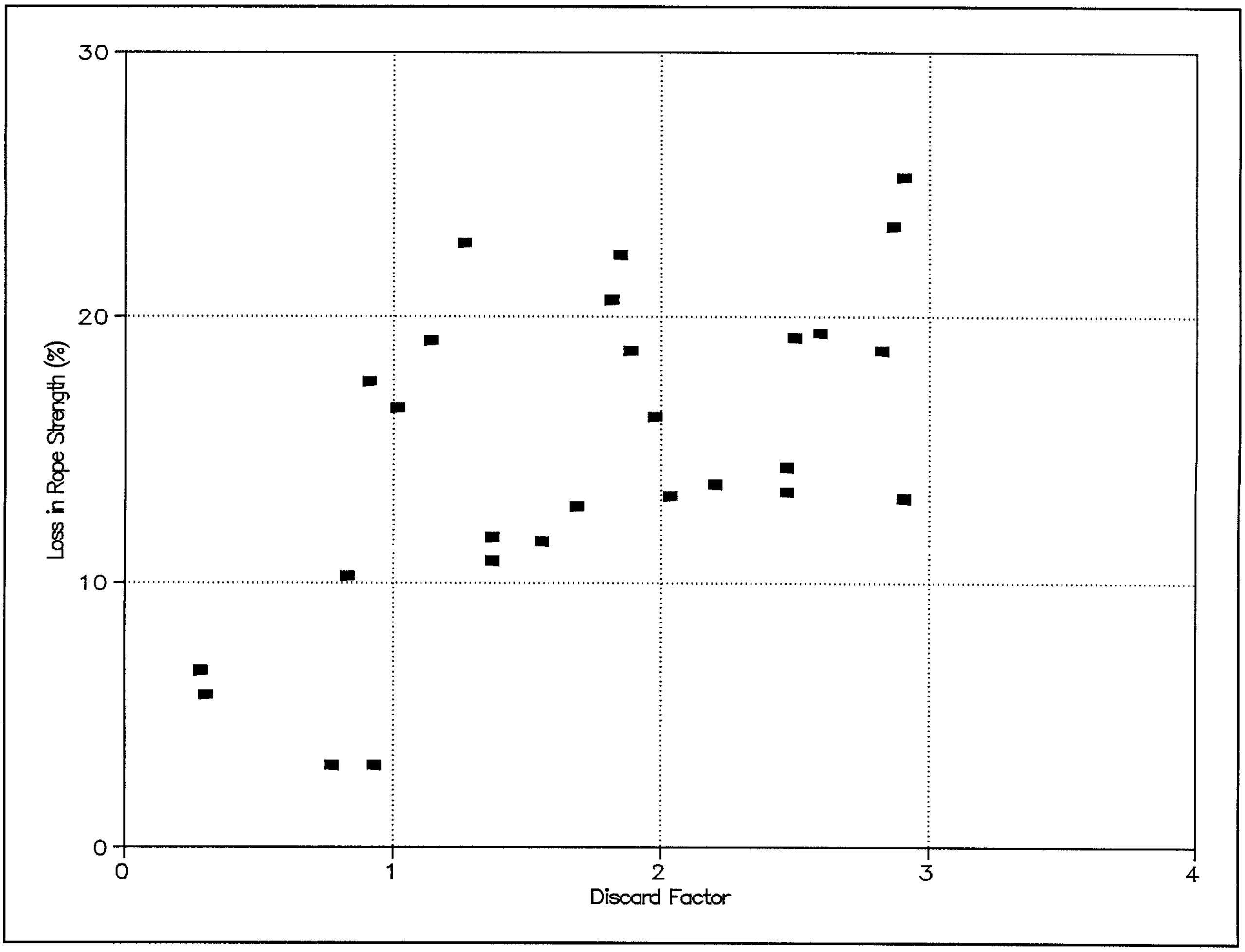


Fig. 4.4.1: ***Loss in strength of discarded non spin rope specimens plotted against discard factor calculated according to the discard criterion in the code of practice***

4.4.2 Discussion of the results

It must be noted that the discard factors used in this section were merely calculated so that some information could be gained from the test results. The RCA code of practice does not specify that a discard factor should be calculated in this manner! It is unfortunate that no further information could be obtained that would cast a light onto the reason why such a large amount of deterioration was present in the rope. No attempt was made by Mattek staff to destrand a specimen with the view to assess the internal damage that the ropes may have accumulated.

When inspecting Fig. 4.4.1 and not resorting to statistical methods, it is obvious that a non-spin rope with a discard factor of one may have a strength loss of up to twenty per cent. This is clearly not acceptable since the objective is to discard a rope before its strength has reduced by ten per cent.

From the history of the rope from which nearly all the specimens were cut, it is evident that the ropes were not properly maintained. The appearance of the specimens showed that there was severe damage on the outside of the rope and there were many cracked and split wires.

Unfortunately not one specimen was destranded to inspect it for internal cracked wires. No internal broken wires were reported to be detected with a magnetic rope test instrument.

The results of the tests described in section 3 led to a proposed discard criterion (see Sect.3.4). Calculating a discard factor accordingly leads to a set of results shown in Fig. 4.4.2. Clearly the discard factors are even less satisfactory than those shown in Fig. 4.4.1.

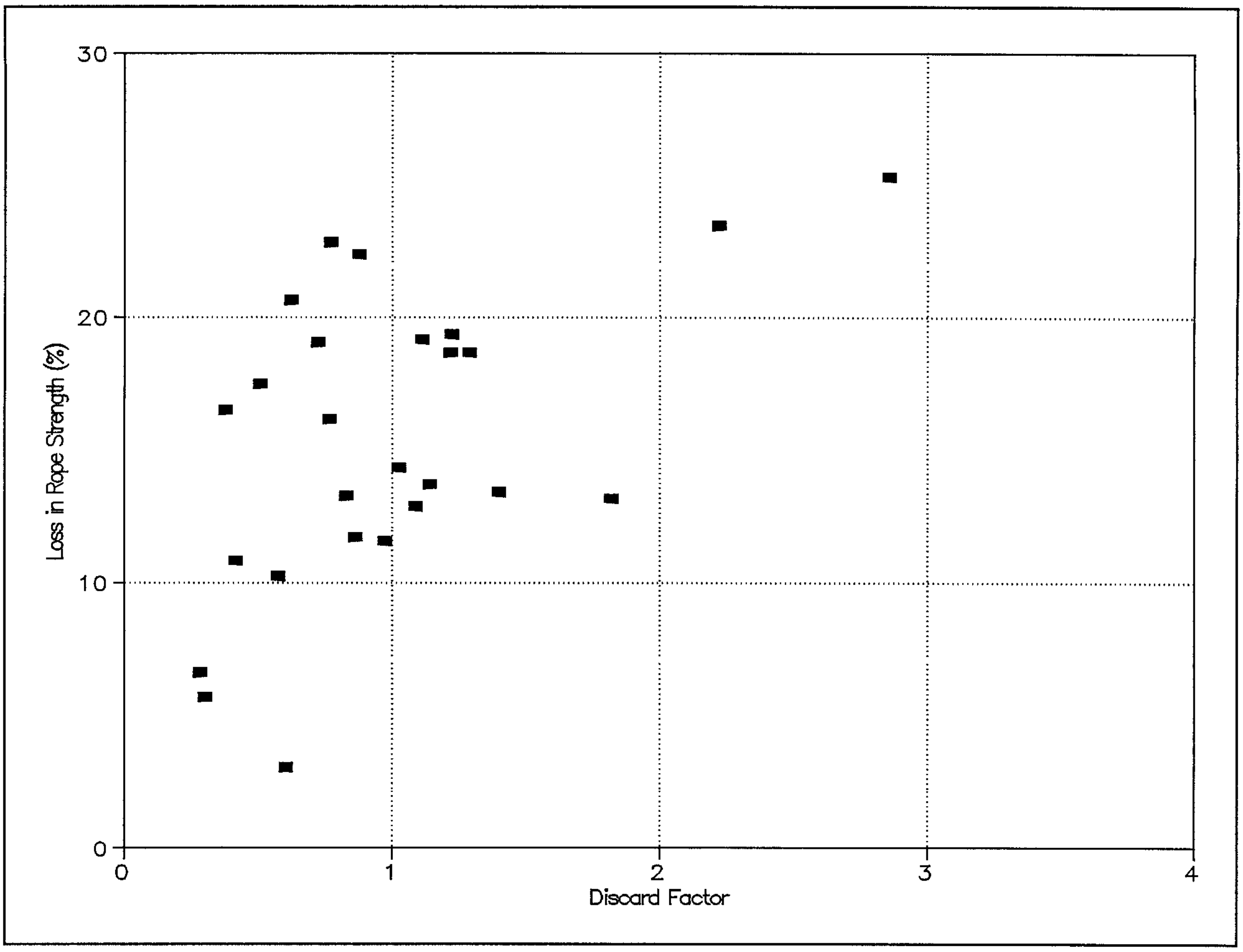


Fig. 4.4.2: ***Loss in strength of discarded non spin rope specimens plotted against discard factor calculated according to the discard criterion based on outer broken wire tests***

In an attempt to obtain a discard criterion that would ensure that such ropes would be discarded, the allowable 40 % of the broken wires was reduced to 30 %. This produced a set of results as shown in Fig. 4.4.3. Comparing this figure to Fig. 4.4.1, it can be seen that the stricter discard criterion would be more suitable for the samples at hand.

If the 30 % criterion were applied to triangular strand ropes as well, calculations for various rope constructions and diameters show that the criterion would lead to discard if the broken wire area in one strand is between three and four per cent of the rope area. In other words, the stricter discard criterion would not lead to earlier discard than the criteria currently in the code of practice.

4.4.3 Recommendations

Based on the discussion in the previous section, it could be recommended that a non-spin rope should be discarded if the number of outer broken wires (which includes cracked, split and damaged wires) in one strand and in one lay length exceeds thirty per cent of the number of outer wires in that strand. However such a recommendation can only be made once tests are done on specimens that are properly inspected. As the results stand, it is recommended that they be noted but no further interpretation be attempted.

The ability of magnetic rope test instruments to detect internal broken wires should be assessed. This should form part of the investigations that are being done under the SIMRAC project GAP 503.

Based on observations on how the RCA code of practice was applied by Mattek staff, it is recommended that greater care be taken in counting broken wires and measuring the rope diameter. Special emphasis should be placed on interpreting the term *broken wire gap* which has been defined to assist in determining whether two broken wires are in one lay length or not. It is also recommended that a series of specimens from a single discarded rope should not be tested to destruction indiscriminately: Each specimen provides an opportunity to gain information.

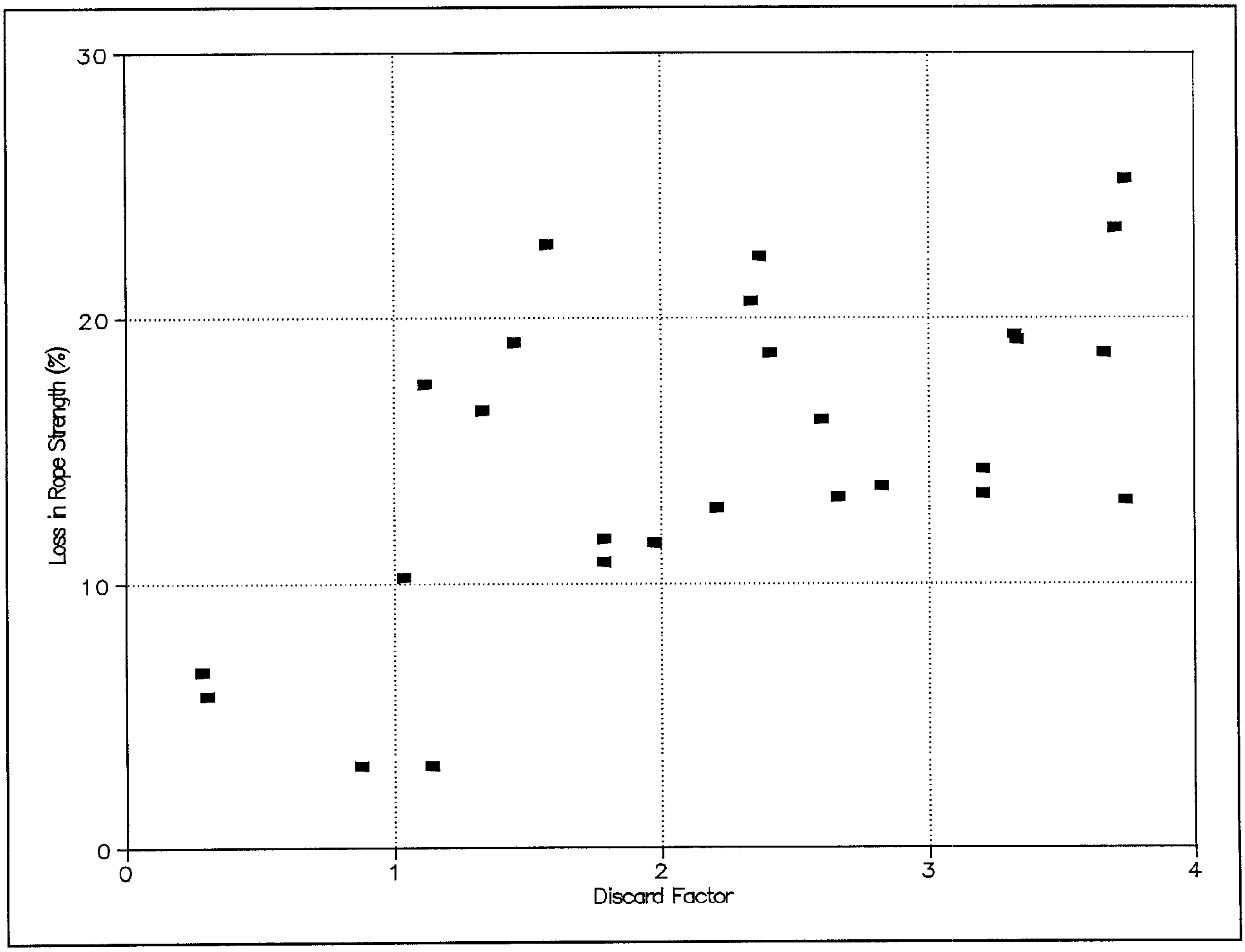


Fig. 4.4.3: ***Loss in strength of discarded non spin rope specimens plotted against discard factor based on 30 % allowable broken outer wires in one strand***

Appendix A: Rope histories

A.1 St Helena No 4 shaft - Winder Permit 2073

Ropes installed:

Coil Number:	Compartment 3 - 147841	Compartment 4 - 147842
Rope construction:	6x31T	
Rope diameter:	46 mm	
Outer wire diameter:	3,2 mm	
Tensile grade:	1750 MPa	
Date of manufacture	1983-09-16	
Date installed	1990-07-08	

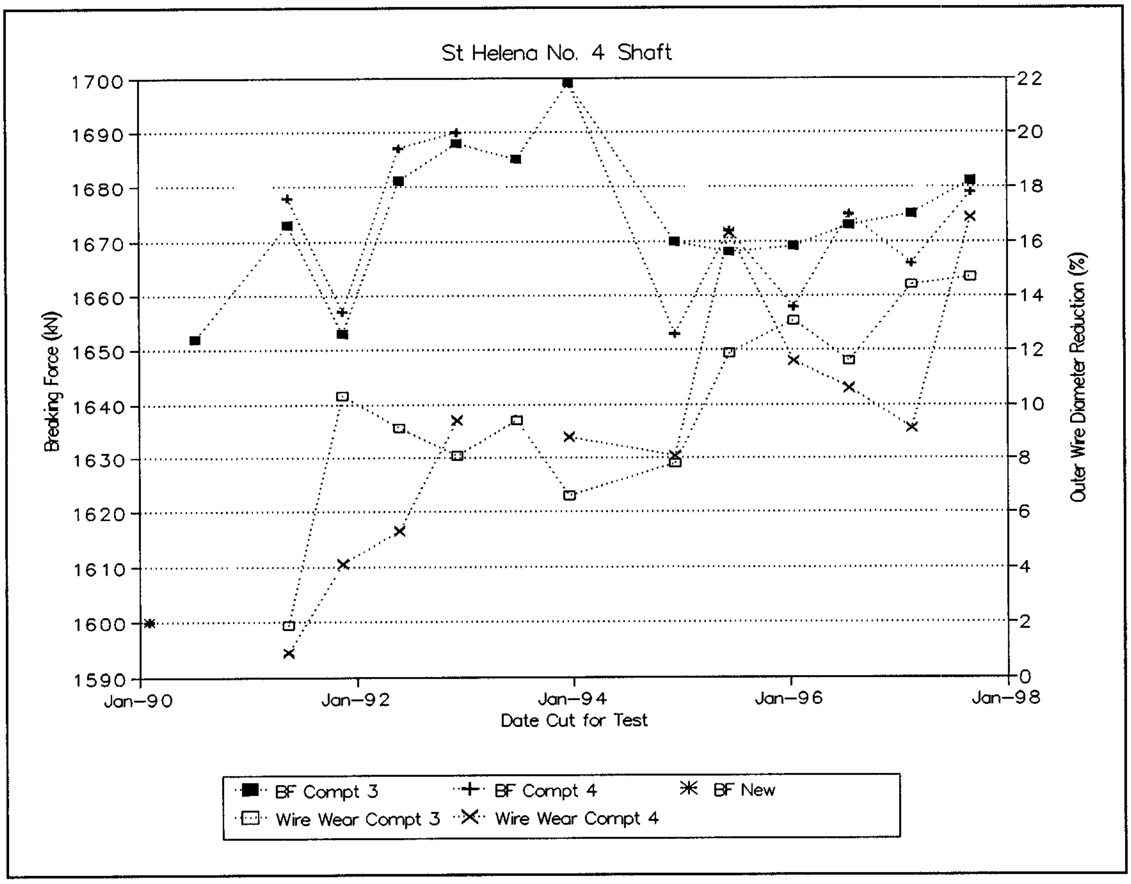


Fig. A.1 ***Front end rope test results on the St Helena ropes***

Records of pulling in back ends. Days listed are given since previous pulling in or date of installation:

Date	Compt. 3	Compt. 4
1990-10-07		91
1991-02-02	209	182
1991-08-17	196	314
1992-03-08	204	204
1993-02-28	357	357
1994-07-17	504	504
1995-02-26	224	224
1995-09-10	196	196
1996-03-10	182	182

The following cycles were retrieved from the record book for the set of ropes being studied:

Date	Cycles
96-08-16	75088
97-04-25	85984

A.2 Hartebeestfontein No 4 shaft - Winder Permit 6523

Ropes installed:

Coil Number:	SW Compartment - 133842/001 NW Compartment - 133842/002
Rope construction:	6x33T
Rope diameter:	54 mm
Outer wire diameter:	3,3 mm
Tensile grade:	1900 MPa
Date of manufacture	93-02-25
Date installed	1995-09-03

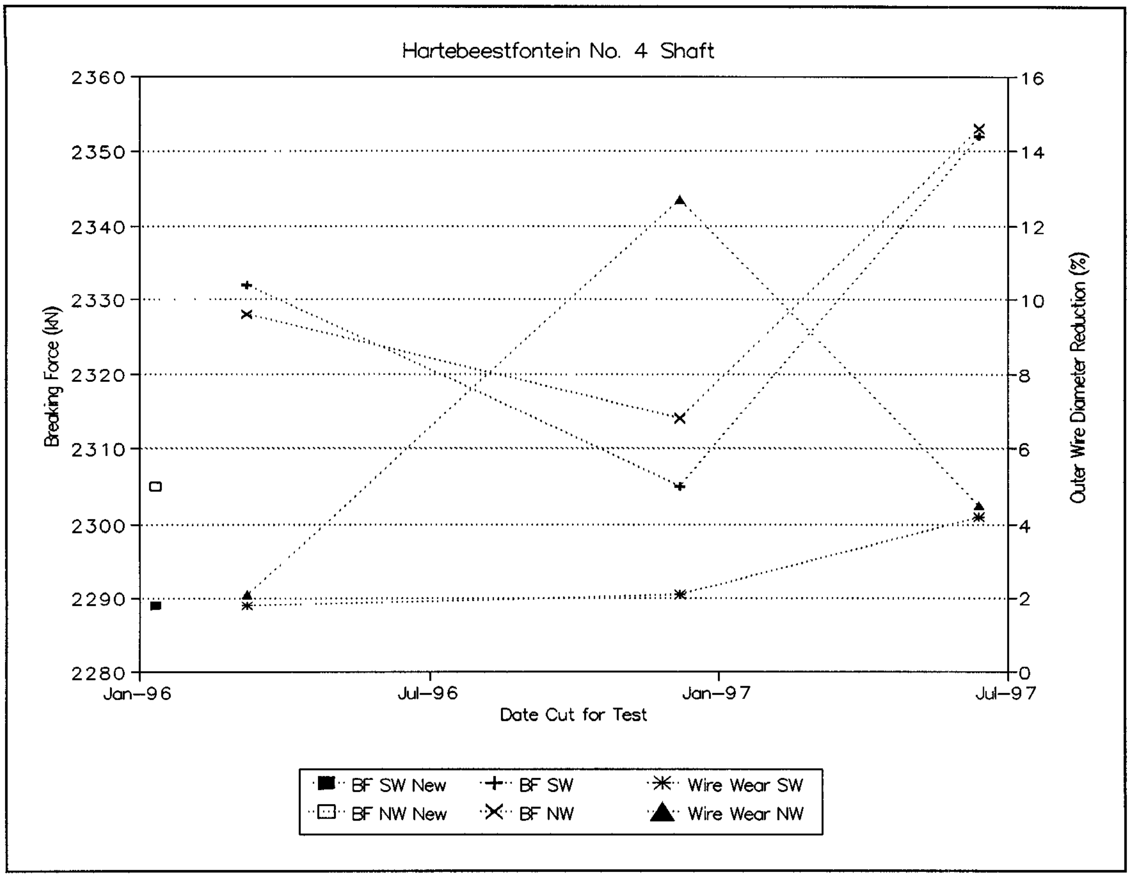


Fig. A.2 Front end rope test results on the Hartebeestfontein ropes

Records of pulling in back ends. Days listed are given since previous pulling in or date of installation.

Date	Both compartments
1995-09-17	14
1995-11-06	50
1995-12-17	41
1996-02-04	49
1996-03-10	35
1996-04-28	49
1996-06-02	35
1996-07-07	35
1996-08-18	42
1996-09-22	35
1996-10-27	35
1996-12-08	42
1997-01-12	35
1997-02-23	42
1997-04-06	42
1997-05-18	42

The following cycles were retrieved from the record book for the set of ropes being studied:

Date	Cycles
96-10-25	31589
97-10-16	65227

A.3 East Driefontein No 2 shaft - Winder Permit 4066

Ropes installed:

Coil Number:	East Compartment Outer Rope - 132585/001 East Compartment Inner Rope - 134798/001 West Compartment Inner Rope - 132585/002 West Compartment Outer Rope - 134798/002
Rope construction:	6x30T
Rope diameter:	45 mm
Outer wire diameter:	3,3 mm
Tensile grade:	1800 MPa
Date of manufacture	1993-08-24
Date installed	1995-09-03
Date discarded	1997-11-22.

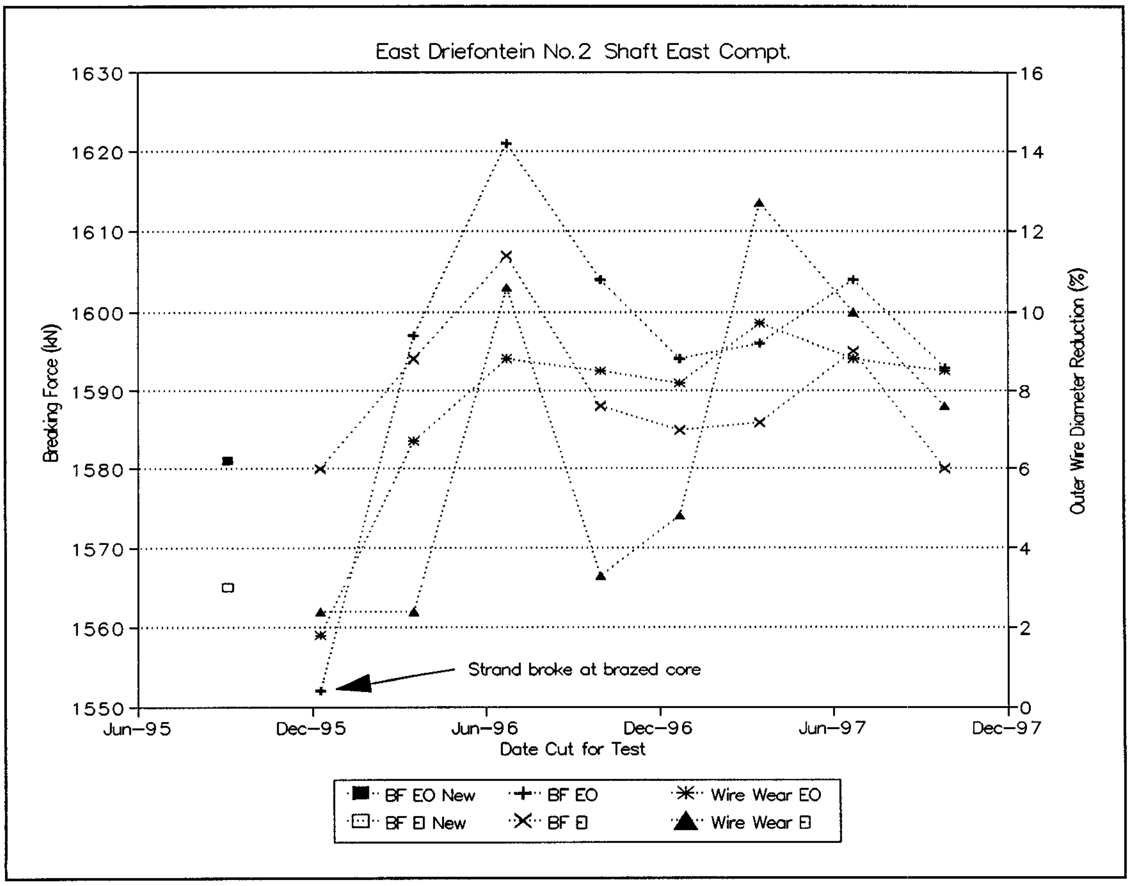


Fig. A.3 ***Front end rope test results - east compartment ropes***

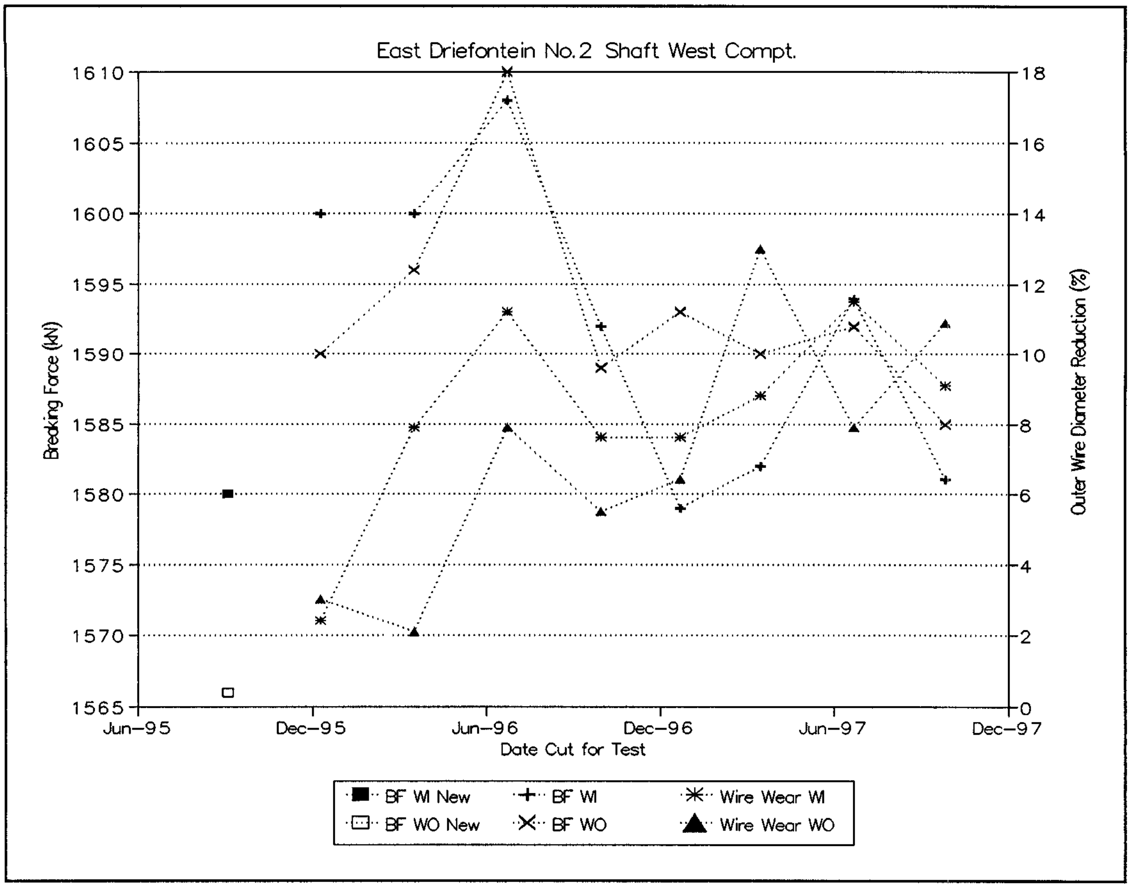


Fig. A.4 ***Front end rope test results - west compartment ropes***

Records of pulling in back ends. Days listed are given since previous pulling in or date of installation.

Date	Both compartments
1995-12-10	98
1996-03-17	98
1996-06-23	98
1996-09-29	98
1996-12-15	77
1997-03-16	91
1997-06-21	97
1997-09-27	98

The following cycles were retrieved from the record book for the set of ropes being studied:

Date	Cycles
1996-08-22	39822
1997-07-24	75324
1997-11-22	90267

A.4 West Driefontein No 4 shaft - Winder Permit 3987

Ropes installed:

Coil Number:	NE Compartment - 122312/001 NW Compartment - 122312/002
Rope construction:	6x31T
Rope diameter:	46 mm
Outer wire diameter:	3,1 mm
Tensile grade:	1800 MPa
Date of manufacture	1988-12-15
Date installed	1996-01-14

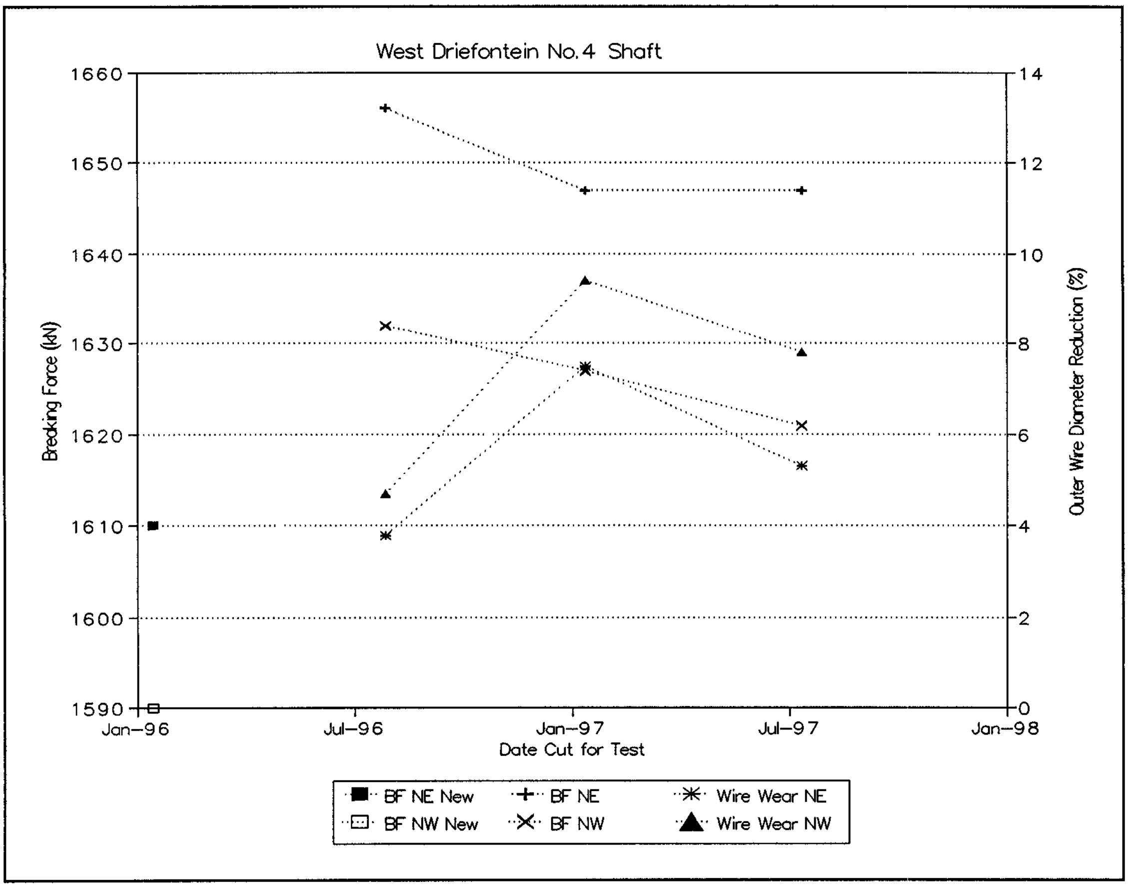


Fig. A.5 Front end rope test results

Records of pulling in back ends. Days listed are given since previous pulling in or date of installation.

Date	Both compartments
1996-07-28	196
1997-01-12	168
1997-07-13	182

The following cycles were retrieved from the record book for the set of ropes being studied:

Date	Cycles
96-08-29	16791
97-07-21	26213

A.5 West Driefontein No 7 shaft - Winder Permit 4120

Ropes installed:

Coil Number:	Cwt Compartment - 111964/001 NE Compartment - 111964/002
Rope construction:	6x32T
Rope diameter:	50 mm
Outer wire diameter:	3,2 mm
Tensile grade:	1900 MPa
Date of manufacture	1987-06-04
Date installed	1989-07-30

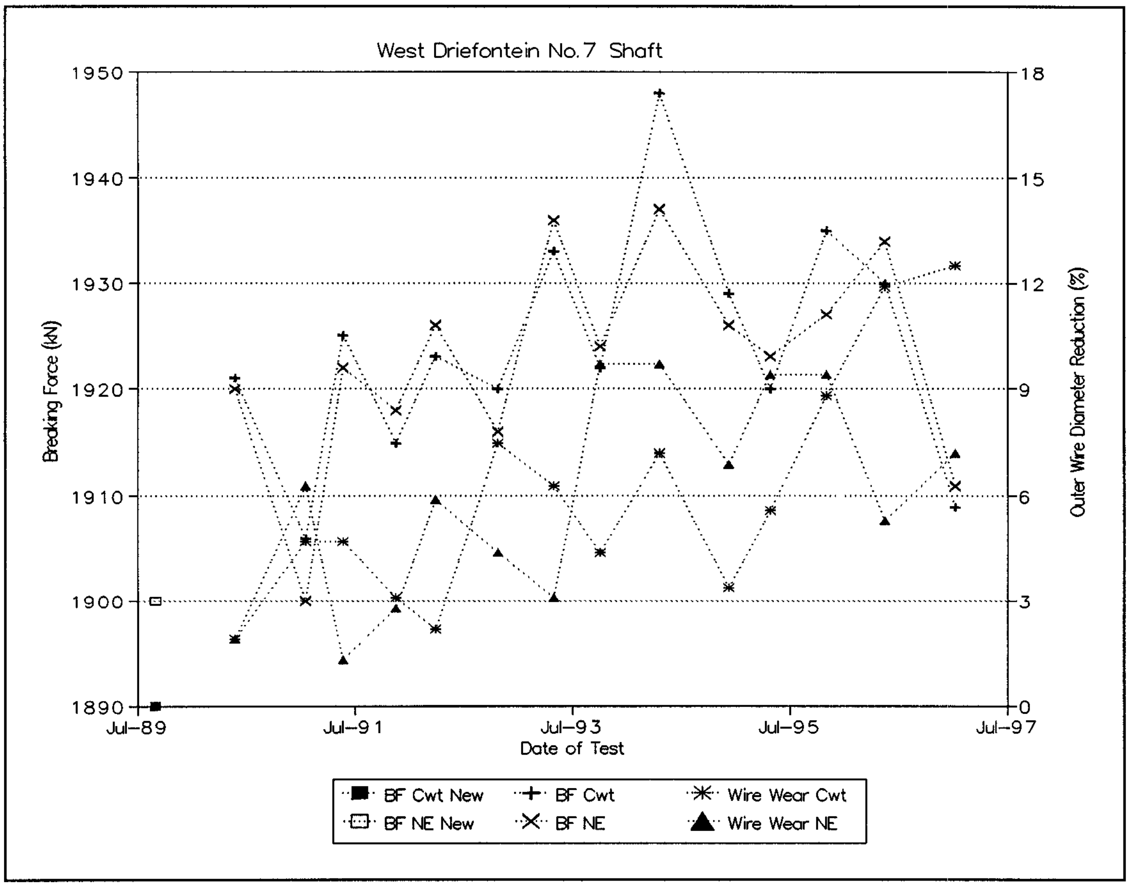


Fig. A.6 Front end rope test results

A.6 Premier No 1 shaft - Winder Permit 4521

Ropes installed:

Coil Number:	No. 3 Compartment - 133578/001 No. 4 Compartment - 133578/002
Rope construction:	6x31T
Rope diameter:	47 mm
Outer wire diameter:	3,2 mm
Tensile grade:	1900 MPa
Date of manufacture	1992-11-25
Date installed	1997-01-19

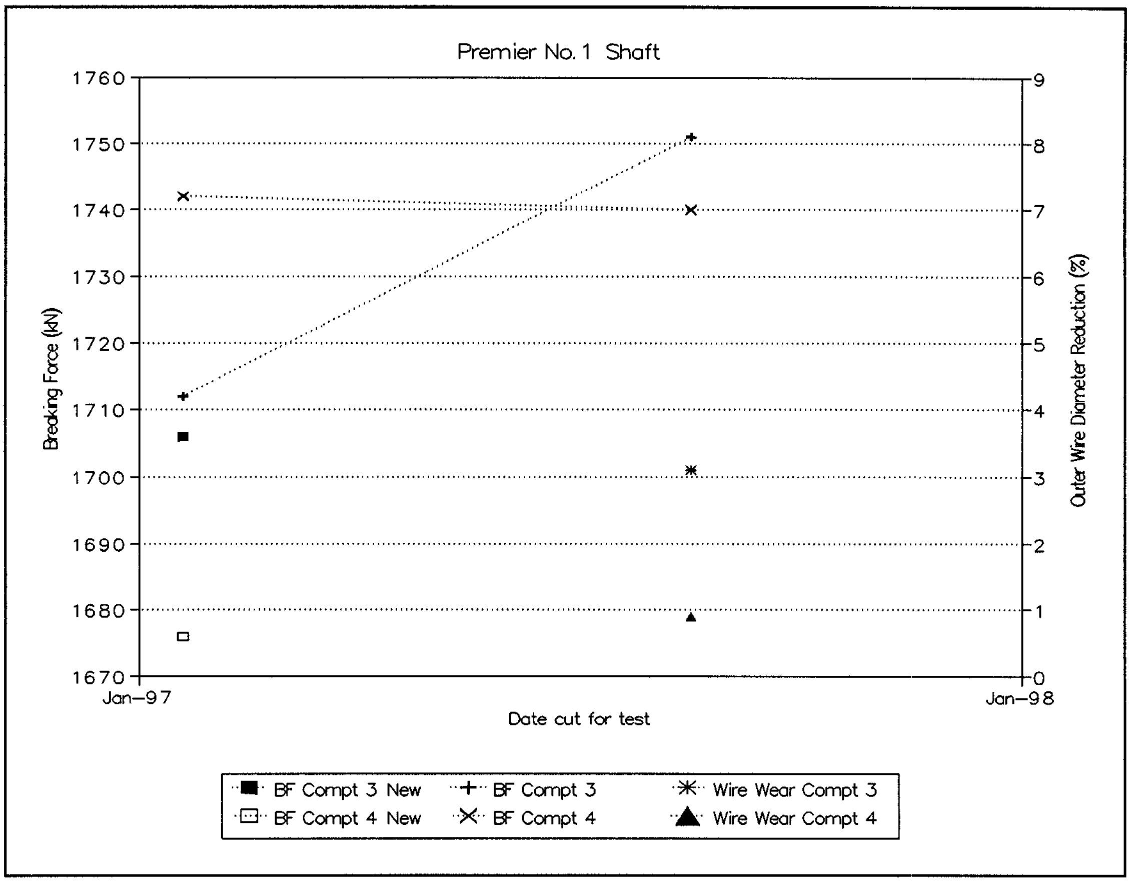


Fig. A.7 Front end rope test results

Records of pulling in back ends. Days listed are given since previous pulling in or date of installation.

Date	Both compartments
1997-04-01	91
1997-08-24	126

The following cycles were retrieved from the record book for the set of ropes being studied:

Date	Cycles
97-08-01	36288
97-11-25	55630

Appendix B: Site measurements

B.1 St Helena No 4 shaft - Winder Permit 2073

Compart-ment	Position	Diameter (mm)	Lay Length (mm)	Ovality (mm)	Wear Length (mm)
96-08-16	Headgear sheaves examined and found to be in excellent condition				
3	Front	46,5	355		27,89
	*	45,8	395	45,5/46,2	45,84
	Back	45,6	445	45,5/45,8	41,48
4	Front	46,7	355	46,5/46,8	29,36
	**	45,6	405	45,5/45,8	51,04
	Back	45,3	440		43,12
97-04-25	Headgear sheaves viewed and found to be running true and as previously reported				
3	Front	46,5	368	46,4/46,8	30,81
	*	45,7	380	45,6/45,9	38,72
	Back	45,5	445	45,3/45,6	41,88
4	Front	46,5	368	46,2/46,6	31,48
	**	45,5	420	45,3/45,6	41,34
	Back	45,3	453	45,0/45,3	41,07

* Examined when winder was stopped for * at Compt. 3
** Examined at broken wires approx. 500/496 m from skip

The wear lengths, expressed as a percentage of the rope circumference, have been plotted in Fig. B.1.

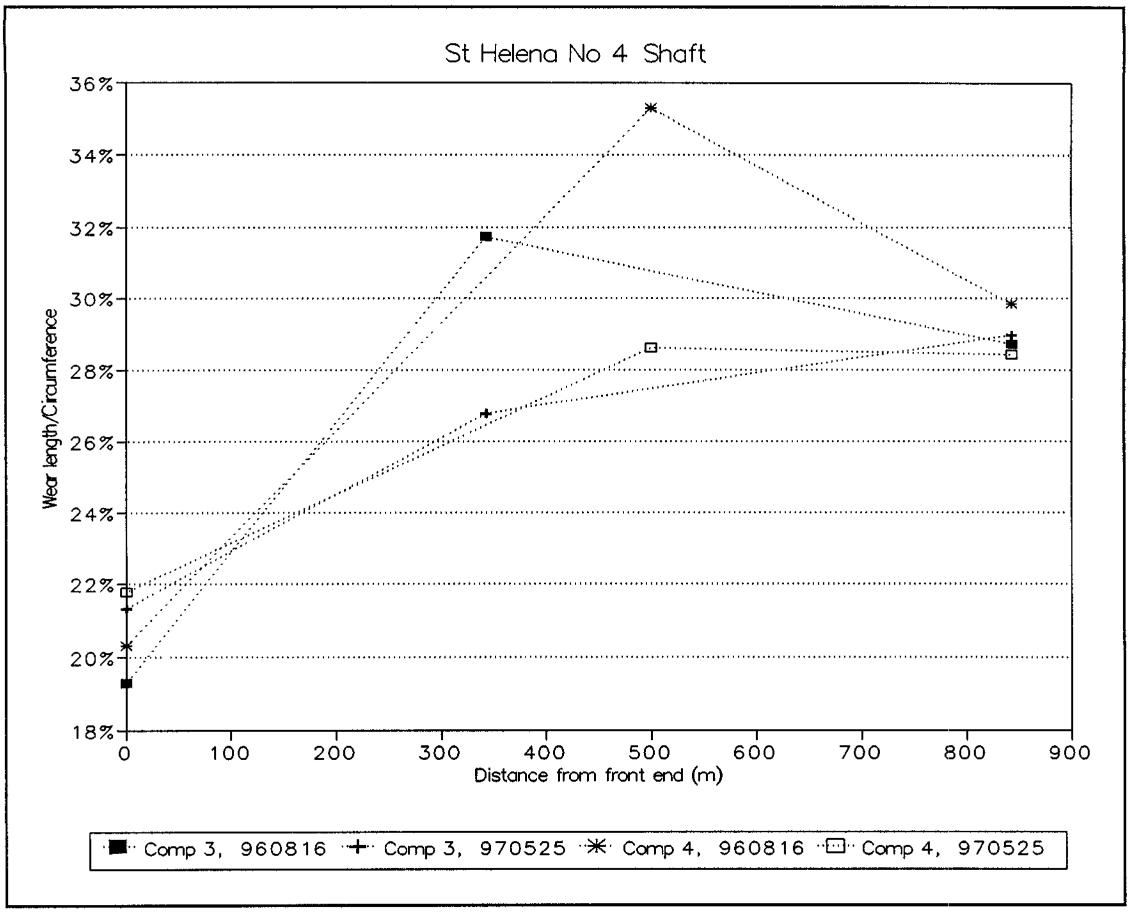


Fig. B.1: ***Measured rope wear at St Helena No.4 shaft***

B.2 Hartebeestfontein No 4 shaft - Winder Permit 6523

Compart-ment	Position	Diameter (mm)	Lay Length (mm)	Ovality (mm)	Wear Length (mm)
96-09-25	Headgear sheaves examined and found to be in fair condition. There was a slight shoulder on both flanges of each sheave and it was noted that the ropes were rubbing on these shoulders				
SW	Front	55,0	350		2,67
	*	53,7	385		31,95
	Back	52,4	610		42,88
NW	Front	54,4	350		3,39
	**	52,2	530		39,97
	Back	52,5	585		42,39
97-09-16					
SW	Front	54,0	370	54,4/54,4/53,7	7,01
	*	53,2	410	53,5/52,9/53,4	36,21
	***	53,2	415	53,8/52,9/53,2	43,36
	Back	51,2	650	51,7/50,9/51,2	58,68
NW	Front	54,0	380	54,4/53,6/54,3	8,17
	**	52,2	605	52,2/52,4/52,6	50,65
	****	51,7	610	51,6/51,4/51,9	46,43
	Back	51,7	650	51,8/51,9/51,6	55,02

* Examined at indication of internal broken wires approx. 385/366 m from skip

** Examined when winder was stopped for examination at SW compartment (*)

*** Examined at indication of internal broken wires approx. 435 m from skip

**** Examined when winder was stopped for examination at SW compartment (***)

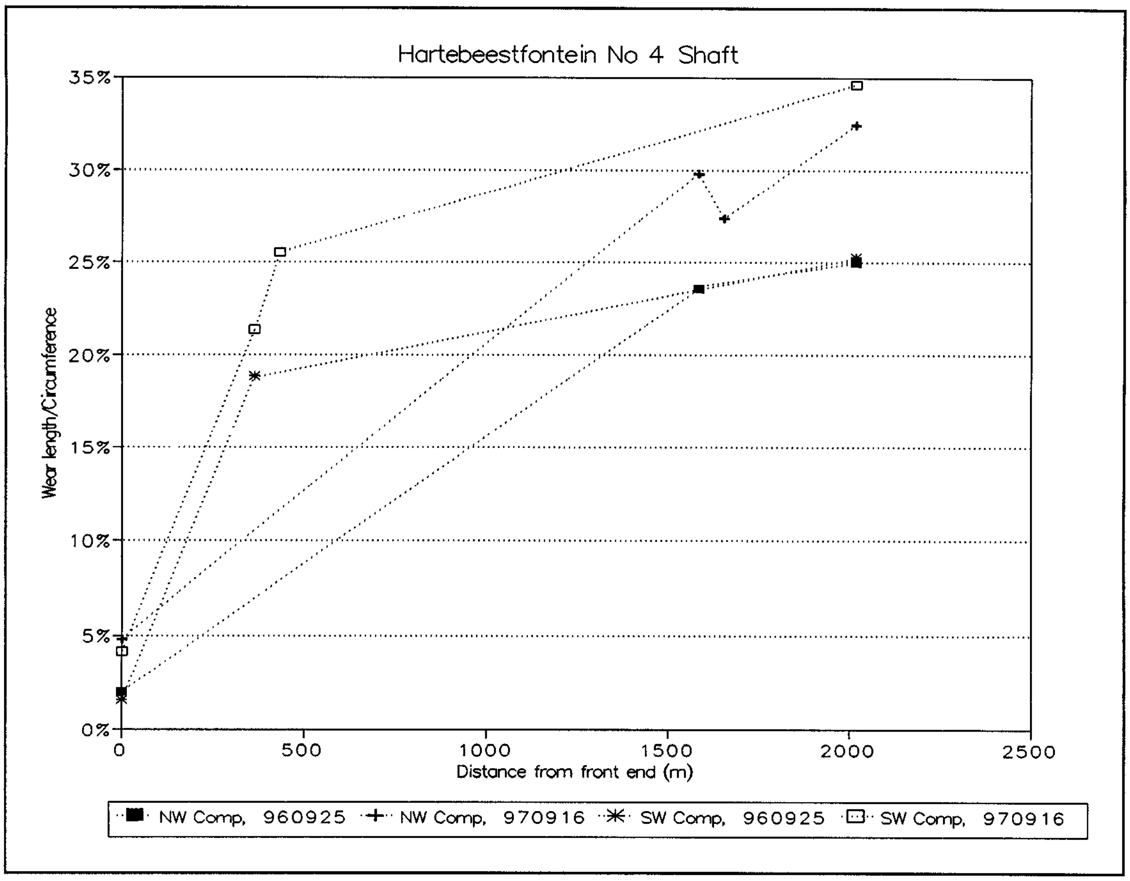


Fig. B.2: ***Measured rope wear at St Helena No.4 shaft***

B.3 East Driefontein No 2 shaft - Winder Permit 4066

Compart-ment	Position	Diameter (mm)	Lay Length (mm)	Ovality (mm)	Wear Length (mm)
96-08-22	Headgear sheaves examined - in excellent condition				
East Outer Inner	Front	45,0 45,5	305 310	44,6/45,2 45,5/45,5	16,38 14,50
	750 m	44,4 44,5	340 343	43,8/44,7 44,2/44,7	38,84 42,29
	1570 m	43,5 43,5	405 417	43,2/43,6 43,3/43,5	52,02 51,25
	Back	43,6 43,6	425 445	43,3/43,5 43,5/43,5	49,03 41,93
West Inner Outer	Front	45,2 45,0	305 310	44,7/45,2 45,0/45,0	17,28 16,77
	525 m	44,3 43,7	320 335	44,2/44,5 44,7/44,9	37,39 38,78
	1239 m	44,1 43,9	370 380	43,8/44,3 43,9/44,2	38,57 40,78
	Back	43,7 43,9	415 430	43,3/43,8 43,7/43,9	42,07 40,22
97-07-24	2 headgear sheaves were replaced ~3 months ago				
East Outer Inner	Front	44,2 45,0	300 325	44,1/44,6/44,5 45,1/45,0/45,3	25,16 32,70
	750 m	44,4 44,2	350 355	44,5/44,1/43,7 44,4/44,1/44,3	44,34 41,49
	1570 m	43,0 43,2	415 420	43,0/42,8/43,2 43,3/43,0/43,6	54,54 55,02
	1574 m	43,0 -	450 -		58,00 -
	Back	43,5 43,8	445 450	43,2/43,6/43,1 13,9/43,7/43,5	44,90 43,22
West Inner Outer	Front	44,7 44,5	313 305	44,3/44,8/44,9 44,3/44,6/44,4	29,83 33,70
	525 m	43,7 44,2	330 330	44,0/43,6/43,6 44,3/44,2/44,2	42,58 41,74
	1239 m	44,0 44,0	360 370	44,0/44,0/43,8 44,0/43,8/44,0	37,30 39,52
	Back	43,5 43,7	445 440	43,4/43,3/43,6 43,8/43,8/43,5	43,02 46,16

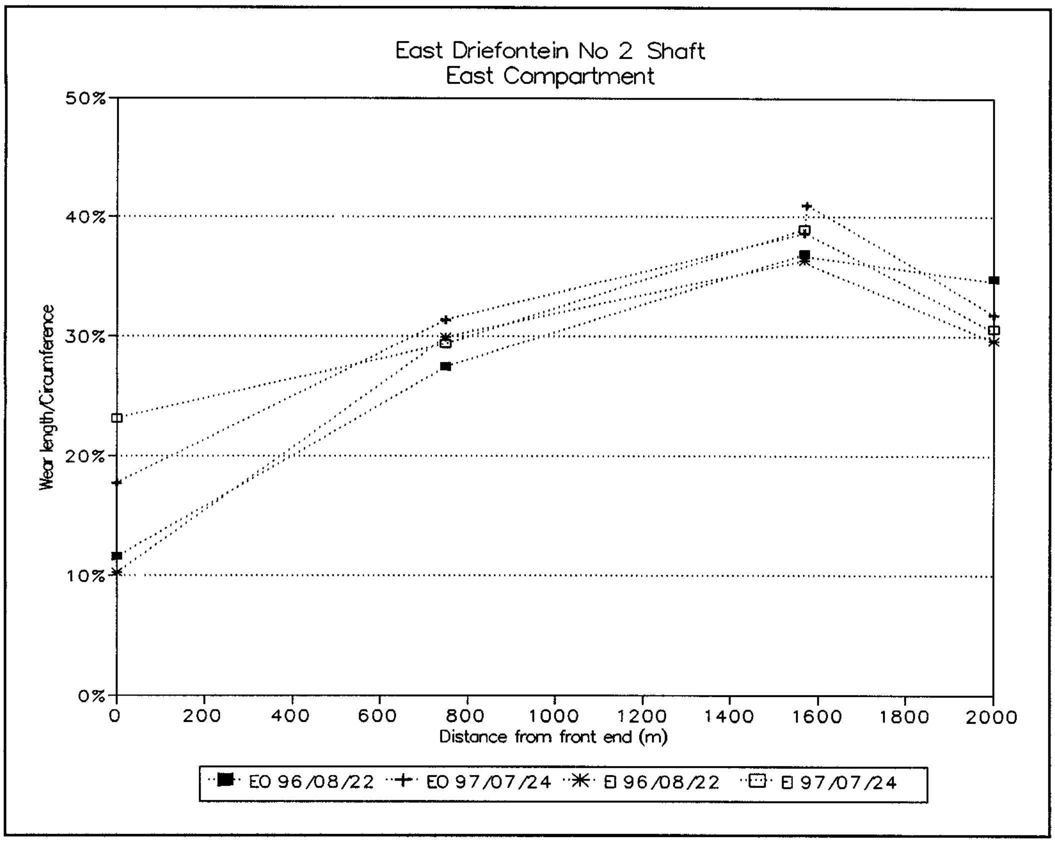


Fig. B.3: ***Measured rope wear at East Driefontein No.2 shaft east compartment***

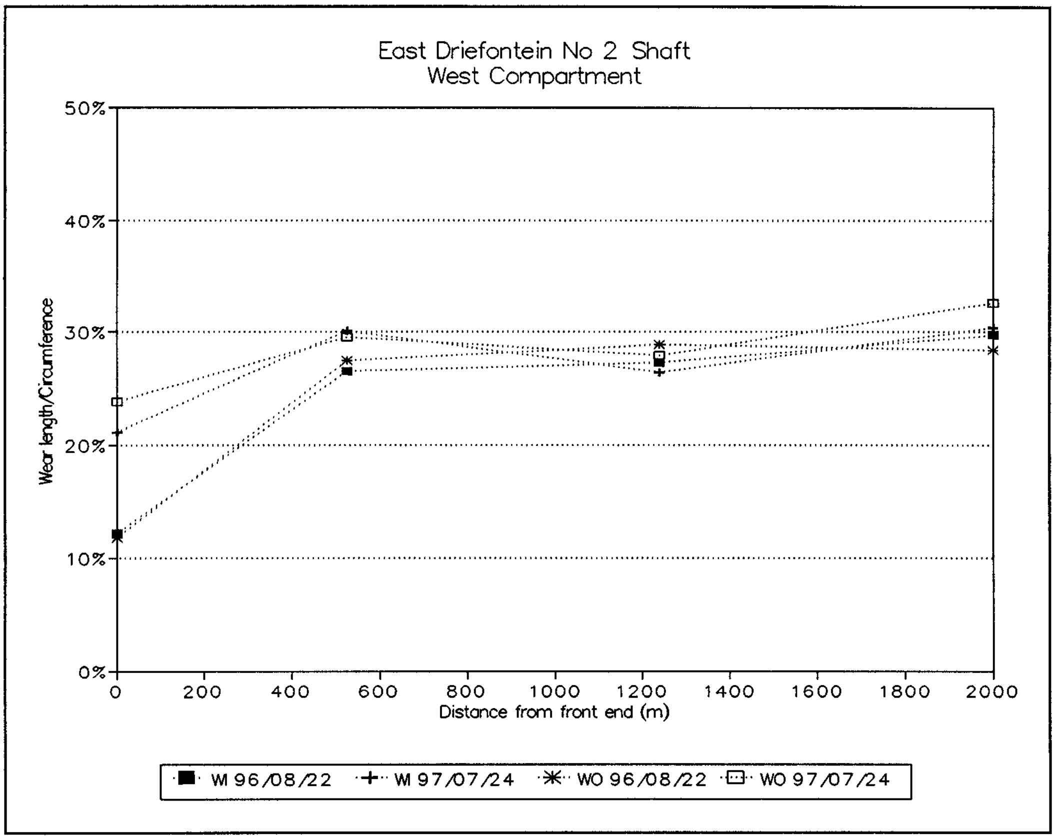


Fig. B.4: ***Measured rope wear at East Driefontein No.2 shaft west compartment***

B.4 West Driefontein No 4 shaft - Winder Permit 3987

Compart-ment	Position	Diameter (mm)	Lay Length (mm)	Ovality (mm)	Wear Length (mm)
1996-09-17					
NE	Front	46,6	322	46,6/46,5	15,07
	*	45,6	343	45,7/45,6	29,69
	Back	45,0	401	45,1/45,0	37,91
NW	Front	46,2	309	46,5/46,2	11,25
	**	45,7	383	46,3/45,3	32,68
	Back	45,0	415	44,9/45,1	38,90
1997-07-31					
NE	Front	46,0	325	45,9/45,8/46,0	15,85
	*	45,0	350	45,4/45,2/44,9	38,61
	Back	44,6	420	44,3/44,6/44,5	42,77
NW	Front	46,0	326	46,4/45,4/45,9	10,20
	**	45,5	383	45,7/45,5/45,9	34,02
	Back	44,8	425	44,8/44,6/44,8	47,84

* Examined when winder was stopped for examination at SW compartment (**)

** Examined at indication of internal broken wires approx. 912 m from skip

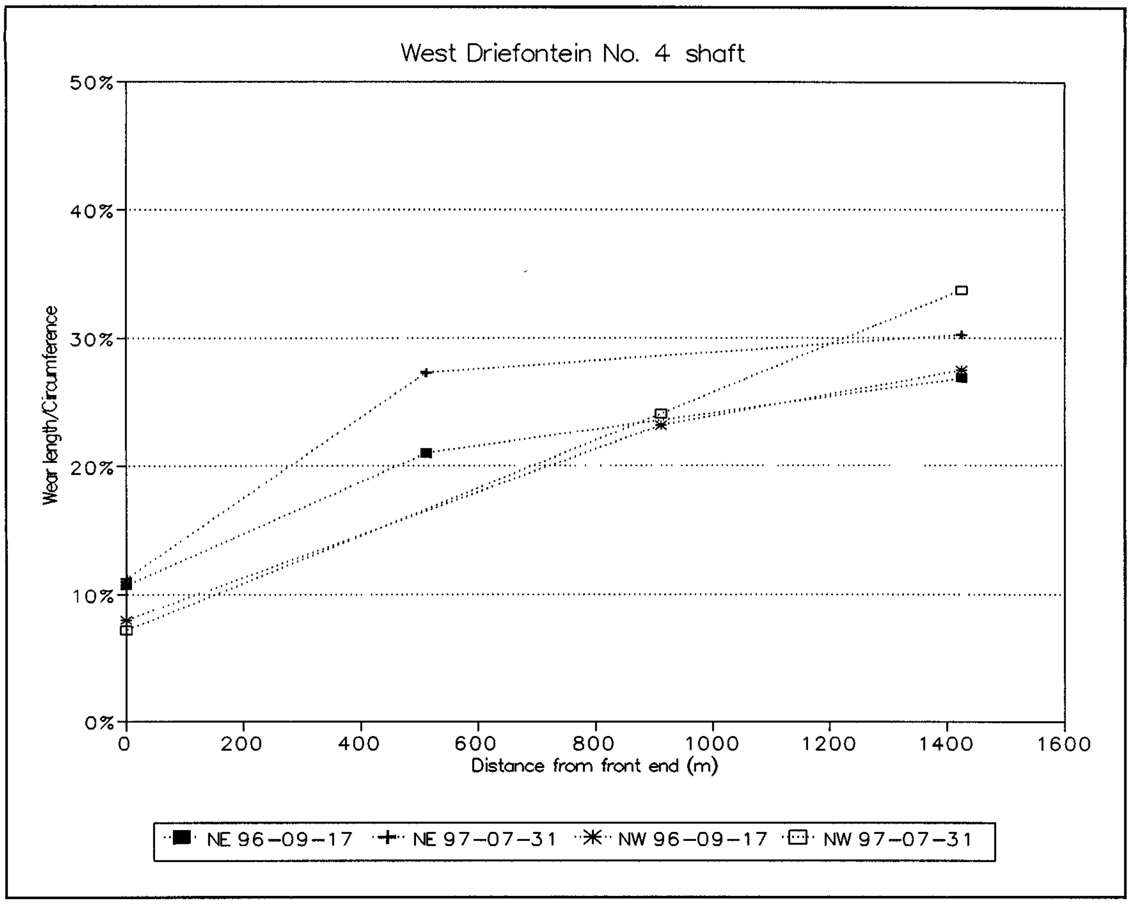


Fig. B.5: Measured rope wear at West Driefontein No.4 shaft

B.5 West Driefontein shaft No 7 shaft - Winder Permit 4120

Compart-ment	Position	Diameter (mm)	Lay Length (mm)	Ovality (mm)	Wear Length (mm)
1997-09-04					
Cwt	Front	49.7	365	49.9/49.6/51.1	21.13
	*	49.2	395	49.4/49.2/49.5	39.52
	* *	47.7	530	47.6//47.7/47.3	44.21
	Back	48.7	525	48.6/48.9/48.9	37.07
NE	Front	49.7	360	4905/49.9/49.6	23.82
	* * *	49.5	380	49.7/49.8/49.5	32.74
	* * *	48.5	505	48.5/48.8/48.9	41.39
	Back	48.8	565	48.4/48.5/48.6	36.59

* Examined at a previous EM indication approx. 370 m from cwt.

* * Examined just above a place identified at a previous examination, approx. 1500 m from cwt, where there was damage to the rope caused be a drum bolt.

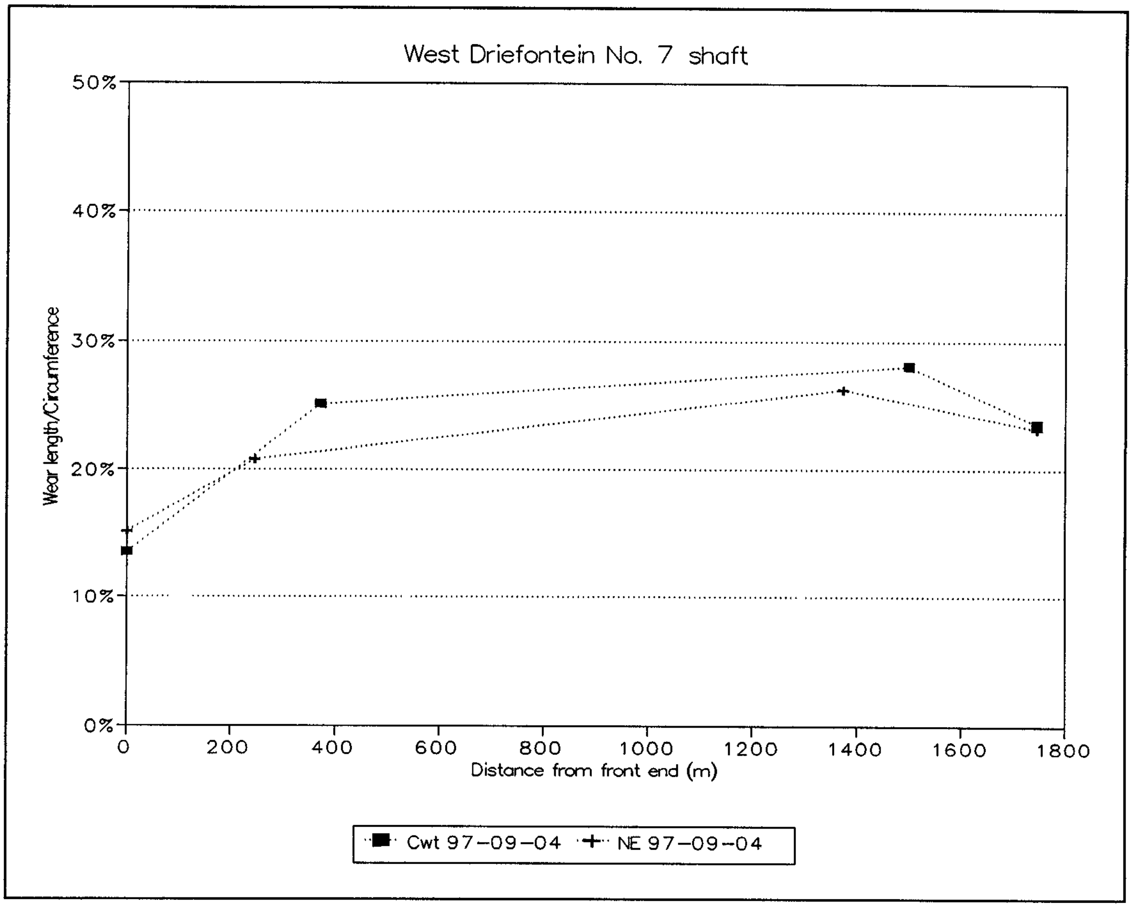


Fig. B.6: *Measured rope wear at Premier No.1 shaft*

B.6 Premier No 1 shaft - Winder Permit 4521

Compart-ment	Position	Diameter (mm)	Lay Length (mm)	Ovality (mm)	Wear Length (mm)
1997-08-01					
3	Front	47.5	360	47.4/47.4/47.7	0.82
	LC	46.6	395	47.3/46.7/46.5	26.72
	Back	46.5	395	46.4/46.7/46.5	43.26
4	Front	47.5	360	47.8/47.7/47.3	0.00
	LC	46.7	385	46.6/46.8/46.7	24.41
	Back	45.5	383	46.5/46.4/46.6	34.25

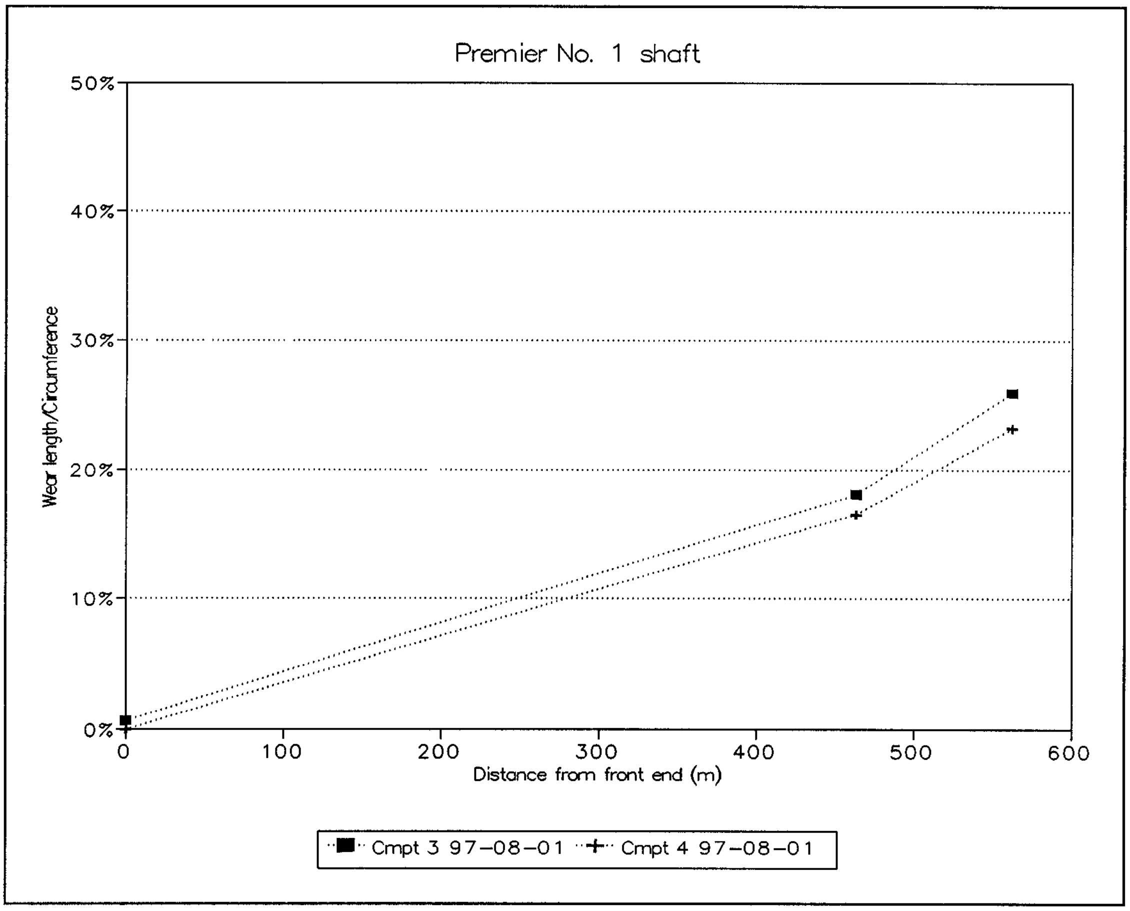


Fig. B.7: ***Measured rope wear at Premier No.1 shaft***

Appendix C: Results of a poor front end test on one of the Premier ropes

CERTIFICATE OF TEST CONDUCTED ON WINDING ROPE

Certificate No.: 214402

Rope received: 97-07-30 | Application received: 97-07-23 | Date of test: 97-08-01

Rope Particulars

Specimen supplied by:	DE BEERS CONSOLIDATED MINES LTD - PREMIER MINE		
Address:	P.O. Box 44, CULLINAN, 1000		
Name of manufacturer:	HAGGIE RAND LIMITED	Date of manufacture	92-11-25
Name of shaft	No 1	Type of shaft	Vertical
Name of compartment	No 3	Length of wind (m)	574
Winder permit No.	4521	Date rope put on	97-01-19
Coil No. of rope	133578001	Length of rope (m)	900
Nominal rope diameter (mm)	47,0	Rope mass (kg/m)	9,31
Construction of rope	Compound Triangular Strand		
Number of strands	6	Type of lay	RHL
Lubricant	Noxal No 8	Nominal lay length (mm)	352
Type of heart of rope	Fibre		
Number of wires in strand	31(13/12/6+3T)		
Diameter of wires (mm)	3,20 2,12 1,80 1,36		
Type of strand core	Plaited		
Tensile grade of steel (MPa)	1900	Wire finish	Ungalvanised
Breaking force of new rope (kN)	1706		
Breaking force at previous test (kN)	1712	Length of specimen supplied (m)	3,50
Minimum allowable breaking force (kN)		Date cut	97-07-20

RESULTS OF TEST AND EXAMINATION

Breaking force of rope (kN)	**1564**	Specimen gauge length (m)	2,75
Least outer wire dimension (mm)	3,08	Measured lay length (mm)	398,0
		Rope diameter (without : with preload) (mm)	49,5 : 48,2

Corrosion: Traces against the heart
Traces inside the strands
Very slight pitting and corrosion on the outside of the rope

Lubrication: Good to fair

Appearance of wires at fracture: Ductile but one outer wire a split failure and six outer wires brittle failures

Number of strands broken: Five

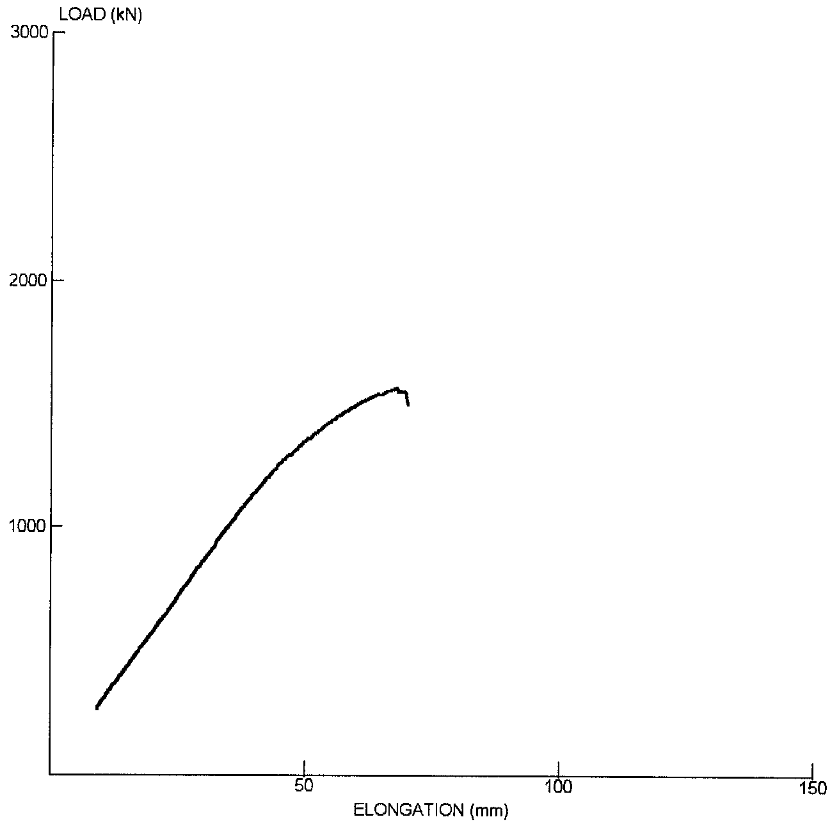
Position of fracture: 250 mm from metal endcap

Remarks: First wire failure at 1150 kN
It appears that the specimen supplied included the section of rope removed from the cappel, this is the probable reason for the poor performance of this specimen when tested

Cottesloe, 14 July 1998 NOTE: Original signed certificates will be sent by post

TEST PROCEDURE: CSIR WORK INSTRUCTION FOR TESTING OF ROPE SPECIMENS

Strain energy to failure	63,8 kN.m	Certificate Number	214402
Plastic fraction of energy	21,6 kN.m	Date of test	97-08-01
Plastic fraction of elongation	14,7 mm (0,5%)	Specimen coil number	133578001
Slope	28,4 kN/mm	Diameter (mm)	47,0
Maximum load carried	1564 kN	Applicant:	
Gauge length	2750 mm	DE BEERS-PREMIER MINE.	



Private Bag x28, Auckland Park, 2006 Tel: (011) 482 1300	Engineer:

Appendix D: Discard factor calculations for triangular strand and round strand ropes

The discard factor for all discarded triangular strand and round strand rope specimens, except one, was calculated from a combination of diameter reduction and broken wires. An example of such a calculation is shown below:

Rope construction 6x32(14/12/6+3T)/F
Nominal diameter 54 mm

Calculation of steel area in one strand:

No. of wires (n)	Wire diameter (d)	Wire area $A_w = \frac{\pi d^2}{4}$	Layer area $A_l = n A_w$
14	3,50	9,62	134,70
12	2,55	5,11	61,28
6	2,16	3,66	21,99
3	1,60	2,01	6,03
		Total:	224,00

The rope area is therefore (6 strands) x (224 mm^2/strand) = 1344 mm^2.
As a check, this calculation can be compared to the manufacturer's approximate formula for the rope area: $A = 0{,}457\ D^2 = 1333\ mm^2$.

During the inspection of the rope, two outer and three inner broken wires were counted. The broken wire area, expressed as a percentage of the rope area, is calculated as

$$\frac{\delta A}{A} = \frac{2 \times 9{,}62 + 3 \times 5{,}11}{1344} \times 100\%$$

$$= 2{,}57\ \%$$

The diameter at that place was measured as 51,8 mm. If the diameter during the first assessment is taken to be 54 mm, he reduction in diameter is

$$\frac{\delta D}{d} = \frac{54{,}0 - 51{,}8}{54{,}0} \times 100\ \%$$

$$= 4{,}07\ \%$$

The discard factor is now calculated as the sum of the above deteriorations, each expressed as a fraction of the allowable amount of deterioration.

All the broken wires are in one strand. The distribution is therefore *asymmetric* and the allowable broken wire area for this distribution is four per cent. The report obtained from the rope inspector does not indicate whether the wear is uniform around the rope or mainly on one side. Noting the plastic deformation reported on the rope, an uneven wear is assumed. The allowable diameter loss is seven per cent. The discard factor is thus calculated as

$$DF = \frac{2,57}{4} + \frac{4,07}{7}$$

$$= 0,64 + 0,58$$

$$= 1,22$$

In many cases it is difficult to judge whether the wear is uniform or not. If the wear were considered to be uniform, nine per cent diameter reduction would be allowed and in the case of this example the discard factor would be calculated as

$$DF = \frac{2,57}{4} + \frac{4,07}{9}$$

$$= 0,64 + 0,45$$

$$= 1,09$$

Just taking this discarded rope specimen as an example, the following points were noted:

- The rope inspector indicated no wear on his report, even though he measured a smaller diameter at the test section than at the back end. He stated the reason for discard as "inner broken wires" and did not do any discard factor calculation.
- The staff at Mattek initially based the discard factor on wrong wire diameters and on the approximate rope area, thus obtaining a discard factor of 0,97.

References

1. Van Zyl, M.N. *Information on 99 drum winders and 711 discarded winder ropes* CSIR contract report MST(90)MHT 3, May 1990

2. Fuchs, D. *Rückblick of 20 Jahre Forschung an Förderseilen (Review of 20 years' winder rope research)* DMT Rope colloquium, November 1996