SAFETY IN MINES RESEARCH ADVISORY COMMITTEE

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Final Project Report

Title: THE SAFE USE OF MINE WINDING ROPES

Volume 4: Studies towards a Code of Practice for Rope Condition Assessment

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RESULTS OF TESTS ON SECTIONS

FROM DISCARDED ROPES

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ABSTRACT

The aim of this investigation was the verification of the Code of Practice for Rope Condition Assessment. Ropes were meant to be discarded according to the discard criteria as outlined in the code and then tested by the CSIR. The results of the tensile tests on these specimens would indicate how accurate the code was and what changes were required to improve it further.

The CSIR tested 63 rope specimens in this investigation which included multiple specimens from a given rope or set of ropes (ropes operating on the same winder). There was a total of 32 main discard specimens (specimens which were the reason for discarding the rope set) and 31 sister discard specimens in the set of 63 specimens tested. Of the 32 main discard specimens only 21 specimens were forwarded to the CSIR with enough data to allow the calculation of a discard factor. The discard factors for these 21 specimens as calculated by the author ranged between 0,49 and 3,56.

If it is assumed that the data set of 32 specimens is representative of how ropes are currently discarded in South Africa, it follows that approximately 25% of ropes are correctly discarded (4% to 10% strength loss), 31% are discarded prematurely (less than 4% strength loss) and 44% are discarded late (strength loss in excess of 10% and in some cases in excess of 35%). Only in very few cases are ropes being discarded correctly. From the data currently available and if ropes were being discarded according to the code of practice, the strength losses of the majority of the specimens should range between 0% and 14% with only isolated cases where the rope strength loss goes outside this range. **This illustrates the function of the code of practice, which is not a device for predicting rope strength loss but, a device for risk management**. Unless this is understood the code cannot be used to its full extent.

It has become evident that although we have rope inspectors with vast experience in rope discard, inspectors seem to discard ropes based on "gut feel" or codes of practice other than the one under discussion here. It is thus extremely important that the code of practice is explained to all rope inspectors and that these rope inspectors are trained and certificated in discarding ropes according to the code. The implications of not carrying out proper training will mean that the code will never be fully implemented.

The Rope Condition Assessment Code of Practice for mine winder ropes in its current form contains the best discard criteria available. With a few minor changes it should meet the short term needs of the mining industry. Like any document, however, it can be improved. For example aspects like discard criteria for non-spin ropes, which are not as comprehensive as those for triangular strands ropes, need further work; the discard criteria for discarding ropes for damage accumulated on a single strand needs to be revised; and the allowable reduction in rope diameter should be rope construction specific. The process of improving or enhancing the code must continue in parallel with its effective implementation.

PREAMBLE

The introduction of this report contains substantial information on rope discard criteria which are currently available around the world. Many of these discard criteria are current standards (DIN 15020[1], ISO 4309[2], BS 6570[3]). This information was included to give the reader an idea of other rope discard criteria available and the applications for which they were intended.

This report refers extensively to the current draft South African Code of Practice for Rope Condition Assessment of Mine Winding Ropes[4]. Unless the reader is familiar with this draft code it is advisable that a copy of this code is at hand when this report is read.

The code of practice[4] which was intended to be used to discard these rope specimens and which assesses the damage accumulated by the rope was largely based on work carried out by Mr T C Kuun (AAC). Mr Kuun designed his original code as a type of "go, no go" gauge. A discard factor of one or more would indicate rope discard and less that one meant that the rope could remain in service (provided the damage was not likely to increase excessively before the next inspection).

To date, most people when reading and applying the code have come to believe that the code can assess the actual rope strength loss, i.e. if a discard factor of 1 is indicative of a 7% strength loss, then a discard factor of 0,5 means the rope has only lost 3,5% of its strength and similarly a discard factor of 2 would indicate a 14% strength loss. Although this was not the original intention of the code it is believed to have some merit by certain mining group representatives and is thus explored further to a limited degree. This method of estimating the actual strength loss is used in the Appendix B of this report where additional information on each rope specimen tested has been provided. The report also contains a plot of estimated rope strength loss versus actual strength loss. As will be seen the correlation between the two is fairly poor which supports the argument that the code is not intended to be used as a rope strength indicator.

CONTENTS

1. INTRODUCTION

The history of mining dates back to the pre Christian era, when early mining involved recovery of coal and minerals on the earth's surface. Even though by the 1400's underground mining was practised with water driven or animal powered mechanical equipment more often than not ore and coal was raised on the backs of women and other workers[5] (Even today this practice is not unheard of). Although acceptable at the time, this practice was nevertheless physically demanding and increases in depth rendered these methods unpracticable. Improvements in equipment were therefore a requirement for further progress.

With an increase in available power the greater loads possible placed excessive demands on fibre ropes and chains which were currently used. Short life and an excessive number of accidents provided the impetus for further development. The first wire ropes were developed in the 1830's and by the middle of the century wire rope haulage had become very common. In the last 150 years steel wire ropes have been almost exclusively used in vertical mine winding, besides becoming common for other applications. Naturally steel wire rope designs and the materials used to make them have improved over the years in parallel with improvements in manufacturing techniques for both wire and rope.

1.1 Wire Ropes

1.1.1 Components of a Rope

ma-chine: *an assemblage of parts...that transmit forces, motion, and energy one to another in some predetermined manner and to some desired end...*

-Webster's Third New International Dictionary

A steel wire rope is in many aspects very much like a machine. It has numerous separate moving parts. A wire rope consists of many individual wires which are laid into a number of strands which are in turn laid around a core.

A wire rope strand in its simplest form contains a wire around which six wires of the same diameter are wound. This type of strand lacks flexibility and thus in most cases more complex strands are used, containing a core which could be a single wire or more, inner wires which are wires wound around the strand core and outer wires which are in turn wrapped around the inner wires and are often of a larger diameter.

The strands of a rope as described above are arranged around a centre core again twisted in a helix pattern to maintain their position. The rope core may be a further steel strand or rope, or a fibre core or a moulded plastic extrusion.

There are many different types of ropes, ranging from single strand ropes for bridges and anchorage purposes to flexible multi-strand ropes for cranes, all designed to suit the application for which they are needed. A winding rope in South Africa, for example, must be circular in cross-section and must maintain its elastic properties while being subjected to its working load. It must also be flexible so as not to deform plastically when it moves over sheaves and drums which are the inevitable parts of a hoisting system. A winding rope must also be structurally stable and be able to withstand the lateral loads imposed on it when it moves over the sheave and during multi-layer coiling, without deformation. A winding rope should also have a large surface contact area in order to resist wear, abrasion and plastic deformation within the physical limits of the steel[6].

1.1.2 When to discard a rope

Any machine which has moving parts and transmits forces will deteriorate; the causes and rate of deterioration are dependent on factors like loading and maintenance. Rope deterioration is dependent on the same factors. Excessive loading, poor maintenance or abuse will reduce the rope life significantly. However, absence of these factors does not imply that a rope will not deteriorate, it means that the rate of deterioration will be significantly reduced. The question which arises at this point is "By how much should a rope be allowed to deteriorate before we discard it". This report documents part of an investigation which is aimed at answering that specific question by confirming or suggesting modifications to the proposed code of practice for rope condition assessment. This is not the first investigation of its kind, in fact (although the author has no proof) it is likely that investigations of this nature started soon after ropes were first put in use.

The Ropeman's Handbook[7] states the following:

As a general rule no rope should remain in service:

- *When the Engineer considers that the factor of safety has become too low (when the reserve of strength is no longer sufficient to ensure that the rope can safely withstand the repeated shock loads, bends etc).*

- *When the loss in rope strength due to wear, corrosion, or both is approaching one-sixth or 16 per cent of the original strength (or any lesser value set by the Engineer).*

- *When the loss in rope strength due to fatigue, corrosion-fatigue, or surface embrittlement, or due to cracked or broken wires of any kind, is approaching one-tenth or 10 per cent of the original strength (or any lesser value set by the Engineer). The loss in strength may be estimated by regarding all broken or cracked wires within a length of two rope lay lengths as no longer contributing any strength to that part of the rope.*

- *When the outer wires have lost about one third or 33 per cent of their depth as a result of any form of deterioration.*

- *When the outer wires are becoming loose and displaced for any reason.*

- *When a rope has become kinked or otherwise deformed, distorted or damaged, and the affected part cannot be cut out.*

- *When the rope has become subjected to a severe overwind or overload, or to severe shock loading, as a result of an accident.*

- *When examination of the rope leaves any doubt as to its safety on any grounds.*

- *When a rope which is still in good condition, reaches the maximum statutory life for its type, as laid down in Regulations, or the maximum life specified by the Engineer.*

Discard criteria such as these are vague and no longer fulfil the requirements of modern day hoisting in South Africa. The number of wire rope constructions and wire rope applications have grown to the point where one general discard criteria for all ropes is no longer acceptable. There are currently numerous standards (ISO 4309 Cranes-Wire ropes-Code of practice for examination and discard[2], DIN 15 020[1], BS 6570:1986[3]) which outline the discard criteria for ropes. Most of the discard criteria described in these standards are aimed at crane ropes, elevator ropes and ropes for general engineering applications. None of these standards are geared towards mine hoisting ropes. The broken wire discard criteria for round strand ropes operating in steel sheaves according to the ISO 4309[2] and DIN 15 020[1] standards are listed in Table 1. The classification groups of the mechanisms referred to in this international standard are in accordance with ISO 4301-1.

TABLE 1: Discard criteria describing the maximum allowable number of broken wires in round strand ropes working steel sheaves according to the standards ISO 4309[2] and DIN 15020[1]

Number of load-bearing wires in outer strands[1)]	Typical examples of rope constructions[2)]	Number of visible broken wires related to the fatigue of the rope in a lifting appliance which gives rise to immediate rejection							
		Classification groups for M1, M2, M3 and M4 mechanisms				Classification groups for M5, M6, M7 and M8 mechanisms			
		Ordinary		Langs		Ordinary		Langs	
		Over a length[3)] of				Over a length[3)] of			
		6 *d*	30 *d*	6 *d*	30 *d*	6 *d*	30 *d*	6 *d*	30 *d*
n < 50	6 x 7(6/1)	2	4	1	2	4	8	2	4
51 < *n* < 75	6 x 19(9/9/1)*	3	6	2	3	6	12	3	6
76 < *n* < 100		4	8	2	4	8	16	4	8
101 < *n* < 120	8 x 19(9/9/1)* 6 x 19(12/6/1) 6 x 19(12/6+6F/1) 6 x 25FS(12/12/1)*	5	10	2	5	10	19	5	10
121 < *n* < 140		6	11	3	6	11	22	6	11
141 < *n* < 160	8 x 19(12/6+6F/1)	6	13	3	6	13	26	6	13
161 < *n* < 180	6 x 36(14/7+7/7/1)*	7	14	4	7	14	29	7	14
181 < *n* < 200		8	16	4	8	16	32	8	16
201 < *n* < 220	6 x 41(16/8+8/8/1)*	8	18	4	9	18	38	9	18
221 < *n* < 240	6 x 37(18/12/6/1)	10	19	5	10	19	38	10	19
241 < *n* < 260		10	21	5	10	21	42	10	21
261 < *n* 280		11	22	6	11	22	45	11	22
281 < *n* < 300		12	24	6	12	24	48	12	24
300 < *n*[2)]		0,04 n	0,08 n	0,02 n	0,04 n	0,08 n	0,16 n	0,04 n	0,08 n

1) Filler wires are not regarded as load-bearing wires and are therefore excluded from the examination. In ropes having a number of layers of strands only the visible outer layer is considered. In ropes having a steel core, this is regarded as an internal strand and is not considered.

2) In the case of a calculation for numbers of visible broken wires, the value is rounded to a whole number. For ropes having outer wires in the external strands of larger size than the norm, the particular construction is down-graded in the table and indicated by an asterisk[(*)]

3) *d* = diameter of the rope

Table 2 compares the discard criteria of the different standards currently available. As can be seen from the table[8], no single standard addresses all the modes of deterioration. In addition these discard criteria are mainly aimed at general engineering ropes and in most cases are not suitable for use on mine ropes.

Table 2: Discard Criteria, comparison of the different standards[8].

	DIN 15020 1954	DIN 15020 1974	ISO 4309	BS 6570	WIRE ROPE USERS MAN.
the (nature and) number of wire breaks	x	x	x	x	x
wire breaks at the termination		x	x	x	x
the localized grouping of wire breaks		x	x	x	
the rate of increase of wire breaks		x	x		
the fracture of strands	x		x		
reduction of rope diameter		x	x	x	x
internal wear and indentation			x		
internal wear by friction			x		
deterioration of fibre core			x		x
fracture of a steel core			x		
fracture of internal layers			x		
decreased elasticity			x		
external and internal wear	x	x	x	x	x
external and internal corrosion	x	x	x	x	x
waviness			x		
basket distortion	x	x	x	x	x
strand extrusion		x	x	x	x
wire extrusion		x	x	x	
local increase in diameter of the rope		x	x	x	
local decrease in diameter of the rope		x	x	x	
flattened portions	x	x	x		x
kinks	x	x	x		x
bends	x	x	x	x	x
damage due to heat or electric arcing		x	x	x	x
rate of increase of perman. elongation			x	x	x
curled distortion		x			x
loosening of wires or strands		x			
time of operation		x			
rope lay					x
cumulative effects			x		

1.1.3 Discarding of Mine Hoisting Ropes

Part of the reason why there are no standards specifically geared to address the discarding of mine winding ropes is that the laws which govern the use of these ropes vary from country to country (these will be discussed in more detail later). Another problem is that the discard criteria for broken wires and for other damage to mining ropes is defined as loss of the rope strength and no additional information relating the damage to loss in rope strength is available.

Ropes used for general engineering applications are in most cases of very similar construction and of relatively small diameter. The small diameter has enabled researchers to conduct literally thousands of tests on these ropes in a laboratory. From this vast amount of data, codes of practice specifying discard levels were drawn up. In most cases the scatter of results was so great that no direct relationship between deterioration and loss in strength could be found. In these cases tables specifying the maximum number of broken wires with different associated levels of rope diameter reduction, corrosion etc. were drawn up to form the discard criteria. With mine ropes however the problem is more complex. The physical size of these ropes and the large number of different constructions made the required number of laboratory tests totally unaffordable.

A code of practice for these large diameter mine winding ropes was thus never drawn up until the present draft code due to a lack of data.

1.1.4 Discard Regulations Governing the Strength of Mine Hoisting Ropes

The discard criteria for mine hoisting ropes is defined as a loss in rope strength. This loss in strength can be caused by various factors. In the case of broken wires the Ropeman's Handbook[7] from the National Coal Board (NCB) England, specifies that ropes should be discarded when they have lost 10% of their original rope strength. This maximum level of deterioration is also prescribed in the Code of Federal Regulation[9], USA and in the South African Minerals Act[10]. The German mining regulations[11] however state that ropes must be discarded at a loss of 15%

In the case of wear and corrosion, a loss of 16% is permissable under British Regulations, but a reduction in strength of 10% due to fatigue, corrosion fatigue, surface embrittlement, etc is likely to be reached before and will thus govern the discard. The South African regulations do not differentiate between the different types of deterioration, the 10% loss in strength rule applies for all types of deterioration.

According to the Seilprüfstelle in Bochum[12], in cases where a rope had broken wires and wear, the ratio of rope strength loss due to broken wires and due to wear was 1:2, ie if a rope had lost 15% of its strength due to this type of deterioration, 5% loss would be due to broken wires and 10% due to wear. In South Africa experience has shown (and this will be seen from the results presented in this report) that ropes operating on drum winders in vertical shafts are generally discarded due to broken wires with considerable plastic deformation of the outer wires but little associated wear. The resulting loss in rope strength is thus mainly attributed to broken wires. This shows that the types and combinations of rope deterioration are rope construction and application (winder) specific.

The German regulations clearly allow a larger reduction in rope strength than the British, USA or South African regulations. The British regulations also specify the maximum loss in outer wire diameter (33%) and similarly the USA regulations limit the reduction in rope diameter due to wear to 6%. In this regard the South Africa regulations are the least comprehensive. For this reason work on producing a document which prescribed the allowable amounts of deterioration commenced in 1992.

2. BACKGROUND

The Steering Committee on Factors of Safety of Winder Ropes decided to draw up a Code of Practice (CoP) for Rope Condition Assessment (RCA) (of which electro-magnetic (EM) testing would form an integral part) in 1992. Once the code had been completed it was the intention of the committee to apply for dispensation with respect to drum winder rope regulations to facilitate hoisting from greater depths. The committee also intended obtaining further dispensation once the discard criteria were verified and it was proven that EM testing enhanced rope safety significantly. The code was drawn up to cover triangular strand ropes operating on drum winders.

The Code of Practice was almost complete when the proposed new regulations were circulated for comment.

Regulation 16.28 of the newly proposed regulations states:

"***The strength of a winding rope, balance rope or tail rope shall be assessed in accordance with an approved code of practice and may not be used if the breaking strength thus assessed at any point in the rope, excluding the splice or end termination, is less than nine-tenths of the initial breaking strength.***"

This clause applies to all types of rope constructions.

The Government Mining Engineer (GME) stipulated that the CoP had to be in the form of a SABS standard and that this CoP had to be in place when the Minister signed the new legislation. The GME approached the South African Bureau of Standards (SABS) to set up a committee to draw up the CoP.

The SABS - RCA working group used the draft code of practice which had been drawn up for triangular strand ropes as a starting point. This document was expanded as a first attempt to include all winding ropes except half-lock and full-lock coil rope constructions. The document at that stage already contained sections on rope discard criteria (for triangular strand ropes), testing equipment and procedures, testing equipment specifications, and on the selection, training and certification of personnel. It must be noted that the code was adapted to include other rope constructions to meet the requirements of the new laws. The code of practice for rope condition assessment is now complete. This code of practice contains discard criteria based on the collective knowledge of rope testers and on some experimental work. These criteria have been accepted as safe and must be accepted as correct until proven otherwise.

This code even when implemented will still have flaws especially as far as the rope constructions other than six strand ropes are concerned. Further work on discarded ropes other than six strand rope needs to be carried out to eliminate these flaws.

The evaluation of the rope discard criteria, is the main thrust of current work. The results of the tests on sections of discarded ropes are presented in this report. What should be kept in mind is that the code is not yet fully implemented and therefore the specimens tested were discarded based on the "gut feel" of the inspector. Irregular inspection intervals (in many cases out of the control of the rope inspector) also contributed to ropes deteriorating to unacceptable levels. The results of tests can not be related to quality of the Code. In this report the code was applied (sometimes incorrectly, which highlights the need for more clarity in some areas of the code) to the rope specimens received to see whether the ropes were discarded correctly according to the code or if the code would have prescribed that the rope should have been discarded earlier or left on longer.

3. OBJECTIVES

The original objective of this investigation was the verification of the Code of Practice for Rope Condition Assessment. The intention was that ropes would be discarded according to the discard criteria as outlined in the code. The results of the tensile tests on these specimens would indicate how accurate the code was and what changes were required to improve it further.

The longer term objective, once a significant number of specimens had been tested was to carry out a statistical analysis on the results. It was expected that from this analysis we would obtain a relationship between accumulated damage which could be measured on site and the corresponding loss in breaking strength. This objective was accepted by industry and the CSIR. What has emerged from the test programme is the recommendation for a change in objective, i.e. determining the mining industry's current status as far as rope discard is concerned.

4. PROCEDURE

4.1 Discarded Rope Specimens

As mentioned in the objectives, this project was aimed at verifying the code of practice for the assessing the condition of steel wire ropes. When the project started the rope inspectors were asked to discard ropes according to the code of practice which existed then (an earlier version of the current draft code of practice). The inspectors were to mark the section of a rope which had deteriorated the most and was the reason for discarding the rope set. The inspectors were also requested to complete an information sheet describing the discarded rope section and forward it to the CSIR. A copy of this questionnaire is included in Appendix A. Once the rope was discarded the marked section was to be cut out by the mine and forwarded to the CSIR for inspection and testing.

The questionnaire had various functions. One of these was to have a way of checking that the specimen which was received by the CSIR was the discarded section. The other information which was supposed to have been supplied was information regarding the condition of the section on site which could not be recovered once the specimen had been discarded. eg. percentage loss in area due to corrosion and wear, lay length measurements, diameter measurements, position of the discarded section of the rope relative to fixed positions etc.

Once the specimen had arrived at the CSIR, the condition of the specimen was compared to the details supplied on the information sheet. The CSIR then extracted where possible additional information (which was not requested on the questionnaire which the inspector completed on site) from the specimen such as exact orientation of broken wires, missing wires etc. Once this pre-test inspection had been completed the specimen was tested to destruction[13].

After the tensile test the specimens were inspected and discarded. In cases where unexpectedly high rope strength losses occurred the specimens were kept for further investigations.

It was originally intended that this process was to be run over three years. Once an adequate number of test results (initially estimated to be 200) was available, a decision on whether the code needed to be changed and what changes were required would have been taken.

The tests on the discarded sections of rope did not yield the results that were expected due to various reasons. The emphasis has subsequently changed.

4.2 Laboratory Prepared Specimens

It was realised at the onset of the investigation that modes of rope deterioration or damage like heat damage would be very rare. An attempt was thus made at simulating two types rope damage in the laboratory. The first was the effect of a weld arc on rope strength and the second was the effect of heat damage, in particular if a oxy-acetylene flame heated the rope.

These test were carried out to give us an idea of the strength loss associated with damage due to a weld arc or a flame which can easily occur, but could be difficult to detect.

4.2.1 Weld Arc

These tests were carried out on five triangular strand rope specimens. The five specimens had different tensile grades ranging from 1800 MPa to 2100 MPa. On each specimen a weld was made across two outer wires on one strand at the centre of the specimen (See Figure 1). The specimen was then prepared and tested.

4.2.2 Heat Effects

These tests were carried out on six triangular strand rope specimens. The six specimens had different tensile grades ranging from 1800 MPa to 2100 MPa. Each specimen was placed in front of a flame produced by an oxy-acetylene at a distance of 300 mm (See Figure 2). The specimen was kept in this position for 60 seconds. Once the specimen had cooled it was prepared and tested.

Figure 1: The photograph shows the weld damage on one of the specimens prior to testing

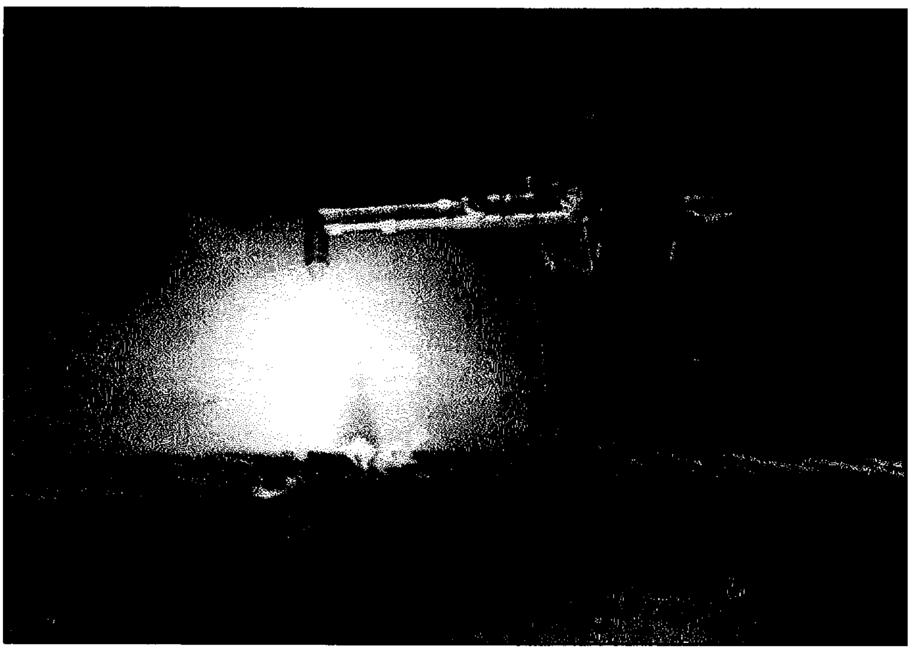

Figure 2: The photograph shows the specimen in front of the oxy-acetylene flame. The specimen was kept at in front of the flame for 60 seconds.

5. RESULTS

5.1 Discarded Rope Tests

Table 3 below summarises the results of the tests carried out on the 63 discarded rope specimens. Column three of the table indicates the specimen in a group of specimens (specimens from the same rope or set of ropes) that showed the worst deterioration from the tensile test. It is assumed that this specimen was the reason for discard of the rope set.

Column four contains the discard factor for each specimen. In the cases where the specimen was supplied with insufficient data, no discard factor has been entered.

Column five of the table gives the reason for discard of each particular specimen in abbreviated form. The explanations of the abbreviations for the reasons for discard as quoted in table 3 are as follows:

BW	: Broken wires
CBW	: Creeping broken wires
CORR	: Corrosion
DIA	: Reduction in rope diameter
KNK	: Rope kinked
RSTA	: Reduction in steel cross-sectional area
TS	: Twisted strand
UNKN	: Reason for discard unknown

Table 3: Summary of the test results of all the discarded rope sections which were forwarded to the CSIR, including reason for discard, the discard factor and actual loss in breaking strength (as a percentage of new rope breaking strength).

Rope Coil Number	Winder Permit Number	Reason for Discard of Rope Set	Discard Factor	Primary Reason for Discard of Specimen	Actual loss in Breaking Strength (%)
124259/001	3886	Yes	1,29	BW	14,7
116728/002	6058	Yes	1,10	BW	19,8
129350/001	6075	Yes	3,06	BW	21,1
122568/003	7610	Yes	2,26	BW	6,7
124931/002	4082	No	1,15	BW + DIA	1,4
119473/001	4082	No	1,17	BW + DIA	3,4
119473/001	4082	No	0,69	DIA	1,5
119473/001	4082	No	0,96	BW + DIA	2,8
119473/001	4082	No	0,94	BW + DIA	3,3
119473/001	4082	Yes	1,16	BW + DIA	4,5
119473/001	4082	No	1,13	BW + DIA	3,8
119473/001	4082	No	1,11	BW + DIA	2,1
119473/001	4082	No	1,26	BW + DIA	3,3
127236/002	5538	Yes	0,76	DIA	0,7
130339/002	8529	Yes	1,21	BW + RSTA	8,0
018733/002	NA	No		CORR	15,3
018689/001	NA	No		CORR	2,6
018732/001	NA	No		CORR	26,7
018734/003	NA	No		CORR	28,6
018690/002	NA	No		CORR	12,9
018691/003	NA	Yes		CORR	28,8
66202	3135A	Yes	0,86	RSTA	2,8
017448/4	7571	Yes		CORR	0,8
115145	6047	Yes	1,36	BW	4,9

Table 3 continued

Rope Coil Number	Winder Permit Number	Reason for Discard of Rope Set	Discard Factor	Primary Reason for Discard of Specimen	Actual loss in Breaking Strength (%)
115146	6047	No	0,74	BW + DIA	3,7
124257/002	6614	No	1,16	BW + DIA	-1,1
124258/001	6614	No	1,26	BW + DIA	3,0
124258/001	6614	No	1,61	BW + DIA	0,2
124258/001	6614	No	1,29	BW + DIA	0,5
124258/001	6614	Yes	1,16	BW + DIA	5,6
128177/002	6592	Yes	1,41	BW + DIA	7,1
005622	3954A	Yes	0,54	BW	1,5
114319/002	22D	Yes	0,00	CORR	35,6
120203/001	2287	No	0,77	BW	2,4
120203/001	2287	No	0,36	BW	-1,7
120203/001	2287	Yes	1,54	BW	8,4
126070/002	4126	No	1,17	BW + DIA	22,3
126070/002	4126	Yes	1,66	BW + DIA	25,2
111968/002	4126	No		TS	-1,2
111968/002	4126	No		TS	-1,5
120228/001	3176B	Yes		CORR	1,4
120228/001	3176B	No		UNKN	-1,0
023297	4129	No		CORR	0,9
120907/001	4129	No	0,43	CBW	0,9
120907/001	4129	No	0,61	CBW	-1,3
120905/001	4129	No	0,40	CBW	-1,2
115478/001	4129	Yes	0,61	CBW	1,9
129603/001	3534	Yes	1,19	BW	14,9
117843/002	78A	Yes		BW + DIA	11,6

Table 3 continued

Rope Coil Number	Winder Permit Number	Reason for Discard of Rope Set	Discard Factor	Primary Reason for Discard of Specimen	Actual loss in Breaking Strength (%)
127839/001	4088	Yes	0,49	BW	1,5
118543/002	7616	Yes		CORR	25,7
118543/003	7616	No		CORR	8,0
118543/004	7616	No		CORR	15,4
140825	6530	No	1,79	BW + DIA	17,42
140824	6530	Yes	2,03	BW + DIA	19,23
127553/001	3132A	Yes		UNKN	-2,5
133862/002	7614	Yes		UNKN	-0,8
126808/001	2837	Yes	1,54	BW + DIA	15,9
028653	3921	Yes		KNK	13,4
116274/002	5024	Yes		KNK	20,4
108709	3552	Yes	3,56	BW	20,27
119926/001	2173	Yes	0,96	BW + DIA	2,98
029230	6530	Yes		KNK	4,20

5.2 Laboratory Prepared Specimens

5.2.1 Weld Arc

The results of the tensile tests conducted on five triangular strand rope specimens of different tensile grades with a weld placed across two outer wires are tabulated below.

Table 4 Results of tests on the five test specimens which were damaged by a weld arc in the laboratory.

Tensile Grade MPa	Rope Diameter mm	New Rope Breaking Strength kN	Breaking Strength of Specimen kN	Loss in Breaking Strength %	First Wire Failure kN	Fracture Relative to Damage mm
1800	40,0	1200	1181	1,58	600	at damage
1900	44,0	1500	1481	1,27	600	at damage
1950	39,0	1240	1223	1,37	700	at damage
2000	44,0	1630	1594	2,21	700	at damage
2100	42,0	1520	1502	1,18	600	at damage

5.2.2 Heat Damage

The results of the tensile tests conducted on six triangular strand rope specimens of different tensile grades which were heated with a naked flame for 60 seconds are summarised in Table 5 below.

Table 5 Results of tests on the six test specimens which were damaged by heat in the laboratory.

Tensile Grade MPa	Rope Diameter mm	New Rope Breaking Strength kN	Breaking Strength of Specimen kN	Loss in Breaking Strength %	First Wire Failure kN	Fracture Relative to Damage mm
1800	40,0	1220	1237	-1,39		900
1900	44,0	1540	1573	-2,14		1000
1950	40,0	1300	1317	-1,31		at damage
2000	44,0	1630	1630	0,00	1530	1000
2050	41,0	1400	1441	-2,93	1410	at damage
2100	44,0	1660	1626	2,05		at damage

6. DISCUSSION

The CSIR collected data and carried out tests on 63 rope specimens discarded during the last eight months of 1993. When the project was started the original objective was to collect rope specimens discarded according to the code of practice and test them. The results would then have been used to enhance the code of practice on rope condition assessment.

Once the results of the 63 discarded rope specimens were available several attempts were made at carrying out an analysis. The relationships which this data produced were in most cases not logical. For example, rope strength loss is apparently inversely proportional to rope diameter loss. It was only after the analysis had produced such results that the data was studied further.

The remainder of this discussion will thus concentrate on the types of discarded rope sections received and aspects relating to their discard. In addition to these comments Appendix B contains comments on each individual specimen. It should however be noted that many of the comments made on the data presented and discussed in this report are the views not only of the author but of consultants such as Mr Kuun (ex AAC) and Mr Wainwright (ex Haggie Rand). In addition it will be shown that any further attempts at deriving a direct relationship between rope discard criteria and loss in rope strength may have limited success as the code is not intended to be used as a measuring stick but rather a "go - nogo" gauge.

6.1 Discarded rope specimens

The next few sections briefly discuss the different types of specimens that were tested by the CSIR. The figures quoted are based on the set of 63 specimens unless otherwise specified. It will be seen later that not all the specimens tested were reasons for discard, in fact only 31 were proper discard specimens. Figure 3 shows the distribution of the strength losses for all the specimens tested. The distribution shows that many of the specimens tested had lost less than 10% of their breaking strength, however the distribution is deceiving due to the inclusion of the results of the sister discard specimens.

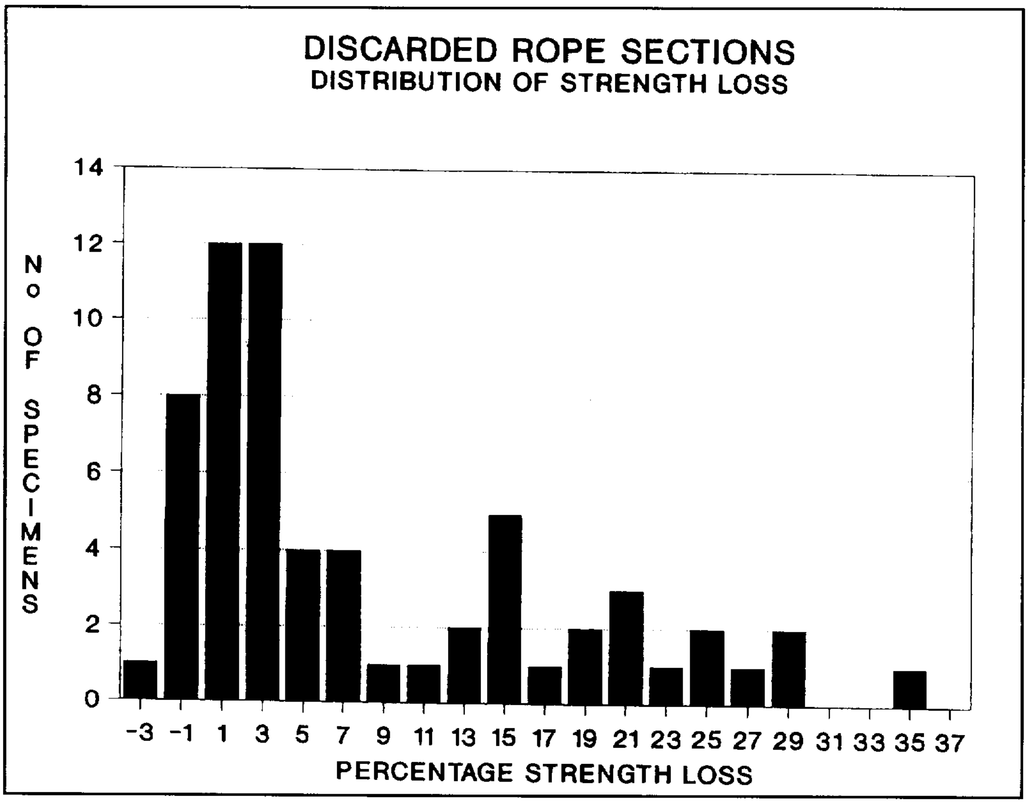

Figure 3: Distribution of the loss in breaking strength of all rope specimens tested.

6.1.1 Specimens discarded due to broken wires

The rope inspectors were asked to indicate the reason for discarding the rope specimen on the reports which were forwarded to the CSIR. In 38 cases the report indicated that the specimens were discarded due to broken wires. In some of these cases no reason for discard was given, however where it was evident that the specimen was discarded due to broken wires that specimen was included in the count. In at least 50% of the cases the specimens were discarded not only due to broken wires but due to a combination of broken wires and a reduction in rope diameter.

In many cases the number of broken wires and the axial distribution of fractures found by the CSIR at the rope pre-test inspection correlated poorly with the field reports[14], in particular Specimen No's 26, 27, 29, 30, 32, 38, and 58. In some cases it was evident that the incorrect specimen had been forwarded to the CSIR as there was no correlation between the CSIR report and the field report on the supposedly same specimen. Specimens where this was clearly evident were No's 4, 28 and 35.

It is thus essential that ropes are properly marked on site and that an accurate report on the axial and circumferential orientation of the broken wires is drawn up. Such reports will firstly enable the CSIR to assess whether the correct specimens have been received. They will also assist in determining to what extent the condition of the rope specimen is affected by the removal process and preparation of the test specimen. In addition to this we may from such reports be able to determine what damage may exist on the specimen which was not visible on site. Without this quality of information from both the rope inspectors and the CSIR further improvement of the code will not be possible.

6.1.1.1 Creeping broken wires

It is sometimes found that a broken wire migrates away from the fracture position. There are various reason why this can happen although an exact cause has not been established. The effect of this however is that the creeping wire starts to stand proud every time it comes to the outside surface of the rope. This results in the same wire fracturing at equally spaced points along the rope. The distance between these points is usually equal to about 60% of the rope lay length[14]. The mistake which can easily be made is to count these broken wires as separate broken wires. One creeping wire which breaks about seven times over five lay lengths should be counted as one broken wire and not seven broken wires over five lay lengths. These types of wire breaks are not always obvious and in cases where the specimen has a large number of broken wires over various lay lengths an accurate assessment of which wires are creeping wires and which are not is no trivial task.

In the set of 38 specimens which were discarded due to broken wires, five specimens (Specimen No's 44, 45, 46, 47 and 50) definitely had creeping broken wires. In addition to these five there were at least three specimens which may have had creeping broken wires. The identification of possible creeping wires was clearly overlooked at the pre-test inspection by the CSIR and on site by the rope inspector. We can at this stage therefore not say with any degree of certainty with the data at hand whether there were creeping broken wires present on those specimens. The lack of this data thus ensures that the discard factor calculated for these specimens is inaccurate. It is thus essential that in all cases the number of outer wires between successive fractures in a given strand is counted in order to ascertain whether creeping wires are present.

It should be noted that creeping broken wires can lead to excessive rope maintenance and could be justification for rope discard without significant strength losses. If specimens from such ropes are submitted for testing this should be stated as the reason for discard.

6.1.1.2 Split Wires

The code of practice states that wires cracked at the crown, split wires and creeping or slack wires should be counted as visible broken wires. A split wire is counted as a broken wire because transverse fractures can develop in the split region at any time following the rope inspection. In all the pre-test inspections where a specimen was found to have split wires or wires which fell into this category these were counted and recorded as broken wires. In the case of a split wire, if the wire has a longitudinal split the effect on the wire strength can be minimal. If the split is transverse however it has a totally different effect. In most cases it is difficult to differentiate between the two types of splits even in the laboratory and in the case of these 63 specimens no attempt to distinguish between the two splits was made.

Wires which are found to be split on site must in future be counted as broken as the code suggests, however for the purposes of improving the code where possible a distinction between the two types must be made at the pre-test inspection. The post-test inspection should then aim to detect whether split wires broke during the test and may have caused the strength reduction.

6.1.1.3 Broken Wires in one strand

In at least 50% of the specimens discarded due to broken wires it was found that the highest discard factor was governed by the number of allowable broken wires in one strand. In many cases this requirement of the code resulted in a very high discard factor (Specimen No 26 for example, although it is assumed that the rope set was not discarded because of this particular specimen) resulting in early discard.

Mr Kuun raised some very good points regarding requirement 8.1.1 (c) and (d) of the code and the author feels it appropriate to quote them verbatim[14]

Validity of code requirements 8.1.1 (c) and (d) of the April 94 draft must be reconsidered (3% and 4% loss of steel in one strand).

- *In the Aug 92 report on the 1959 test results it was shown that the single strand situation was catered for adequately by the asymmetric case. Limited further results obtained by AAC during Nov 93 do not differ substantially from the 1959 data.*

- *It is likely that the single strand requirement is based - quite incorrectly - on an old rule of thumb that was popular before introduction of the new criteria. In terms of the old rule, discard is required when three or more wires are broken close together in one strand. At that time it was also assumed that one outer wire represented about 1% of rope steel area. For normal deterioration of a triangular strand rope the loss in diameter at discard is about 3% to 6% and is symmetric. Coupled to a loss of three wires, the old one-strand requirement then translates into a 6% loss of rope steel area for the <u>new</u> rope:*

  $$DF = (4{,}5) \div (9\%) + (3x1\%) \div (6\%) = 1{,}0$$

Properly interpreted, the old rule of thumb calls for 6% in 8.1.1 (c) rather than the 3% now specified, and is therefore less conservative than the 5% asymmetric requirement in 8.1.1 (a). This makes 8.1.1 (c) superfluous.

- *A further misinterpretation was introduced in the April 94 draft by applying the requirement to any single strand with no regard to the condition of the other strands (unbalance). The previous draft - Aug 92 - clearly referred to the situation where all the broken wires in the rope section were in one strand only.*

- *The new single strand requirement 8.1.1 (c) is up to 67% more severe than the asymmetric case and prevailed in 23 of the 40 broken wire samples considered in the present review. Application of 8.1.1 (c) leads to excessively early discard, as is illustrated to some extent in the summary of results in the next section.*

Requirements 8.1.1 (c) and (d) should be deleted. In addition, it is useful to note that for triangular strand ropes the requirement 8.1.1 (e) - 40% of the number of outer wires per strand - comes into play only at and beyond 6 x 30 constructions.

It is clear that a very valid point has been made. This requirement of the code needs more refinement before the code is finalised. The current work that the CSIR is carrying out on the effect of the distribution of broken wires on rope strength should assist in addressing the matter. The mining industry could lose large sums of money if any requirement of the code is overly conservative or unsafe.

6.1.1.4 Broken Wire Gap

Any fractured or broken wire is essentially a missing wire over a certain distance, usually from where it emerges to where it enters the rope again (from the point of contact of the mother strand and the strand on the left to the contact point of the mother and the strand on the right, or vice versa). In some cases these broken wires are "broken out" to prevent damage to adjacent wires and the gap is more apparent. This gap must be measured parallel to the axis of the rope and in the case of triangular strand ropes is about 20% of rope lay length.

The rope inspector must be made aware of the existence of this gap and it must be taken into account when determining broken wire density. For the purpose of determining the number of broken wires in one or five lay lengths, the maximum separation between the broken wires gap centres, left hand ends or right hand ends is equal to the measured broken wire gap plus the actual lay length or five lay lengths. This was overlooked by the CSIR staff and the majority of rope inspectors and had an effect on the broken wires density of various specimens.

6.1.2 Specimens discarded due to corrosion.

Thirteen of the 63 specimens tested were discarded due to corrosion. Of these 13 specimens, 9 were cut from two rope sets which allowed the calculation of the multiplication factor for two rope-instrument combinations. In the first case Figure 4 shows the multiplication factor for the RAU instrument on a 42 mm diameter round strand rope of a six strand 6×25(12/6F+6/1) construction. In the second case Figure 5 shows the multiplication factor for the RAU instrument on a 29 mm diameter round strand rope also of a six strand 6×25(12/6F+6/1) construction. As can be seen from the figures the multiplication factors vary with varying levels of corrosion and with different diameter ropes of the same construction.

The importance of these multiplication factors cannot be overemphasised. One of the biggest problems in assessing rope deterioration is assessing the levels of internal corrosion. This was one of the main reasons these instruments are used and for internal corrosion the rope inspector relies on his instrument. If multiplication factors are not available the benefit of having an instrument is limited.

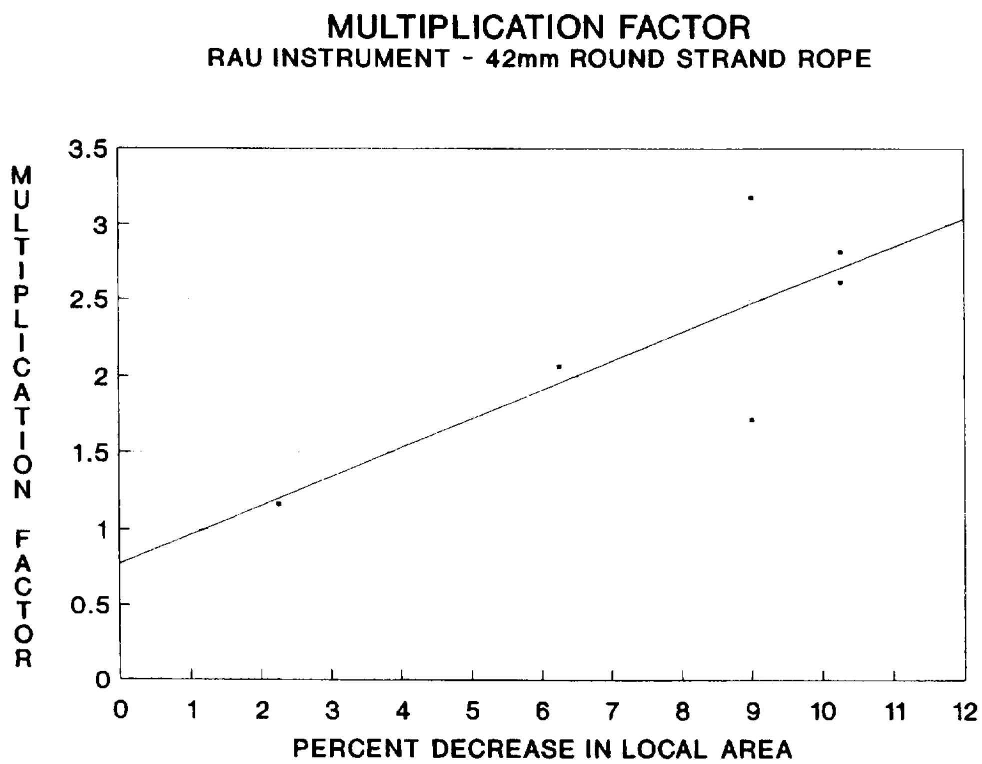

Figure 4: Derivation of the multiplication factor for the RAU instrument on a 42 mm round strand rope of a six strand 6×25(12/6F+6/1) construction.

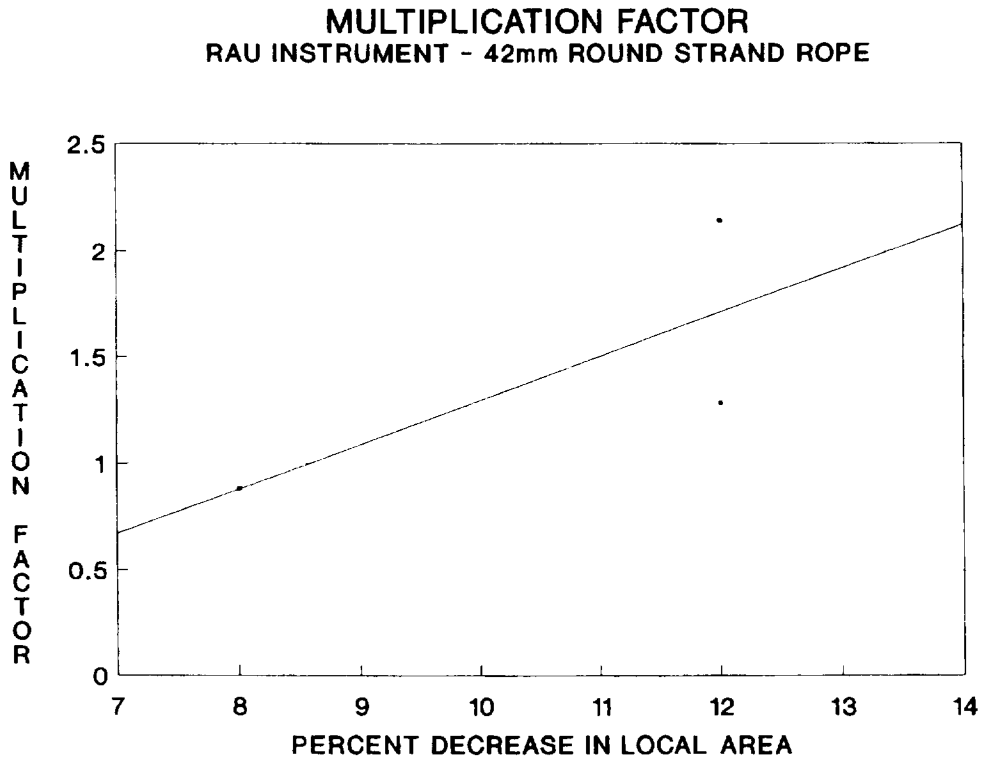

Figure 5: Derivation of the multiplication factor for the RAU instrument on a 29 mm round strand rope of a six strand 6×25(12/6F+6/1) construction.

6.1.3 Specimens discarded due to reductions in diameter.

Reductions in rope diameter are usually combined with broken wires or corrosion and in most cases (with the exception of ropes operating on incline winders which are exposed to significant amounts of abrasive wear) the latter is the main reason for discard. Only two of 63 specimens were discarded due to reductions in rope diameter alone. In both cases although the reduction in diameter was significant (7% in one case) the associated strength loss was very small (in the order of 1%). The main reason for this is that in both cases the reduction in rope diameter was caused by plastic deformation of the outer wires and very little material was lost. Had this rope diameter reduction been caused by abrasion the results would have been totally different.

One aspect that has not been mentioned is symmetry. Reduction in rope diameter on six strand ropes is usually symmetrical, due to the torque tension properties of a six strand rope. However mechanical damage caused by proud sleeve bolts, objects falling down the shaft and other abnormal incidents can result in an asymmetric rope cross-section over small distances. Asymmetric distribution of wear on a rope has a larger impact on the loss in strength of the rope than symmetric wear for the same loss in cross-sectional area and should be looked out for.

In all the 63 cases the diameter measurement of the rope both at the CSIR and in the field was carried out using a rope diameter tape. (It should be noted that the diameter measurements taken in the rope laboratory were taken in such a way as to duplicate what was being done on site.) A rope diameter tape does not allow one to quantify asymmetric wear. Therefore if an EM instrument indicates a local anomaly, careful visual examination should include the measuring of rope symmetry. A rope vernier should be used to measure the rope diameter to complement the measurements taken with the rope tape. The use of large jaw verniers for measuring rope diameters is not advised in these cases as the wide jaws of the vernier prevent the measuring of local diameter changes.

It is important in future that the reference rope diameter is determined once a rope has been in service for a certain amount of time (few weeks maximum). If this is not done it will be difficult to discard a rope based on rope diameter reduction. It must be remembered that new rope diameters variations caused by the rope manufacturing process can range from +0% to +5% above nominal. A rope which is 5% oversize can lose 14% of its actual diameter before the code recommends discard if the diameter reduction is based on the nominal value.

This diameter effect could explain why in some of the results of the specimens tested it appeared that the result was positively influenced by taking rope diameter into account and in other cases it was negatively influenced.

6.1.4 Kinked specimens

Three kinked specimens were tested. Of these three specimens the one specimen was kinked very close to the splice. This specimen had to be tested with the splice. The splice failed and the loss in strength at the kink could not be determined. What can however be said is that the loss in strength of the kinked section was less than 20,4%.

A kink is classified as severe rope damage. In cases of new ropes with low tensile grades (1800 MPa) a kink sometimes has very little effect on the breaking strength of the rope. The cases of older used rope, especially ropes with corrosion a kink can reduce the strength of the rope by 50%. Although it is accepted that ropes with kinks must be discarded, testing of kinked specimens should continue so that a data base on this type of damage can be compiled.

6.1.5 Specimens with unexpected high strength losses

Specimen No's 2, 37 and 38 fall into this category. In the case of Specimen No 2 the rope inspector did not specify a reason for discard. From the pre-test inspection it is believed that this rope was discarded due to broken wires and a reduction in diameter (although site diameter measurement is not available). The specimen had, according to the code three broken wires (one broken, two split) asymmetrically distributed over one lay length and a considerable amount of plastic deformation on the outer wires. The fraction of the discard factor for the broken wires is 0,61. If we consider the broken wires on their own the rope should not have been discarded. The diameter measurements taken during the pre-test inspection indicated no reduction in diameter.

The actual strength loss of the specimen was found to the 19,8%. The post-test inspection of the rope specimen indicated one broken strand and the presence of a brazed core at the point of failure. The brazed core thus did have an effect on the strength of the specimen. The evidence indicates that the brazed core may have also been slightly oversize causing a slight not easily visible bulge in the strand. This in turn caused the outer wires of that strand to deteriorate at a higher rate than those in the adjacent strands. This case highlights the need for manufacturing ropes with no brazed cores, especially ropes that will be operating at the low design factors (safety factors).

Specimen No's 37 and 38 were cut from the same rope. Both specimens had the same appearance and are possibly the most interesting yet concerning of all the specimens reported on in this report. According to the rope inspectors report (note that two identical reports were supplied for Specimen No's 37 and 38) both specimens were cut from a point 1520 m from the front end of the rope which corresponds to a point 360 m below the sheave. In addition the report stated that the rope was discarded due to broken wires (four broken wires), and heavy plastic deformation. The site rope diameter measurement indicated a 6,3% reduction. Specimen No 37 was found to have a total of 7 broken wires concentrated over two lay lengths at the pre-test inspection. Four of these broken wires were asymmetrically distributed over one lay length. According to the code of practice the discard factor for the damage accumulated by this specimen is 1,2. The actual loss in strength was an unexpected 22,3%.

Specimen No 38 had a total of six broken wires, five broken wires asymmetrically distributed in one lay length. According to the code of practice the discard factor for this number and distribution of broken wires was 0,95 and 0,70 due to reduction in diameter. The actual loss in strength was an unexpected 25,2%. Due to the unexpected results of these specimens they were subjected to further investigation.

Both specimens were found to have a high number of brittle wire failures all located on one side over a 1 m distance. The majority of these brittle wire failures were found to have fatigue cracks at the break which had propagated in some cases up to three-quarters of the way through the wire cross-section. A broken wire was selected at random and was sectioned close to the area of the break. The cross-section was mounted and polished. Figure 6 shows the working edge of the wire (the edge which made contact with the drum and sheave). The thin white stripe across both photographs (arrowed) indicates the presence of martensite. Martensite is formed on the surface of a wire when the surface is heated and rapidly cooled. This martensite layer is extremely brittle and is prone to fatigue crack initiation. It has not been possible to establish the exact cause for the martensite layer, but it is obvious that this rope rubbed against either the shaft steelwork, the sheave, the drum or onto another layer of rope which had this rapid heating and cooling effect. These small fatigue cracks in the wires were thus responsible for the strength loss.

Additional micrographs shown in Figure 7 revealed the presence of a crack running what appeared to be longitudinally down the centre of the wire. This crack was apparently in the wire at the time of manufacture but due to it running longitudinally along the wire had no significant effect on the strength of the rope.

This type of damage cannot be detected until the wires break, but the code of practice on winder operation, performance and maintenance may have a role to play in preventing this type of damage from occurring in the future.

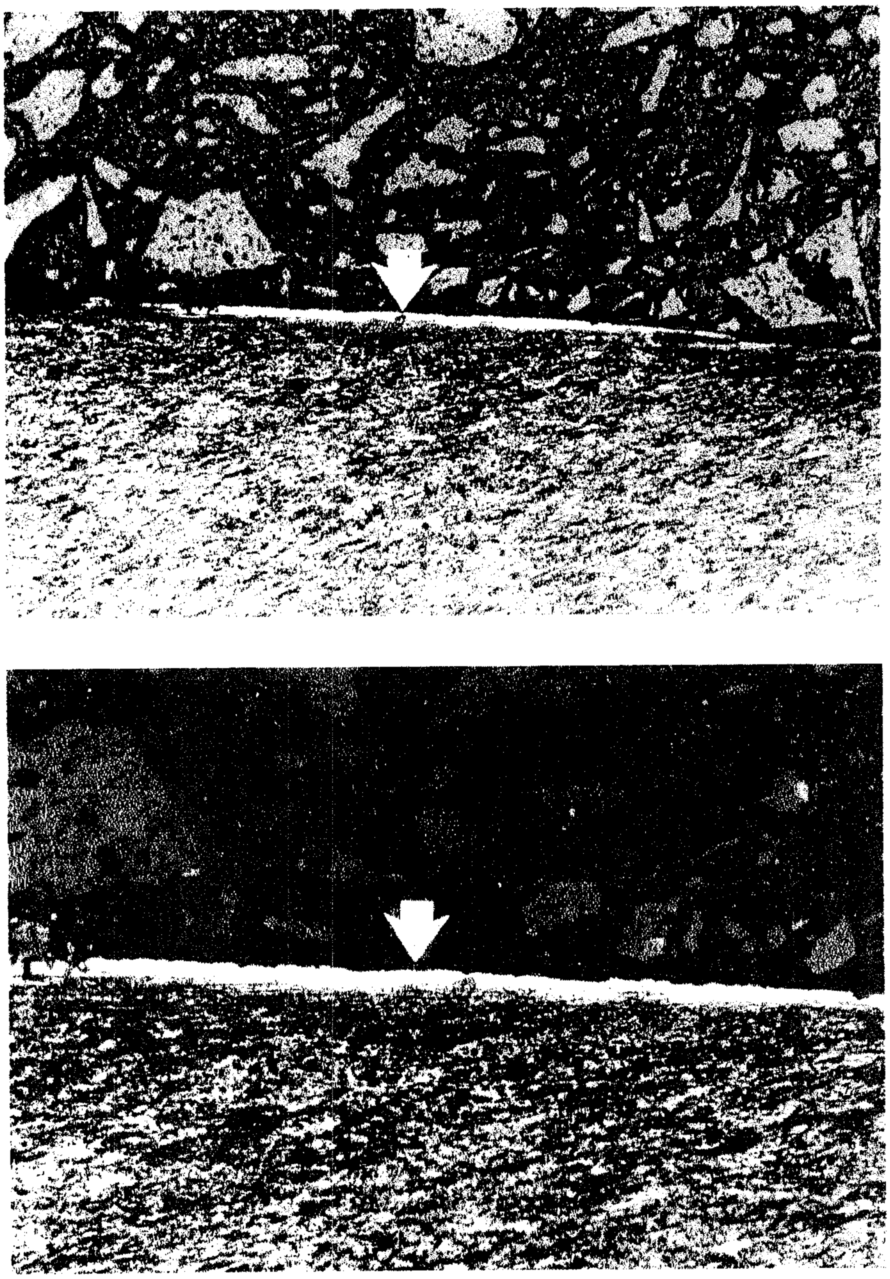

Figure 6: Micrographs of the cross-section of a wire showing the presence of martensite (arrowed) on the surface of the wire.

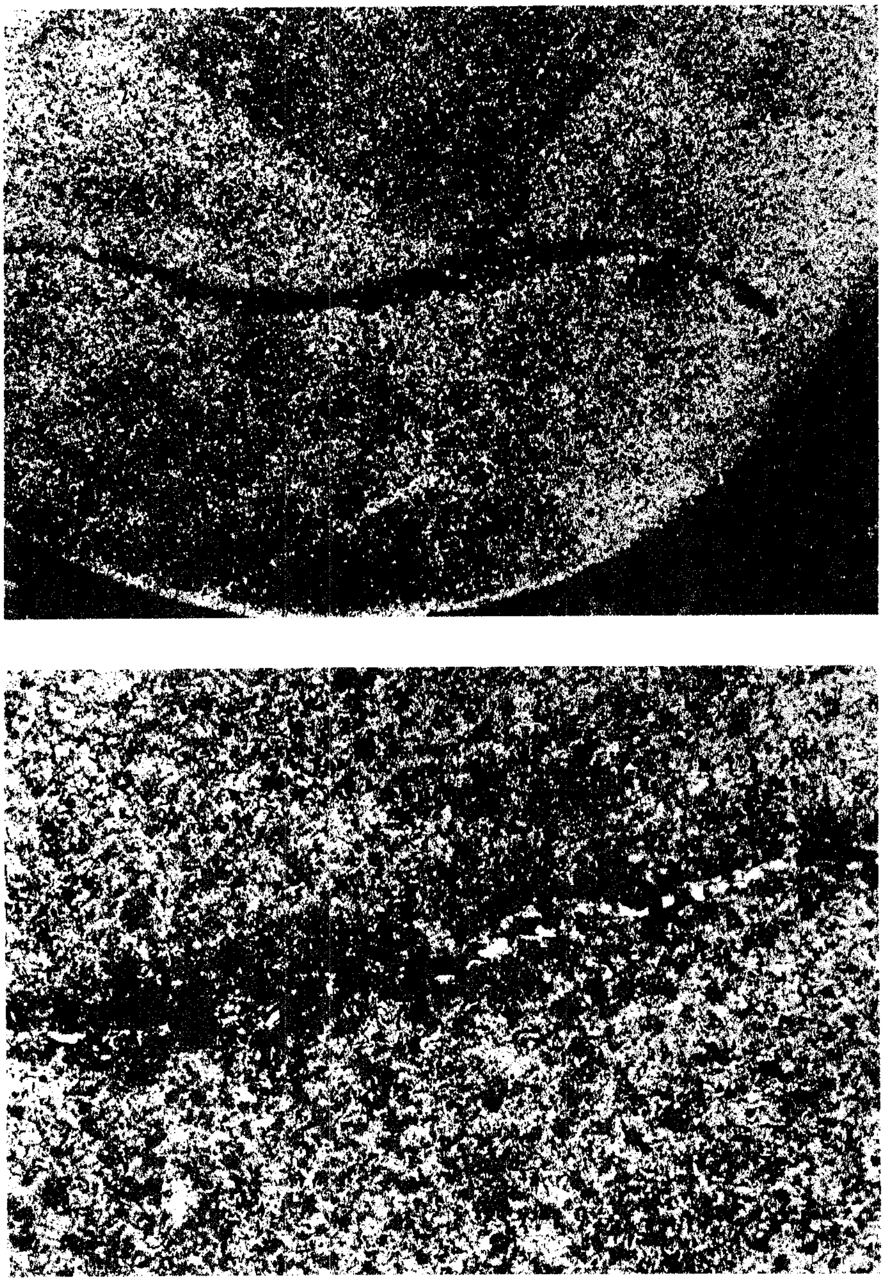

Figure 7: Micrographs of the cross-section of a wire showing the presence of an internal crack running longitudinally down the length of the wire.

6.1.6 Other observations

6.1.6.1 Increases or decreases in rope strength

The Rope Condition Assessment Code of Practice does not take into account any likely increases in rope breaking strength common to most ropes in service. Although this is conservative and proper it can result in seemingly early rope discard at times. The opposite, although less common is also true. Factors such as ageing are not considered and can reduce the rope strength which can result in seemingly late discards. An example of this is the case with Specimen No 32 (the only specimen for which a proper rope history was supplied). Discard was based on broken wires and diameter reduction with a discard factor of 1,1. The breaking strength was 1,5% below new rope breaking strength, but 6,4% below the strength of the front end specimen. If the rope had aged and lost some of its original strength, the damage accumulated by this specimen would have appeared to have had a more significant effect on the rope strength than was actually the case.

6.1.6.2 Wasted work

Three specimens were supplied to the CSIR with either no field report, or a report that did not indicate the reason for discard. The CSIR examination found nothing wrong with the specimens and there was no loss in breaking strength. Rope inspectors who do not mark specimens properly and mines that send in incorrect specimens end up wasting their own time and money if this is not addressed.

6.1.6.3 Incorrect use of code

Figure 8 relates the predicted loss in strength (obtained by multiplying the discard factor by 7%) to the actual loss in strength. Although it may be desirable to find a straight line relationship between the predicted rope strength loss and the actual strength loss it must be pointed out that this is not the function of the code. The code is meant to ensure that if a rope is discarded when the discard factor is in a ceratin bandwidth (say 1,0 to 1,2) the probability of the strength of that rope being reduced by more than certain value (say 14%) is minimal.

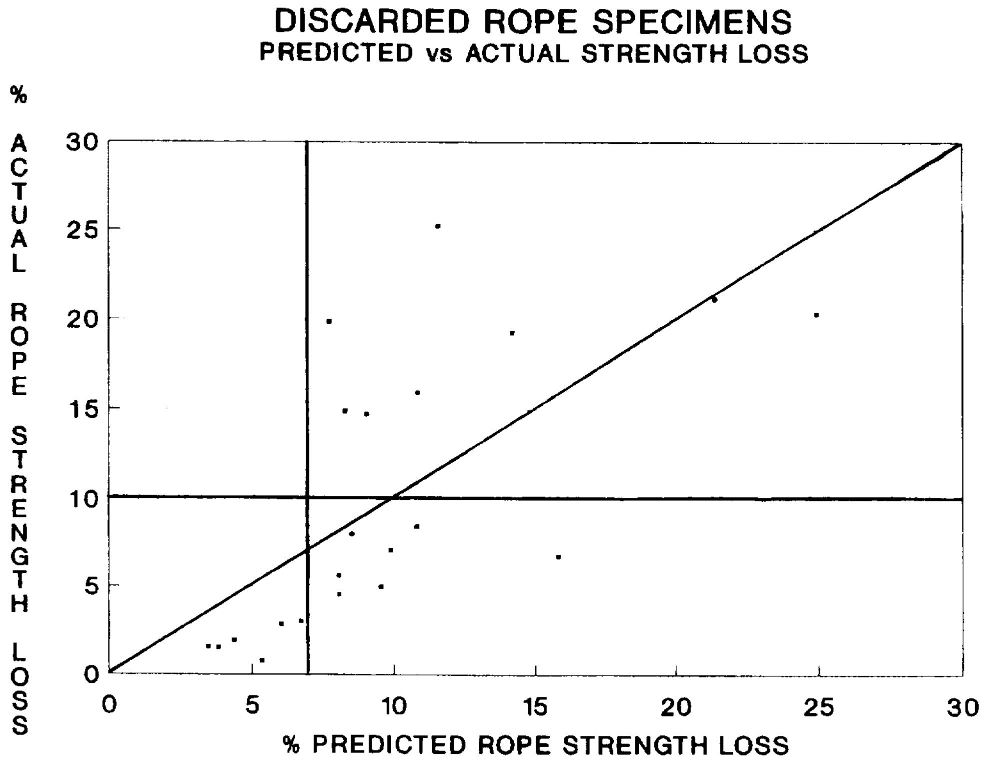

Figure 8: Plot of estimated rope strength loss versus actual strength loss.

6.1.7 Concluding remarks

The 63 rope specimens which were tested by the CSIR (see Table 3) included multiple samples from a given rope or set of ropes. In the cases where more than one specimen was tested from a rope or rope set, for the purposes of this discussion, it was assumed that the specimen which had lost the most strength was the specimen which presented justification for discard. The data can thus be divided up into two groups[14] namely:

Main Discard: The specimen in a group of specimens (specimens from the same rope or set of ropes) that showed the worst deterioration from the tensile test.

Sister Discard: The other specimens from that group.

There was a total of 32 main discard specimens and 31 sister discard specimens in the set of 63 specimens tested. Figure 9 shows the distribution of the strength losses of the 32 main discard specimens. As can be seen a large proportion (44%) of these specimens had lost more than 10% of their strength. Of the 32 main discard specimens only 21 specimens were supplied to the CSIR with enough data to allow the calculation of a proper value for the discard factor. The discard factors for these 21 specimens as calculated by the author ranged between 0,49 and 3,56. If we now assume that if a specimen is correctly discarded it should be discarded when the discard factor ranges between 0,6 and 1,4 then 11 of the 21 specimens currently under discussion were correctly discarded, 2 specimens were discarded prematurely and 8 specimens were discarded too late. Figure 10 shows the distribution of the strength loss of the specimens which were discarded in the above mentioned bandwidth. This figure gives some indication of the type of results we can expect when ropes are discarded according to the code. The majority of ropes will be discarded with breaking strength losses of 10% or less, however we will still find that some ropes will be discarded with strength losses in excess of 10%.

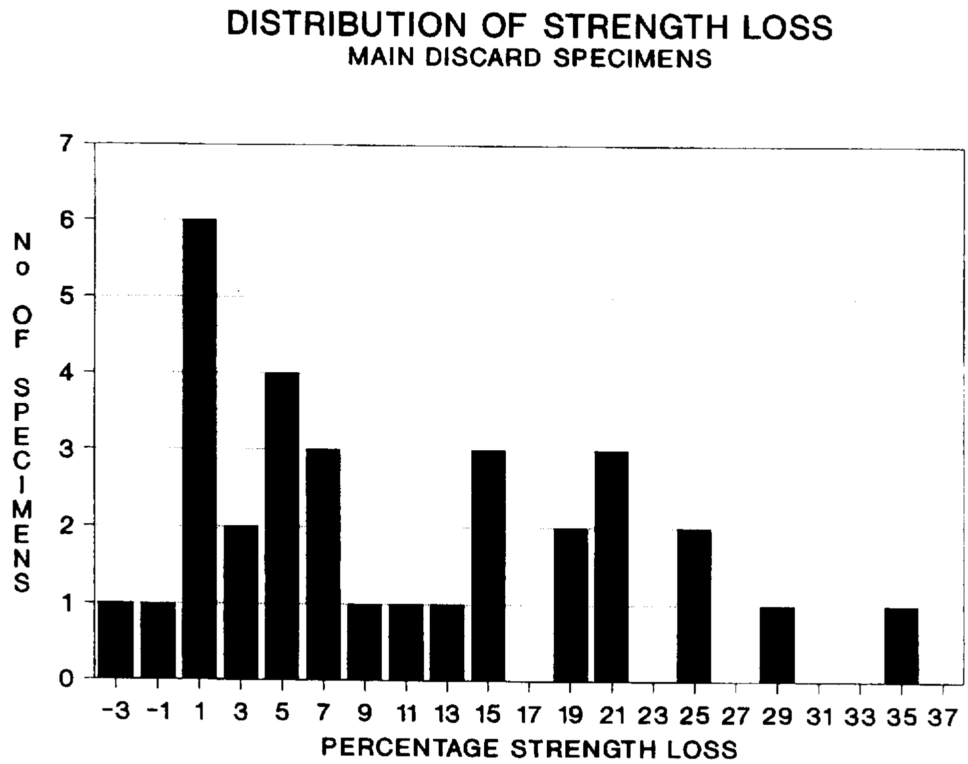

Figure 9: Distribution of the loss in breaking strength of the rope specimens tested which were the cause for the discard of the rope set.

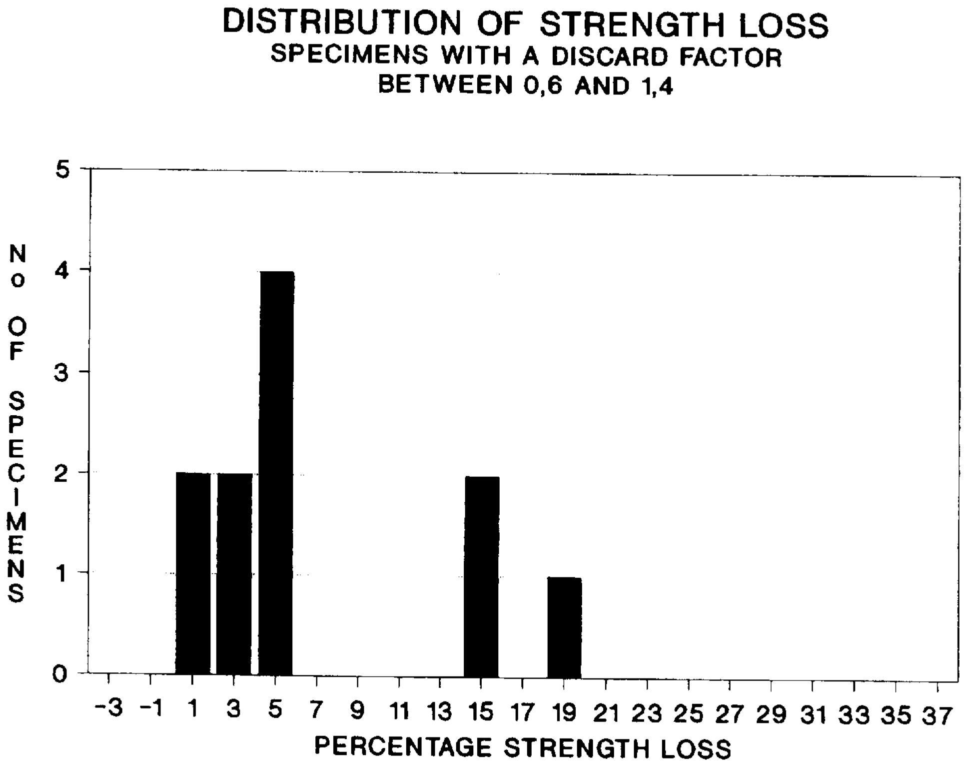

Figure 10: Distribution of the loss in breaking strength of the rope specimens tested which were the cause for the discard of the rope set and for which the discard factor was 1 ±0,4.

In a study of the data on the 63 specimens tested by the CSIR, Mr Kuun further subdivided the main discard specimens as follows:

Premature discard: Specimens with a discard factor of less than 1,0 or, in the absence of useful field data, a loss in strength less than 10%.

Proper discard: Specimens with a discard factor greater and equal to 1,0 but smaller or equal to 1,2

Late discard: Specimens with a discard factor greater than 1,2 or in the absence of useful field data, a loss in strength greater than 10%.

Table 6 shows the number of specimens in each category with the range of strength variations in brackets

Table 6: Classification of Main discard specimens by Mr Kuun

Main discards			
Premature	Proper	Late	Total
10 (+2% to -4%)	3 (-2% to -15%)	19 (-5% to -36%)	32

The way in which the data in Table 6 above has been sub-divided is a little extreme. All the specimens in the set of 32 which were not supplied with data to enable the calculation of a discard factor have either been classified as premature or late discards. If we assume that the data set of 32 specimens is representative of how ropes are currently being discarded in South Africa it is evident that approximately 25% of ropes are correctly discarded, 31% are discarded prematurely and 44% are discarded late (with strength losses in some cases in excess of 35%). It is evident that only in very few cases are ropes being discarded correctly. From the data currently available if ropes were being discarded according to the code of practice the strength losses of the majority of the specimens should range between 0% and 16% with only isolated cases where the rope strength loss goes outside this range. This illustrates the function of the code of practice, which is not a device for predicting rope strength loss, but a device for risk management. Unless this is understood the code cannot be used to its full extent.

It has become evident that although we have rope inspectors with vast experience in rope discard, inspectors tend to discard ropes based on "gut feel" or codes of practice other than the one under discussion here. It is thus extremely important that the code of practice is explained to all rope inspectors and that these rope inspectors are trained and certificated in discarding ropes according to the code. The implications of not carrying out proper training will mean that the code will never be fully implemented.

Although this investigation set out to verify the code, the absence of specimens discarded according to the code has made this task impossible. However, as was seen in the paragraph above, South African mines are discarding approximately 44% of their ropes too late. If in the future ropes are discarded according to the code with discard factors of approximately one, we will find that the percentage of ropes discarded late will decrease significantly. Only in isolated cases will it then be found that specimens will have been discarded with strength losses in excess of 16%. What must however be kept in mind is that of the 32 main discard specimens, 28 were of triangular strand construction and 4 of round strand construction. Most of the comments in this report are thus mainly applicable to triangular strand ropes. The effect the code will have on the discarding of ropes other than ropes of six strand construction is not known.

6.2 Laboratory prepared specimens

As mentioned earlier in the report, it was realised at the onset of the investigation that certain modes of rope deterioration or damage like heat damage would be very rare. An attempt was thus made at simulating this and other types of damage in the laboratory which had partial success. Two types of damage were simulated. The first was the effect of a weld arc on rope strength and the second was the effect of heat damage, in particular if a oxy-acetylene flame heated the rope.

6.2.1 Weld Arc

No specimens with weld arc damage were submitted for testing. This indicates that this type of damage is not very common, but does exist as the author has seen at least three specimens which were submitted for statutory tensile testing with this type of damage over the same number of years. The ISO 4309 standard recommends that a rope which has been subject to electric arcing be discarded. This may be essential on ropes with small wires, but the author felt that this may not be applicable for ropes with large outer wires. Five rope specimens of different tensile grades ranging from 1800 MPa to 2100 MPa were used in this investigation. A weld was placed across two adjacent outer wires of each specimen to simulate accidental arcing as shown in Figure 1. The specimens were then tested. In all five tests the two wires affected by the weld were the first wires to fail. Failure of these wires occurred at fairly low loads (approximately 50% of new rope strength). Subsequent to the failure of the wires the rope behaved normally and the loss in strength was between 1,18% and 2,21% (See Table 4). The results of these tests are similar to a rope with two broken wires in one strand.

The effect of electric arcing seems to be very localised and affect only the wires with which it comes into direct contact. It would thus be a little extreme to have to discard a rope because one or two wires were affected by an electric arc. What may be a recommended alternate procedure is break these wires out from valley to valley or to count them as broken wires.

6.2.2 Heat Damage

The are a few ways in which a rope can be damaged by extreme heat. A rope can be heated by a fire while in storage, or while in service. In the case where a rope is damaged in storage the rope should be discarded and in the cases of fires in the shaft, head gear or winder house, the damage is usually so severe that almost everything is discarded. The possible cause for concern is when maintenance work is being done and oxy-acetylene flames are used. If these flames are accidently left close to the rope, what effect does it have. Naturally there are factors such as time of exposure, distance of the flame from the rope, flame temperature etc, which all play a part in the resulting damage.

As an exercise six rope specimens of different tensile grades ranging from 1800 MPa to 2100 MPa were placed at a distance of 300 mm from a naked flame as shown in Figure 2. The specimens were left in front of the flame for 60 seconds and then removed. The temperature of the outer wires in direct contact with the flame (measured after the flame was removed) in all six cases ranged between 150° and 210° Celsius. Once the specimens had cooled they were tested. The results (shown in Table 5) indicated that the flame had little or no effect on the strength of the specimens. The only specimen which had lost any strength (2,05% of new rope breaking strength) was the specimen with a 2100 MPa tensile grade.

A few conclusions can be drawn from these results. Although the test seemed severe at the time it was carried out the strength of the rope specimens were not severely affected. It is therefore very difficult to determine how much heat a rope has been exposed to without using any sophisticated equipment. Even with all the necessary equipment if measurements are not taken at the time of the occurrence it may not be possible to accurately assess the damage later. In cases where ropes are heated before the metallurgical properties are affected the lubricant is burnt out (See Figure 2) and the core may be charred. This affects the rope performance and life significantly even though the rope strength may not be immediately affected. Due to the fact that assessment of the damage caused by heat to a rope is difficult to assess and the fact that lubricant and core are usually affected by heat even before the metallurgical properties of the rope, ropes that have any discolouration from being exposed to heat should be discarded immediately.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Discarded rope specimens

- In the set of 63 discarded rope specimens that were tested by the CSIR only 31 were actual discard specimens.

- The most common reasons given for discard were broken wires (38 specimens), corrosion (13 specimens), kinks (3 specimens), reduction in diameter (2 specimens) and twisted strands (2 specimens). In some cases no reason for discard was given. In at least 50% of the cases the specimens that were discarded due to broken wires were discarded not only due to broken wires but due to a combination of broken wires and a reduction in rope diameter.

- Requirements 8.1.1 (c) and (d) of the code for broken wires in one strand are of doubtful validity and should be revised. The current work that the CSIR is carrying out on the effect of the distribution of broken wires on rope strength should assist in addressing this.

- The rope inspector must be made aware of the existence of the gap (or missing wire) created by a broken wire and it must be taken into account when determining broken wire density.

- The multiplication factors for two rope instrument combinations were obtained from the discarded rope specimens. The importance of these multiplication factors cannot be overemphasised and must take high priority for future work by rope inspectors. If multiplication factors are not available the benefit of having an instrument is limited.

- It is sometimes found that a broken wire migrates away from the fracture position. Such wires are called creeping wires. The identification of possible creeping wires was overlooked. The lack of this data thus ensures that the discard factor calculated for these specimens is inaccurate. It is thus essential to ascertain whether creeping wires are present on a specimen.

- Asymmetric distribution of wear on a rope has a larger impact on the loss in strength of the rope than symmetric wear for the same loss in cross-sectional area and should be looked out for.

- The reference rope diameter at various point along the length of the rope must be determined once a rope has been in service for a certain amount of time (few weeks maximum). Tolerance variations inherent in the rope manufacturing process can range from +0% to +5% above nominal and can affect the discard levels.

- A kink is classified as severe rope damage. To date neither the CSIR nor the rope inspectors have made any attempt at measuring rope distortion on the specimens which were tested. This should not be overlooked in the future.

- Three specimens were found to have unexpected high strength losses. In the one case the loss in strength was affected by the presence of a badly manufactured brazed core which in turn caused the outer wires of that strand to deteriorate at a higher rate than those in the adjacent strands. This case highlights the need for manufacturing ropes with no brazed cores, especially ropes that will be operating at low design factors (safety factors).

  In the other two cases the specimens were found to have a high number of brittle (fatigue) wire failures. The majority of these brittle wire failures were found to have fatigue cracks at the break which had propagated in some cases up to three-quarters of the way through the wire cross-section. The initiation of these fatigue cracks was caused by martensite which had formed on the surface of a wire. It has not been possible to establish the exact cause for the martensite layer, but it is obvious that this rope rubbed against either the shaft steelwork, the sheave, the drum or onto another layer of rope which had the rapid heating and cooling effect. This damage cannot be detected, but the code of practice on winder design, performance and maintenance may have a role to play in preventing this type of damage from occurring in the future.

- The Rope Condition Assessment Code of Practice does not take into account likely increases or decreases in rope breaking strength common to most ropes in service. This can result in seemingly early or late discards unless it is addressed.

- Three specimens were supplied to the CSIR with either no field report, or a report that did not indicate the reason for discard. The CSIR examination found nothing wrong with the specimens and there was no loss in breaking strength. Rope inspectors who do not mark specimens properly and mines that send in incorrect specimens end up wasting time and money.

  Selection, identification and control of discarded rope specimens must be done with care.

- If it is assumed that the data set of 32 specimens (actual discard specimens) is representative of how ropes are currently being discarded in South Africa it is evident that approximately 25% of ropes are correctly discarded, 25% are discarded prematurely and 50% are discarded late (with strength losses in some cases in excess of 40%).

- It is evident that the discarded ropes discussed in this report were not discarded based on the current draft code of practice. It is thus extremely important that the code of practice is explained to all rope inspectors and that these rope inspectors are trained and certificated in discarding ropes according to the code. The implications of not carrying out proper training will mean that the code will never be fully implemented.

- Although it may be desirable to find a straight line relationship between the predicted rope strength loss and the actual strength loss it must be pointed out that such a relationship is not appropriate because of scatter.

- If in the future ropes are discarded according to the code with discard factors of approximately one, we will find that the percentage of ropes discarded late will decrease significantly. Only in isolated cases will it be found that specimens will be discarded with strength losses in excess of 16%.

- Of the 32 main discard specimens, 28 were of triangular strand construction and 4 of round strand construction. Most of the comments in this report are thus mainly applicable to triangular strand ropes. The effect the code will have on the discarding of ropes other than ropes of six strand construction is not known. Tests on discarded ropes of other constructions are thus needed to further evaluate the code.

7.2 Laboratory prepared specimens

- The effect of electric arcing seems to be very localised and affect only the wires with which it comes into direct contact. It would thus be a little extreme to have to discard a rope because one or two wires were affected by an electric arc. What may be a recommended alternate procedure is break these wires out from valley to valley or to count them as broken wires.

- It is very difficult to determine how much heat a rope has been exposed to without using any sophisticated equipment. In cases where ropes are heated before the metallurgical properties are affected the lubricant is burnt out and the core may be charred. This affects the rope performance and life significantly even though the rope strength may not be immediately affected. Ropes that have any discolouration from being exposed to heat should therefore be discarded immediately.

8. ACKNOWLEDGEMENTS

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APPENDIX A - Blank rope inspectors report

Copy of the blank report which rope inspectors were asked to complete and submit with the discarded rope specimen.

PARTICULARS OF ROPE DISCARD

Installation particulars

Mine:	Shaft:	Winder Permit:
Coil No.	Date installed:	Normal life:

First inspection

	Front	Middle	Back
Diameter (mm)			
Laylength (mm)			

Discard inspection

	Front	Middle	Back
Diameter (mm)			
Laylength (mm)			

Comments on area trace + intrument used:	
Comments on contact trace + intrument used:	
Comments on broken wire trace + intrument used:	
Drum groove diameter	Sheave groove diameter
Date rope removed:	Rope life in months
Rope life in trips	Rope life in cycles

Inspection of Test Specimen

	Distance from end:	
Corrosion strength loss = Area loss X Multiplication factor= .... X .... =		
Diameter (mm):	Wear uniform/assym (U/A)	Deformation (Y/N)
Laylength (mm):	Corrosion:	Heat damage:
Kinks present (Y/N)	Waviness in mm/4L	Angluar bend in mm/2L
Broken wire count:		
Summation of combined effects	Please show calculation details on the reverse side of this form	
Reason for discard (list discard criteria according to the code of practice)		

NOTES:

Please provide any additional information on the reverse of this form.

APPENDIX B - Additional information on the discarded specimens

SPECIMEN No 1

This rope coil No 124259/001 was installed on the 28 October 1990 and removed from service on the 13 September 1992 after the set of ropes (Coil No's 124259/001 and 124259/002) had completed 120612 trips ie 60 306 cycles. The information supplied by the rope inspectors regarding this specimen stated that the specimen originated from a layer cross over. The attached information sheet indicated that it was cut from a point 1490 m from the splice. This point is located 416 m below the sheave with the skip at the loading bay. The point therefore corresponds to the cross-over point from the bottom layer to the second layer. The instrument used to detect the anomaly was a DC 313.

The specimen had a badly worn area approximately 800 mm long at the centre. The diameter of this section of rope as measured (with a diameter tape) under a pre-load of 10% of the new rope breaking strength was 46,1 mm. This signifies a 5,8% reduction in rope diameter. If the rope diameter at this point had been measured in service the actual reduction in diameter would have been significantly greater due to load and lay length effects. The rope specimen had three visible broken wires on one strand in one lay length as reported by the rope tester and in addition, had two split wires on the opposite side of the rope. Thus according the code of practice the specimen had five broken wires symmetrically distributed over one lay length. The discard factor for this specimen was thus 0,64 for broken wires and 0,64 for a reduction in rope diameter due to symmetrically distributed wear and plastic deformation. The total discard factor was thus 1,28 which indicated that the rope had to be discarded according to the code of practice. The loss in breaking strength from the destructive test was 14.7%.

SPECIMEN No 2

This rope coil No 116728/002 was installed on the 7 October 1990 and removed from service on the 1 August 1992 after it had completed 198 000 cycles. No information was supplied by the rope inspectors regarding this specimen. A notice of removal of ropes was sent to the CSIR by the mine manager. This notice indicated that the primary reason for the discard of this rope was that the rope was too short. The secondary reason for the discarding of the ropes was "various broken wires at the back-end". The exact position along the length of the rope where this specimen was cut is unknown.

The rope inspector did not specify a reason for discard. From the pre-test inspection it is believed that this rope was discarded due to broken wires and a reduction in diameter (although site diameter measurement is not available). The specimen had according to the code three broken wires (one broken, two split) asymmetrically distributed over one lay length and a considerable amount of plastic deformation on the outer wires. The least outer wire diameter was 2,44 mm which indicates that the reduction in rope diameter on site must have been at least 1,52 mm. This obviously neglects lay length and other effects. A 1,52 mm reduction in rope diameter converted to a percentage diameter reduction is equivalent to 3,5% loss in diameter. The maximum allowable reduction in rope diameter is 9% for evenly distributed wear. The fraction of the discard factor for the broken wires is 0,61. If we consider the broken wires on their own the rope should not have been discarded. The diameter measurements taken during the pre-test inspection indicated no reduction in diameter. If we assume that the analogy relating the reduction in outer wire diameter to the reduction in rope diameter is true, the discard factor is increased by 0,38 taking it to 0,99. Using the code this would have reached the discard level provided the assumption regarding the diameter reduction made above is correct.

The expected strength loss of a specimen with a discard factor of 1 is 7%, which is however substantially less than the actual strength loss of this specimen (19,8%). This is cause for concern. The post-test inspection of the rope specimen indicated one broken strand and the presence of a brazed core at the point of failure. The fact that the only strand that failed during the test was the one with the brazed core indicated that the brazed core did have an effect on the strength loss of the specimen. The evidence indicates that the brazed core may have also been slightly oversize causing a slight not easily visible bulge in the strand. This in turn caused the outer wires of that strand to deteriorate at a higher rate than those in the adjacent strands. This case highlights the need for manufacturing ropes with no brazed cores, especially ropes that will be operating at the low design factors (safety factors).

When there are broken wires distributed in this manner there is always the possibility of a badly made brazed core and special attention should be given to assessing if the broken wires are due to this type of defect.

SPECIMEN No 3

The CSIR MD208 which was completed by the mine indicated that the rope was discarded due to a "badly fractured crossover on the bottom layer crossover". The rope had completed 31 500 cycles. A letter received from the rope tester indicated that there were eleven broken wires in one lay length at a point 1205 m from the splice (The length of wind is 1505 m). The subsequent laboratory inspection revealed fifteen broken wires in one lay length, four more than detected on site. In addition the pre-test inspection also revealed seventeen split wires in the same lay length. Figure B1 shows the outside of the rope, the split and broken wires are visible. It is evident that it becomes very difficult to count the total number of broken wires on site when there are so many over a small area. The number of split wires also increase dramatically when there are large quantities of broken wires. An error that was made during the pre-test inspection was that no attempt was made by the CSIR to identify if any of the broken wires were creeping wires. This could have significantly affected the discard factor. The COP discard factor for this specimen was 3,05. It should be noted that the diameter of the rope specimen as measured in the laboratory was used to determine the diameter discard fraction. If the on site value was available the discard factor would have been higher. The actual loss in rope strength was 21,12%.

This specimen was allowed to deteriorate beyond what is recommended by the code of practice. It should however be noted that the code of practice in its current form states that: "If two thirds or fewer of the visible broken wires, at most, are distributed symmetrically then the total loss in nominal wire area due to **visible broken wires** shall not exceed 8% of the nominal rope steel area". It should be remembered that on site only eleven broken wires were recorded. If the related loss in steel area is calculated it means that the rope had lost 7% of its cross-sectional area. Therefore if we calculate a rope discard factor using the data provided from site we end up with a discard factor of 1,2 (0,875 (broken wires) and 0,32 (reduction in rope diameter)). It is thus debatable whether this specimen should be considered as having been discarded according to the code or not.

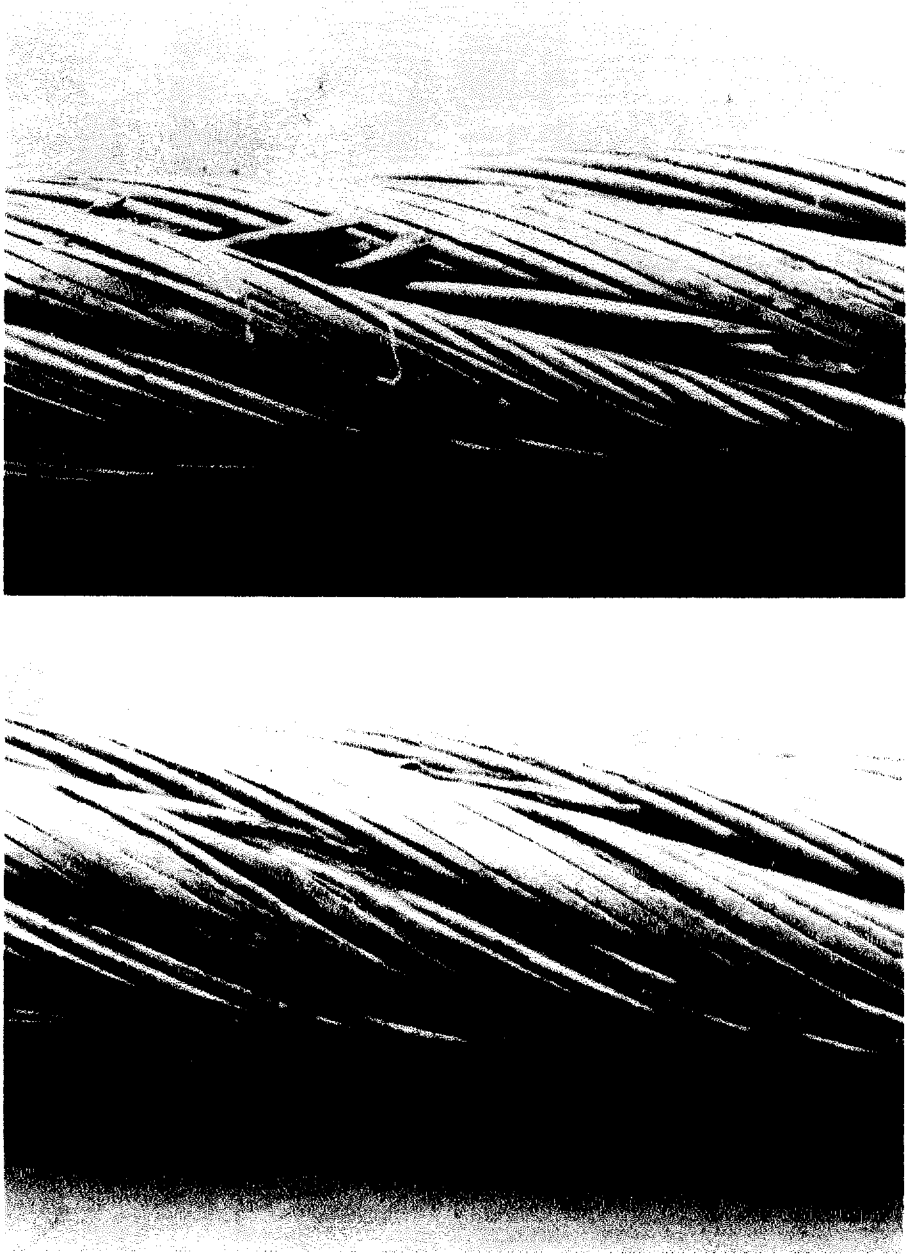

Figure B1: The photographs show the outside of the rope at the deteriorated section of the rope specimen. The broken and split wires are visible.

SPECIMEN No 4

This rope had completed a total of 60 964 trips before discard. A notice of removal of ropes which was supplied by the mine indicated that the primary reason for discard was mechanical damage. The information sheet supplied by the rope inspector indicated that the reason for discard was 6 broken wires (the distance over which these wires were detected is not mentioned). The rope pre-test inspection indicated that there were 13 broken wires over one lay length asymmetrically distributed. The discard factor for this amount of deterioration is 1,84. This specimen also had 16 broken wires on one strand over five lay lengths. The discard factor for this damage is 1,88 ie not much different. In addition the rope specimen had a discard factor of 0,362 due to diameter reduction. The accumulative discard factor for this rope is thus 2,26. This discard factor indicates a loss in rope strength far in excess of 7%. The predicted loss in strength in this case was in excess of the actual of 6,74%. A possible cause for this was that the split wires which were counted as broken wires may not have been split to a point where they significantly reduced the wire strength. As with Specimen No 3 an error that was made during the pre-test inspection was that no attempt was made by the CSIR to identify if any of the broken wires were creeping wires. The cause for concern with this specimen is that the rope inspector indicated six broken wires whereas the specimen had 25 broken wires of which eight were on one strand in one lay length.

The loss in breaking strength was exceptionally low for the number of broken wires (according to the code). The possible explanation for this is that the 16 broken wires on one strand over one lay length were most likely 16 wire breaks not necessarily on different wires but possibly due to creeping wires. This was not noted at the time of the test and cannot be determined from the information available at this stage.

SPECIMEN No 5

This rope specimen was cut from the underlay rope which operated on the Siemens Rock winder, Elandsrand Gold Mine at a safety factor of four[15]. The rope had completed a total of 77 981 cycles. The specimen had three broken wires of which two were on one strand and over one lay length. The discard factor was in excess of one (largely contributed to by the reduction in rope diameter). This specimen was cut from a point 250 m from the dead turns ie 170 m below the sheave with the skip at the loading bay. As is common with the back end of drum winder ropes the outer wires were plastically deformed which resulted in the diameter reduction.

The strength loss of the specimen compared to the new rope strength was negligible. The discard factor was heavily affected by the reduction in rope diameter which appeared not to have a significant effect on the loss in strength of the specimen. This was the only specimen submitted for test from the underlay rope. This rope was still fit for service based on the result of the destructive test, however it had a discard factor in excess of 1 and thus was discarded according to the code of practice.

SPECIMEN No 6 to 13

This is one specimen of eight which were cut from the overlay rope which operated on the Siemens Rock winder, Elandsrand Gold Mine at a safety factor of four[15]. The rope had completed a total of 78 982 cycles. This specimen had been cut from a point approximately 35 m below the sheave with the skip at the loading bay. The discard factor for this specimen was 1,17 which indicated discard however, as with Specimen No 5 the discard factor is heavily affected by the reduction in rope diameter, which as with the previous specimen appeared not to affect the strength of the rope significantly. As mentioned above a total of eight specimens from this rope were submitted for testing. All of them had been cut from the bottom layer and had approximately the same amount of damage and the discard factors varied between 0,7 and 1,26. The loss in strength of these specimens varied between 1,5% to 4,5%. The specimens with the highest discard factor was Specimen No 13, however the specimen with the largest drop in breaking strength was Specimen No 10 which had a discard factor of 1,15. It is evident that this rope was discarded due to significant deterioration at various points along the rope. If the rope inspector had been asked which single specimen he thought would be the cause for discard (prior to testing these specimens), he would have selected the specimen with the highest discard factor. For the purposes of this report it is assumed that the section of the rope with the greatest loss in strength is the main discard specimen.

It should however be noted that the rope inspectors only detected two broken wires in one lay length on specimen 13. This specimen actually had three broken wires and one split wire in one lay length. This is another example showing that the full extent of the damage may not always be visible on site.

SPECIMEN No 14

This specimen was discarded due to a 7% reduction in rope diameter (from nominal). The cause for the diameter reduction was wear and plastic deformation. The current draft code of practice states that the reduction in rope diameter due to abrasive wear only, symmetrically distributed around the rope may not exceed 7%. In the case where the reduction in rope diameter is caused by plastic deformation and wear (also symmetrically distributed around the circumference of the rope) the loss in rope diameter may not exceed 9%.

This specimen is unusual but very valuable because it only had one mode of deterioration. It thus gives us an indication of the loss in strength that can be expected with this type of deterioration only. This specimen originated from a point on the back end of the rope approximately 80 m below the sheave with the skip in the loading position. The specimen had no broken wires and little corrosion. The result of the tensile test indicated that this specimen had lost less than 1% of its original strength and from this it can be concluded that this rope should have remained in service. The discard factor of 0,76 indicated that it was approaching the required discard level. This indicates that despite a fairly significant reduction in rope diameter, if the loss in diameter is due to plastic deformation and there are no broken or split wires present, the strength of the rope is not significantly affected. The results of this test would have been more valuable had the rope diameter been allowed to reduce by 9%.

SPECIMEN No 15

This specimen was discarded because of broken wires and a 3,5% reduction in indicated area. It had been in service for 1 year and had completed 66 375 cycles. The CSIR MD208 supplied by the mine stated that the reason for discard was three broken wires at a point approximately 260 m from the back end of the rope. The sheet with the particulars of rope discard which was forwarded by the rope inspector to the CSIR was very incomplete. It gave no reason for rope discard. A comment on the area trace stated that there was a sharp reduction of 3,5% in indicated area measured using the Rotescograph instrument. The comments on the broken wire trace stated that there were multi-wire breaks which coincided with a sharp steel reduction. The rope inspector estimated the loss in rope strength at 10%. The actual number of broken wires was not stated. This either means that this rope section was not visually inspected by the rope inspector or he did inspect the rope but was not aware of the detail of the information needed for the report. The information gathered during the pre-test inspection indicated that the specimen had six broken wires asymmetrically distributed over one lay length. One strand had four broken wires over one lay length. This information supports the argument that the rope was not properly inspected on site, however it is not uncommon that all the broken wires on a specimen are not detected on site.

The discard factor calculated for this specimen is based only on the number of broken wires since no site diameter measurement was entered on the information sheet. The diameter measurement of the specimen taken in the rope test machine with the specimen under a 10% pre-load indicated that the specimen had a fairly insignificant (0,65%) reduction in diameter. The discard factor for this specimen was calculated to be 1,21 ie in excess of 7%. The rope inspector predicted a 10% loss in strength and the specimen when tested had a 8,0% loss in strength. This specimen was discarded at the correct time according to the code of practice. It should however be kept in mind that the reason for discarding the rope on site was three broken wires in one strand which is not reason for discard according to the code.

SPECIMEN No 16

This specimen was cut from a round strand rope which had operated on a Koepe winder. This winder has six head ropes. When this set of ropes was discarded a specimen was cut from each of these six ropes (specimens 16 to 21). This specimen was cut from a point 229 m from the cage. The rope had completed 66 083 cycles. The pre-test inspection revealed no outer broken wires which tied up with the rope testers report. This specimen was discarded due to corrosion and a local reduction in rope diameter. The rope inspectors reports states that the RAU instrument showed a sudden decrease of 6,6 divisions on the local and 2 divisions on the normal area trace. An additional report forwarded to the CSIR by the rope tester stated that the instrument deflection on the local area trace indicated a 9% area loss and that on the normal area trace a 2,5% area loss. The report further indicated that the corrosion was concentrated over a 250 mm section of the specimen which caused an hour glass effect reducing the diameter by 5,24%. The rope inspectors report did not contain any information on the multiplication factor of this instrument-rope combination. For this reason no estimate of the strength loss of the specimen could be made. The actual strength loss of this specimen as determined by the destructive tests was 15,3%.

SPECIMEN No 17

This is the second specimen tested (cut from No 1 rope) of a set of six, cut from round strand ropes which operated on the Keope winder mentioned in the previous paragraph. This rope also completed 66 083 cycles. The type of deterioration on this rope section was very similar to that seen on specimen 16. This specimen did not have any outer broken wires. It had been cut from a point on the rope 229 m from the cage. The loss in local and normal area as indicated on the RAU instrument was 1,9 and 0,9 divisions respectively. An additional report forwarded to the CSIR by the rope inspector stated that the instrument deflection on the local area trace indicated a 2,25% area loss and that on the normal area trace a 1,13% area loss. The report further indicated that the corrosion was concentrated over a 200 mm section of the specimen which caused an hour glass effect reducing the diameter by 3,57%. As with the previous specimen the rope inspectors report did not contain any information on the multiplication factor of this instrument-rope combination. For this reason no estimate of the strength loss of the specimen could be made. The actual strength loss of this specimen as determined by the destructive tests was 2,6%.

SPECIMEN No 18

This is the third specimen tested (cut from No 4 rope) of a set of six, cut from round strand ropes which operated on the Keope winder mentioned previously. This rope also completed 66 083 cycles. The type of deterioration on this rope section was very similar to that seen on specimens 16 and 17. This specimen did not have any outer broken wires. It had been cut from a point on the rope 229 m from the cage (the same distance from the cage as the previous two specimens). The loss in local and normal area as indicated on the RAU instrument was 8,1 and 2,3 divisions respectively. As with the previous two specimens an additional report forwarded to the CSIR by the rope inspector stated that the instrument deflection on the local area trace indicated a 10,25% area loss and that on the normal area trace a 3,25% area loss. The report further indicated that the corrosion was concentrated over a 200 mm section of the specimen which caused an hour glass effect reducing the diameter by 5,95%. As with the previous specimen the rope inspectors report did not contain any information on the multiplication factor of this instrument-rope combination. For this reason no estimate of the strength loss of the specimen could be made. The actual strength loss of this specimen as determined by the destructive tests was 26,7%.

It is evident that a 6% reduction in rope diameter due to plastic deformation on a triangular strand rope can result in very little or no loss in rope strength. However, the same reduction in diameter caused by corrosion has very severe implications.

SPECIMEN No 19

This is the fourth specimen tested cut from (No 6 Rope) a set of six round strand ropes which operated on the Keope winder mentioned previously. This rope like all the other ropes in this batch had completed 66 083 cycles. The type of deterioration on this rope section was very similar to that seen on specimens 16, 17 and 18. This specimen did not have any outer broken wires. It had been cut from a point on the rope 229 m from the cage (the same distance from the cage as the previous two specimens). The loss in local and normal area as indicated on the RAU instrument was 7,2 and 4,0 divisions respectively. As with the previous two specimens an additional report forwarded to the CSIR by the rope inspector stated that the instrument deflection on the local area trace indicated a 9,0% area loss and that on the normal area trace a 5,0% area loss. The report further indicated that the corrosion was concentrated over a 200 mm section of the specimen which caused an hour glass effect reducing the diameter by 7,86%. As with the previous specimen the rope inspectors report did not contain any information on the multiplication factor of this instrument-rope combination. For this reason no estimate of the strength loss of the specimen could be made. The discard factor for diameter reduction alone was 0,87. The actual strength loss of this specimen as determined by the destructive tests was 28,6%.

SPECIMEN No 20

This is the fifth specimen tested cut from (No 2 Rope) a set of six round strand ropes which operated on the Keope winder mentioned previously. This rope like all the other ropes in this batch had completed 66 083 cycles. The type of deterioration on this rope section was very similar to that seen on specimens 16, 17, 18 and 19. This specimen did not have any outer broken wires. It had been cut from a point on the rope 229 m from the cage (the same distance from the cage as the previous two specimens). The loss in local and normal area as indicated on the RAU instrument was 4,1 and 2,2 divisions respectively. As with the previous two specimens an additional report forwarded to the CSIR by the rope inspector stated that the instrument deflection on the local area trace indicated a 6,25% area loss and that on the normal area trace a 3,0% area loss. The report further indicated that the corrosion was concentrated over a 150 mm section of the specimen which caused an hour glass effect reducing the diameter by 6,43%. As with the previous specimen the rope inspectors report did not contain any information on the multiplication factor of this instrument-rope combination. For this reason no estimate of the strength loss of the specimen could be made. The discard factor for diameter reduction alone was 0,71. The actual strength loss of this specimen as determined by the destructive tests was 12,9%.

SPECIMEN No 21

This is the sixth specimen tested cut from (No 3 Rope) a set of six round strand ropes which operated on the Keope winder mentioned previously. This rope like all the other ropes in this batch had completed 66 083 cycles. The type of deterioration on this rope section was very similar to that seen on specimens 16, 17, 18, 19 and 20. This specimen did not have any outer broken wires. It had been cut from a point on the rope 229 m from the cage (the same distance from the cage as the previous two specimens). The loss in local and normal area as indicated on the RAU instrument was 7,0 to 8,1 and 3,1 divisions respectively. As with the previous two specimens an additional report forwarded to the CSIR by the rope inspector stated that the instrument deflection on the local area trace indicated a 10,25% area loss and that on the normal area trace a 4,0% area loss. The report further indicated that the corrosion was concentrated over a 300 mm section of the specimen which caused an hour glass effect reducing the diameter by 9,05%. As with the previous specimen the rope inspectors report did not contain any information on the multiplication factor of this instrument-rope combination. For this reason no estimate of the strength loss of the specimen could be made. The discard factor for diameter reduction alone was 1,01. The actual strength loss of this specimen as determined by the destructive tests was 28,9%.

SPECIMEN No 22

This specimen was discarded based on the trace of an instrument. Apart from one split wire which was noticed on the specimen in the lab, there were no other broken wires on the specimen. The measurement of the rope diameter taken on site at the anomaly showed a 4,15% reduction compared to the nominal. Apart from the reduction in rope diameter and one split wire noticed on the specimen at the pre-test inspection there appeared to be no additional deterioration on the rope specimen. The information supplied by the rope inspector on the reason for the rope discard stated that the EM test instrument (ACRTI1) had indicated a 5,3% steel area loss and 2,3% reduction in contact at a point 69m from the splice. The specimen failed during the test at the point where the smallest rope diameter was measured. The loss in rope strength as determined by the tensile test was 2,8%. This specimen did not meet the discard criteria and from the result of the test it can be seen that it was discarded prematurely.

SPECIMEN No 23

There were no broken wires on this specimen. The rope inspector indicated that the rope was discarded due to corrosion. The rope diameter measurement taken on site showed a 5,2% reduction in rope diameter in the middle of the rope. The rope inspectors report indicated that the specimen had been cut 70 m from the end. The report indicated that the rope diameter was measured at the middle of the rope (length of wind 216 m). It is thus not certain whether the diameter measurement recorded was taken at the point where the discarded specimen was cut. The rope inspectors report also indicated that the area loss due to corrosion was 5% and that the multiplication factor was 2. The estimate for the strength loss was thus 10% (5×2). The post-test inspection revealed corrosion levels from slight to considerable. No trace was supplied.

The code of practice stipulates that a rope should be discarded if severe/considerable corrosion and pitting is noted on the outer wires. This specimen had considerable pitting and corrosion on the outer wires, however the percentage strength loss was only 0,84%.

SPECIMEN No 24

This specimen was discarded because of three broken wires in one lay length. It had been in service for 57 months and had completed 55 113 cycles. The rope diameter measurement taken on site indicated a 2,8% reduction in diameter at the middle of the rope. This specimen was cut from a point 650 m from the end of the rope. The discard factor for this specimen was 1,36. This specimen was thus discarded correctly and the estimated rope strength loss at discard would have been in excess of 7%. The actual loss in rope strength was 4,94%. If the reduction in rope diameter had been neglected in this calculation, the predicted loss in strength would have been less than 7% which is substantially more accurate in this case. It is however not yet possible to distinguish when the diameter measurement should or should not be used in predicting the rope strength. What is however apparent is that it should be weighted depending on the cause of the diameter reduction which sometimes has a significant effect on the strength.

What must be realised is that no reference diameters were taken for any of these ropes once they were put into service, and the diameter reductions are based on nominal values. The effects of manufacturing tolerances must be taken into account when the actual effect of reduction in rope diameter is studied.

SPECIMEN No 25

The report submitted by the rope inspector indicated three broken wires in one stand as being the reason for discard. This report is slightly confusing, the rope report states that the specimen had three broken wires and then later states that the specimen had two broken wires. The pre-test inspection revealed only two broken wires in one strand. This specimen had been cut from a point 380 m from the end of the rope. The diameter measurement taken at the middle of the rope on site indicated a reduction in rope diameter of 5,1%. This rope was discarded prematurely as the discard factor was only 0,74. This rope was obviously discarded along with its partner but the reason for discard of the set of ropes was specimen 24. The loss in strength as determined by the tensile test was 3,7%.

SPECIMEN No 26

This rope was discarded because of two broken wires asymmetrically distributed, over one lay length and in one strand at a point 463 m from the dead turns. The rope inspectors report also stated that the specimen had 3 broken wires symmetrically distributed over five lay lengths. The specimen which was inspected in the CSIR laboratories only had two broken wires. The diameter of the rope was measured in service and found to be 4,9% below nominal. The discard factor for this rope specimen was 1,15 due to 2 broken wires in one strand and a reduction of 4,9% in diameter. The actual rope strength was 1,1% higher than the new rope strength. If the reduction in rope diameter was ignored the discard factor would have been lower and more accurate. This is another case where the actual reduction in rope diameter (reduction from new) is not known and a reduction in rope diameter based on the nominal value has resulted in an over estimation of the loss in rope strength.

SPECIMEN No 27

This specimen operated on the same winder as Specimen No 26, but not in the same compartment. The rope inspectors report indicated that this specimen was cut at a point 230 m from the dead coils ie at a position approximately 150 m below the sheave with the skip at the loading position. The reason for discard according to the inspectors report, was 2 broken wires in one strand and in one lay length and a reduction of 5,8% in diameter. The combined effects resulted in a discard factor of 1,25, ie an estimated loss in strength in excess of 7%. The loss in rope strength was overestimated, the actual loss in rope strength was 3,0%. Once again the incorrect assessment of the reduction in rope diameter (due to a lack of actual rope diameter values at installation) may have a role to play in the high discard factor. This specimen did not fail at the point where the smallest diameter was measured and where the broken wires were located. It failed near the end cap, two lay lengths away from the damaged point. This indicates that the point (where the broken wires were located) was the reason for discard but not the weakest point in the rope. The post-test inspection revealed that there were four outer wires with a brittle failure. There was thus other damage at this point which significantly affected the strength of the rope but was not identified by any measurements or visual inspections.

SPECIMEN No 28

This specimen and Specimen No 27 were cut from the same rope. This specimen was cut from a point 235 m from the dead coils and had 8 broken wires over five lay lengths. In addition to this the diameter was measured to be 6,5% below the nominal. The report supplied by the rope inspectors stated that there were five broken wires in one lay length. This was not correct. The pre-test inspection revealed only three broken wires in one lay length. The discard factor was calculated to be 1,62 i.e. an estimated loss in breaking strength of about 11,0%. This predicted loss in strength prediction was largely contributed to by the 6,5% reduction in diameter. This specimen had no loss in strength. This case highlights two aspects of the Code of Practice. The first is that the 8 broken wires over five lay lengths (the laboratory rope pre-test inspection revealed only 7 broken wires) was effectively only 2 broken wires, one in one strand and the other a creeping wire which had fractured five times over five lay lengths in the adjacent strand. This specimen thus only had two broken wires in one lay length. The second aspect is the loss in rope diameter. In this case it significantly increased the rope discard factor without having an effect on the strength.

It should however be note that even if the number of effective broken wires was correctly counted the discard factor would have been 0,98 which indicates discard. It is thus important that a creeping broken wire is counted as one broken wire despite the number of breaks and that the effect of rope diameter reduction is weighted. Fracture of this specimen occurred at the point where the least diameter was measured, and where there was only one broken wire.

SPECIMEN No 29

This was the third of four specimens cut from rope Coil No 124258/001. The rope inspectors report indicated that this section had been cut from a point 240 m from the dead turns and that it had 2 broken wires in one lay length (four broken wires in five lay lengths) with a reduction of 6,04% in rope diameter. The discard factor was calculated to be 1,28%, an estimated loss in rope strength was in excess of 7%. This specimen like Specimen No 28 failed at a breaking strength higher than expected (0,54% loss in strength). Once again this was caused by a creeping wire which was counted as 4 broken wires, but was actually only one broken wire. If the discard factor had been calculated based on only one broken wire it would have been 0,82 i.e. sufficiently low not to be discarded.

The loss in rope diameter also had less of an impact on the rope strength than expected. The predicted strength loss would have once again been more accurate if the reduction in rope diameter had not been taken into consideration. It is important that the reduction in diameter is weighted so that its effect on the rope strength loss is represented more accurately.

SPECIMEN No 30

This specimen, the fourth from rope Coil No 124258/001 was cut from a point 436 m from the dead coils. The inspectors report indicated that the specimen had two broken wires in one lay length, 4 broken wires in five lay lengths and a reduction in rope diameter of 4,88%. The discard factor for this specimen was 1,15. The loss in rope strength was thus estimated to be slightly in excess of 7%. The actual loss in breaking strength was 5,6% which indicates that the estimation was relatively accurate. However at the test pre-inspection it was found that the one strand had a creeping wire. The effective number of broken wires was thus two over one lay length and two over five lay lengths. We thus do not have four broken wires in one strand over five lay lengths which is equivalent to a discard factor of 0,61 but two broken wires asymmetrically distributed in one lay length. The discard factor is thus 0,18 which when added to the discard factor due to the reduction in rope diameter, results in a discard factor of 0,72, ie an estimated 5,0% loss in breaking strength. The specimen failed at the point where the two broken wires (in two adjacent strands) were located. The loss in strength prediction which took the creeping wire into account, slightly under estimated the strength loss but was highly accurate.

What should however be noted is that if the reduction in diameter had been ignored the predicted loss in rope strength would have been highly underestimated.

SPECIMEN No 31

This specimen was cut from a point 57 m from the dead turns measured with the skip at the loading bay. The rope had completed 66 400 trips. The reason for rope discard as indicated on the rope inspectors report was 5 broken wires in one lay length asymmetrically distributed and 10 broken wires over five lay lengths symmetrically distributed. The rope pre-test inspection revealed five broken wires on one strand in one lay length. Of these five wires four were clustered together, and one was approximately 450 mm away. There were an additional two broken wires on that strand spaced at regular intervals indicating that one of the four wires had crept. Five broken wires in one strand and in one lay length is reason for discard and the discard fraction was 1,08. An additional fraction of 0,33 was added to take loss of rope diameter into account. The final discard factor was 1,41 and thus the estimated rope strength loss was 10,0%. However there was only effectively four broken wires in one strand which resulted in a 2,57% loss in area, i.e. a discard factor of 0,86 added to the discard factor caused by the reduction in rope diameter results in a total discard factor of 1,2. This discard factor indicates a loss in strength in excess of 7% which is very close to the actual. In this case had the reduction in diameter been ignored, the predicted loss in strength would have been about 6,0% which is an under estimation but still was very close to the 7,1% actual. This specimen was correctly discarded.

This case once again highlights the importance of identifying creeping wires and treating them as one broken wire when counted over a certain number of lay lengths.

SPECIMEN No 32

The report issued by the rope inspector for this specimen indicated that the specimen had five asymmetrically distributed broken wires in one lay length. This specimen was cut from a point 240 m from the front end of the rope which had apparently been mechanically damaged. The lab pre-test inspection indicated that there were only three visible broken wires on the specimen which were all concentrated in one lay length. There were also no reported signs of mechanical damage. There is thus a distinct possibility that the specimen which was forwarded for testing was not the specimen on which the inspector wrote his report. If we evaluate the damage, accumulated on the specimen (three asymmetrically distributed broken wires with no reduction in rope diameter), according to the code the discard factor is 0,54 which is not reason for discard. The actual rope strength loss for this specimen was 1,5%.

SPECIMEN No 33

This specimen was forwarded for testing without an information sheet. The corrosion levels in the specimen were found to be excessive and the loss in breaking strength falls in the same category. It is obvious that this specimen was discarded due to corrosion, but no data (traces, diameter measurements etc.) was available from site. The rope pre-test inspection revealed excessive amounts of corrosion on the outside of the rope. This level of corrosion takes a fair amount of time to develop even in the most aggressive of environments. The fact that the corrosion was located on the outside of the rope meant that it should have been detected without an EM instrument.

The diameter of the rope measured at the pre-test inspection was 9,1% below the nominal value. It must be remembered that this diameter measurement was taken in the laboratory, a site measurement may have revealed even greater diameter reductions due to lay length effects. The specimen failed at the point where the smallest diameter was measured. It is clear that this specimen was over looked, and allowed to deteriorate beyond what is recommended by the code of practice. The actual loss in breaking strength of the specimen was 35,6%. This specimen should have been discarded at a previous inspection

SPECIMEN No 34

This specimen was cut from a round strand rope at point 15 m from the front end. This specimen had a total of 18 broken wires along its length. The broken wires were well distributed along the length of the specimen and consequently as can be seen from the test result did not cause a large reduction in breaking strength. The most significant cluster of broken wires was six broken wires, symmetrically distributed, in one lay length. However the damage which resulted in the highest discard factor was the 16 broken wires, symmetrically distributed, over five lay lengths. In addition the site report revealed a reduction in diameter of 1%. The discard factor for this specimen was 0,76. The loss in strength of the specimen as determined by the tensile test was 2,43% which is less than expected. There is a possible explanation for this difference. The distribution of the broken wires in each strand as shown on the pre-test report indicates that there may have been a few creeping wires in this specimen. If this was the case the effective number of broken wires would be reduced thereby reducing the discard factor. There is also the doubt over the accuracy of the on site diameter measurement as one value was supplied for three specimens (Specimens No's 34, 35 and 36). This would have an effect on the discard factor.

SPECIMEN No 35

This specimen was cut from the same rope as specimen 34. The data sheet forwarded by the inspector for Specimen No 34 was identical to that supplied for this specimen. The diameter and other values measured on site were supplied common to three Specimen No 34, 35 and 36. This indicates that the rope inspector who discarded these specimens did not fully understand what was required of him. For this reason these values supplied can not be used to determine discard values. The discard factor thus calculated (0,35) was based on the results of the lab inspection. There were only two broken wires on the specimen and very little reduction in diameter. The specimen showed no loss in breaking strength (1,74% above new rope strength) as expected and should not have been submitted or tested as a discarded rope test.

SPECIMEN No 36

As mentioned in the previous two paragraphs, Specimen No 36 was cut from the same rope as Specimens No's 34 and 35. This specimen however had 27 broken wires over its length. Eighteen of these broken wires were concentrated in one lay length. The code of practice discard factor for this amount of damage is 1,4. There was also a slight reduction in diameter (measured in the lab) which resulted in an additional discard fraction of 0,143. The discard factor for this specimen thus amounted to 1,54 which relates to an estimated strength in excess of 7%. This is very close to the actual strength loss of 8,4%. Of the three specimens cut from rope Coil No 120203/001/3, this is the only specimen that should have been submitted for testing. Despite this valuable information was however also obtained from the test on specimen 34

It is becoming very obvious that if we want to predict the strength loss of a rope to a high accuracy it is important that the damage accumulated by a rope is correctly assessed.

SPECIMEN No 37

This specimen along with Specimen No 38 are possibly the most interesting yet concerning of all the specimens reported on in this report. According to the rope inspectors report (note that two identical reports were supplied for Specimen No's 37 and 38) this specimen was cut from a point 1520 m from the front end of the rope which corresponds to a point 360 m below the sheave with the conveyance in the loading position. In addition it stated that the rope was discarded due to broken wires (four broken wires), and heavy plastic deformation. The on site rope diameter measurement indicated a 6,3% reduction. This specimen was found to have a total of 7 broken wires concentrated over two lay lengths at the pre-test inspection. Four of these broken wires were asymmetrically distributed over one lay length. According to the code of practice the discard factor for the damage accumulated by this specimen is 1,2 which relates to an expected loss in strength slightly in excess of 7%. The actual loss in strength was an unexpected 22,3%. Due to this unexpected result this specimen was subjected to further investigation.

The specimen was found to have a high number of brittle wire failures all located on one side of the specimen over a 1 m distance. The majority of these brittle wire failures were found to have fatigue cracks at the break which had propagated in some cases up to three-quarters of the way through the wire cross-section. A broken wire was selected and was sectioned close to the area of the break. The cross-section was mounted and polished. Figure 1 shows the working edge of the wire (the edge which made contact with the drum and sheave). The thin white stripe across the both photographs (arrowed) indicates the presence of martensite. Martensite is formed on the surface of a wire when the surface is heated and rapidly cools. This martensite layer is extremely brittle and is prone to fatigue crack initiation. It has not been possible to establish the exact cause for the martensite layer, but it is obvious that this rope rubbed against either the shaft steelwork, the sheave, the drum or onto another layer of rope which had this rapid heating and cooling effect.

Additional micrographs shown in Figure 2 revealed the presence of a crack running what appeared to be longitudinally down the centre of the wire. This crack was apparently in the wire at the time of manufacture but due to it running longitudinally along the wire had no significant affect on the strength of the rope.

SPECIMEN No 38

This specimen was cut from rope Coil No 126070/002 ie the same rope from which Specimen No 37 was cut. Unfortunately as mentioned in the previous paragraph identical information sheets were supplied for both specimens. It was not possible to identify to which of the two specimens the data on the information sheet actually pertained as the indicated number of broken wires in the report did not correspond to either of the specimens. Specimen No 38 had a total of six broken wires, five broken wires asymmetrically distributed in one lay length. According to the code of practice the discard factor for this number and distribution of broken wires was 0,947 (an estimated loss in strength of nearly 7%) and 0,703 due to reduction in diameter. The estimated strength loss was thus in the order of 12%. It should however be kept in mind that due to the nature of the information supplied on the rope diameter measured on site the discard factor is most likely slightly incorrect. This specimen like Specimen No 37 had an unexpected high loss in breaking strength, being 25,2%. The type of deterioration and mode of failure of the specimen during the tensile test was very similar to that of Specimen No 37. The wire failures were predominantly brittle with fatigue cracks and like the previous specimen concentrated on one side of the specimen. A metallurgical investigation on one of the wires revealed the presence of martensite on the outer surface of the wire.

SPECIMEN No 39

This specimen was discarded due to a twisted strand. The information sheet supplied by the rope inspector indicated that this rope was discarded due to a twisted strand. The location of this twisted strand along the length of the rope was not specified but the report does state that the strand was twisted for approximately 30 m. Diameter measurements taken on site revealed no significant reduction in rope diameter. The rope had been in operation for twelve months. There were no broken wires present on this specimen before testing. The code of practice states that damage of this kind is reason for discard. A twisted strand is like a corkscrew in a rope. This type of damage does not necessarily result in a loss in rope strength, but if a rope is continued to be used under these conditions, it will lead to rapid deterioration of the strand in question and thus a rapid strength loss. The result of the tensile test showed that the strength of this specimen was 1,2% above the new rope strength and confirms the fact that this type of anomaly by itself does not result in a strength loss.

SPECIMEN No 40

This specimen was cut from the same rope as Specimen No 39 but at the opposite end of the twisted strand, where the strand reverted to its original position. Very little is known about this specimen in particular as only one rope inspectors report was supplied for both specimens. The comments made for Specimen No 39 apply for this specimen too. The strength of the specimen when tested was 1,5% higher than the new rope breaking strength.

SPECIMEN No 41

The site report for this specimen which was supplied by the rope inspector is very vague. The report does not contain any rope diameter or lay length measurements that were supposed to have been taken on site. The coil number of the rope for which this report was completed is not mentioned. For this reason it cannot be concluded with any absolute certainty that the little data that this report contains applies to this specimen. The reasons for discard were reported to be corrosion fatigue and comments on the report stated that the RAU instrument used indicated a 2% reduction in LMA. The report also stated that the broken wire trace indicated internal nicking and corrosive pitting. The rope pre-test inspection revealed no broken wires and slight pitting and corrosion on the outside of the rope. The breaking strength of this specimen was found to be 1,4% below new rope breaking strength.

A second rope inspectors report was supplied with this specimen. This report did not contain any rope coil numbers and the name of the shaft did not correspond to that on the rope test application form. The report contained a comment about a "possible breakdown of galvanising". The rope test certificate and visual examination indicated that the specimen tested was ungalvanised. This report should be ignored due to poor and conflicting information.

SPECIMEN No 42

Very little information was supplied in the rope inspectors report for this specimen. The specimen was apparently cut from a point 120 m from the front end. There was according to the supplied report no reduction in rope diameter at that point. It also appears that the report supplied was written by someone other than the rope inspector. No reason for discard was given. The rope pre-test inspection revealed no broken wires, and insignificant levels of corrosion. As expected the specimen had a breaking strength in excess of new rope breaking strength. If this specimen was the worst section of the rope this rope should not have been discarded.

SPECIMEN No 43

The rope inspectors report on this specimen did not give any reason for discard. The report stated that the rope had 17 broken wires along its length and that this specimen was cut from a point 120 m from the end (front end is assumed). The report stated that the RAU instrument used indicated no LMA and an indication of corrosion. It thus appears that this rope was discarded due to an indicated area loss as a result of corrosion. No area trace was supplied and a loss in indicated area as indicated by the instrument was classified as not considerable. We therefore cannot make a prediction of the estimated strength loss nor can we calculate an instrument multiplication factor.

The rope diameter measurement taken on site indicated a 2,19% reduction in rope diameter. The reduction in diameter as determined by a visual pre-test inspection was found to be due to abrasive wear. The discard factor for this damage alone, was calculated to be 0,23.

During the preparation of the specimen for testing three wires broke within the brush. The post test inspection revealed that there was a considerable amount of corrosion inside the strands. Despite the diameter reduction and the corrosion damage which was not incorporated in the discard factor the predicted loss in rope strength was higher than the actual of 0,9%. This rope should not have been discarded if the damage on this specimen was the sole reason for discard.

SPECIMEN No 44

According to the rope inspectors report this specimen was cut from a point 988 m from the front end of the rope. The reason for discard of the rope was stated to be "numerous spots with creeping broken wires". The on site rope diameter measurements indicated that the rope diameter had reduced by 2,3%.

The pre-test inspection revealed that this specimen had a total of fifteen broken wires along its length. The maximum number of broken wires in one lay length was four. This data is however very misleading as there were actually only two creeping broken wires, one in each of two adjacent strands. These two wires were in some places broken in two points over one lay length which can lead us to believe that there were four broken wires in one lay length where there were actually only two.

Assessment of the damage resulted in a discard factor of 0,18 for broken wires and 0,25 for diameter reduction. This results in a discard factor of 0,43 which indicates that the specimen had not reached its discard level. This was verified by the result of the tensile test which showed that the actual strength loss was 0,9%.

It is clear from this case and other similar cases mentioned previously that a single creeping wire does not significantly reduce the strength of the rope. The assessment of the damage must be correctly carried out. If three creeping wires over five lay lengths are counted as 15 broken wires it will result in an overestimation of the strength loss. A clause should be built into the code emphasising that a creeping wire must be counted as one broken wire. Once again this case shows that if the loss in diameter is ignored the strength loss prediction is more accurate.

SPECIMEN NO 45

Specimen No 45 was cut from the same rope as Specimen No 44. It was cut from a point on the rope 2100 m from the front end. This is another specimen with a creeping broken wire. The slack wire over five lay lengths should as mentioned in previous paragraphs be treated as one broken wire. This resulted in a discard factor of 0,18 due to broken wires. If we add the discard factor due to the 4,0% diameter reduction we end up with a discard factor of 0,61 which indicates that the specimen had not reached its discard level. The actual loss in breaking strength of the specimen was 1,3%. This is another case where the apparent loss in rope diameter calculated from nominal values inflated the discard factor.

No pattern seems to be emerging as to when the rope diameter loss should be included and when it should not. This issue can only be resolved if correct rope diameter values are taken and used as reference values. This problem must be addressed.

SPECIMEN NO 46

As with the previous two specimens numbers 44 and 45, we had slack wires along the full length of the specimen in this case as well. This specimen was cut from a point 910 m from the front end. The maximum number of broken wires in one lay length is four, but these four broken wires are effectively two creeping broken wires on two adjacent strands. These wires failed at sixteen points along the length of the rope specimen. The discard factor for two broken wires over one lay length is 0,18. To this should be added the discard factor for the diameter reduction which gives a discard factor of 0,4. The specimen was found to have a breaking strength 1,2% greater than the new rope breaking strength.

It is important that an inspector is properly trained and experienced especially in cases with this type of damage. What appears to be serious damage is actually the opposite and an unexperienced inspector may panic and discard a rope when it is actually not necessary.

SPECIMEN No 47

This specimen was cut from a point 1130 m from the front end of the rope. The damage visible on this specimen is similar to that in Specimen No's 44, 45 and 46. This specimen had one creeping wire in one strand which broke in eight places along the length of the specimen. The maximum number of broken wires in one lay length was three, two of which were as a result of the creeping wire mentioned previously. The effective number of broken wires was thus two which corresponds to a discard factor of 0,18. The rope measured on site was 46,1 mm. The discard factor for this specimen was thus 0,62. The actual loss in strength was 1,9%.

What has become evident from the four specimens above (No's 44, 45, 46 and 47) which had creeping wires, is that if the damage is correctly assessed the associated discard factor can be converted to the strength loss fairly accurately. These are however only isolated cases but with more accurate data in the future we may establish this relationship for most specimens even though it is not the intended function of the code.

SPECIMEN No 48

The pre-test inspection of this specimen found seven broken outer and one broken inner wire along the length of the specimen. Of these wires six outer and one inner wire were broken symmetrically in one lay length. The site report supplied by the rope inspector stated that the specimen had ten broken wires, four of which were located in one strand. The number of broken wires from the rope inspectors report did thus not correspond with the findings of the pre-test inspection. This can mean that the specimen which was supplied was not the section of rope which was cause for discard, or an error was made in counting the number of broken wires on site due to the difficult conditions.

Despite this discrepancy the rope inspector predicted loss in strength to be between 15% and 20%. The actual loss in strength was 14,9%. However, this estimate was based on an inspection which did not reveal the correct number of broken wires. It is believed that had the inspector realised at the time that there were only six broken wires, he would have estimated the reduction of strength to be between 7% and 10%. Assuming that the correct specimen was tested, this shows that it is very difficult to determine the actual number of broken wires in a rope on site. It is thus unlikely that for example a rope inspector would ever detect split wires unless they have split open completely. Despite the concerns of how this prediction came about, it was accurate. The discard factor for this specimen according to the code was 1,18. From this discard factor we would have expected a strength loss slightly in excess of 7%.

SPECIMEN No 49

Very little information was supplied in the first rope inspectors report. No rope diameter measurements or position on the rope where the specimen was cut was given, in fact the rope coil number was also omitted. The report did state that the rope was discarded due to excessive fractures and mechanical damage. At the CSIR's request a second report was issued which stated that the specimen had seventeen broken wires and that the rope was discarded due to the rate of increase in number of broken wires (±10 over two weeks). The pre-test inspection revealed thirteen broken wires over the length of the specimen, four broken wires in one lay length. Most of these broken wires appear to be two creeping wires in two adjacent strands. The discard factor for three effective broken wires in one lay length is 0,45. No site diameter measurement of the specimen was included in either of two reports. An accurate discard factor for this specimen can thus not be determined. If we use the diameter measurement of the specimen taken in the laboratory before the test we end up with a discard factor of 0,7. The actual loss in strength as determined by the tensile test was 11,6%.

SPECIMEN No 50

This specimen is another prime example of a creeping wire. The rope inspectors report indicated that this specimen was cut from a point 1750 m from the front end. The diameter measurement taken on site indicated a 3,3% reduction from nominal. The reason for discard was "numerous broken wires for 50 m". The broken wire count according to the report was 2 broken wires in one strand.

At the rope pre-test inspection, twelve broken wires were counted in one strand along the length of the specimen. Although in some cases there were two broken wires in one lay length, all the broken wires were as a result of one creeping wire. The result was thus one effective broken wire in one lay length. The broken wire discard factor according to the code of practice was 0,12 and for the rope diameter reduction 0,37. The accumulated discard factor was thus 0,49. The actual rope strength loss for this specimen was 1,51% which is very close to what was expected.

SPECIMEN No 51

The report submitted by the rope inspector stated that the RAU instrument used indicated a 12% area loss. The predicted loss in strength of the specimen according to the report was 12% (using a multiplication factor of one, how this factor was obtained is unknown). The loss in area was definitely caused by corrosion which was found to be almost excessive throughout the cross-section of the rope at the post-test inspection. The inspectors report indicated that the specimen had no broken wires and this was confirmed by the pre-test inspection.

The measured reduction in rope diameter was fairly small. What has become very obvious is that a small reduction in rope diameter (0-4%) due to plastic deformation of the outer wires on a rope with large outer wires and no corrosion is fairly insignificant, but when the loss in diameter is caused by corrosion, it has severe effects on the strength of the rope. The strength loss of the specimen was 25,7%.

From the results of this test it appears that for the level of corrosion present in this specimen and for this instrument-rope combination the multiplication factor appears to be approximately two provided the stated percentage area loss of 12% is correct. The multiplication factor is however not constant and varies for different amounts of corrosion in any instrument-rope combination. It is thus important that the multiplication for varying amounts of corrosion and for every instrument-rope combination be established.

SPECIMEN No 52

The report submitted by the rope inspector stated that the RAU instrument used indicated a 9% area loss. The predicted loss in strength of the specimen according to the report was 9% (using a multiplication factor of one, once again how this factor was obtained is unknown). The loss in area was definitely caused by corrosion which was found to vary between slight and considerable throughout the cross-section of the rope at the post-test inspection. The inspectors report indicated that the specimen had no broken wires and this was confirmed by the pre-test inspection.

From the results of this test it appears that for the level of corrosion present in this specimen and for this instrument-rope combination the multiplication factor appears to be approximately one provided the stated percentage area loss of 9% is correct. The multiplication factor is however not constant as can be seen by the difference in multiplication factors of specimens 51 and 52 which were inspected using the same EM test machine. In the case of this specimen the rope inspector made a correct estimate of the rope strength loss. He predicted 10% and the actual loss in strength was 8%. For this specimen the multiplication factor was correct but it would have been better if the rope inspector had used a higher multiplication as an initial guess, in that way he would have discarded Specimen No 51 earlier as was required. This once again highlights the importance of having the correct multiplication factor for varying amounts of corrosion and for every instrument-rope combination.

SPECIMEN No 53

The same comments that were made for specimens 51 and 52 are valid for this specimen. The report submitted by the rope inspector stated that the RAU instrument used indicated a 12% area loss. The predicted loss in strength of the specimen according to the report was 12% (using a multiplication factor of one, how this factor was obtained is unknown). The loss in area was definitely caused by corrosion which was found to be considerable throughout the cross-section of the rope at the post-test inspection. The inspectors report indicated that the specimen had no broken wires and this was confirmed by the pre-test inspection.

The results of the tensile test showed that the specimen had lost 15,4% of its new rope strength. It appears that for the level of corrosion present in this specimen and for this instrument-rope combination the multiplication factor appears to be approximately 1,3 provided the stated percentage area loss of 12% is correct. This raises some concern since the stated area loss for specimen 51 was 12% and it had a 25,7% loss in strength. This specimen which was cut from a rope of the same construction and diameter as that of specimen 51 and inspected using the same instrument also had an indicated area loss of 12%, but the loss in strength was 15,4%. This means that either the output of the instrument was incorrectly interpreted

or the variability in the rope loss predictions (despite having multiplication factors) is very high.
More such specimens are thus required to answer some of these questions.

SPECIMEN No 54

The information supplied by the rope inspector for this specimen stated that the predicted loss in strength was 406 kN i.e. 16,9% of new rope breaking strength. This estimation came within 0,5% of the actual loss in strength of the specimen. The inspectors report stated that the rope was discarded due to deformation of the rope and an increase in broken wires. The broken wire count on site found seven broken wires on the 5 m specimen supplied. The pre-test inspection found eight broken outer and two broken inner wires in one strand and over one lay length which corresponded very closely with the report.

The inspectors report however did not specify the location on the rope were this specimen was cut. The report is slightly confusing. It states that there was a 11,12% indicated area reduction on the area trace ±300 m from the back end. It also states that the broken wires trace detected 14 broken wires at various places between 1780 m and 1800 m from the front end. It is thus not known whether the section of the rope with the indicated area loss coincided with the specimen supplied. The on site rope diameter was found to be 54,1 mm which is very similar to the front end rope diameter measurements which were taken at the discard inspection according to the report. This means that this specimen was cut from the front end of the rope.

The COP discard factor was 1,78 due to eight broken wires in one strand. The actual strength loss of the specimen was 17,4%.

SPECIMEN No 55

This specimen and Specimen No 54 were discarded by the same rope inspector. The information supplied by the rope inspector for this specimen stated that the predicted loss in strength was 431,6 kN i.e. 17,6% of new rope breaking strength. This estimation came within 2,0% of the actual loss in strength of the specimen. The inspectors report stated that the rope was discarded due to deformation of the rope and an increase in broken wires (similar to Specimen No 54). The broken wire count on site found nine broken wires on the 5 m specimen supplied. The pre-test inspection found ten broken outer and two broken inner wires in one strand over the length of the specimen. Nine of the outer and two of the inner broken wires were concentrated in one strand over one lay length which corresponded very closely with the site report.

The inspectors report indicated that the specimen was cut from a point ± 300 m from the drum. This means that this specimen was cut from a point approximately 230 m below the sheave (1980 m from the front end). This report as with the previous report is slightly confusing. It states that there was a 25,23% indicated area reduction (Tester type RAV 301) on the area trace ±300 m from the back end. This value seems excessive, but the location of this indicated loss does coincided with the point where this specimen was cut. The report also states that the broken wires trace detected 25 broken wires at various places between 1600 m and 1850 m from the front end. The on site rope diameter was found to be 54,1 mm which is very similar to the front end rope diameter measurements. If this diameter measurement was correct it conflicts with the diameter measurements taken in the area where this specimen was claimed to be cut ie it means that this specimen was cut from the front end of the rope.

According to the COP, the discard factor for this specimen was 2,0 for the broken wires and 0,026 due to diameter reduction (based on the diameter measure at the pre-test inspection). The actual strength loss of the specimen was 19,23%.

SPECIMEN No 56

No rope inspectors report was received by the CSIR for this specimen. The test of this specimen was witnessed by the rope inspector who discarded the rope. After the test the inspector claimed that this was an incorrect specimen, i.e. the specimen that he had marked had not been forwarded for test. The pre-test inspection found nothing wrong with the specimen and the breaking strength was higher that the new rope breaking strength. This result is thus null and void.

SPECIMEN No 57

A rope inspectors site report was not issued with this specimen. It is not known exactly why this specimen was discarded (due to the lack of the site report) but the specimen did have a wave over the full length. This is thus expected to be the reason for discard. It is well known that a wave does not usually result in a rope strength loss and this was again proved from the results of this test. The breaking strength was 0,8% above new rope breaking strength. No discard factor is calculated for this type of damage, although the code of practice is very explicit in such areas. If a rope has a wave that has a valley deeper than 25% of the rope diameter, the rope must be discarded. Despite the fact that this distortion does not have a significant effect on the rope breaking strength, a rope may not operate with this type of damage as it will result in very rapid deterioration of the proud strands.

Apart from not having any site measurements of the distortion, no measurements of the distortion were taken by the CSIR at the pre-test inspection. Although the data may not be significant, since the rope specimen will have had an opportunity to unwind and the wave would most likely have been less pronounced than by the time it reached the laboratory, these measurements should still be taken.

SPECIMEN No 58

The site report for this specimen supplied by the rope tester indicated that this specimen had been discarded due to three broken wires in one strand and heavy plastic deformation. Comments made by the inspector on the area trace stated that they found a 2% steel area loss using the Rotesco. The report further indicated that this specimen had a diameter of 46,0 mm and was cut 90 m from the end. The inspector must have been referring to the back end in this case since the diameter of the front end of the rope as measured at the time of discard was 48,4 mm. It is not known what end the inspector used as a reference, drum or sheave.

Pre-test inspection revealed four broken wires in one strand and in one lay length. The discard factor for the broken wires was 1,08 and for the reduction in diameter 0,46. The estimated strength loss was 10,8%. The actual loss in strength was found to be 15,9%. In this case the prediction would be better if the diameter loss is included.

The slight discrepancy between the number of broken wires counted on site and the broken wires counted in the pre-test inspection again illustrates the difficulty in assessing the damage accumulated by a rope on site.

SPECIMEN No 59

This was another specimen which was not accompanied by a rope inspectors information sheet. The rope specimen had a kink in it and this was undoubtedly the reason for discard. It is well known that a kinked rope should be discarded, or at least where possible have the kinked section removed. This is clearly stated in the COP. A kink is classified as severe rope damage. No site measurements of the kink were made available. In cases of new ropes with low tensile grades (1800 MPa) a kink sometimes has very little effect on the breaking strength of the rope. In cases of older, used ropes with corrosion a kink can reduce the strength of the rope by 50%. This specimen had a 13,4% reduction in rope strength due to the kink. Although it is accepted that ropes with kinks must be discarded testing of kinked specimens should continue so that a data base on this type of damage can be compiled. In addition to this the CSIR should start taking measurements of the deflection of the rope at the kink at different rope tensions in an attempt to establish whether there are degrees of kink severity and the effects on the breaking strength.

SPECIMEN No 60

This specimen was supplied with no rope inspectors report. The damage on this specimen was obvious, it was kinked at a point approximately 600 mm from the last tuck of the splice. The splice and approximately 1,5 m of rope including the kinked section was submitted for testing. The complete specimen (rope and splice) was tested and the breaking strength was found to be 20,4% below the new rope breaking strength. Failure occurred at the last tuck of the splice (as predicted). It is well known that a splice has an average efficiency of 85% but can be lower (this varies due to various factors) and unless the rope was weakened to such an extent that the result in strength loss was 15% - 20% or greater, the weakest point would be the last tuck of the splice. This test result thus did not determine the loss in strength of the rope due to the kink, but rather the strength of the splice. All that can be ascertained is that the strength loss of the rope as a result of the kink, was less than 20,4%.

SPECIMEN No 61

The site report for this specimen appears to have been completed by the section engineer or his foreman and not the rope tester. The report did not give a reason for discard but stated that the specimen had numerous broken wires on one side which appeared to be mechanical damage. It is not clear from which point on the rope this section was cut, but the report did state that this section was part of the dead coils before 350 m of rope were cut from the front end of the rope. This specimen had ten broken wires asymmetrically distributed in one lay length. The discard factor as a result of the broken wires was 3,28. The rope diameter was measured on site and found to be 31,2 mm. The combined discard factor for the specimen as a result of the broken wires and the rope diameter reduction is 3,56. This exceeds the maximum allowable discard factor of one. The actual strength loss of the specimen was 20,27% which was expected from such a high discard factor.

The rope appears to have deteriorated to this level very rapidly as a possible result of mechanical damage. It is not clear what the report meant by mechanical damage since there was no evidence of this when the specimen was inspected prior to it being tested. However the mechanical damage theory may explain why this specimen was allowed to deteriorate to this level prior to it being discarded.

Normal test intervals cater for strength losses due to normal deterioration and for this reason it is very important that the rope is not mechanically or otherwise damaged. Daily rope inspections have a very important role to play in (and should concentrate on) identifying any mechanical damage. It is also important that either the responsible engineer or any other suitable person on the mine be trained in interpreting and implementing the code of practice. If a rope is found to have deteriorated more than expected at one of the daily inspections the mine should have a staff member on site who can decide whether a rope can or cannot continue operating until the rope inspector is on site. This highlights the need for a "new breed" of highly competent engineers who will be made responsible for winders that have ropes operating at high loads. These engineers will be made responsible for the new "high tech" winders and their understanding of the new codes of practice should be mandatory.

SPECIMEN No 62

This specimen was cut from a point 1420 m from the front end of the rope according to the rope inspectors report. According to the MD208 the length of wind for the winder from which this rope was removed was 1358 m. This means that if the data supplied by the rope inspector is correct this section of rope was cut from the back end catenary or dead coils. The inspectors report did not indicate what the reason for rope discard was, and no comments on the area, contact or broken wire traces were made. The rope diameter measured on site was 44,2 mm according to the report. It is thus assumed that the 6,0% reduction in rope diameter and the two broken wires over one lay length (noted at the pre-test inspection) were reason for discard. The specimen had a total of three broken wires along its length.

An additional report supplied by the rope inspector listed numerous sections along the length of the rope that had significant diameter reductions and in some cases broken wires. The section which is believed to have been the one tested was reported to have been a section from a point 1042 m from the front end. This report however states that the section of rope under discussion had one broken wire which conflicts with the information gathered at the pre-test inspection (three broken wires).

The discard factor for this specimen was 0,959. The actual loss in rope strength was 2,98%. It is becoming more and more apparent that we must address the loss in rope diameter problem. As stated earlier, until accurate information is available we cannot assess the true effect of diameter reductions.

SPECIMEN No 63

No rope inspectors report was submitted with this specimen. The reason for discard was a kink which lay at the centre of the specimen. This type of damage is reason for rope discard. An interesting fact is that the strength loss was only 4,2%. There appears to be a pattern forming here which has been briefly discussed previously. If a rope is relatively new, the strength loss due to a kink can be relatively low, (although the energy absorbing capabilities of the rope are significantly reduced). If however a rope is old and more brittle, the loss in strength as a result of a kink, is much more significant.

It is evident that very little information has been gathered (by the rope tester on site and the CSIR at the pre-test inspection and during the test) when rope with a kink or a wave is discarded. This must be addressed.

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THE EFFECT OF CUT WIRES ON THE STRENGTH OF WINDING ROPES

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SUMMARY

Criteria now in use for the discard of local winding ropes are based, in part, on the results of tests carried out more than 35 years ago. It is essential to expand the information on the effect of damage on the strength of ropes. Further tests were therefore undertaken. Analysis of the results and conclusions based on the findings are discussed in this report.

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DEFINITIONS

For the purposes of this report the following definitions apply:

Existing

Symmetric	-	When broken wires are evenly distributed around the circumference of the rope. If two thirds or more of the total number of broken wires, at most, are in more than three adjacent strands.
Asymmetric	-	When broken wires are concentrated on one side of the rope. If more than two thirds of the total number of broken wires are in three or fewer adjacent strands in a six strand rope.

New definition

Symmetric	-	When broken wires are evenly distributed around the circumference of the rope. If half or more of the total number of broken wires are distributed in more than two adjacent strands in a six strand rope.
Asymmetric	-	When broken wires are concentrated on one side of the rope. If more than half the total number of broken wires are in two adjacent strands in a six strand rope.

ABBREVIATIONS

ASC	-	Rope samples from the batch of 46 tested in this investigation with asymmetrically distributed broken wires
ASC*	-	Rope samples from the batch of 46 tested in this investigation with asymmetrically distributed broken wires according to the new definition.
ASHK	-	Rope samples from the batch tested by Harvey and Kruger[2] with asymmetrically distributed broken wires
SYC	-	Rope samples from the batch of 46 tested in this investigation with symmetrically distributed broken wires
SYHK	-	Rope samples from the batch tested by Harvey and Kruger[2] with symmetrically distributed broken wires
SASC	-	Rope samples from the batch of 46 tested in this investigation with symmetrically and asymmetrically distributed broken wires (sample with broken wires in only one strand are excluded).

NOMENCLATURE

m:	Number of terms in regression equation
n:	Number of data sets; array size, Table 4
σ:	Estimate of population standard deviation with (n-m-1) degrees of freedom
x:	Loss in area, %, for given loss in area; test result
y:	Loss in strength, %, for given loss in area; test result
y :	Mean loss in strength, %, of all test results at given loss in area
B:	Regression equation coefficient
Q:	Regression equation quotient
S:	$\sum$ from 1 to n
X:	Loss in area, %; analytical
Y:	Loss in strength, %, for given loss in area; analytical

1. INTRODUCTION

The South African mining industry has been actively furthering the use of electro-magnetic (EM) rope testing equipment for at least thirty years. The electro-magnetic testing of wire ropes was developed by and introduced to the mining industry by South African engineers who felt a need for a more scientific approach to the problem of statutory rope examination. While this method of rope testing is at present not a legal requirement, almost all mines are using it. The new regulations which are expected to come into effect in 1995 will however make electro-magnetic rope testing compulsory.

Although electro-magnetic rope testing has been used to identify regions on winding ropes with anomalies, the anomaly must still be visually inspected so that the extent of the damage can be assessed. In the past most ropes were discarded due to a defect or series of defects without thereafter establishing the actual loss in rope strength loss due to the anomaly. However, even if this procedure had been carried out, only a limited amount of this data could have been used in research work today due to changes in testing equipment, rope design and wire metallurgy.

Since the advent of electro-magnetic rope testing, it has been known that detecting of the defect alone is not sufficient. It is essential that the cause and magnitude of the defect is established.

There are currently no specific standards applicable to the discarding of mine winding ropes (apart from the one currently being draughted). Part of the reason why this is the case is that the discard criteria for mining ropes is defined in terms of loss in rope strength. Limited additional information relating the actual damage (broken wires and other damage) to loss in rope strength is available.

With this in mind, the Steering Committee on Factors of Safety of Winder Ropes drew up a Code of Practice (CoP) for Rope Condition Assessment (RCA) (of which electro-magnetic testing would form an integral part) in 1992. Once the code had been completed it was the intention of the committee to apply for dispensation with respect to drum winder rope regulations to facilitate hoisting from greater depths. The committee also intended obtaining further dispensation once the discard criteria were verified and it was proven that EM testing enhanced rope safety significantly. The code was drawn up to cover triangular strand ropes operating on drum winders. This code was later expanded to include other rope constructions. The discard criteria described in the code are in the process of being refined.

The enhancement of these rope discard criteria is a project currently being undertaken at the CSIR. The results of the tests on sections cut from ropes discarded during 1993 have been presented in a previous report[1]. It was found that a large number of ropes had been allowed to deteriorate beyond the legal limit. What should however be kept in mind is that the code is not yet fully implemented, therefore many of the specimens tested were discarded based on the "gut feel" of the inspector. Irregular inspection intervals (in many cases out of the control of the rope inspector) also contributed to ropes deteriorating to unacceptable levels. The results of these tests are thus not a reflection on the quality of the Code.

It was very difficult, from the work mentioned above[1], to determine whether the discard levels for broken wires which were specified in the code were correct. It was therefore proposed that an exercise be carried out where selected wires of a new rope are cut in a symmetrical, asymmetrical or single strand distribution after which the specimen is tested. This work had previously been undertaken by Harvey and Kruger[2], but the combination of broken wire distributions was limited. It was believed that the above mentioned tests results would contain valuable information with regards to the current specified broken wire discard levels.

2. BACKGROUND

In previous analysis of test results of new ropes with cut wires presented by Harvey and Kruger in 1959, a strategy was devised to separate the data into two sub sets (asymmetric and symmetric loss in area) with little overlap[3]. Within each sub set the ratio of loss in area to loss in strength was not a clear function of change in area and was used to derive means and variances for probability considerations. On the basis of these findings the single strand case was included in the asymmetric set and discard levels of 5% and 8% for asymmetric and symmetric broken wires emerged (A discard level is the maximum allowed loss in rope cross-sectional area).

A peculiarity of the test results was that symmetric distribution of cut wires generally resulted in loss of strength less than the change in area, a feature that was difficult to explain. If these results are not valid then the derived definition of asymmetry as well as the resulting discard criteria would be in doubt, even for the given rope size (1,75" or 44,5 mm)

Furthermore, the test results referred to ropes made some 35 years ago. Meaningful advances have been made since that time in rod metallurgy, wire drawing, rope design and in laying up of the strands and ropes. There is no certainty that findings based on the old test results are applicable to modern ropes or to other rope sizes or constructions.

Although this type work has been carried out before[4] by people other than Harvey and Kruger, the ropes used were for general engineering applications and the reductions in area ranged between 32% and 84% which is outside the values allowable for winding ropes. The results[4] did however show that there was a significant difference in residual breaking strength between samples with symmetrical and asymmetrical cut wires (the definition of symmetry and asymmetry was however not clearly defined).

Tests were therefore recently carried out at the CSIR to clarify this situation. Paired tests were used throughout in order to assess internal variation in rope behaviour. On the basis of availability, a 48 mm, triangular strand rope with an 1800 MPa tensile grade was selected. This rope was donated to the CSIR by Haggie Rand Limited for this investigation. A copy of the new rope test certificate containing all the rope particulars has been included in Appendix A.

3. OBJECTIVES

The objective of the work documented in this report is to determine the maximum number and distribution of broken wires allowable on a new rope, without reducing the rope strength by more than 10%. This data will assist in setting the discard levels for used ropes.

4. PROCEDURE

A section of 48 mm diameter rope approximately 180 m long was cut into sections of 3,25 m. Once cut, the rope specimens were prepared for testing by casting white metal end cones on each end[5]. Each specimen was then installed in a 10 MN Avery Tensile testing machine and subjected to 500 loading and unloading cycles with loads that ranged between 5% and 25% of new rope breaking strength. This ensured that the specimens had bedded in before any wires were cut.

The sample was then removed from the fatigue testing machine and the required wires were cut out at the same cross section. The wires were cut one at a time, taking care not to damage any adjacent wires. A small grinder was used to grind the wire as much as possible. The ground wire was then lifted using a flat spike and the wire was then ground further until it parted. Each end of the parted wire was then bent back at the valley. This wire cutting procedure was then repeated for other wires on the same specimen.

It should be noted that wire breaks on triangular strand ropes operating on drum winders occur on the outside of the rope. For this reason only the outside wires of the respective strands were cut out in this exercise.

A regression analysis was then carried out on the test results.

5. TEST RESULTS

The cut wire distribution is denoted in this report as follows:

NNNNNN, where the first N is the number of cut outer wires in strand No 1
the second N is the number of cut outer wires in strand No 2
etc.

Table 1: The table contains the test results of all 46 rope samples along with the cut wire distributions

Test Number	Distribution of cut wires	Loss in steel area %	Actual breaking strength kN	Actual strength loss %
1	000000	0,00	1821	N/A
2	400000	2,88	1748	3,82
3	400000	2,88	1742	4,15
4	500000	3,60	1728	4,92
5	500000	3,60	1739	4,32
6	600000	4,32	1686	7,23
7	600000	4,32	1632	10,21
8	700000	5,04	1574	13,40
9	700000	5,04	1592	12,41
10	330000	4,32	1707	6,08
11	330000	4,32	1680	7,57
12	440000	5,76	1648	9,33
13	440000	5,76	1683	7,40
14	550000	7,20	1605	11,69
15	550000	7,20	1617	11,03
16	660000	8,64	1581	13,01
17	660000	8,64	1519	16,42
18	444000	8,64	1565	13,89
19	444000	8,64	1625	10,59
20	606000	8,64	1636	9,99
21	606000	8,64	1637	9,93
22	303000	4,32	1737	4,43
23	303000	4,32	1731	4,76
24	222222	8,64	1638	9,88
25	222222	8,64	1621	10,81
26	404000	5,76	1692	6,91
27	404000	5,76	1673	7,95
28	000000	0,00	1814	N/A
29	300300	4,32	1724	5,14
30	300300	4,32	1734	4,59
31	400400	5,76	1702	6,35
32	400400	5,76	1671	8,06
33	505000	7,20	1640	9,77
34	505000	7,20	1662	8,56
35	500500	7,20	1676	7,79
36	500500	7,20	1653	9,05
37	600600	8.64	1648	9,33
38	600600	8,64	1645	9,49
39	642000	8,64	1546	14,94
40	642000	8,64	1584	12,84
41	622200	8,64	1566	13,84
42	622200	8,64	1620	10,87
43	442200	8,64	1609	11,47
44	442200	8,64	1511	16,86
45	422220	8,64	1632	10,21
46	422220	8,64	1630	10,32

The data in Table 1 for the triangular strand rope has been worked on the following basis.

Loss in area: rope steel area = 1035,1 mm^2
construction = 32(14/12/6+3T)
wire sizes = 3,08; 2,22; 1,90; 1,42 mm
area of one outer wire = 0,7198% of the rope steel area

New rope strength: the mean of the two cases with no cut wires (test 1 and 28), the strength of the rope = 1817,5 kN.

Loss in strength : calculated from the mean of the two cases with no cut wires

For example, results for wires cut in a single strand are shown in Table 2 below, with

x = loss in steel area, %
y = loss in rope strength, %

Table 2: The table contains the results for wires cut in a single strand

Wire cuts	x%	y%
400000	2,88	3,82 4,15
500000	3,60	4,92 4,32
600000	4,32	7,24 10,21
700000	5,40	13,40 12,41

Other results considered in this analysis include Harvey and Kruger (HK) data summarised in a previous note[3] and results of three tests carried out on three 63 mm, 6×36 ropes. The results of these three tests are summarised in Table 3. Data set designations are given in Table 4.

Table 3: Results of tests on three 63 mm ropes.

Tensile Grade	Reduction in area %	New Rope Breaking Strength (kN)	Specimen Breaking Strength (kN)	Reduction in Breaking Strength (kN)
1950	3,47	3170	2867	9,6
1950	3,47	3220	2952	8,3
1950	3,47	3220	2833	12,0

Table 4: The data sets analyzed

Designation	Array size (n×2)	Source	Range of loss in strength, %
Single strand SSC SSHK	 8 6	 Table 1 HK[3]	 3-14 2-12
Asymmetry ASC ASC* ASHK	 26 18 8	 Table 1 Table 1 HK[3]	 4-17 6-17 4-17
Symmetric SYC SYC*	 12 20	 Table 1 Table 1	 4-11 4-11
Combination SASC	 38	 ASC+SYC	 4-17

Note: * New definition of asymmetry (See Discussion): > ½ of broken wires over one lay length in two adjacent strands.

Both definitions apply to ASHK.

Table 5: Results of regression analysis: $Y=X+BX^Q$

Case	B	Q	S(y-Y)	$S(y-Y)^2$	σ	Internal Variance $S(y-y)^2$	X% for Y=7%
Single strand							
SSC	0,00587	4,46	0,08	7,02	1,19	5,14	4,0
SSHK	0,000356	5,68	0,01	2,15	0,85	NA	4,7
Asymmetric							
ASC	0,164	1,47	-0,02	88,6	1,96	88,6	5,2
ASC*	0,648	0,883	0,00	61,9	2,03	61,1	4,5
ASHK	0,124	1,70	-0,11	41,3	2,87	NA	5,1
Symmetric							
SYC	0,293	0,727	-0,03	4,45	0,70	3,94	5,9
SYC*	0,279	0,784	-0,13	8,17	0,69	5,95	5,9
Combination							
SASC	0,158	1,39	-0,06	125,7	1,90	125,6	5,4

6. DISCUSSION

6.1 Comparison of test results

A scatter plot of the 46 test results is shown in Figure 1. In no case was the loss in strength less than the loss in area. This is at variance with the HK data, see Figure 1 of Ref 1. The results of HK symmetric cuts (less than ⅔ of the broken wires in 3 or more adjacent strands) were therefore not considered in the analysis that follows.

From Figure 1 it is clear that there is overlap between the asymmetric and symmetric sub sets, but that the latter has substantially lower variance than the former. A clearer separation between these two sub sets is achieved if we redefine asymmetry as: more than 50% of the broken wires in two adjacent strands.

The new definition of asymmetry means that the cut pattern N0N000 (where N = 3, 4, 5, 6) is now defined as symmetric and not asymmetric. This situation is illustrated in Figure 1.

6.2 Analysis of results

Regression analysis strategies outlined in Appendix B were used to study the data sets identified in Table 4. Sub sets can be merged only when similar ranges of loss in area apply for given rope.

For the cases under consideration, the regression equation coefficients satisfy the curve slope requirement (Appendix B) more consistently when A = 1 than when it is free to vary. The preferred form of the equation is therefore $Y = X + BX^Q$. Results for this relationship are listed in Table 5. Internal variance is defined in Appendix B and X-intercepts at Y = 7 are included merely as a matter of interest.

This form of the equation is related to that used by Harvey and Kruger[2]. However, they used the relationship in summation across the strands and with fixed constants for all the test results. Their approach and the present strategy are therefore comparable only for the single strand case: their values for B and Q (0,001 and 5) are at variance with the more appropriate values (0,00036 and 5,7) given in Table 5 for their data set SSHK. For the other data sets the present approach gives substantially better correlation with the test results.

6.3 Asymmetry

Separation efficiencies of the old and new definition of asymmetry can be assessed on the basis of the aggregate internal variance of the two sub sets, Table 5:

Old: > ⅔ in three adjacent strands - $S(y-y)^2 = 88,6 + 3,9 = 92,5$
New: > ½ in two adjacent strands - $S(y-y)^2 = 61,1 + 6,0 = 67,1$

This confirms the previous findings based on inspection, Figure 1.

As was the case previously, there is no certainty that the new definition is applicable generally. None the less, it is the best now available and should be used. Future work must aim at further improvements.

6.4 Distribution of results

Validity of the assumption that the loss in strength is normally distributed, Appendix B, can be assessed in terms of the distribution of the error (y-Y), where

y is individual loss in strength test result and
Y is the value derived from the regression equation for the given loss in area.

This distribution is shown in Figure 2. Although no clear pattern emerges for the three sub sets individually, mainly due to small sample size, the aggregate distribution does not differ significantly from the normal.

6.5 Discard criteria

Broken wire discard criteria for the ropes under consideration are derived on the basis of the regression constants and population variance estimates given in Table 5, and in terms of the probability of exceeding specified levels of loss in strength. Results are summarised in Table 6. Round values of loss in strength were used to satisfy practical requirements.

A previous approach[3] of equalising population fractions with loss in strength < 3% and > 15%, has some merit for lognormal distributions (mean discard level is 6,67%) but is of little utility when the distribution is normal (mean discard level of 9%). With the paucity of information now available, a situation that is unlikely to change significantly in the medium term, it is probably more appropriate to revert to simple engineering decisions in terms of population fractions beyond, say 10%, 12%, or 15% loss in strength, a view previously frowned upon[3].

Results in Table 6 suggest a discard level of 5% for both the single strand and the asymmetric distributions in the case of the HK 44,5 mm rope. This is in agreement with the previous finding[3].

Three possible discard strategies emerge from the 48 mm rope tests conducted in this investigation.

They are:

i) Single strand: 4% loss in area due to broken wires
Asymmetric: 4,5%
Symmetric: 7%

or ii) Single strand: 4% loss in area due to broken wires
Other cases: 5%

or iii) Single strand and asymmetric: 4% loss in area due to broken wires
Symmetric: 7%

The latter is the most conservative in the majority of practical cases and is the preferred route. It compares with the previous recommendation of 5% and 8% based on the HK data for a 44,5 mm 6×30 rope of 1959 vintage[3], and adopted in the draft SABS Discard Criteria for Mine Winder Ropes.

Table 6: Loss in area discard levels with loss in strength probabilities

Case	Loss in area %	Mean loss in strength %	Population percentage with loss in strength			
			<3%	>10%	>12%	>15%
Single strand						
SSC	4	6,83	0,01	0,38	<0,01	
	4,5	9,29	<0,01	27,5	1,1	<0,01
SSHK	5	8,34	<0,01	2,5	<0,01	
Asymmetric						
ASC	5	6,75	2,8	4,9	<0,01	
ASC'	4	6,21	5,7	3,1	0,2	<0,01
	4,5	6,95	2,6	6,7	0,6	<0,01
	5	7,69	1,1	12,7	1,7	0,02
ASHK	4	5,31	21,1	5,1	1,0	0,04
	5	6,91	8,7	14,1	3,8	0,2
Symmetric						
SYC	7	8,21	<0.01	0,5	<0,01	
	8	9,33	<0,01	17,0	<0,01	
SYC'	7	8,28	<0,01	0,6	<0,01	
	8	9,42	<0,01	20,1	<0,01	
Combination						
SASC	5	6,48	3,3	3,1	0,2	<0,01
	6	7,90	0,5	13,4	1,5	<0,01

Note: These results were derived from laboratory tests with cut wires in **new** rope samples

What should however still be kept in mind is that these discard levels are for new ropes with cut wires. In practice, rope strength can increase which will make these values slightly conservative. On the other hand ropes in service also deteriorate due to other factors such as corrosion and wear. It would therefore be unwise to allow a rope to loose the above mentioned amounts of cross-sectional area due to broken wires when additional deterioration mechanisms are present. All this must be kept in mind when specifying the maximum allowable reduction in rope cross-sectional area due to broken wires on a used rope.

What is becoming very clear is that a general broken wire discard criterion for all ropes is not feasible. Different broken wire discard criteria will have to be specified for ropes of different type, size and possibly of different tensile grade.

6.6 Size effect

Table 3, as well as a scatter plot of all the available cut wire test results, not shown here imply that a rope size effect could well be present. Single strand tests on a 63 mm ropes gave a mean loss in strength of 9,97% for a loss in area of 3,47%. Equivalent loss in strength for the HK 44,5 mm and the 48 mm ropes tested in this investigation were derived via the regression equation with values of the constants listed in Table 7:

The best simple least squares fit of these results gives a linear relationship with a correlation coefficient better than 0,99:

$Y = -10{,}83 + 0{,}33D$ (Y: loss in strength, %; D: rope diameter, mm)

This level of correlation must be fortuitous. If a size effect does exist, it is unlikely to be linear with rope diameter, nor will it have a positive diameter intercept at zero loss in strength (32,8 mm for the above equation). Be that as it may, this situation cannot be ignored as it could have an important bearing on discard criteria now being applied in the field: unsafe conditions could exist in the case of larger ropes.

Table 7: Loss in strength of different diameter ropes with the same loss in area and cut wire orientation (Loss in area=3,47%).

Case	Rope Diameter mm	Loss in Strength %
SSHK	44,5	3,89
SSC	48,0	4,97
Table 3	63,0	9,97

6.7 Effect of rope tensile grade

What should be kept in mind is that the tensile grade of the ropes listed in Table 7 ranged between 1750 MPa and 1950 MPa. This may have had an effect (possibly only a secondary effect) on the results. This needs to be investigated further.

6.8 Further tests

As the single strand case is paralleled closely by asymmetric wire fracture distributions at discard levels, and consequently represents about 95% of practical broken wire cases[1], the size effect is best explored initially by concentrating on single strand cut wires only. This also applies to the investigations into the effect of tensile grade. Ropes listed below should be tested as soon as samples from new ropes made by Haggie Rand become available. Sufficient rope should be obtained for at least ten tests in every size. Repeat tests are required on the new rope and at each of the three levels of cut wires shown in Table 8 and 9. The programme should be reviewed as soon as a size effect and tensile grade effect has been refuted or confirmed. Naturally if a size effect exists, it will be due to a combination of rope diameter and rope construction since ropes of identical construction do not exist across such a wide diameter range. It is essential to have this work done by the same team that handled the 48 mm rope tests in this investigation, and in close co-operation with Haggie Rand. Larger sizes should be tested first as this is where possible unsafe conditions could exist with broken wire discard levels now specified in the draft SABS code.

Table 8: Rope sizes to be tested to establish whether a rope size (combination of rope diameter and rope construction) effect does exists.

Rope Diameter mm	Construction	Wire area as a percentage of rope area %	Number of cut wires in one strand.
32*	6×26	1,61	2,3,4
36	6×27	1,39	2,3,4
40*	6×29	1,04	3,4,5
52	6×32	0,72	4,5,6
56*	6×33	0,64	4,5,7
60	6×34	0,57	4,5,7
63*	6×34	0,57	4,5,6

Note: * preferred initial tests.

Table 9: Ropes of different tensile grade to be tested to establish whether a tensile grade effect does exists.

Rope Diameter mm	Construction	Wire area as a percentage of rope area %	Number of cut wires in one strand.	Tensile Grade MPa
32	6×26	1,61	3,4	1800, 2000, 2100
40	6×29	1,04	4,5	1800, 2000, 2100
52	6×32	0,72	5,6	1800, 2000, 2100
63	6×34	0,57	5,7	1800, 1900, 2000

7. CONCLUSIONS AND RECOMMENDATIONS

In none of the 46 cut wire tests was the loss in strength less than the loss in area. This is at variance with the HK data. The results of HK symmetric cuts (less than ⅔ of the broken wires in 3 or more adjacent strands) were therefore not considered in the analysis.

There is overlap between the asymmetric and symmetric sub sets for the results of the 46 tests. A clearer separation between these two sub sets was achieved by redefining asymmetry as: more than 50% of the broken wires in two adjacent strands.

The new definition of asymmetry means that the cut pattern N0N000 (where N = 3, 4, 5, 6) is now defined as symmetric and not asymmetric.

New winding ropes of 48 mm diameter and 6×32 construction should be discarded when the loss in steel area due to broken wires over one rope lay length is equal to or greater than

4% - when all the broken wires are in one strand or when more than 50% of the failures are in two adjacent strands,

7% - when 50% or less of the failures are in two adjacent strands.

This compares with values of 5% and 8%, respectively, now being used for all triangular strand drum winder ropes.

Recommendation

A review of all the available data suggests that a rope size effect and possibly a tensile grade effect could be present. This matter should be investigated without delay as it may have an important bearing on current practice. Detailed recommendations regarding additional tests are given in paragraph 6.7 and 6.8 of this report.

8. ACKNOWLEDGEMENTS

The authors would like to thank Haggie Rand Limited for donating the rope used in this investigation.

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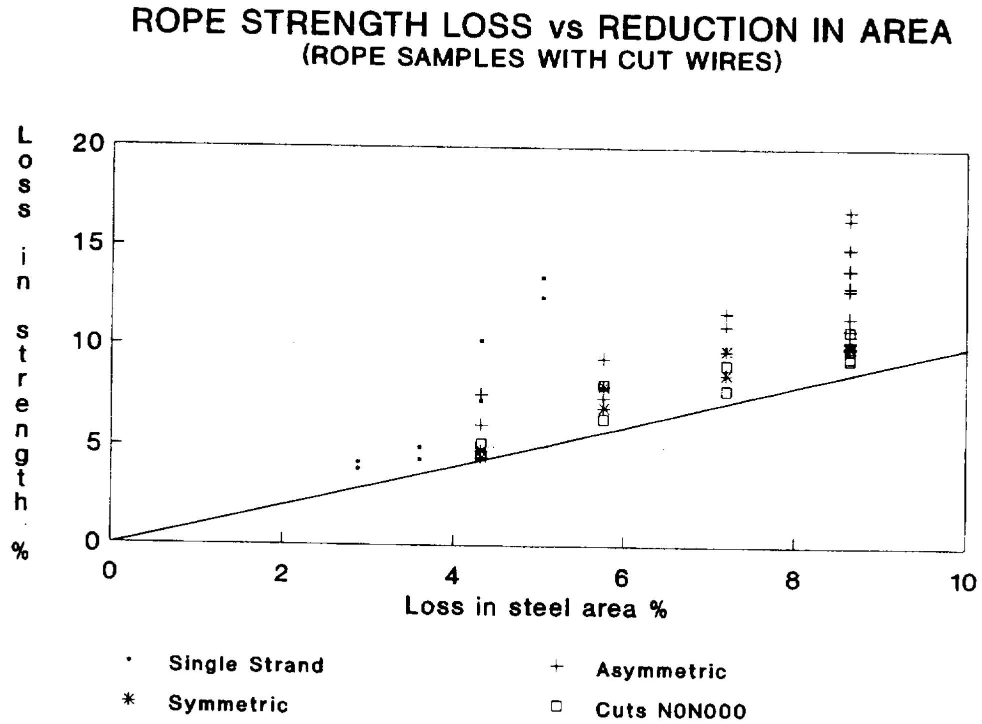


Figure 1: Variation of loss in strength with loss in area due to cut wires in a 48 mm 6×32 1800 MPa winding rope.

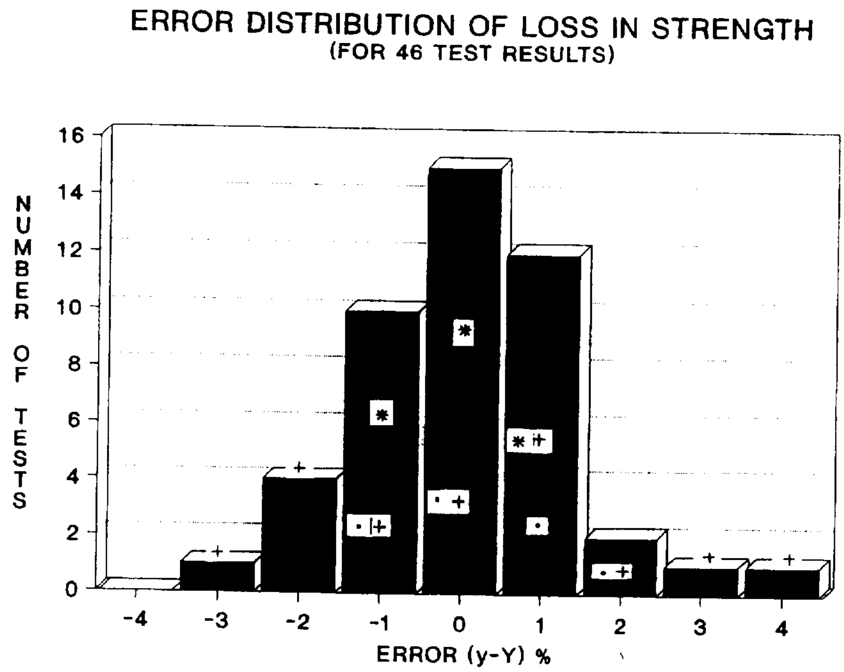


Figure 2: Distribution of the error (y-Y) in loss of strength (%) for 46 test results.
y: test result at given loss in area
Y: Value derived from the regression equation for each of the sub sets.
Graphic symbols as for Figure 1 : total = block height

Appendix A: New Rope Test Certificate

Materials Science and Technology
CSIR

Mine Hoisting Technology

Private Bag X28
Auckland Park
2006 South Africa

Navorsinn
Auckland Park

National (011) 726-7100
International + 27 11
Fax: (011) 726 6418

Cor. Migdon Road and Frost Avenue
Cottesloe 2092 Johannesburg

Application received	89.02.20	Certificate No	164249
Rope received	89.02.17	Date of Test	89.02.22

CERTIFICATE OF TEST CONDUCTED ON WINDING ROPE

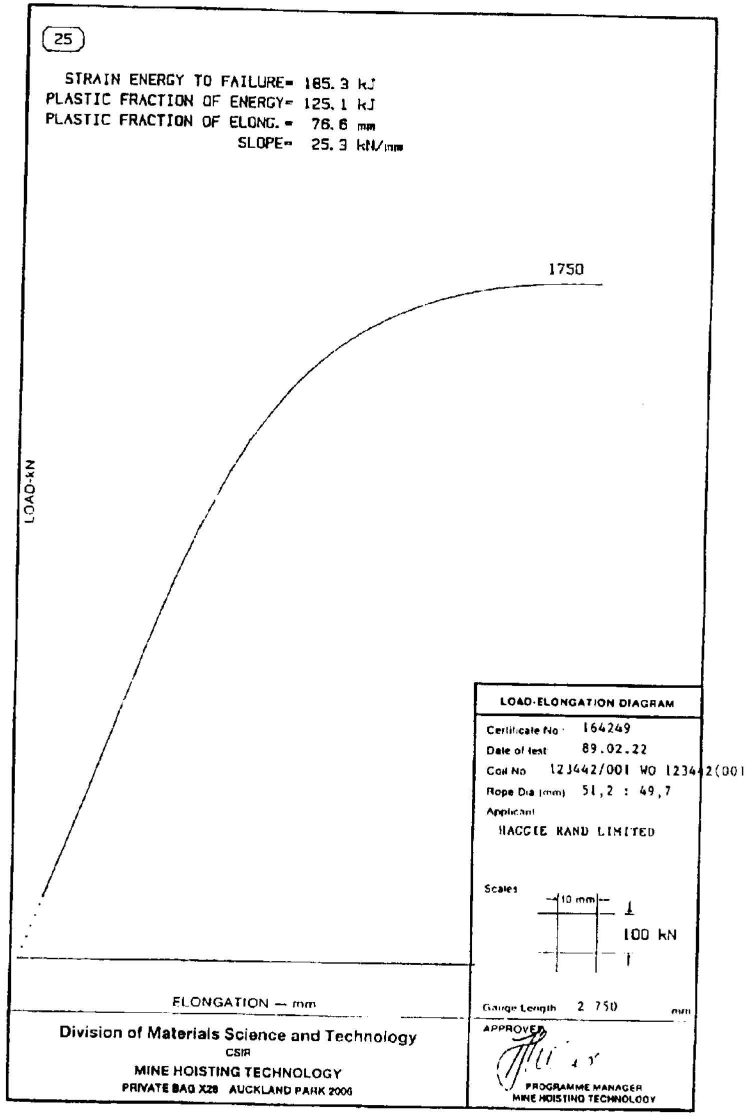
Particulars supplied by Applicant

Name of mine (if applicable)			
Specimen supplied by	HAGGIE RAND LIMITED		
Name of manufacturer	Haggie Rand Limited	Date of manufacture	89.02.14
Name of shaft		Type of shaft	
Name of compartment		Length of winding	
Winding plant cert. no		Date in operation	
Coil no. of rope	123442/001 W/O 123442 (001)		
Nom. diameter of rope (mm)	48,0	Length of rope (m)	1 005
Construction of rope	Compound Triangular Strand 6x32(14/12/6+3T)/F	Mass per length (kg/m)	9,81
Number of strands	6	Type of lay	RHL
Lubricant		Nom. length of lay (mm)	361
Type of heart of rope	Fibre		
Number of wires in strand	32(14/12/6+3T)		
Diameter of wires (mm)	3,10 2,24 1,92 1,44		
Type of strand core	Plaited		
Tensile grade of steel	1 800 MPa	Wire finish	Ungalvanized
Breaking force of new rope	kN		
Breaking force of previous test	kN	Length of specimen supplied (m)	3,58
Minimum allowable breaking force	kN	Date cut	

RESULTS OF TEST AND EXAMINATION

Breaking force of rope	1 750 kN	Gauge length of test specimen (m)	2,75
Least dimension of outer wire (mm)		Length of lay (mm)	396
		Diameter of rope (mm)	51,2 : 49,7
Corrosion	None		
Condition of lubrication	Good		
Appearance of wires at fracture	Ductile		
Number of strands broken	Four		
Position of fracture	500 mm from metal endcap		
Remarks			
Date of issue	89.02.22		

Testing Officer [signature] Programme Manager, Mine Hoisting Technology [signature]



Appendix B: Regression Analysis

B1. General

For normal distribution of a dependent variable y at any given value of the independent variable x and with variance either constant or a known function of x, a regression relationship between y and x can be written as

$Y1=A.X1+B.X2+....+K.Xk$

where X1 .....Xk are specified functions of x[6,7]

Coefficients [A B ...K] for a given set of n data points (x,y) can be found by minimising the sum of the squares of the deviations.

$SSD=s(y-Y1)^2$, where $S=\sum(\ )$ from 1 to n.

Equating to zero, in turn, the derivative of SSD with respect to each of the coefficients A B ....K yields a set of k simultaneous equations with solution

$$[A\ B\ ....K] = [S(Y1.X1)\ \ S(Y1.X2)......S(Y1.Xk)] \ / \ \begin{bmatrix} S(X1^2) & S(X2.X1)..... & S(Xk.X1) \\ S(X1.X2) & S(X2^2)..... & S(Xk.X2) \\ . & . & ..... \ . \\ . & . & ..... \ . \\ S(X1.Xk) & S(X2.Xk)..... & S(Xk^2) \end{bmatrix}$$

This general solution can be applied directly in the case of simple regression equations of exponential, power and other forms that can be linearised.

For instance, the relationship

$y=a.e^{bx}.x^c$ can be written as $\ln(y)=\ln(a)+bx+c\ln(x)$

Using $Y1=\ln(y)$, $X1=1$, $X2=x$, $X3=\ln(x)$ in the three term general solution yields $a=e^A$, $b=B$, $c=C$.

Alternatively, on the basis of the n sets of (x,y) data, a set of n linear k-term equations can be set up in matrix format

$[A\ B....K].[M]=[V]$

and the overdetermined system ($n>k$) is solved by transposing the matrix[8]:

$[A\ B\ \ldots.K]=(M^t.V)/(M^t.M)$, where $M^t_{nk}=M_{kn}$

For regression equations that cannot be linearised, the coefficients can be found by suitable single or multiple simultaneous iteration either via the general solution or directly for minimum SSD.

Where a predetermined number m of x values apply, as in paired data, it is a simple matter to solve a system of m simultaneous equations with m unknowns in terms of the mean (x,y) test results. Due to the effects of random variation such a curve fitted to a limited set of test results could have multiple undulations. This curve will understate the variance of the actual central tendency and could also yield unreliable curve intercepts. With limited test results it is therefore necessary to arrive at the approximate form of the basic equation on the basis of graphical analysis of the test results and in terms of engineering principles related to the data. The equation must have as few terms as possible. Estimation of population variance is based on (n-m-1) degrees of freedom, where n is the number of test results and m is the number of terms in the equation. Extrapolation beyond the range of the test results is hazardous[7].

B2. Ropes with cut wires

Since loss in strength (y,%) is a function of loss in area (x,%) and the latter is an independent variable, regression analysis can be used to assess the relationship.

In the present case it is reasonable to postulate that the regression equation $Y=f(X)$ must satisfy the following requirements:

* $Y=0$ at $X=0$
* $dY/dX < 1$, and
* d^2Y/dX^2 must not change sign for $0< X <17\%$, that is, $Y=f(X)$ must have no undulations (points of inflection) in this range;
* the same form of the equation must apply to all the data sets.

These requirements can be satisfied, for instance by the form

$Y=A.X+B.X^Q$

depending on the values of the constants. Various cases of this general relationship were considered, with

$A=0$, 1, and free to vary, and $B=0$.

The simple single term power function ($A=0$) does not satisfy the curve slope requirement for small values of X but was assessed purely as a matter of interest.

For the special case $A=1$, iteration via the general two-term least squares algorithm was used to find Q such that A=1, with B resulting from the consequence. Simultaneous iteration in Q and B for minimum SSD gave similar results.

Similarly, two strategies were assessed where A was free to vary.

* Simultaneous triple iteration in A, B and Q for minimum SSD.
* Iteration in Q for minimum SSD, with simultaneous values of A and B via the two term algorithm.

Comparable results were obtained again. The second procedure is preferred due to greater computational efficiency.

Minimum internal variance of a data set consisting of repeat tests can be found as the sum of the variances $(y\text{-}y)^2$ at every given value of x. Although this variance is the lower limit attainable by any regression equation, it must not be used as a measure of the adequacy of the fit achieved for reasons outlined in the previous paragraph.

A consequence of the least squares procedure is that seemingly widely different regression equations could yield comparable variances and curve intercepts within the range of the test results. Substantially divergent intercepts could occur outside this range, thus emphasising the hazards of extrapolation.

Project No.: MHEAG

DISCUSSION OF RESULTS OF TESTS ON DISCARDED ROPES - IN TERMS OF THE DRAFT CODE OF PRACTICE ON ROPE CONDITION ASSESSMENT

by

E.J. Wainwright

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Prepared by:

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Submitted to:
Safety in Mines Research Advisory Committee
Engineering Advisory Group

MINE HOISTING TECHNOLOGY
DIVISION OF MATERIALS SCIENCE AND TECHNOLOGY
CSIR

SUMMARY

The CSIR has been testing samples of discarded ropes to evaluate the discard criteria in the draft Code of Practice for Rope Condition Assessment. The results of the tests are to be used to validate or, alternatively, to refine the discard criteria.

The test results show that the discard criteria may be applied for triangular strand and round strand ropes but not to non-spin ropes. Suggestions are made to refine the discard criteria. Due to the limited number of samples tested, not all discard criteria could be evaluated.

The results also show that not all ropes were assessed and discarded according to the draft Code of Practice. About half of the ropes were overdue for discard.

CONTENTS

DISCUSSION OF RESULTS OF TESTS ON DISCARDED ROPES - IN TERMS OF THE DRAFT CODE OF PRACTICE ON ROPE CONDITION ASSESSMENT.

1 INTRODUCTION.

As a result of the great depths at which mines in South Africa are operating, hoisting depths are so great that hoisting adequate payloads poses severe problems. In order to economically hoist from even greater depths considerable research has been undertaken into various aspects of the operation of steel wire hoisting ropes. This research has clarified requirements for the safe operation of mine hoisting systems, especially wire rope. It had initially been assumed that safety could be legislated by merely specifying a Factor of Safety for winding ropes. Experience over the years has proved this approach to be incorrect. The requirement by the mining industry to hoist safely from greater depths has meant a complete reappraisal of the means for achieving safety.

"It is now accepted that, even at high factors of safety, no rope can be used safely unless:

- o normal deterioration of the rope is monitored and controlled by means of regular and efficient rope inspection.
- o abnormal damage to the rope is avoided, and where it does occur it is detected early.
- o the normal and the maximum forces acting on the rope are controlled within specified limits."[1]

Regular rope inspection is specified in the regulations[2]. Also specified in proposed amendments to the regulations[3] is the requirement that inspections be carried out in accordance with an approved Code of Practice. A draft SABS Code of Practice - Condition Assessment of Steel Wire Ropes on Mine Winders[4] - has been produced. It is the purpose of this report to attempt to validate this code by comparing test results on discarded ropes with retirement criteria specified in the code.

1.1 CODE OF PRACTICE.

The Code of Practice has been developed from an initial document submitted by Anglo American giving the guidelines for discarding triangular strand winding ropes used on drum winders. The scope of the draft Code is to include requirements for all winding ropes and whatever winders they operate on.

Besides specifying the retirement requirements, the code also gives guidance on procedures and the frequency of inspection.

1.2 CORRELATION TESTING.

The mining industry was requested to supply samples from discarded ropes, which were the reason for the decision to discard the rope. In addition it was requested that a full report be submitted showing measurements and other details related to the discard in terms of the Code of Practice.

The first samples were tested in October 1992 and by the end of the first year only 63 specimens had been submitted for test and evaluation. A report[5] on these tests was circulated in June 1994.

A further 46 specimens have been submitted since then and the relevant results included in this discussion. Concise details of test results and the pre-test examination are to be found in the appendix at the end of this document.

2 TESTS ON DISCARDED ROPES.

Ropes which had been discarded for a variety of reasons were submitted for test. In many cases several samples from the same rope were submitted for evaluation. These were examined and tested although not representing the reason for discard, since they provided additional information.

The discarded samples exhibited the following deterioration or defects:

- Wear, both abrasive and plastic deformation.
- Reduction in rope diameter.
- Corrosion.
- Broken wires.
- Split wires.
- Damage from falling objects.
- Kinks.
- Waves.
- Heat damage.

Rope constructions varied from the normal triangular strand drum winder ropes to round strand ropes of various constructions used on Lifts or Koepe winders and non-spin ropes used as tail-ropes and Koepe head-ropes.

2.1 PROCEDURE.

On receipt of the rope sample and the rope inspector's report, if any, the sample was carefully inspected to establish conformance with the report. The position of all broken and split wires was measured and recorded. The visual amount of corrosion was recorded and the rope diameter measured, while tensioned to 10 % of the initial breaking force.

After the tensile test to destruction the rope was examined in accordance with normal test procedures and a test certificate produced.

In many cases the rope inspector involved wished to witness the test and in one or two cases it was established that the incorrect sample had been submitted for test. On the other hand there were many cases where the rope inspector's report had not been submitted and very little interest shown in the test.

2.2 RESULTS.

Of the 109 specimens listed in the appendix, not all have been tested. There are a few specimens awaiting further information or instruction. In one or two cases incorrect samples were submitted and not tested.

The presentation of the detailed test results of either the first 63 samples or the subsequent 46 will not be made in this document. However, if required, a detailed report can be made for specific samples.

3 CORRELATION WITH CODE OF PRACTICE.

Not enough information was submitted with each sample for test to enable direct comparisons to be made. In no case was there a comprehensive rope inspector's report detailing the observations and explaining how discard factors were arrived at. In some cases a discard factor was indicated, but there was insufficient information for this factor to be used in an analysis.

Because of this lack of information, it was decided to attempt to assign discard factors based on the pre-test inspection of each sample. The basis for assigning these factors is described as follows:

1. If an inspector's report was available with an actual diameter measured on site, this measurement was used. In the absence of this information the measurement made by the CSIR under a 10 % tensile load was used. Based on reports and observations of symmetrical or asymmetrical wear discard factors were calculated in terms of the Code of Practice and the highest value, obtained from either source, was used. In the absence of diameter measurements taken soon after installation of the rope it was not possible to do a comparative assessment of the two bases for calculation, the nominal rope diameter was used as the initial diameter for calculation.
2. The number and exact position of broken wires was determined. Unfortunately, on samples with large numbers of broken or split wires, not enough attention was given by the rope inspector or the CSIR examiner to identify which wire fractures occurred in the same wire. The CSIR reports have been evaluated in terms of rope lay length, affected length of wire in each break and rope construction to assess the actual number of wires actually involved in wire fractures. This approach, although based on simple assumptions , seems to have yielded acceptable results. On the basis of numbers of broken wires, distribution and rope construction the code was applied to produce a discard factor for broken wires.

3. The assessment of discard factors for corrosion presented some difficulty. When the CSIR pre-test inspection indicated "excessive corrosion" a discard factor of 1 was assigned. The greatest difficulty arose in assessing internal corrosion reported by the rope inspector. In most cases besides giving instrument readings the inspector gave an estimated percentage loss of area due to corrosion. However, in no case was comprehensive information and an assessment with an appropriate multiplication (or conversion) factor given, as required in the draft code. Although not strictly correct, a multiplication factor of 1 was assumed and the percentage was divided by 7 % in order to assess a reasonable discard factor. In certain cases where the rope inspector had merely indicated advanced corrosion a discard factor of 0,5 was assigned and for this series of ropes, where two samples were marked "adjacent samples" a factor of 0,3 was assigned.
4. A discard factor of 1 was automatically assigned for kinks.
5. There were ropes which were found to be wavy when examined by the CSIR. No details of measurements such as depth of wave were given. Consequently it was assumed that these ropes had been discarded due to the wave and a discard factor of 1 was assigned.
6. One heat damaged rope was submitted. The rope inspector had identified the damaged area by means of the electro-magnetic test and visual examination established discolouration due to heat. There was also a marked reduction in rope diameter at this point. A discard factor of 1 was automatically assigned for this defect.

On the basis that mandatory discard of ropes with kinks or wavy ropes with a certain depth of wave is required, because of expected rapid deterioration of the rope and not necessarily because of loss in strength, test results are considered in various groups:

- Triangular strand and round strand ropes discarded due to wear, corrosion or broken wires.
- Kinked ropes.
- Wavy ropes.
- Triangular strand and round strand ropes discarded due to wear or corrosion only.
- Non-spin ropes.

3.1 DISCARD, IN CONFORMANCE WITH THE CODE.

The 109 samples submitted for test were cut from 77 discarded ropes. The percentage loss in strength of these ropes varied from nil to a maximum of 69 %. The distribution of strength loss with respect to the number of ropes discarded is shown in Figure 1 on page 5. It can be seen that only 11 ropes were discarded where the loss in strength at discard was below the regulation requirement of 10 % but more than 5 %, which was an appropriate lower value for discard.

This discard pattern is regarded as abnormal because not all discarded ropes had been submitted for test and greater interest is often shown for the results of tests on ropes which exhibit an interesting anomaly. The true pattern of rope discard can only be ascertained when all discarded ropes are submitted for evaluation.

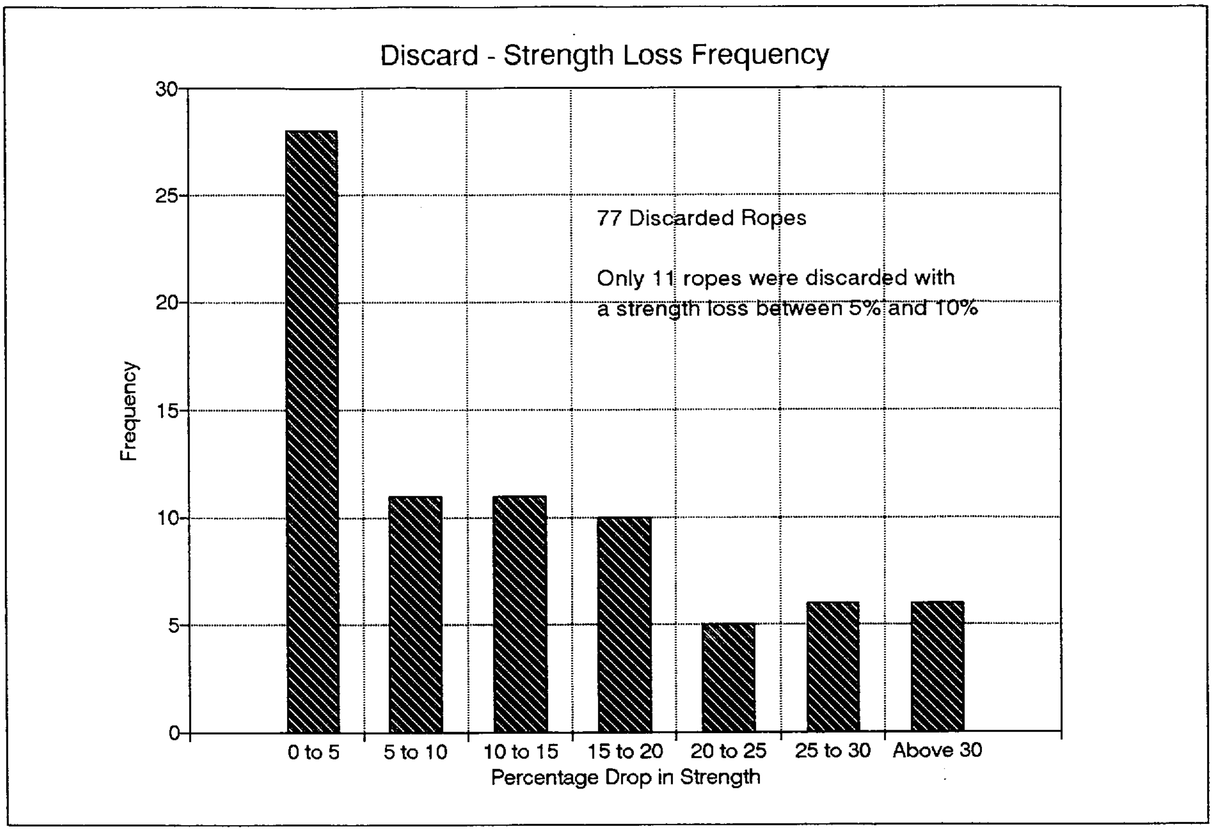

Figure 1. Frequency Distribution of Loss in Strength

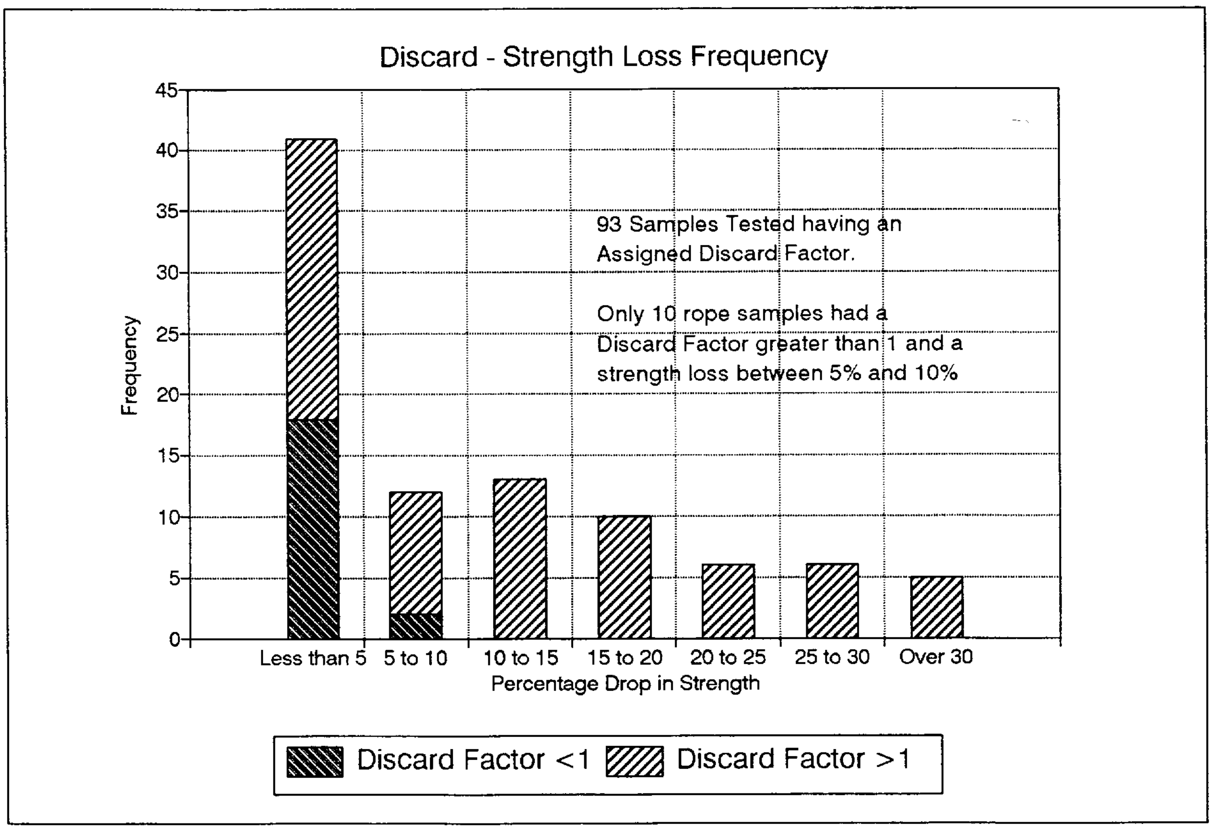

Figure 2. Frequency Distribution of Loss in Strength for Discard Factors Above and Below 1

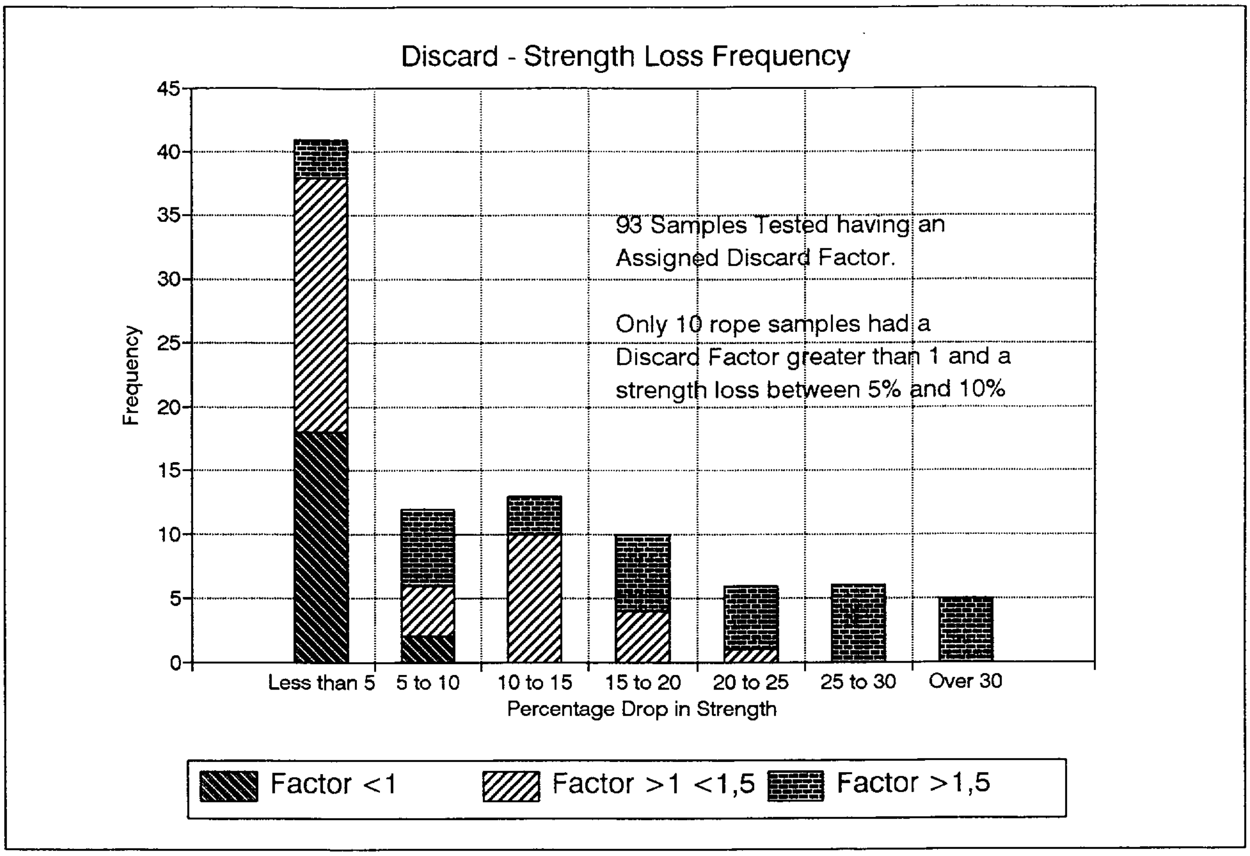

Figure 3. Frequency Distribution of Loss in Strength
Discard Factors Below 1, Between 1 and 1,5 and Above 1,5

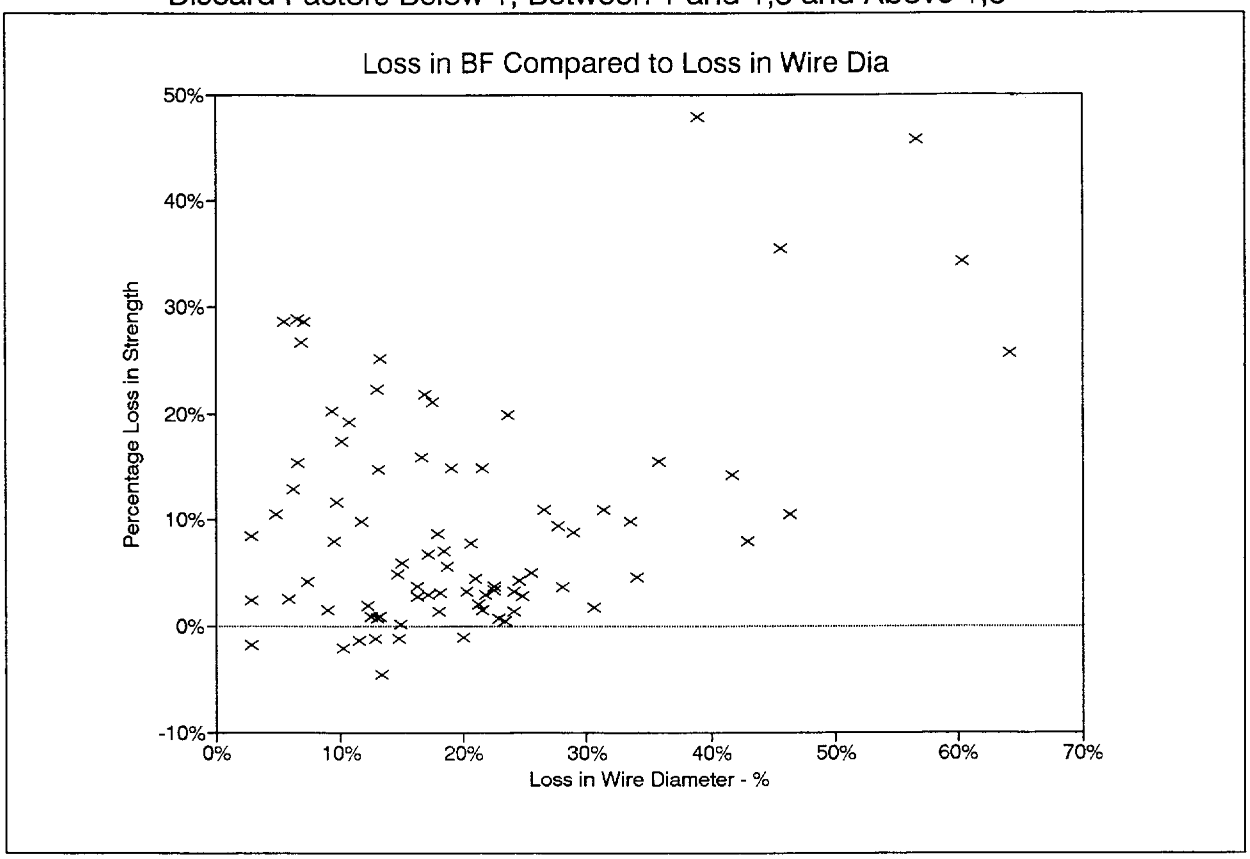

Figure 4. Comparison of Loss in Breaking Strength with Loss in Wire Diameter

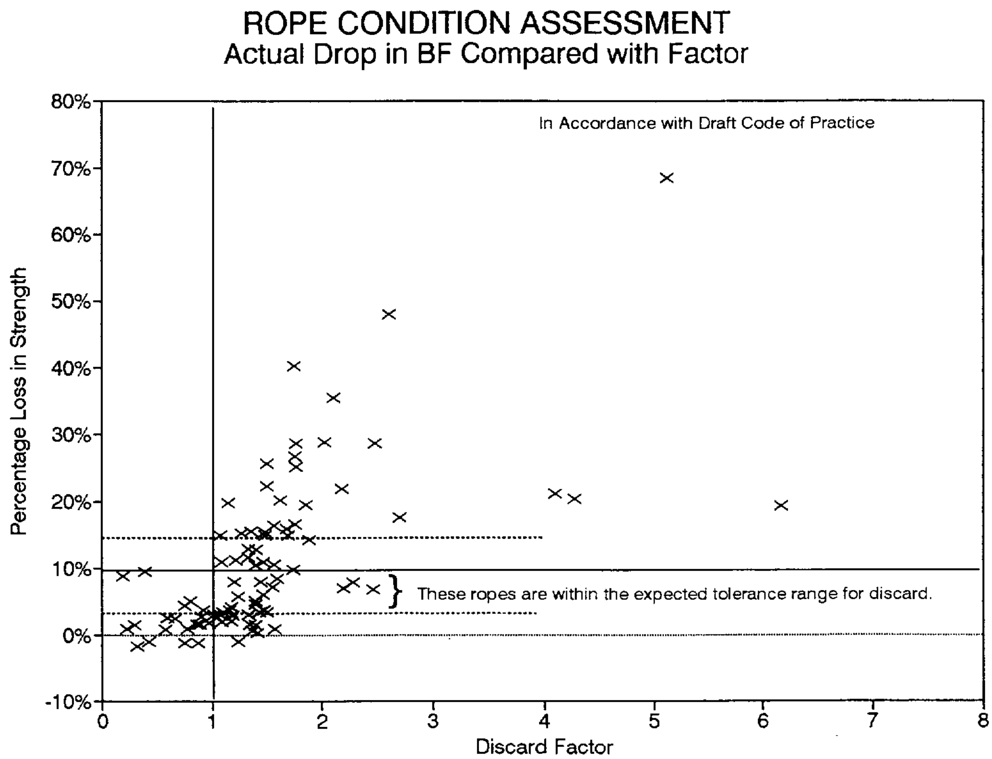

Figure 5. Loss in Strength Compared with Assessed Discard Factor

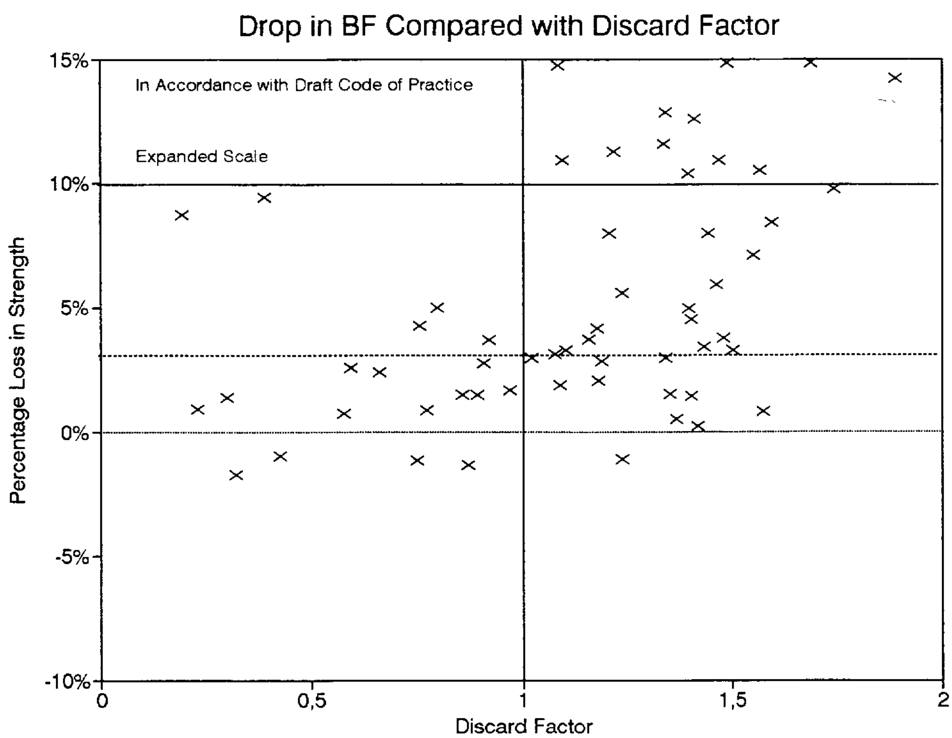

Figure 6. Portion of Figure 3 with Expanded Scale

Figure 2 on page 5 and Figure 3 on page 6 show the distribution of all the samples tested which have been assigned a discard factor. The patterns shown are very much the same as in Figure 1, but illustrate considerable discrepancies with respect to the discard factors which need to be evaluated and explained. This global approach gives an inappropriate correlation pattern due to discard requirements which cater for such aspects as the possibility of rapid deterioration due to distortion or other factors.

As a first consideration, the requirement for a generalised Code of Practice for Condition Assessment needs to be considered:

Direct relationships between rope strength loss and the various measurable rope parameters such as "reduction in rope diameter", "reduction in wire diameter" or "number of broken wires" would be easily applied. However, reference to Figure 4 on page 6, which plots a scatter graph of loss in wire diameter against loss in rope strength, indicates that although there is a general relationship between the two parameters, there is not a sufficiently close relationship to assist in making rational discard decisions without reference to other factors. The same applies to other parameters.

The Code of Practice - Condition Assessment of Steel Wire Ropes on Mine Winders is designed to provide a means for combining these relationships on a "go/no-go" basis. Relationships for the various parameters have been determined and methods for combining the information, in an intelligible manner, provided. The effectiveness of the Code is evaluated and discussed in the remainder of this report.

3.2 TRIANGULAR STRAND AND ROUND STRAND ROPES.

Scatter graphs showing the percentage drop in breaking strength, for discarded triangular strand and round strand ropes tested, plotted for the corresponding discard factor are shown in Figures 5 and 6 on page 7. Figure 5 contains all points and Figure 6 is the relevant part of the same information shown on an expanded scale. The discard factor has been assessed in terms of the code of practice and is the sum of individual factors for broken wires, loss in rope diameter and corrosion. Dotted lines are plotted at the 12 % and 3 % loss in strength positions to give an indication of ropes discarded within the practical tolerance to be expected of discard at an assessed loss of strength of 7 %.

It can be seen that in most cases the discard criterion of 1 makes an appropriate cut-off for discard. Some of the anomalies need to be considered.

There are two points which are regarded as unacceptable. The rope discard strength is near the 10 % discard limit specified in the regulations whereas the discard factors are less than one.

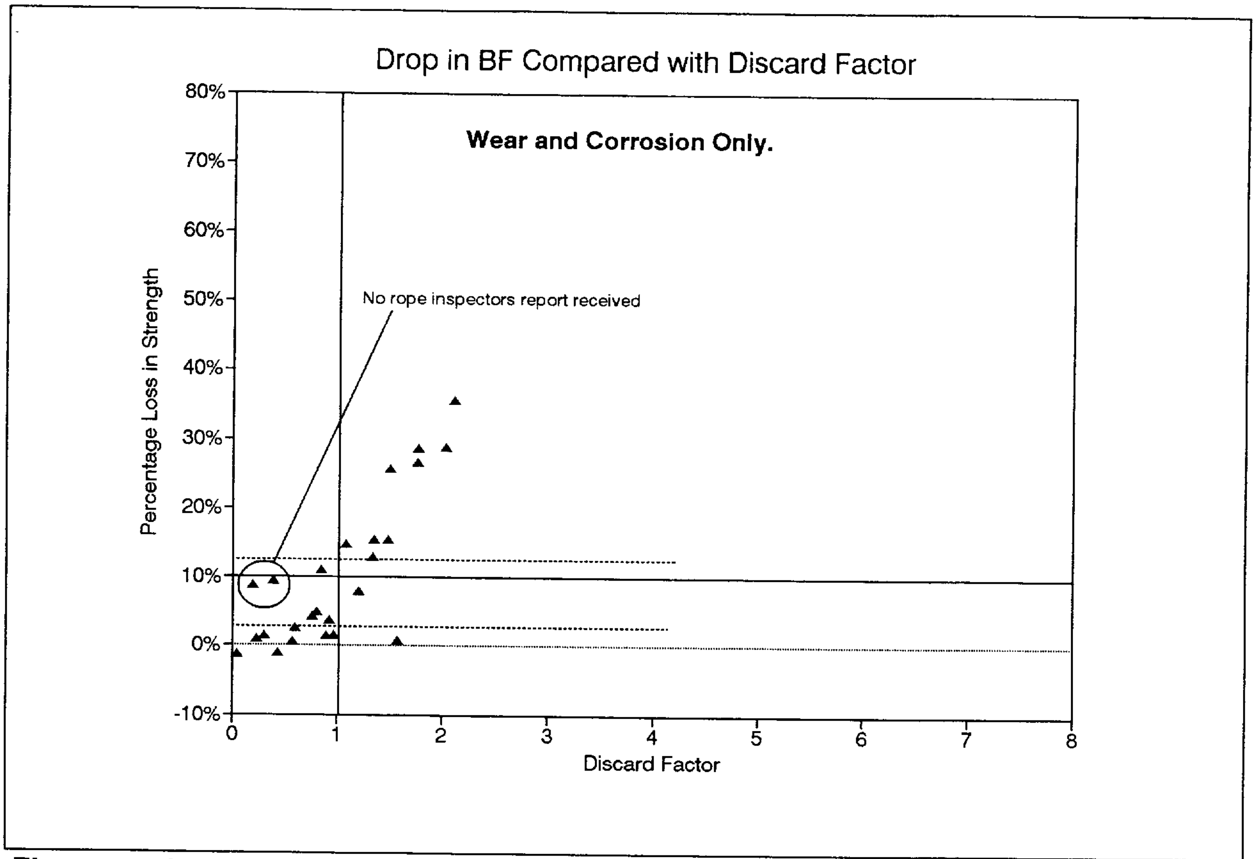

Figure 7. Loss in Strength Compared with Assessed Discard Factor - Wear and Corrosion Only

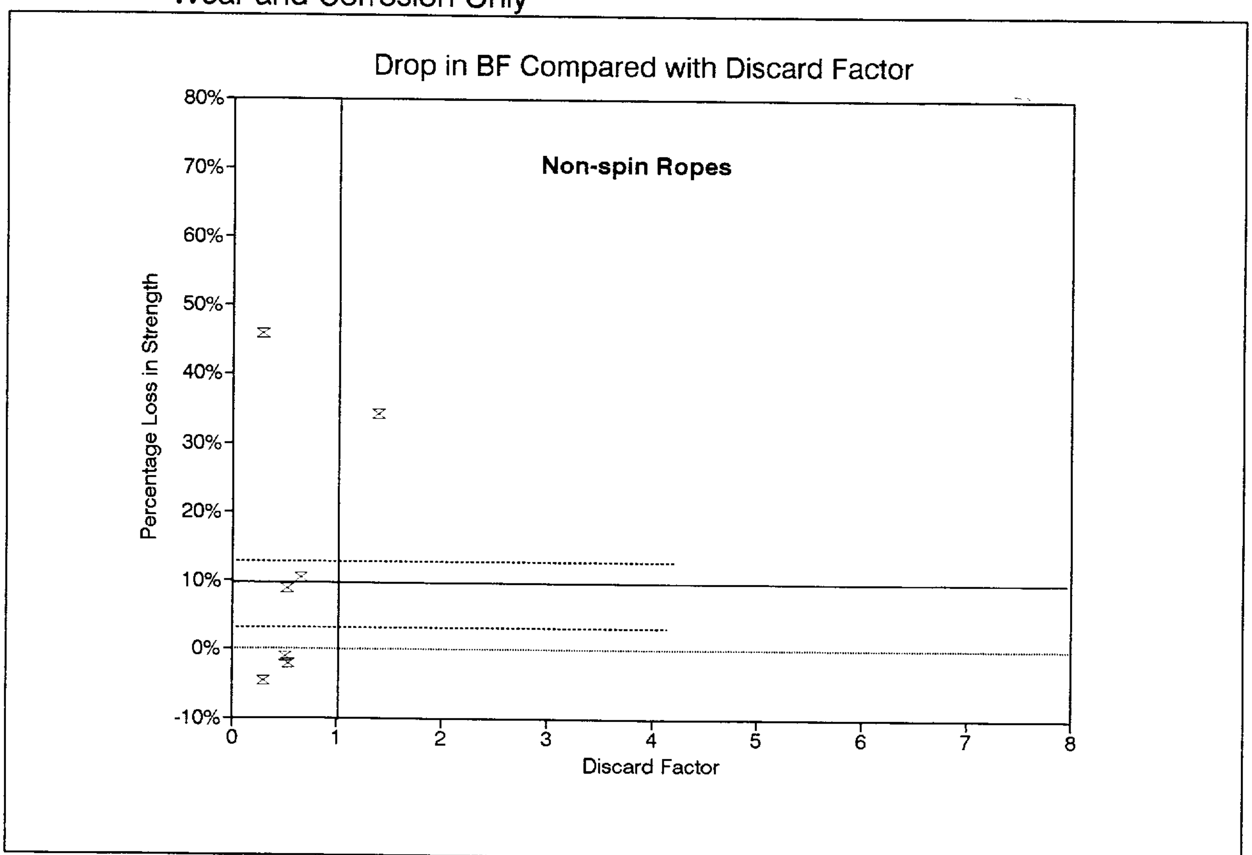

Figure 8. Loss in Strength Compared with Assessed Discard Factor - Non-spin Ropes

- These two samples were not accompanied by inspector's reports and discard factors were assessed purely on the basis of the pre-test CSIR inspection. There were no broken wires in either sample so the loss in strength approaching 10 % was something of a surprise. It may be assumed that these ropes were discarded due to wear or loss in diameter and that the measured dimensions on site were somewhat smaller than those taken at the pre-test examination. Of course this is pure speculation, but it illustrates the importance of correctly measuring and reporting on rope condition.

There were about 8 samples where the loss in strength was less than 3 % and discard factors in excess of 1 were assessed on the basis of the rope inspector's report with respect to rope diameter and on the pre-test inspection for broken wires. In one case it appears that the broken wire count may have been incorrectly assessed and in all the other cases reduction in diameter was the reason for the discard factor assessment. All these ropes operated on deep winds, in excess of 2000 m, and the samples taken from operating rope near the back end. Lay length variations coupled with high tension and a certain amount of wear contributed to diameter measurements which were sufficiently small as to give a discard factor in excess of 1. This is not a dangerous condition but does have some financial effect in that ropes are discarded slightly prematurely.

Figure 7, on page 9, shows ropes discarded for only wear and/or corrosion. Considering the acceptable correlation between loss in strength and discard factor shown in this figure, it is not considered appropriate at this stage to attempt revision of the method for assessing reduction in diameter.

3.3 NON-SPIN ROPES.

The original concept of the discard criteria in the Code of Practice was only related to round strand and triangular strand ropes. The extension of the code to non-spin ropes needs to be assessed separately. Figure 8 on page 9 is a scatter graph for non-spin ropes which were submitted for examination and test.

It can be seen that in its present form the discard criteria given in the code are not appropriate for this type of rope. Most of the non-spin samples submitted were cut from tail-ropes and one of the ropes was a Koepe head-rope. Because of the fatigue distribution pattern in ropes operating on Koepe winders, normal deterioration is found to be fatigue of inner wires in the rope which cannot be identified by visual examination. The existence and extent of the broken wires was not correctly assessed by the electro magnetic examinations on site but was confirmed in the post test examinations.

The relevance of the discard criteria to non-spin ropes operating on drum winders still has to be assessed and it is hoped that suitable specimens will be submitted in the near future.

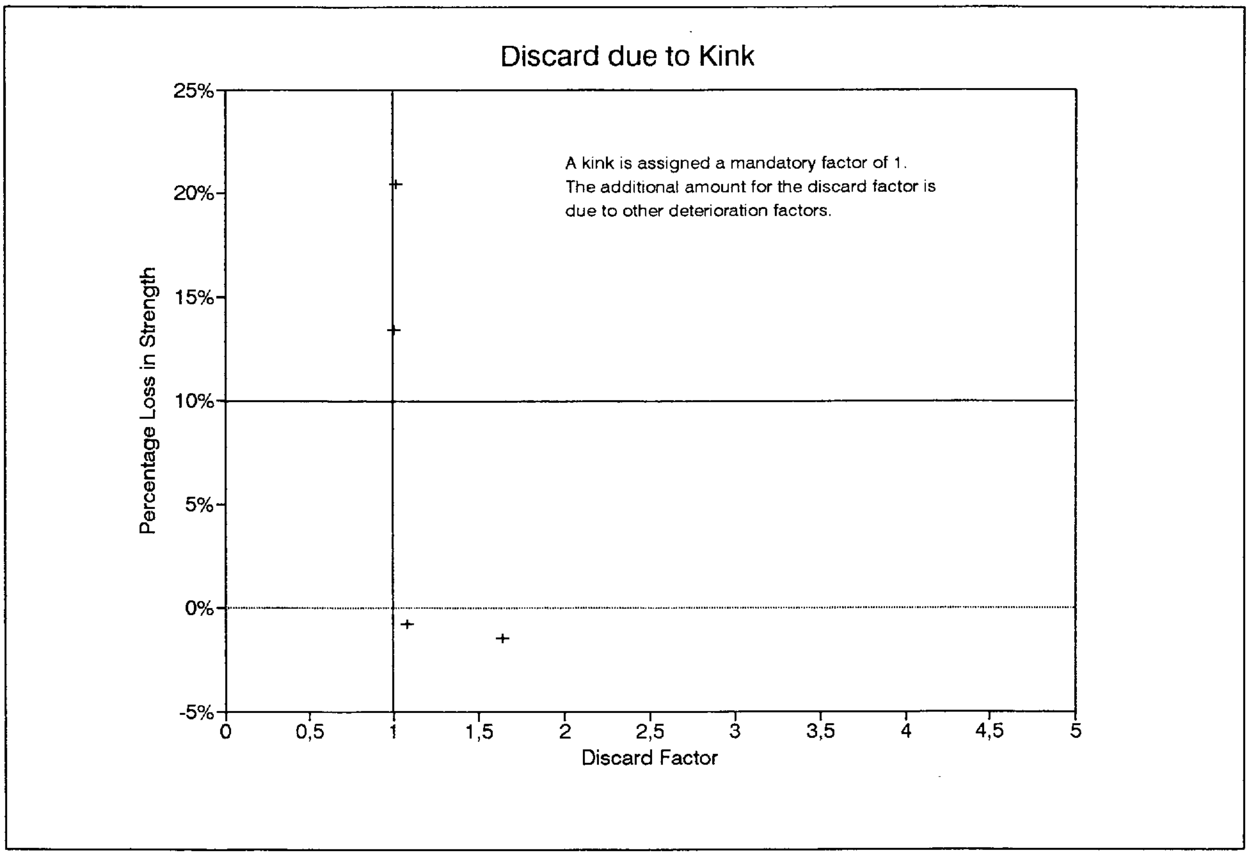

Figure 9. Loss in Strength Compared with Assessed Discard Factor - Kinks

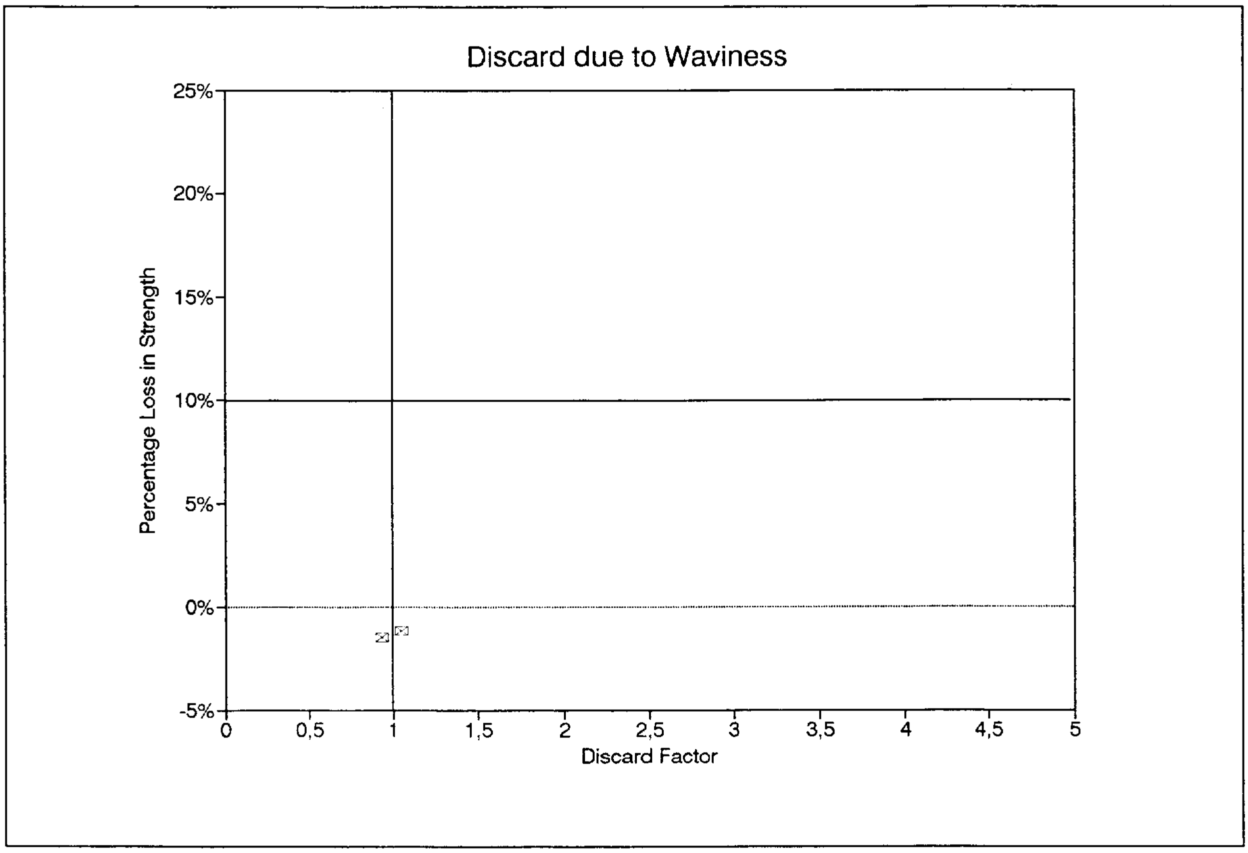

Figure 10 Loss in Strength Compared with Assessed Discard Factor - Waviness

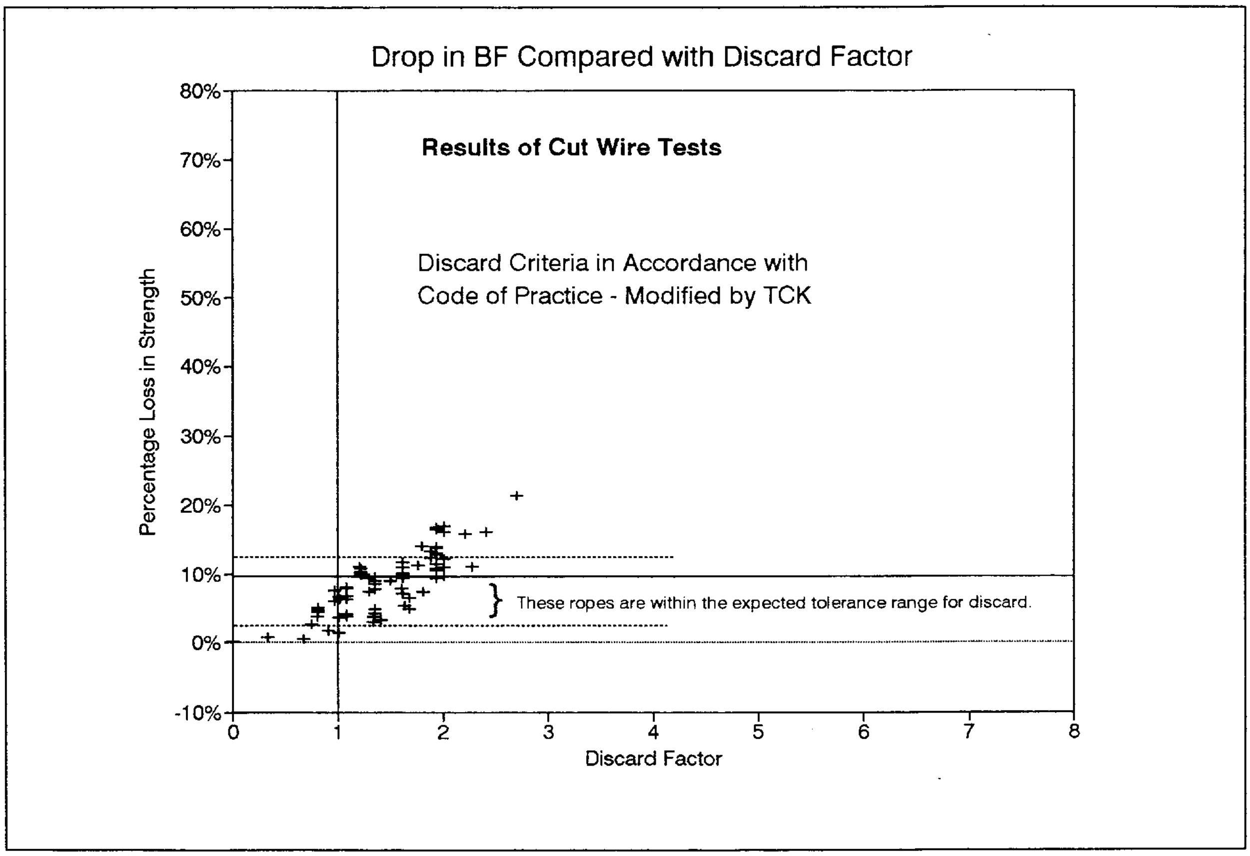

Figure 11 Loss in Strength Compared with Assessed Discard Factor - Cut Wire Tests

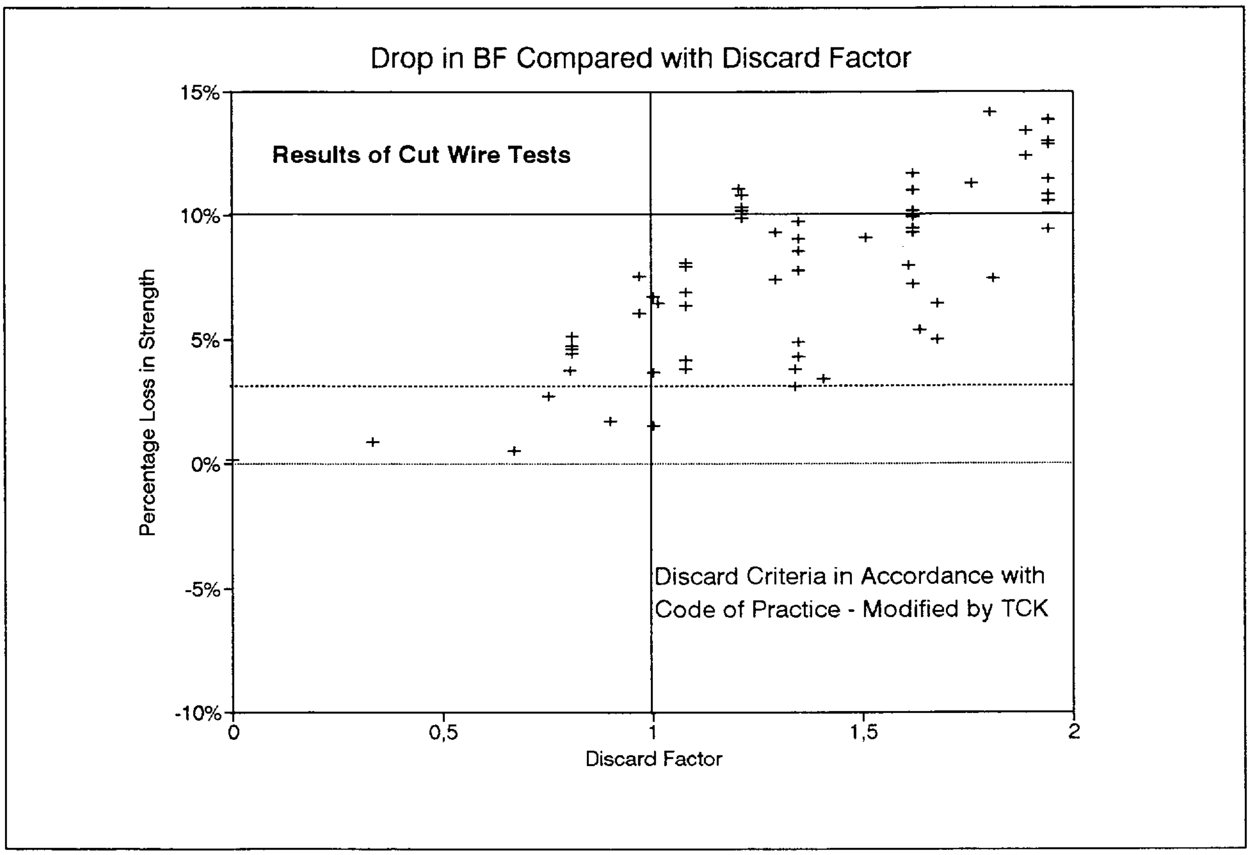

Figure 12 Portion of Figure 9 with Expanded Scale

3.4 KINKED ROPES.

Several kinked specimens were submitted for examination and test. The scatter graph shown in Figure 9 on page 11 shows the variability of the effect on rope strength. In view of the large reductions of strength noted, it is considered that the requirements of the code with respect to kinks are appropriate.

3.5 WAVY ROPES.

Two wavy ropes were submitted. These samples were somewhat unusual in that the deformation was still visible in the short sample length. No satisfactory rope inspector's report was submitted with the samples so the extent of the wave was not known. Figure 10 on page 11 illustrates that there was no loss in rope strength. The discard criterion for wavy ropes was formulated to prevent excessively rapid rope deterioration and to encourage the repair of affected ropes.

3.6 CUT WIRE TESTS.

The effect of broken wires on the strength of a rope is not only a function of the steel area lost, but also is dependant on the symmetry of the remaining load carrying wires. This relationship has been investigated in the two reports listed in the references[6 7]. The report on the work done in 1957 and 1959 was the basis of initial discard parameters and the recent tests have been done to confirm and enlarge on these findings. Figures 11 and 12 on page 12 illustrate the relationship between discard factor and loss in breaking strength. It was found that the Draft Code of Practice definition of symmetry gave results which overemphasized certain asymmetrical broken wire patterns. In the report on the recent series of tests, an alternative definition was proposed and this has been used in plotting the graphs.

It can be seen that the relationships for assessing a discard factor give safe results, although in a few instances ropes may be discarded prematurely. Further work still needs to be done to refine the requirements, especially when other factors such as wear or corrosion are introduced.

4 CONCLUSIONS.

Samples from only 77 discarded ropes have been submitted for this project. This is disappointing because approximately 200 winding ropes are discarded every year.

The range of deterioration patterns of the ropes submitted has been wide enough for an initial assessment of the Code of Practice. However there have been insufficient test samples submitted and the rope inspector's reports have either not been submitted with the samples or have been inadequate in many details which could help in refining the code.

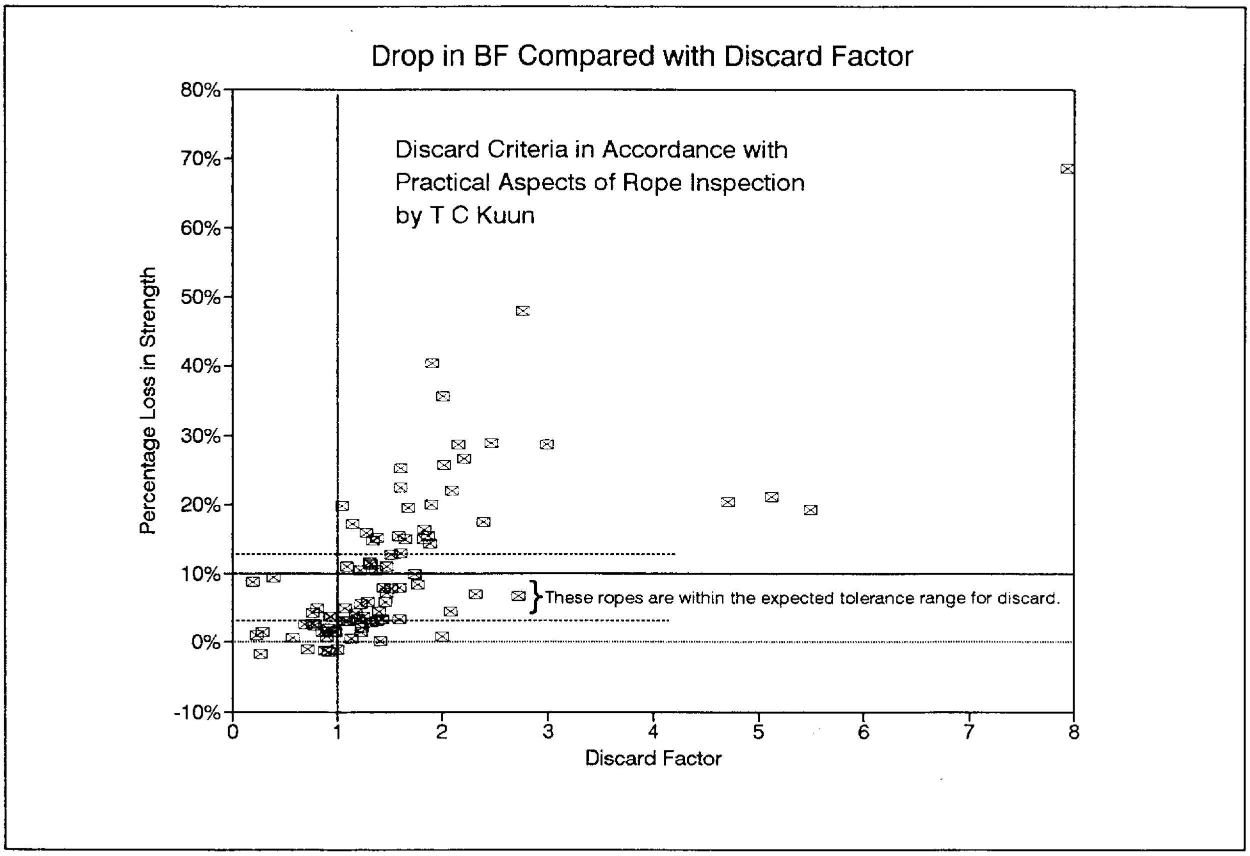

Figure 13 Loss in Strength Compared with Assessed Discard Factor - T.C.Kuun

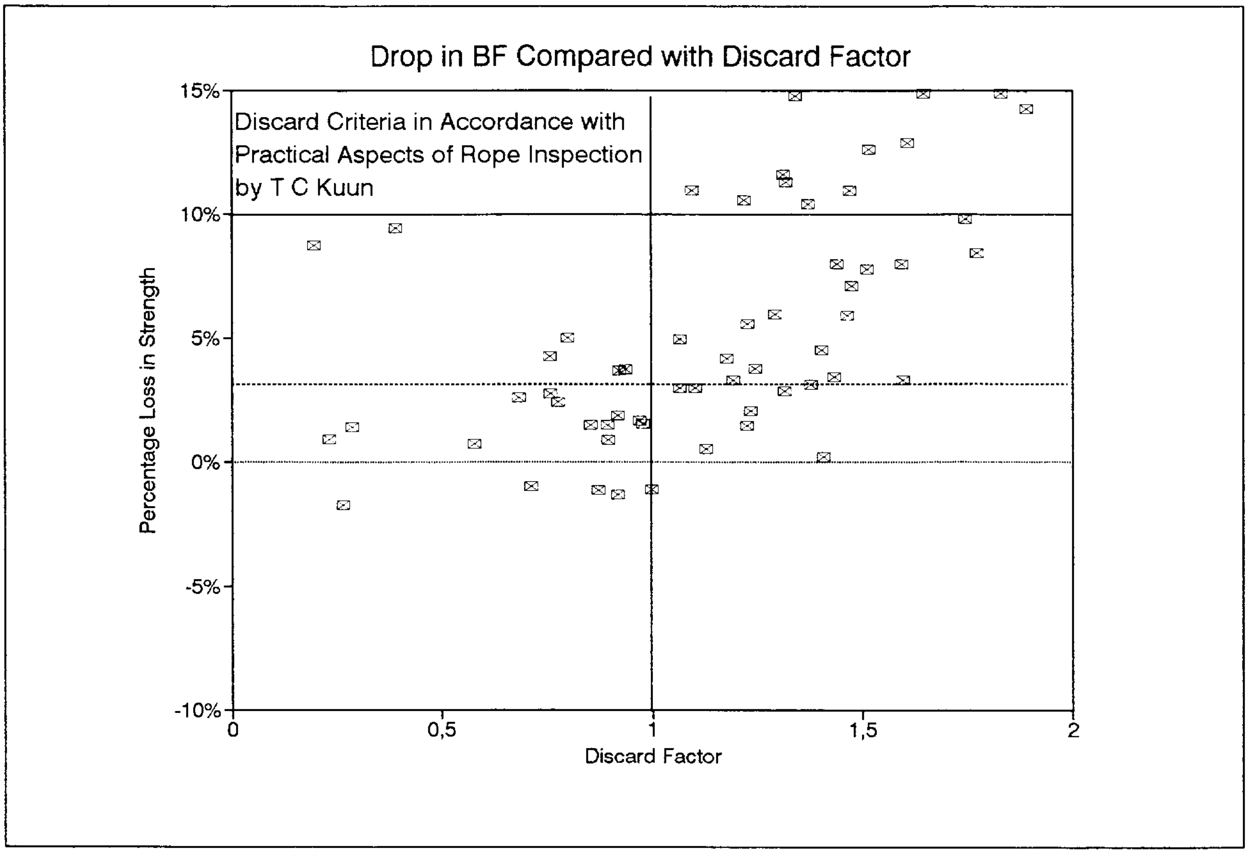

Figure 14 Portion of Figure 11 with Expanded Scale

4.1 EFFECTIVENESS OF CODE OF PRACTICE.

The results using assessed discard factors have shown that the discard criteria in the Draft Code of Practice are generally satisfactory for round strand and triangular strand ropes. The discard criteria are completely inappropriate for assessing non-spin ropes, especially those used on Koepe winders.

4.1.1 Proposal for Improved Correlation.

Comparing Figures 13 and 14 on page 14 with Figures 5 and 6 on page 7 illustrates how small alterations to the definition of symmetry and to the method of assessing the effect of broken wires in one strand can improve the spread of results by a modification for the assessment of discard factors. In Figures 13 and 14 the discard factors are assessed in terms of proposals made by Mr T.C. Kuun in his draft "Practical Aspects of Rope Inspection".

"Distribution of broken wires is called asymmetric if the defective wires are not uniformly distributed in the rope. For triangular strand and round strand ropes the following definitions apply.

- *Symmetric : when one-half or fewer of the defective wires are in two adjacent strands.*
- *Asymmetric : when more than one-half of the defective wires are in two adjacent strands (this includes the case where **all** the defective wires are in one strand only).*

A triangular strand or round strand rope must be discarded when the percentage loss in rope steel area due to defective wires over one actual lay length of the rope at any position in the rope is equal to or greater than the values listed below. It should be noted that large ropes are more sensitive to asymmetric defective wires than smaller ropes are.

Rope Diameter	*Broken Wires*	*Discard loss in rope steel area over one actual lay length due to defective wires, %*
Less than or equal to 55 mm	*Symmetric*	*7*
	Asymmetric	*4*
Larger than 55 mm	*Symmetric*	*7*
	Asymmetric	*3*

For defective wires over five actual lay lengths of the rope, the percentage loss in steel area at discard must not exceed two times the values listed above.....

...c) The number of broken wires in a single strand (in one actual lay length) shall not exceed 40 % of the total number of outer wires in that strand."

The basic differences in approach between this and the Draft Code relate to the method of assessing the effect of multiple broken wires in one strand, the definition of asymmetric broken wires and in the allowable percentage loss in steel area for both symmetric and asymmetric broken wires.

Comparison

Item	Draft Code	T.C. Kuun Proposals
Allowable loss in area - Symmetric	8 %	7 %
- Asymmetric	5 %	4 %
Allowable broken wires in one strand	3 % of steel area	40 % of number of outer wires in one strand

Based on the improved correlation, consideration should be given to modifying the Code in accordance with Mr Kuun's proposals.

4.1.2 Other Aspects.

Because of the lack of suitable inspector's reports on samples submitted an assessment of the discard criteria was attempted in accordance with the Code, in the laboratory prior to testing. This was of course a method of gaining meaningful results from the tests done on discarded ropes. The frequency distribution graph shown in Figure 1 confirmed that the samples submitted for test were mostly not cut from ropes discarded in accordance with the Code.

From many of the inspector's reports it became obvious that there was a lack of understanding of how to interpret and apply the code. It was also clear that in some cases ropes were discarded in accordance with some other criteria and not the Draft Code. There were also verbal reports that, although recommendations were made for discard, certain ropes were left in service at the discretion of the engineer in charge.

These problems need to be addressed with some urgency.

4.2 IMPORTANCE OF CORRECT OBSERVATIONS.

In the discussion there have been many references to incorrect or missing information in reports from rope inspectors, both as to rope diameter measurements, corrosion assessment and the count and distribution of broken wires. Accurate and correct information is essential for useful discard factors to be arrived at so that ropes are discarded appropriately and not, as sometimes happens, when they have become unsafe.

5 RECOMMENDATIONS.

Consequent on some of the comments in this document there is scope for further work to improve and correct the Draft Code of Practice. These recommendations are not listed in order of importance.

1. The draft code should not be used for assessing non-spin ropes. Further work is required in interpreting electro-magnetic test traces of these ropes and combining them with revised requirements for non-spin ropes. Requirements for Koepe ropes should be different to those for non-spin ropes operating on drum winders.
2. The alternative discard factors proposed by Mr T.C. Kuun should be incorporated in a revised Draft Code of Practice.
3. Considerably more discarded rope samples should be submitted for evaluation. If possible all ropes discarded in the next two years should be assessed.
4. There is a need to provide clearer guidelines for assessing broken wires when only two to four broken wires are present in adjacent strands. The current position regarding asymmetric distribution sometimes results in discard factors in excess of 1 when rope strength has hardly been affected. Further cut wire tests in this range are required.
5. Further work is required in clarifying how corrosion is assessed. It may be that the only thing needed is more explicit instructions to rope inspectors. On the other hand adequate arrangements must be made for the various types of electro-magnetic test instrument used.
6. The importance of correct measurements and observations has been emphasised. The coordination of the work of the rope inspectors and the responsible engineer needs to be clarified and all responsible engineers should be made conversant with the code and the requirements for correct measurement.

REFERENCES.

1. KUUN, T.C. "Practical Aspects of Rope Inspection." Draft of a module prepared for Safety in Mines Research Advisory Committee.

2. "Minerals Act (Act 50 of 1991) and Regulations". Government Printer.

3. DEPARTMENT OF MINERAL AND ENERGY AFFAIRS. "Proposed Amendments to the Regulations of the Minerals Act (Act 50 of 1991)".

4. SOUTH AFRICAN BUREAU OF STANDARDS. "Code of Practice - Condition Assessment of Steel Wire Ropes on Mine Winders." SABS xxxx:199x.

5. BORELLO, M. "Results of Tests on Sections from Discarded Ropes." CSIR Report MST(94)MC2122 No 940126, June 1994. Submitted to: Safety in Mines Research advisory Committee, Engineering Advisory Group.

6. BORELLO, M. AND KUUN, T.C. "The Effect of Cut Wires on the Strength of Winding Ropes." CSIR Contract Report MST(94)MC2333, Report No. 940286. Submitted to Safety in Mines Research Advisory Committee, Engineering Advisory Group. December 1994.

7. "Effect of Localised Broken Wires on Strength of Triangular Strand Rope - Simulation Tests Carried out in 1957 and 1959." Report issued by Haggie Rand Ltd. August 1990.

APPENDIX.

Abbreviated details of samples submitted for test, inspectors report (when submitted), CSIR examination of samples and discard values assigned, based on the CSIR examination, are listed in the following pages.

Winder Certificate No: 3886

SAMPLE NO: 1

Coil No:	Rope Dia:	Rope Construction:	Tensile Strength:
124259/001	49 mm	6x33T	1800 MPa
Initial BF:		*Discard BF:*	*Percentage Loss:*
1820 kN		1550 kN	14,84%

Discard Criteria **Inspectors Report**

Rope Dia: 47,8 mm

Wear/Plastic Deformation:

Broken Wires	Total:	1 Lay:	1 Lay, 1 Strand:	5 Lays:	Sym/asym:
	3	3	3		

Corrosion: Nil

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 47,9 mm

Wear/Plastic Deformation: 800 mm badly worn area. Heavy plastic flow on the outer wires.

Broken Wires	Total:	1 Lay:	1 Lay, 1 Strand:	5 Lays:	Sym/asym:
	5	5	3	5	asym

Corrosion: Very Slight

Other Comments:

Assigned Discard Factors

Rope Dia:	Broken Wires:	Corrosion:	Other:	Total Factor:
0,85	0,64			1,49

Winder Certificate No: 6058

Sample No: 2					
Coil No: 116728/002	*Rope Dia:* 44 mm	*Rope Construction:* 6x30T		*Tensile Strength:* 1900 MPa	
Initial BF: 1470 kN		*Discard BF:* 1179 kN		*Percentage Loss:* 19,8%	
Discard Criteria		**Inspectors Report**			
Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:					
Other Comments:					
Discard Criteria		**CSIR Pre Test Assessment**			
Rope Dia: 43,7 mm	*Wear/Plastic Deformation:* A mechanically damaged wire				
Broken Wires	*Total:* 6	*1 Lay:* 4	*1 Lay, 1 Strand:* 3	*5 Lays:* 6	*Sym/asym:* asym
Corrosion:	Traces				
Other Comments:	Rope failed at a badly made triangular core braze, when tested.				
Assigned Discard Factors					
Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*	
0,13	1,03			1,15	

It is not known if the badly made braze was identified at the time of discard. There is no report from the mine or the rope inspector, other than that the rope was discarded because it was too short.

Winder Certificate No: 6075

SAMPLE NO: 3

Coil No:	*Rope Dia:*	*Rope Construction:*		*Tensile Strength:*	
129350/001	52 mm	6x33T		2100 MPa	
Initial BF:		*Discard BF:*		*Percentage Loss:*	
2282 kN		1800 kN		21,12%	

Discard Criteria **Inspectors Report**

Rope Dia:	*Wear/Plastic Deformation:*				
mm	Heavy impact fatigue wear at inter layer cross-over.				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
		11			sym

Corrosion:

Other Comments: Indicated loss of 3% on EM tester.

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia:	*Wear/Plastic Deformation:*				
50,5 mm					
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	36	30	11	36	asym

Corrosion: More than slight

Other Comments: Numerous split wires.

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,32	3,78			4,10

Winder Certificate No: 7610

SAMPLE NO: 4

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
122568/003	49 mm	6x32T	1800 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1810 kN	1688 kN	6,74%

Discard Criteria **Inspectors Report**

Rope Dia:	*Wear/Plastic Deformation:*
47,4 mm	

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	6				

Corrosion: Nil

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia:	*Wear/Plastic Deformation:*
47,7 mm	

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	17	13	4	17	asym

Corrosion: Very slight

Other Comments: Lay length varied along the gauge length. Minimum 450 mm.

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,38	2,08			2,46

Winder Certificate No: 4082

SAMPLE NO: 5

Coil No:	*Rope Dia:*	*Rope Construction:*		*Tensile Strength:*	
124931/002 Sample A	48 mm	6x32T		1800 MPa	
Initial BF:		*Discard BF:*		*Percentage Loss:*	
1730 kN		1705 kN		1,45%	

Discard Criteria **Inspectors Report**

Rope Dia:	*Wear/Plastic Deformation:*				
45,1 mm					
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	4	2	1	4	sym

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia:	*Wear/Plastic Deformation:*				
46,5 mm					
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	3	2	2	3	asym

Corrosion: Very Slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,86	0,54			1,40

Winder Certificate No: 4082

Sample No: 6

Coil No:	*Rope Dia:*	*Rope Construction:*		*Tensile Strength:*	
119473/001 Sample A	48 mm	6x32T		1800 MPa	
Initial BF:		*Discard BF:*		*Percentage Loss:*	
1730 kN		1671 kN		3,41%	

Discard Criteria		**Inspectors Report**			
Rope Dia: 45,0 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:* 3	*1 Lay:* 2	*1 Lay, 1 Strand:* 1	*5 Lays:* 3	*Sym/asym:* sym
Corrosion:					
Other Comments:					

Discard Criteria		**CSIR Pre Test Assessment**			
Rope Dia: 46,0 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:* 4	*1 Lay:* 3	*1 Lay, 1 Strand:* 2	*5 Lays:* 4	*Sym/asym:* asym
Corrosion:	Very slight				
Other Comments:					

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,89	0,54			1,43

Winder Certificate No: 4082

SAMPLE NO: 7

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
119473/001 Sample B	48 mm	6x32T	1800 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1730 kN	1736 kN	1,5%

Discard Criteria — **Inspectors Report**

Rope Dia: 45,0 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion:

Other Comments:

Discard Criteria — **CSIR Pre Test Assessment**

Rope Dia: 45,9 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: Very slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,89	0			0,89

Winder Certificate No: 4082

SAMPLE NO: 8

Coil No:	*Rope Dia:*	*Rope Construction:*		*Tensile Strength:*	
119473/001 Sample C	48 mm	6x32T		1800 MPa	
Initial BF:		*Discard BF:*		*Percentage Loss:*	
1730 kN		1681 kN		2,83%	

Discard Criteria **Inspectors Report**

Rope Dia:	*Wear/Plastic Deformation:*				
45,1 mm					
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	4	2	1	4	sym

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia:	*Wear/Plastic Deformation:*				
46,0 mm	A mechanically damaged wire				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	5	2	1	5	asym

Corrosion: Very slight

Other Comments: The mechanically damaged wire was not counted as a broken wire.

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,86	0,32			1,19

Winder Certificate No: 4082

Sample No: 9

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
119473/001 Sample D	48 mm	6x32T	1800 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1730 kN	1673 kN	3,29%

Discard Criteria **Inspectors Report**

Rope Dia: 45,2 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	2	2	1	2	sym

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 46,2 mm

Wear/Plastic Deformation: A mechanically damaged wire.

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	4	2	1	4	sym

Corrosion: Very Slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,83	0,27			1,10

Winder Certificate No: 4082

SAMPLE NO: 10

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
119473/001 Sample E	48 mm	6x32T	1800 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1730 kN	1652 kN	4,51%

Discard Criteria — **Inspectors Report**

Rope Dia: 45,1 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	6	3	1	6	sym

Corrosion:

Other Comments:

Discard Criteria — **CSIR Pre Test Assessment**

Rope Dia: 46,2 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	6	2	2	6	asym

Corrosion: Very slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,86	0,54			1,40

Winder Certificate No: 4082

Sample No: 11

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
119473/001 Sample F	48 mm	6x32T	1800 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1730 kN	1665 kN	3,76%

Discard Criteria **Inspectors Report**

Rope Dia: 45,2 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	4	3	1	4	sym

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 46,2 mm

Wear/Plastic Deformation: 2 mechanically damaged wires.

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	6	4	2	6	asym

Corrosion: Very Slight

Other Comments: The mechanically damaged wires were not counted as broken wires.

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,83	0,65			1.48

Winder Certificate No: 4082

SAMPLE NO: 12

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
119473/001 Sample G	48 mm	6x32T	1800 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1730 kN	1694 kN	2,08%

Discard Criteria **Inspectors Report**

Rope Dia: 45.0 mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	4	3	1	4	sym

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 46,0 mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	4	3	1	4	asym

Corrosion: Very slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,69	0,49			1,18

Winder Certificate No: 4082

SAMPLE NO: 13

Coil No: 119473/001 Sample H	*Rope Dia:* 48 mm	*Rope Construction:* 6x32T	*Tensile Strength:* 1800 MPa
Initial BF: 1730 kN		*Discard BF:* 1673 kN	*Percentage Loss:* 3,29%

Discard Criteria **Inspectors Report**

Rope Dia: 45,0 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	4	3	1	4	sym

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 45,8 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	6	5	2	6	asym

Corrosion: Very slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,69	0,81			1,50

Winder Certificate No: 5538

Sample No: 14					
Coil No: 127236/002	*Rope Dia:* 48 mm	*Rope Construction:* 6x32T		*Tensile Strength:* 1800 MPa	
Initial BF: 1751 kN		*Discard BF:* 1738 kN		*Percentage Loss:* 0,74%	
Discard Criteria		**Inspectors Report**			
Rope Dia: mm	*Wear/Plastic Deformation:* Heavy wear at back end.				
Broken Wires	*Total:* 0	*1 Lay:* 0	*1 Lay, 1 Strand:* 0	*5 Lays:* 0	*Sym/asym:*
Corrosion:					
Other Comments:					
Discard Criteria		**CSIR Pre Test Assessment**			
Rope Dia: 45,5 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:* 0	*1 Lay:* 0	*1 Lay, 1 Strand:* 0	*5 Lays:* 0	*Sym/asym:*
Corrosion:	Very Slight				
Other Comments:					
Assigned Discard Factors					
Rope Dia: 0,58	*Broken Wires:* 0	*Corrosion:*	*Other:*	*Total Factor:* 0,58	

Winder Certificate No: 8529

Sample No: 15

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
130339/002	46 mm	6x30T	1950 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1778 kN	1636 kN	7,99%

Discard Criteria **Inspectors Report**

Rope Dia: mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 45,7 mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	6	6	4	6	asym

Corrosion: Very slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,07	1,37			1,44

Winder Certificate No:

SAMPLE NO: 16

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
018733/002	42 mm	6x25/F	1800 MPa
Initial BF:		*Discard BF:*	*Percentage Loss:*
1290 kN		1092 kN	15,35%

Discard Criteria **Inspectors Report**

Rope Dia: 39,8 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: Concentrated corrosion within 250 mm causing an hourglass effect.

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 39,9 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: More than slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,58	0	0,90		1,48

Based on the inspectors remarks a discard factor of 0,9 was assigned for corrosion.

Winder Certificate No:

SAMPLE NO: 17

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
018689/001	42 mm	6x25/F	1800 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1280 kN	1247 kN	2,58%

Discard Criteria **Inspectors Report**

Rope Dia: 40,5 mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: Concentrated corrosion within 200 mm causing an hourglass effect.

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 40,5 mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: More than slight.

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,4	0	0,20		0,60

Based on the inspectors report a discard factor of 0,20 was assigned for corrosion.

Winder Certificate No:

SAMPLE NO: 18

Coil No:	Rope Dia:	Rope Construction:	Tensile Strength:
018732/001	42 mm	6x25/F	1800 MPa

Initial BF:	Discard BF:	Percentage Loss:
1290 kN	946 kN	26,67%

Discard Criteria **Inspectors Report**

Rope Dia: 39,5 mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: Concentrated corrosion within 200 mm causing an hourglass effect

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 39,2 mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: Slight on outside of rope

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,74	0	1,03		1,77

Based on the inspectors report a discard factor of 1,03 was assigned for corrosion.

Winder Certificate No:

SAMPLE NO: 19

Coil No:	*Rope Dia:*	*Rope Construction:*		*Tensile Strength:*	
018734/003	42 mm	6x25/F		1800 MPa	
Initial BF:		*Discard BF:*		*Percentage Loss:*	
1290 kN		921 kN		28,6%	

Discard Criteria | **Inspectors Report**

Rope Dia:	*Wear/Plastic Deformation:*				
38,7 mm					
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: Concentrated corrosion within 200 mm causing an hourglass effect.

Other Comments:

Discard Criteria | **CSIR Pre Test Assessment**

Rope Dia:	*Wear/Plastic Deformation:*				
38,8 mm					
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: More than slight on outside of rope.

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,87	0	0,90		1,77

Based on the inspectors report a discard factor of 0,90 was assigned for corrosion.

Winder Certificate No:

SAMPLE NO: 20

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
018690/002	42 mm	6x25/F	1800 MPa
Initial BF:		*Discard BF:*	*Percentage Loss:*
1280 kN		1115 kN	12,89%

Discard Criteria **Inspectors Report**

Rope Dia: 39,3 mm — *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: Concentrated corrosion within 150 mm causing an hourglass effect.

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 39,9 mm — *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: More than slight on outside of rope.

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,71	0	0,63		1,34

Based on the inspectors report a discard factor of 0,63 was assigned for corrosion.

Winder Certificate No:

Sample No: 21

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
018691/003	42 mm	6x25/F	1800 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1280 kN	911 kN	28,83%

Discard Criteria **Inspectors Report**

Rope Dia: 38,2 mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: Concentrated corrosion within 300 mm caused an hourglass effect.

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 40,1 mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: More than slight on outside of rope.

Other Comments: Kink in rope 100 mm from endcap

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
1,01	0	1,03		2,03

Based on the inspectors report a discard factor of 1,03 was assigned for corrosion. The kink reported by the CSIR was probably caused in handling; at the reduced diameter where the rope was most prone to deformation in handling. No discard factor was assigned due to the kink.

Winder Certificate No: 3135A

SAMPLE NO: 22

Coil No: 66202	*Rope Dia:* 38,5 mm	*Rope Construction:* 6x28T	*Tensile Strength:* 1800 MPa
Initial BF: 1115 kN		*Discard BF:* 1084 kN	*Percentage Loss:* 2,78%

Discard Criteria **Inspectors Report**

Rope Dia: 36,9 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion: Slight

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 36,9 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	1	1	1	1	asym

Corrosion: Very slight

Other Comments: Split wire

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,46	0,45			0,91

Winder Certificate No: 7571

Sample No: 23

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
017448/004	29 mm	6x25/F	1800 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
597 kN	592 kN	0,84%

Discard Criteria **Inspectors Report**

Rope Dia: 27,5 mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion: Considerable

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 27,5 mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: Considerable

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,57	0	1,00		1,57

Based on inspectors report the discard factor of 1,00 was assigned for corrosion.

Winder Certificate No: 6047

SAMPLE NO: 24

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
115145	46 mm	6x31T	1800 MPa
Initial BF:		*Discard BF:*	*Percentage Loss:*
1660 kN		1578 kN	4,94%

Discard Criteria **Inspectors Report**

Rope Dia: 44,1 mm
Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	3	3	3	3	asym

Corrosion: Nil

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 44,9 mm
Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	3	3	3	3	asym

Corrosion: Very slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,46	0,94			1,40

Winder Certificate No: 6047

SAMPLE No: 25					
Coil No: 115146	*Rope Dia:* 46 mm	*Rope Construction:* 6x31T		*Tensile Strength:* 1800 MPa	
Initial BF: 1660 kN		*Discard BF:* 1598 kN		*Percentage Loss:* 3,73%	

Discard Criteria		**Inspectors Report**			
Rope Dia: 43,8 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:* 3	*1 Lay:* 3	*1 Lay, 1 Strand:* 2	*5 Lays:* 3	*Sym/asym:*
Corrosion:	Nil				
Other Comments:					

Discard Criteria		**CSIR Pre Test Assessment**			
Rope Dia: 44,4 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:* 2	*1 Lay:* 2	*1 Lay, 1 Strand:* 2	*5 Lays:* 2	*Sym/asym:* asym
Corrosion:	Very slight				
Other Comments:					

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,53	0,63			1,16

Winder Certificate No: 6614

SAMPLE NO: 26					
Coil No: 124257/002	*Rope Dia:* 43 mm	*Rope Construction:* 6x30T		*Tensile Strength:* 1900 MPa	
Initial BF: 1480 kN		*Discard BF:* 1496 kN		*Percentage Loss:* -1,08%	
Discard Criteria		**Inspectors Report**			
Rope Dia: 40,9 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:* 3	*1 Lay:* 3	*1 Lay, 1 Strand:* 3	*5 Lays:* 3	*Sym/asym:*
Corrosion:					
Other Comments:					
Discard Criteria		**CSIR Pre Test Assessment**			
Rope Dia: 41,5 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:* 2	*1 Lay:* 2	*1 Lay, 1 Strand:* 2	*5 Lays:* 2	*Sym/asym:* asym
Corrosion:	Very slight				
Other Comments:					
Assigned Discard Factors					
Rope Dia: 0,54	*Broken Wires:* 0,69	*Corrosion:*	*Other:*	*Total Factor:* 1,24	

Winder Certificate No: 6614

SAMPLE NO: 27

Coil No:	*Rope Dia:*	*Rope Construction:*		*Tensile Strength:*	
124258/001 Sample A	43 mm	6x30T		1900 MPa	
Initial BF:		*Discard BF:*		*Percentage Loss:*	
1470 kN		1426 kN		2,99%	

Discard Criteria **Inspectors Report**

Rope Dia:	*Wear/Plastic Deformation:*				
40,5 mm					
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	3	2		3	

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia:	*Wear/Plastic Deformation:*				
41,5 mm					
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	3	2	2	3	asym

Corrosion: Very slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,65	0,69			1,34

Winder Certificate No: 6614

Sample No: 28

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
124258/001 Sample B	43 mm	6x30T	1900 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1470 kN	1467 kN	0,20%

Discard Criteria **Inspectors Report**

Rope Dia: 40,2 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	8	5	3	8	

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 41,4 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	3	3	2	3	asym

Corrosion: Very slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,72	0,69			1,42

Winder Certificate No: 6614

SAMPLE NO: 29

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
124258/001 Sample C	43 mm	6x30T	1900 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1470 kN	1462 kN	0,54%

Discard Criteria **Inspectors Report**

Rope Dia: 40,4 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	4	2	2	4	

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 41,5 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	3	2	2	3	asym

Corrosion: Very slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,67	0,69			1,37

Winder Certificate No: 6614

SAMPLE NO: 30

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
124258/001 Sample D	43 mm	6x30T	1900 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1470 kN	1388 kN	5,58%

Discard Criteria **Inspectors Report**

Rope Dia: 40,9 mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	4	2		4	

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 41,5 mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	6	3	2	6	asym

Corrosion: Very slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,54	0,69			1,24

Winder Certificate No: 6592

SAMPLE NO: 31

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
128177/002	53 mm	6x33T	2050 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
2452 kN	2278 kN	7,10%

Discard Criteria **Inspectors Report**

Rope Dia: 51,4 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	10	5		10	asym

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 52,0 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	7	5	5	7	asym

Corrosion: Very slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,34	1,22			1,55

Winder Certificate No: 3954A

SAMPLE NO: 32

Coil No: 005622	*Rope Dia:* 45 mm	*Rope Construction:* 6x31T		*Tensile Strength:* 1800 MPa
Initial BF: 1540 kN		*Discard BF:* 1517 kN		*Percentage Loss:* 1,49%

Discard Criteria **Inspectors Report**

Rope Dia: 44,0 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:* 5	*1 Lay:* 5	*1 Lay, 1 Strand:*	*5 Lays:* 5	*Sym/asym:* asym

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 44,2 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:* 3	*1 Lay:* 3	*1 Lay, 1 Strand:* 2	*5 Lays:* 3	*Sym/asym:* asym

Corrosion: Very slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,25	0,61			0,86

Winder Certificate No: 22D

SAMPLE NO: 33					
Coil No: 114319/002	*Rope Dia:* 44 mm	*Rope Construction:* 6x30T		*Tensile Strength:* 1900 MPa	
Initial BF: 1510 kN		*Discard BF:* 973 kN		*Percentage Loss:* 35,56%	

Discard Criteria **Inspectors Report**

Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:					
Other Comments:					

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 40,0 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:* 0	*1 Lay:* 0	*1 Lay, 1 Strand:* 0	*5 Lays:* 0	*Sym/asym:*
Corrosion:	Excessive				
Other Comments:					

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
1,01	0	1,10		2,11

No inspectors report received.

Winder Certificate No: 2287

SAMPLE NO: 34

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
120203/001 Sample 1	50 mm	6x36/F	1800 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1730 kN	1688 kN	2,43%

Discard Criteria **Inspectors Report**

Rope Dia: 49,5 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments: Exceeds broken wire specification area.

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 49,5 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	15	7	2	15	sym

Corrosion: Very slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,11	0,55			0,66

Winder Certificate No: 2287

SAMPLE NO: 35

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
120203/001 Sample 2	50 mm	6x36/F	1800 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1730 kN	1760 kN	-1,73%

Discard Criteria **Inspectors Report**

Rope Dia:	*Wear/Plastic Deformation:*
49,5 mm	

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments: Exceeds broken wire specification area.

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia:	*Wear/Plastic Deformation:*
49,5 mm	

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	2	1	1	2	asym

Corrosion: Very slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,11	0,21			0,32

Winder Certificate No: 2287

SAMPLE NO: 36					
Coil No: 120203/001 Sample 3	*Rope Dia:* 50 mm	*Rope Construction:* 6x36/F		*Tensile Strength:* 1800 MPa	
Initial BF: 1730 kN		*Discard BF:* 1584 kN		*Percentage Loss:* 8,44%	

Discard Criteria		**Inspectors Report**			
Rope Dia: 49,5 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:					
Other Comments:	Exceeds broken wire specification area.				

Discard Criteria		**CSIR Pre Test Assessment**			
Rope Dia: 49,2 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:* 27	*1 Lay:* 18	*1 Lay, 1 Strand:* 4	*5 Lays:* 27	*Sym/asym:* sym
Corrosion:	Very slight				
Other Comments:					

Assigned Discard Factors				
Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,18	1,42			1,60

Winder Certificate No: 4126

SAMPLE NO: 37

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
126070/002	49 mm	6x32T	1900 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1863 kN	1448 kN	22,28%

Discard Criteria **Inspectors Report**

Rope Dia:	*Wear/Plastic Deformation:*
45,9 mm	Heavy plastic deformation

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments: Broken wires

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia:	*Wear/Plastic Deformation:*
47,4 mm	

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	7	5	3	7	asym

Corrosion: Slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,70	0,80			1,50

Winder Certificate No: 4126

Sample No: 38

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
111968/002	49 mm	6x32T	1900 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1870 kN	1892 kN	-1,18%

Discard Criteria **Inspectors Report**

Rope Dia: 48,8 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments: Twisted strand 30 m.

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 49,4 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion:

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,05	0		1,00	

A discard factor of 1 was assigned due to the twisted strand.

Winder Certificate No: 4126

SAMPLE NO: 39

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
126070/002	49 mm	6x32T	1900 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1863 kN	1394 kN	25,17%

Discard Criteria **Inspectors Report**

Rope Dia: 45,9 mm

Wear/Plastic Deformation: Heavy plastic deformation

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments: Broken wires

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 47,5 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	6	5	4	6	asym

Corrosion: Very Slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,70	1,07			1,77

Winder Certificate No: 4126

SAMPLE NO: 40

Coil No:	Rope Dia:	Rope Construction:	Tensile Strength:
111968/002	49 mm	6x32T	1900 MPa
Initial BF:		*Discard BF:*	*Percentage Loss:*
1870 kN		1898 kN	-1,50%

Discard Criteria **Inspectors Report**

Rope Dia: mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 49,3 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion:

Other Comments: One twisted strand noted

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
-0,07	0		1,00	

A discard factor of 1 was assigned due to the twisted strand. This would mean compulsory discard.

Winder Certificate No: 3176B

SAMPLE NO: 41

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
120228/001	26 mm	6x26T	1800 MPa
Initial BF:		*Discard BF:*	*Percentage Loss:*
504 kN		497 kN	1,39%

Discard Criteria **Inspectors Report**

Rope Dia: mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion: Corrosion fatigue

Other Comments: Numerous indications throughout of internal nicking and corrosion pitting.

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 26,0 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: Slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0	0	0,30		0,30

Winder Certificate No: 3176B

Sample No: 42

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
120338/001	26 mm	6x26T	1800 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
504 kN	509 kN	-0,99%

Discard Criteria **Inspectors Report**

Rope Dia: mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion: Corrosion fatigue

Other Comments: Numerous indications throughout of internal nicking and corrosion pitting.

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 25,0 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: Slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,43	0			0,43

Winder Certificate No: 4129

SAMPLE NO: 43

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
123297	48 mm	6x33T	1900 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1830 kN	1813 kN	0,93%

Discard Criteria **Inspectors Report**

Rope Dia: 47,0 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion: Indication of surface corrosion.

Other Comments: 17 broken wires throughout the length of wind.

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 47,8 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: Slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,23	0			0,23

Winder Certificate No: 4129

SAMPLE NO: 44

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
120907/001 Sample B	48 mm	6x33T	1900 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1840 kN	1824 kN	0,87%

Discard Criteria **Inspectors Report**

Rope Dia: 46,9 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	10	4	4	10	sym

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 48,2 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	7	4	2	7	asym

Corrosion: Very slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,25	0,52			0,77

Winder Certificate No: 4129

Sample No: 45

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
120907/001 Sample R	48 mm	6x33T	1900 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1840 kN	1864 kN	-1,30%

Discard Criteria **Inspectors Report**

Rope Dia: 46,1 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	11	2		11	

Corrosion:

Other Comments: Numerous spots with creeping broken wires.

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 47,2 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	4	3	2	4	asym

Corrosion: Very slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,44	0,43			0,87

Winder Certificate No: 4129

SAMPLE NO: 46

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
120905/001 Sample R/B	48 mm	6x33T	1900 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1800 kN	1821 kN	-1,17%

Discard Criteria **Inspectors Report**

Rope Dia: 47,0 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments: 90 broken wires throughout the full length of wind.

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 48,3 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	7	4	2	7	asym

Corrosion: Very slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,23	0,52			0,75

Winder Certificate No: 4129

SAMPLE NO: 47

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
115478/001 Sample Y	48 mm	6x33T	1900 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1800 kN	1766 kN	1,89%

Discard Criteria **Inspectors Report**

Rope Dia: 46,1 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments: 43 broken wires throughout the full length of wind.

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 48,2 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	4	3	3	4	asym

Corrosion: Very slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,44	0,65			1,09

Winder Certificate No: 3534

Sample No: 48

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
129603/001	49 mm	6x32T	1900 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1850 kN	1575 kN	14,86%

Discard Criteria **Inspectors Report**

Rope Dia:	*Wear/Plastic Deformation:*
46,5 mm	Slight wear on wires

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	10	7	4	10	asym

Corrosion:

Other Comments: Estimated reduction in breaking strength 15% to 20 %

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia:	*Wear/Plastic Deformation:*
46,9 mm	

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	8	7	3	8	asym

Corrosion: Very slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,57	1,12			1,69

Winder Certificate No: 78A

SAMPLE NO: 49

Coil No: 117843/002	*Rope Dia:* 41 mm	*Rope Construction:* 6x29T	*Tensile Strength:* 1800 MPa
Initial BF: 1300 kN		*Discard BF:* 1149 kN	*Percentage Loss:* 11,62%

Discard Criteria **Inspectors Report**

Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:* 17	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments: Excessive fractures and mechanical damage.

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 40,0 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:* 8	*1 Lay:* 4	*1 Lay, 1 Strand:* 3	*5 Lays:* 8	*Sym/asym:* asym

Corrosion: Very slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,27	1,06			1,33

Winder Certificate No: 4088

SAMPLE NO: 50

Coil No:	Rope Dia:	Rope Construction:	Tensile Strength:
127839/001	45 mm	6x31T	2050 MPa

Initial BF:	Discard BF:	Percentage Loss:
1786 kN	1759 kN	1,51%

Discard Criteria **Inspectors Report**

Rope Dia: 43,5 mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	2		2		

Corrosion: Nil

Other Comments: Numerous broken wires for 50 m.

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 44,1 mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	4	3	3	4	asym

Corrosion: Very slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,37	0,98			1,35

Winder Certificate No: 7616

SAMPLE NO: 51

Coil No:	*Rope Dia:*	*Rope Construction:*		*Tensile Strength:*	
118543/002	29 mm	6x25/F		1800 MPa	
Initial BF:		*Discard BF:*		*Percentage Loss:*	
568 kN		422 kN		25,70%	

Discard Criteria **Inspectors Report**

Rope Dia:	*Wear/Plastic Deformation:*				
28,2 mm					
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: More than slight

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia:	*Wear/Plastic Deformation:*				
28,5 mm					
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: More than slight

Other Comments: RAU area loss 12%

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,31	0	1,20		1,51

Based on the inspectors report a discard factor of 1,20 was assigned for corrosion.

Winder Certificate No: 7616

SAMPLE NO: 52

Coil No:	Rope Dia:	Rope Construction:	Tensile Strength:
118543/003	29 mm	6x24/F	1800 MPa

Initial BF:	Discard BF:	Percentage Loss:
564 kN	519 kN	7,98%

Discard Criteria **Inspectors Report**

Rope Dia: 28,2 mm *Wear/Plastic Deformation:*

Broken Wires	Total:	1 Lay:	1 Lay, 1 Strand:	5 Lays:	Sym/asym:
	0	0	0	0	

Corrosion: More than slight

Other Comments: RAU area loss 9%

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 29,1 mm *Wear/Plastic Deformation:*

Broken Wires	Total:	1 Lay:	1 Lay, 1 Strand:	5 Lays:	Sym/asym:
	0	0	0	0	

Corrosion: More than slight

Other Comments:

Assigned Discard Factors

Rope Dia:	Broken Wires:	Corrosion:	Other:	Total Factor:
0,31	0	0,90		1,21

Based on the inspectors report a discard factor of 0,90 was assigned for corrosion.

Winder Certificate No: 7616

Sample No: 53				
Coil No: 118543/004	*Rope Dia:* 29 mm	*Rope Construction:* 6x24/F		*Tensile Strength:* 1800 MPa
Initial BF: 564 kN		*Discard BF:* 477 kN		*Percentage Loss:* 15,43%

Discard Criteria **Inspectors Report**

Rope Dia: 28,6 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:* 0	*1 Lay:* 0	*1 Lay, 1 Strand:* 0	*5 Lays:* 0	*Sym/asym:*

Corrosion: More than slight

Other Comments: RAU area loss 12%

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 28,6 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:* 0	*1 Lay:* 0	*1 Lay, 1 Strand:* 0	*5 Lays:* 0	*Sym/asym:*

Corrosion: More than slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,15	0	1,20		1,35

Based on the inspectors report a discard factor of 1,20 was assigned for corrosion.

Winder Certificate No: 6530

SAMPLE NO: 54

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
140825	53 mm	6x33T	1950 MPa
Initial BF:		*Discard BF:*	*Percentage Loss:*
2405 kN		1986 kN	17,42%

Discard Criteria **Inspectors Report**

Rope Dia:	*Wear/Plastic Deformation:*				
54,1 mm	Asymmetrical				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	7				

Corrosion: Nil

Other Comments: 11,12% area reduction, RAV 301 type tester.

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia:	*Wear/Plastic Deformation:*				
53,0 mm					
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	5	5	5	5	asym

Corrosion: Very slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0	1,11		1,59	2,70

Based on inspectors report a discard factor of 1,59 was assigned for asymmetrical area loss.

Winder Certificate No: 6530

SAMPLE NO: 55					
Coil No: 140824	*Rope Dia:* 53 mm	*Rope Construction:* 6x33T		*Tensile Strength:* 1950 MPa	
Initial BF: 2449 kN		*Discard BF:* 1978 kN		*Percentage Loss:* 19,23%	
Discard Criteria		**Inspectors Report**			
Rope Dia: 54,1 mm	*Wear/Plastic Deformation:* Asymmetrical				
Broken Wires	*Total:* 9	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:	Nil				
Other Comments:	25,23% area reduction, RAV 301 type tester.				
Discard Criteria		**CSIR Pre Test Assessment**			
Rope Dia: 52,4 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:* 12	*1 Lay:* 11	*1 Lay, 1 Strand:* 11	*5 Lays:* 12	*Sym/asym:* asym
Corrosion:	Very slight				
Other Comments:					
Assigned Discard Factors					
Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*	
0,13	2,44		3,60	6,17	

Based on inspectors report a discard factor of 3,60 was assigned for asymmetrical area loss.

Winder Certificate No: 3132A

SAMPLE No: 56

Coil No:	*Rope Dia:*	*Rope Construction:*		*Tensile Strength:*	
127553/001	44 mm	6x30T		2050 MPa	
Initial BF:		*Discard BF:*		*Percentage Loss:*	
kN		kN		%	

Discard Criteria **Inspectors Report**

Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*

Incorrect specimen submitted.

Winder Certificate No: 7614

SAMPLE NO: 57

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
133862/002	55 mm	6x32T	1900 MPa
Initial BF:		*Discard BF:*	*Percentage Loss:*
2411 kN		2430 kN	-0,79%

Discard Criteria **Inspectors Report**

Rope Dia:	*Wear/Plastic Deformation:*				
mm					
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia:	*Wear/Plastic Deformation:*				
55,6 mm					
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: Traces

Other Comments: Specimen was wavy over full length of the sample.

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
-0,12	0		1,2	1,08

No inspector's report was received. The CSIR reported that the rope was wavy before it was tested.

Based on the fact that the rope was discarded and that it is uncommon for discarded ropes to exhibit this type of distortion a discard factor of 1,2 was assigned to cover the fact of the discard.

Winder Certificate No: 2837

SAMPLE NO: 58

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
126808/001	48 mm	6x31T	1800 MPa
Initial BF:		*Discard BF:*	*Percentage Loss:*
1799 kN		1513 kN	15,90%

Discard Criteria **Inspectors Report**

Rope Dia: 46,0 mm

Wear/Plastic Deformation: Asymmetric, heavy plastic flow.

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
			3		

Corrosion: Nil

Other Comments: Heat damage.

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 47.2 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	4	4	4	4	asym

Corrosion: Very slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,46	1,22			1,69

It is not known why the inspector marked the Discard Information Sheet: Heat Damage: Yes - Plastic flow

Winder Certificate No: 3921

SAMPLE NO: 59					
Coil No: 028653	*Rope Dia:* 47 mm	*Rope Construction:* 6x31T		*Tensile Strength:* 1800 MPa	
Initial BF: 1700 kN		*Discard BF:* 1472 kN		*Percentage Loss:* 13,41%	

Discard Criteria		**Inspectors Report**			
Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:					
Other Comments:					

Discard Criteria		**CSIR Pre Test Assessment**			
Rope Dia: 47,0 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:* 0	*1 Lay:* 0	*1 Lay, 1 Strand:* 0	*5 Lays:* 0	*Sym/asym:*
Corrosion:	Very slight				
Other Comments:	The specimen was kinked.				

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0	0		1	1

The sample was supplied as a kinked specimen for special test. There was no rope inspectors report submitted.

Winder Certificate No: 5024

SAMPLE NO: 60

Coil No: 116274/002	*Rope Dia:* 50 mm	*Rope Construction:* 6x33T	*Tensile Strength:* 1800 MPa
Initial BF: 1860 kN		*Discard BF:* 1480 kN	*Percentage Loss:* 20,43%

Discard Criteria **Inspectors Report**

Rope Dia: mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 51,3 mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
-0,29			1,3	1,01

A complete spliced end termination with a kink 0,6 m from the last tuck was submitted for a special test. A rope inspector's report was not submitted with the sample.

The specimen failed at the last tuck of the splice.

Winder Certificate No: 3552

SAMPLE NO: 61

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
108709	32 mm	6x26T	1800 MPa
Initial BF:		*Discard BF:*	*Percentage Loss:*
750 kN		598 kN	20,27%

Discard Criteria **Inspectors Report**

Rope Dia: 31,2 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments: Broken wires are all on one side of the rope and appear to be due to mechanical damage.
This section of rope used to be in the dead turns, but we cut 350 m of rope off the front end.

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 31,7 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	11	11	4	11	asym

Corrosion: Very slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,28	4,00			4,28

Winder Certificate No: 2173

SAMPLE No: 62

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
119926/001	47 mm	6x31T	1800 MPa
Initial BF:		*Discard BF:*	*Percentage Loss:*
1680 kN		1630 kN	2,98%

Discard Criteria **Inspectors Report**

Rope Dia:	*Wear/Plastic Deformation:*				
44,2 mm					
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia:	*Wear/Plastic Deformation:*				
44,7 mm					
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	3	2	1	3	asym

Corrosion: Traces

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,66	0,36			1,02

Winder Certificate No: 9530

SAMPLE NO: 63

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
029230	54 mm	6x33T	1900 MPa
Initial BF:		*Discard BF:*	*Percentage Loss:*
2290 kN		2196 kN	4,15%

Discard Criteria **Inspectors Report**

Rope Dia: mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 54,9 mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments: Specimen was kinked.

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
			1	1

A kinked specimen was submitted for a special test. No rope inspector's report was submitted with the specimen.

Winder Certificate No: 6534

SAMPLE NO: 64

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
124536/001 Sample R	45 mm	17x19/WMC non-spin	1600 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1180 kN	1233 kN	-4,49%

Discard Criteria **Inspectors Report**

Rope Dia: mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments: Broken wire indication

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 43,8 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: Traces

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,30	0			0,30

8 broken inner wires noted by CSIR during specimen preparation.

Winder Certificate No: 6534

SAMPLE NO: 65

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
130926/002 Sample G	44 mm	18 str "Fishback" Non-spin	1800 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1513 kN	1530 kN	-1,12%

Discard Criteria **Inspectors Report**

Rope Dia: 42,0 mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion: Indication of corrosion

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 42,8 mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: More than slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,51	0			0,51

Winder Certificate No: 6534

SAMPLE NO: 66

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
130926/001 Sample R/W	44 mm	18 str "Fishback" Non-spin	1800 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1536 kN	1568 kN	-2,08%

Discard Criteria **Inspectors Report**

Rope Dia: 41,9 mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion: Indication of corrosion

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 42,7 mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: More than slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,53	0			0,53

Winder Certificate No: 3994

SAMPLE NO: 67

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
127451/001 Sample 1	44 mm	18 str Compact Strand Non-spin	1600 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1427 kN	938 kN	34,27%

Discard Criteria **Inspectors Report**

Rope Dia: mm

Wear/Plastic Deformation: Heavy external abrasive and internal wear

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion: Heavy corrosion

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 42,0 mm

Wear/Plastic Deformation: Asymmetrical abrasive wear on exterior of rope

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion:

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,65	0	0,74		1,39

Based on inspector's report a discard factor of 0,74 was assigned due to corrosion.

Winder Certificate No: 3994

SAMPLE NO: 68

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
127451/001 Sample 2	44 mm	18 str Compact Strand Non-spin	1600 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1427 kN	1301 kN	8,83%

Discard Criteria **Inspectors Report**

Rope Dia: mm

Wear/Plastic Deformation: Heavy internal wear

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion: Heavy corrosion

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 43,5 mm

Wear/Plastic Deformation: Asymmetrical abrasive wear on exterior of rope

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	1	1	1	1	sym

Corrosion: Excessive

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,16	0,02	0,34		0,53

Based on inspector's report a discard factor of 0,34 was assigned due to corrosion.

Winder Certificate No: 3994

SAMPLE NO: 69

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
127451/001 Sample 3	44 mm	18 str Compact Strand Non-spin	1600 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1427 kN	774 kN	45,76%

Discard Criteria **Inspectors Report**

Rope Dia: mm

Wear/Plastic Deformation: External abrasive wear

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion: Slight internal corrosion

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 43,8 mm

Wear/Plastic Deformation: Severe localised asymmetrical abrasive wear on exterior of rope. Some of the outer wires worn to an hourglass shape.

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: More than slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,06	0	0,21		0,28

Based on inspector's report a discard factor of 0,21 was assigned due to corrosion. No assignment was made related to the excessive asymmetrical localised wear.

Winder Certificate No: 3994

SAMPLE NO: 70

Coil No:	Rope Dia:	Rope Construction:	Tensile Strength:
127451/001 Sample 4	44 mm	18 str Compact Strand Non-spin	1600 MPa

Initial BF:	Discard BF:	Percentage Loss:
1427 kN	1287 kN	9,81%

Discard Criteria **Inspectors Report**

Rope Dia:	Wear/Plastic Deformation:
mm	

Broken Wires	Total:	1 Lay:	1 Lay, 1 Strand:	5 Lays:	Sym/asym:

Corrosion: Slight corrosion

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia:	Wear/Plastic Deformation:
44,3 mm	Slight symmetrical abrasive wear on exterior of rope

Broken Wires	Total:	1 Lay:	1 Lay, 1 Strand:	5 Lays:	Sym/asym:
	0	0	0	0	

Corrosion: Slight

Other Comments:

Assigned Discard Factors

Rope Dia:	Broken Wires:	Corrosion:	Other:	Total Factor:
-,08	0	0		-0,08

Winder Certificate No: 3994

SAMPLE NO: 71

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
127451/001 Sample 5	44 mm	18 str Compact Strand Non-spin	1600 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1427 kN	1277 kN	10,51%

Discard Criteria **Inspectors Report**

Rope Dia: mm

Wear/Plastic Deformation: Heavy internal abrasive and internal wear

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion: Heavy corrosion

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 43,3 mm

Wear/Plastic Deformation: Excessive asymmetrical abrasive wear on exterior of rope

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: More than slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,23	0	0,43		0,66

Based on inspector's report a discard factor of 0,43 was assigned due to corrosion.

Winder Certificate No: 3535

SAMPLE NO: 72					
Coil No: 127621/001	*Rope Dia:* 40 mm	*Rope Construction:* 15 str Non-spin Stage rope		*Tensile Strength:* 1800 MPa	
Initial BF: 1237 kN		*Discard BF:* 1178 kN		*Percentage Loss:* 55,88%	

Discard Criteria **Inspectors Report**

Rope Dia: 36,5 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments: EMT instrument indicated 14 % loss of steel area, visual inspection revealed dark blue discolouration.

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 37,1 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments: Sample submitted as a heat damaged stage rope.

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,97			2,0	2,97

HEAT DAMAGED ROPE.
Based on inspectors report a discard factor of 2,0 was assigned due to EM instrument indication.

Winder Certificate No: 2142

SAMPLE NO: 73

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
136263	46 mm	6x31T	1800 MPa
Initial BF:		*Discard BF:*	*Percentage Loss:*
1800 kN		1522 kN	7,76%

Discard Criteria **Inspectors Report**

Rope Dia: mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments: Damaged section. Car fell down the shaft.

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 45,7 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	10	7	7	10	asym

Corrosion:

Other Comments: Broken wires the result of localised mechanical damage.

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,09	2,19			2,28

Winder Certificate No: 4015

SAMPLE NO: 74

Coil No:	*Rope Dia:*	*Rope Construction:*		*Tensile Strength:*	
55070	46 mm	6x31T		1800 MPa	
Initial BF:		*Discard BF:*		*Percentage Loss:*	
1585 kN		1351 kN		14,76%	

Discard Criteria **Inspectors Report**

Rope Dia:	*Wear/Plastic Deformation:*				
mm	Excessive wear uniformly distributed				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	4	3		4	sym

Corrosion: Heavily pitted

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia:	*Wear/Plastic Deformation:*				
44,3 mm					
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: Slight pitting

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,48	0	0,60		1,08

The incorrect sample was supplied, however, because the rope had been prepared it was tested. On the assumption that the diameter measurements and the EM test corrosion readings were similar, discard factors of 0,48 for diameter reduction and 0,60 for corrosion were assigned.

Winder Certificate No: 5022

Sample No: 75

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
118790/001	50 mm	6x33T	1800 MPa
Initial BF:		*Discard BF:*	*Percentage Loss:*
1820 kN		1621 kN	10,93%

Discard Criteria **Inspectors Report**

Rope Dia:	*Wear/Plastic Deformation:*				
46,2 mm	Symmetrical				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion: Nil

Other Comments: Rope deformed

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia:	*Wear/Plastic Deformation:*				
47,6 mm	Uniform abrasive wear and plastic deformation of outer wires.				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: Very slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,84	0		0,25	1,09

Based on the inspectors report of deformation, a discard factor of 0,25 was assigned for other.

Winder Certificate No:

SAMPLE NO: 76

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
203138/002	28 mm	6x19/F	1750 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
528 kN	473 kN	10,42%

Discard Criteria **Inspectors Report**

Rope Dia:	*Wear/Plastic Deformation:*				
mm					
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion: EM test trace showed 2 %

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia:	*Wear/Plastic Deformation:*				
26,5 mm	Slight plastic deformation				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	1	1	1	1	asym

Corrosion: None

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,77	0,43	0,20		1,39

Based on the EM trace a discard factor of 0,20 was assigned for corrosion.

Winder Certificate No: 3506

Sample No: 77

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
125655/001	51 mm	6x32T	1800 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
2020 kN	1626 kN	19,50%

Discard Criteria **Inspectors Report**

Rope Dia: mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments: Rope discarded due to broken wires

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 49,9 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	13	8	6	13	asym

Corrosion: None

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,24	1,62	0		1,86

Winder Certificate No: 3506

SAMPLE NO: 78

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
125655/002	51 mm	6x32T	1800 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
2020 kN	1765 kN	12,62%

Discard Criteria **Inspectors Report**

Rope Dia: mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments: Rope discarded due to broken wires

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 49,0 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	11	6	3	11	asym

Corrosion: None

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,44	0,97	0		1,41

Winder Certificate No: 1775

SAMPLE NO: 79

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
115812/001 Sample A	34 mm	6x28T	1800 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
881 kN	459 kN	47,9%

Discard Criteria **Inspectors Report**

Rope Dia: mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 31,0 mm

Wear/Plastic Deformation: Heavy plastic deformation

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	6	6	3	6	asym

Corrosion: None

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,98	1,64	0		2,62

Winder Certificate No: 1775

SAMPLE NO: 80

Coil No:	Rope Dia:	Rope Construction:	Tensile Strength:
115812/001 Sample B	34 mm	6x28T	1800 MPa

Initial BF:	Discard BF:	Percentage Loss:
881 kN	841 kN	4,54%

Discard Criteria **Inspectors Report**

Rope Dia: mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 33,1 mm

Wear/Plastic Deformation: Excessive plastic flow

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	6	6	3	6	asym

Corrosion: Slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,29	1,64	0		1,93

It is not known if there was a mix-up with this sample because the description and position measurements of the broken wires exactly duplicated Number 79.

Winder Certificate No: 1775

Sample No: 81

Coil No:	*Rope Dia:*	*Rope Construction:*		*Tensile Strength:*	
124823/004 Sample A	34 mm	6x28T		1800 MPa	
Initial BF:		*Discard BF:*		*Percentage Loss:*	
870 kN		794 kN		8,74%	

Discard Criteria		**Inspectors Report**			
Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:					
Other Comments:					

Discard Criteria		**CSIR Pre Test Assessment**			
Rope Dia: 33,4 mm	*Wear/Plastic Deformation:* Plastic deformation				
Broken Wires	*Total:* 0	*1 Lay:* 0	*1 Lay, 1 Strand:* 0	*5 Lays:* 0	*Sym/asym:*
Corrosion:	Traces				
Other Comments:					

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,20	0	0		0,20

In the absence of the rope inspector's report the assigned discard factors are based only on the CSIR inspection before the test. These do not reflect the condition of the rope as determined in the test. It is possible that important on-site inspection information such as accurate rope diameter measurements may have given more appropriate discard factors.

Winder Certificate No: 1775

SAMPLE NO: 82					
Coil No: 124823/004 Sample B	*Rope Dia:* 34 mm	*Rope Construction:* 6x28T		*Tensile Strength:* 1800 MPa	
Initial BF: 870 kN		*Discard BF:* 788 kN		*Percentage Loss:* 9,43%	
Discard Criteria		**Inspectors Report**			
Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:					
Other Comments:					
Discard Criteria		**CSIR Pre Test Assessment**			
Rope Dia: 32,8 mm	*Wear/Plastic Deformation:* Plastic deformation				
Broken Wires	*Total:* 0	*1 Lay:* 0	*1 Lay, 1 Strand:* 0	*5 Lays:* 0	*Sym/asym:*
Corrosion:					
Other Comments:					
Assigned Discard Factors					
Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*	
0,39	0	0		0,39	

In the absence of the rope inspector's report the assigned discard factors are based only on the CSIR inspection before the test. These do not reflect the condition of the rope as determined in the test. It is possible that important on-site inspection information such as accurate rope diameter measurements may have given more appropriate discard factors.

Winder Certificate No: 6592

SAMPLE NO: 83

Coil No:	*Rope Dia:*	*Rope Construction:*		*Tensile Strength:*	
126959/001	53 mm	6x33T		2050 MPa	
Initial BF:		*Discard BF:*		*Percentage Loss:*	
2469 kN		1974 kN		20,5%	

Discard Criteria **Inspectors Report**

Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:					
Other Comments:					

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 50,8 mm	*Wear/Plastic Deformation:* Plastic deformation on outer wires				
Broken Wires	*Total:* 11	*1 Lay:* 9	*1 Lay, 1 Strand:* 5	*5 Lays:* 11	*Sym/asym:* asym
Corrosion:	Traces				
Other Comments:					

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,46	1,16	0		1,62

Winder Certificate No: 6592

SAMPLE NO: 84

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
126959/002	53 mm	6x33T	2050 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
2432 kN	2034 kN	16,37%

Discard Criteria **Inspectors Report**

Rope Dia: mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 51,1 mm

Wear/Plastic Deformation: Plastic deformation on outer wires

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	10	9	4	10	asym

Corrosion: Traces

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,40	1,16	0		1,56

Winder Certificate No: 5096

Sample No: 85					
Coil No: 128111/001	*Rope Dia:* 49 mm	*Rope Construction:* 6x32T		*Tensile Strength:* 2000 MPa	
Initial BF: 2063 kN		*Discard BF:* 1846 kN		*Percentage Loss:* 10,52%	
Discard Criteria		**Inspectors Report**			
Rope Dia: 46,8 mm	*Wear/Plastic Deformation:* Uniform				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:* 4	*5 Lays:*	*Sym/asym:*
Corrosion:	Very slight				
Other Comments:					
Discard Criteria		**CSIR Pre Test Assessment**			
Rope Dia: 47,4 mm	*Wear/Plastic Deformation:* Plastic deformation				
Broken Wires	*Total:* 4	*1 Lay:* 4	*1 Lay, 1 Strand:* 4	*5 Lays:* 4	*Sym/asym:* asym
Corrosion:	Traces				
Other Comments:					
Assigned Discard Factors					
Rope Dia: 0,50	*Broken Wires:* 1,07	*Corrosion:* 0	*Other:*	*Total Factor:* 1,57	

Winder Certificate No: 8529

SAMPLE NO: 86

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
130339/003	46 mm	6x30T	1950 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1790 kN	1519 kN	15,14%

Discard Criteria **Inspectors Report**

Rope Dia: mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 45,0 mm

Wear/Plastic Deformation: Plastic deformation

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	5	5	2	5	asym

Corrosion:

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,24	1,03			1,27

Winder Certificate No:

Sample No: 87

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
130339/003 Sample B	46 mm	6x30T	1950 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1790 kN	kN	%

Discard Criteria **Inspectors Report**

Rope Dia: mm *Wear/Plastic Deformation:*

Broken Wires *Total:* *1 Lay:* *1 Lay, 1 Strand:* *5 Lays:* *Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: mm *Wear/Plastic Deformation:*

Broken Wires *Total:* *1 Lay:* *1 Lay, 1 Strand:* *5 Lays:* *Sym/asym:*

Corrosion:

Other Comments:

Assigned Discard Factors

Rope Dia: *Broken Wires:* *Corrosion:* *Other:* *Total Factor:*

Sample has not been inspected or tested.

Winder Certificate No: 5525A

SAMPLE NO: 88

Coil No: 129357/002	*Rope Dia:* 44 mm	*Rope Construction:* 6x31T		*Tensile Strength:* 1800 MPa	
Initial BF: 1511 kN		*Discard BF:* 1421 kN		*Percentage Loss:* 1,29%	

Discard Criteria **Inspectors Report**

Rope Dia: 44,1 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:* 5	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion: Slight

Other Comments: Broken wires and wear

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 43,0 mm	*Wear/Plastic Deformation:* Plastic deformation				
Broken Wires	*Total:* 6	*1 Lay:* 5	*1 Lay, 1 Strand:* 3	*5 Lays:* 6	*Sym/asym:* asym

Corrosion: Traces

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,28	0,93			1,20

Winder Certificate No:

SAMPLE NO: 89

Coil No:	*Rope Dia:*	*Rope Construction:*		*Tensile Strength:*	
132173 Sample A	28 mm	6x19/F		1800 MPa	
Initial BF:		*Discard BF:*		*Percentage Loss:*	
467 kN		147 kN		68,53%	

Discard Criteria **Inspectors Report**

Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 25,4 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:* 29	*1 Lay:* 20	*1 Lay, 1 Strand:* 9	*5 Lays:* 29	*Sym/asym:* sym

Corrosion: Excessive

Other Comments: Mechanical damage along the entire length of the sample

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
1,03	3,59	0,50		5,12

Based on CSIR pre test inspection a discard of 0,50 was assigned for corrosion.

Winder Certificate No:

SAMPLE NO: 90

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
132173 Sample A	28 mm	6x19/F	1800 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
467 kN	474 kN	-1,50%

Discard Criteria **Inspectors Report**

Rope Dia: mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 26,4 mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion:

Other Comments: Slight kink at centre of specimen.
Mechanical damage along entire length.

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,63	0		1	1,63

The sample had a kink at the centre.
A discard factor of 1 was assigned because of the kink in the sample.

Winder Certificate No: 5002

SAMPLE NO: 91

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
119924/001	47 mm	6x31T	1800 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1660 kN	1632 kN	1,69%

Discard Criteria — **Inspectors Report**

Rope Dia: 42,9 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion: Nil

Other Comments:

Discard Criteria — **CSIR Pre Test Assessment**

Rope Dia: 44,6 mm

Wear/Plastic Deformation: Plastic flow

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: Slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,97	0			0,97

Winder Certificate No: 5002

Sample No: 92

Coil No:	*Rope Dia:*	*Rope Construction:*		*Tensile Strength:*	
119925/001	47 mm	6x31T		1800 MPa	
Initial BF:		*Discard BF:*		*Percentage Loss:*	
1650 kN		1589 kN		3,70%	

Discard Criteria **Inspectors Report**

Rope Dia:	*Wear/Plastic Deformation:*				
43,1 mm	Very heavy crown wear				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	1	1	1	1	sum

Corrosion: Nil

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia:	*Wear/Plastic Deformation:*				
44,0 mm	Heavy crown wear Plastic flow				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: Slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,92	0			0,92

Winder Certificate No: 6023A

SAMPLE NO: 93

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
019150	34 mm	6x26T	1900 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
906 kN	751 kN	17,11%

Discard Criteria **Inspectors Report**

Rope Dia: mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 34,2 mm

Wear/Plastic Deformation: Heavy crown wear, considerable plastic flow

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	3	3	3	3	asym

Corrosion: Slight

Other Comments: Metal label attached to specimen indicated Coil No 019098

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
-0,07	1,83			1,76

Coil No 019098 was the other rope of the pair installed on this winder.

Winder Certificate No: 3521

SAMPLE NO: 94

Coil No: 127709/001	*Rope Dia:* 56 mm	*Rope Construction:* 6x32T	*Tensile Strength:* 1800 MPa
Initial BF: kN		*Discard BF:* kN	*Percentage Loss:* %

Discard Criteria **Inspectors Report**

Rope Dia: mm *Wear/Plastic Deformation:*

Broken Wires *Total:* *1 Lay:* *1 Lay, 1 Strand:* *5 Lays:* *Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: mm *Wear/Plastic Deformation:*

Broken Wires *Total:* *1 Lay:* *1 Lay, 1 Strand:* *5 Lays:* *Sym/asym:*

Corrosion:

Other Comments:

Assigned Discard Factors

Rope Dia: *Broken Wires:* *Corrosion:* *Other:* *Total Factor:*

Sample still to be inspected and tested.

Winder Certificate No: 1

SAMPLE NO: 95

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
129543/001	40 mm	6x30T	1800 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1208 kN	1124 kN	6,95%

Discard Criteria **Inspectors Report**

Rope Dia: mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 38,2 mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	10	8	5	10	sym

Corrosion: Traces

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,50	1,70			2,20

No rope inspector's report submitted with the sample.

Winder Certificate No:

SAMPLE NO: 96

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
304847/002	42 mm	6x29T	1900 MPa
Initial BF:		*Discard BF:*	*Percentage Loss:*
1375 kN		1075 kN	21,82%

Discard Criteria **Inspectors Report**

Rope Dia: 39,0 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	9				

Corrosion: None

Other Comments: 9 broken wires in two strands, one strand apart

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Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 39,5 mm

Wear/Plastic Deformation: Plastic flow on outer wires

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	5	5	4	5	asym

Corrosion: None

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,79	1,39	0		2,19

Winder Certificate No:

SAMPLE NO: 97

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
304847/001	42 mm	6x29T	1900 MPa
Initial BF:		*Discard BF:*	*Percentage Loss:*
1377 kN		983 kN	28,61%

Discard Criteria **Inspectors Report**

Rope Dia: 40,5 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	8				

Corrosion: None

Other Comments: This section was found at the hawse hole.

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 42 mm

Wear/Plastic Deformation: Slight plastic deformation

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	10	10	6	10	asym

Corrosion: None

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,40	2,09	0		2,49

Winder Certificate No: 5052

SAMPLE NO: 98

Coil No: 127441/001	*Rope Dia:* 50 mm	*Rope Construction:* 6x33T	*Tensile Strength:* 1800 MPa
Initial BF: 1923 kN		*Discard BF:* 1827 kN	*Percentage Loss:* 4,99%

Discard Criteria **Inspectors Report**

Rope Dia: 46,4 mm	*Wear/Plastic Deformation:* Heavy crown wear				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 47,6 mm	*Wear/Plastic Deformation:* Heavy crown wear, plastic flow				
Broken Wires	*Total:* 0	*1 Lay:* 0	*1 Lay, 1 Strand:* 0	*5 Lays:* 0	*Sym/asym:*

Corrosion: Slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,80	0	0		0,8

Winder Certificate No: 5052

SAMPLE NO: 99

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
127441/002	50 mm	6x33T	1800 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1923 kN	1841 kN	4,26%

Discard Criteria **Inspectors Report**

Rope Dia:	*Wear/Plastic Deformation:*
46,6 mm	Heavy crown wear

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia:	*Wear/Plastic Deformation:*
47,3 mm	Plastic flow on outer wires

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: Slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,76	0	0		0,76

Winder Certificate No:

SAMPLE NO: 100

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
125217/002 Sample A	47 mm	6x32T	1800 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1640 kN	979 kN	40,30%

Discard Criteria **Inspectors Report**

Rope Dia: mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia:	*Wear/Plastic Deformation:*
45,8 mm	Plastic deformation

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	12	9	3	12	asym

Corrosion: Slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,28	1,47			1,75

Winder Certificate No:

SAMPLE NO: 101

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
125217/002 Sample B	47 mm	6x32T	1800 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1640 kN	1455 kN	11,28%

Discard Criteria **Inspectors Report**

Rope Dia: mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 46,0 mm

Wear/Plastic Deformation: Plastic deformation

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	6	6	3	6	asym

Corrosion: Slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,24	0,98			1,22

Winder Certificate No: 4084

SAMPLE NO: 103					
Coil No: 122314/001	*Rope Dia:* 48 mm	*Rope Construction:* 6x32T		*Tensile Strength:* 1800 MPa	
Initial BF: 1730 kN		*Discard BF:* kN		*Percentage Loss:* %	
Discard Criteria		**Inspectors Report**			
Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:					
Other Comments:					
Discard Criteria		**CSIR Pre Test Assessment**			
Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:					
Other Comments:					
Assigned Discard Factors					
Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*	

Incorrect specimen sent.

Winder Certificate No: 8513

SAMPLE NO: 104

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
120603 Sample A	38 mm	6x26C/F	1800 MPa
Initial BF:		*Discard BF:*	*Percentage Loss:*
1060 kN		956 kN	9,81%

Discard Criteria **Inspectors Report**

Rope Dia:	*Wear/Plastic Deformation:*				
33,75 mm					
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion: Advanced corrosion

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia:	*Wear/Plastic Deformation:*				
34,2 mm	Extensive plastic flow				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: Extensive surface corrosion

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
1,24	0	0,50		1,74

Based on inspectors comments a discard factor of 0,50 was assigned for corrosion.

Winder Certificate No: 8513

Sample No: 105

Coil No:	*Rope Dia:*	*Rope Construction:*		*Tensile Strength:*	
120604/001 Sample A	38 mm	6x26C/F		1800 MPa	
Initial BF:		*Discard BF:*		*Percentage Loss:*	
1060 kN		997 kN		5,94%	

Discard Criteria **Inspectors Report**

Rope Dia:	*Wear/Plastic Deformation:*				
34,7 mm					
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion: Advanced corrosion

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia:	*Wear/Plastic Deformation:*				
35,1 mm	Plastic deformation				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: Extensive external corrosion

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,96	0	0,50		1,46

Based on inspectors comments a discard factor of 0,50 was assigned for corrosion.

Winder Certificate No: 8513

SAMPLE NO: 106					
Coil No: 120603 Sample B	*Rope Dia:* 38 mm	*Rope Construction:* 6x26C/F		*Tensile Strength:* 1800 MPa	
Initial BF: 1060 kN		*Discard BF:* 1027 kN		*Percentage Loss:* 3,11%	
Discard Criteria		**Inspectors Report**			
Rope Dia: 35,0 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:	Advanced corrosion				
Other Comments:					
Discard Criteria		**CSIR Pre Test Assessment**			
Rope Dia: 35,6 mm	*Wear/Plastic Deformation:* Plastic flow				
Broken Wires	*Total:* 0	*1 Lay:* 0	*1 Lay, 1 Strand:* 0	*5 Lays:* 0	*Sym/asym:*
Corrosion:	Extensive surface corrosion				
Other Comments:					
Assigned Discard Factors					
Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*	
0,88	0	0,20		1,08	

Based on inspectors comments a discard factor of 0,20 was assigned for corrosion.

Winder Certificate No: 8513

SAMPLE NO: 107

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
120604 Sample B	38 mm	6x26C/F	1800 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1060 kN	909 kN	14,25%

Discard Criteria **Inspectors Report**

Rope Dia: 33,25 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion: Advanced corrosion

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 34,0 mm

Wear/Plastic Deformation: Plastic flow

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: Extensive surface corrosion

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
1,39	0	0,50		1,89

Based on inspectors comments a discard factor of 0,50 was assigned for corrosion.

Winder Certificate No: 8513

SAMPLE NO: 108

Coil No:	*Rope Dia:*	*Rope Construction:*	*Tensile Strength:*
120603 Sample C	38 mm	6x26C/F	1800 MPa

Initial BF:	*Discard BF:*	*Percentage Loss:*
1060 kN	1016 kN	4,15%

Discard Criteria **Inspectors Report**

Rope Dia: 35,0 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments: Adjacent sample

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 35,6 mm

Wear/Plastic Deformation: Plastic deformation

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: Extensive surface corrosion

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,88	0	0,30		1,18

Based on CSIR pre test inspection, a discard factor of 0,30 was assigned for corrosion.

Winder Certificate No: 8513

SAMPLE NO: 109

Coil No:	Rope Dia:	Rope Construction:	Tensile Strength:
120604 Sample C	38 mm	6x26C/F	1800 MPa

Initial BF:	Discard BF:	Percentage Loss:
1060 kN	944 kN	10,94%

Discard Criteria **Inspectors Report**

Rope Dia: 34,0 mm

Wear/Plastic Deformation:

Broken Wires	Total:	1 Lay:	1 Lay, 1 Strand:	5 Lays:	Sym/asym:

Corrosion:

Other Comments: Adjacent sample

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 34,2 mm

Wear/Plastic Deformation: Plastic flow throughout

Broken Wires	Total:	1 Lay:	1 Lay, 1 Strand:	5 Lays:	Sym/asym:
	0	0	0	0	

Corrosion: Extensive external corrosion

Other Comments:

Assigned Discard Factors

Rope Dia:	Broken Wires:	Corrosion:	Other:	Total Factor:
1,17	0	0,30		1,47

Based on CSIR pre test inspection, a discard factor of 0,30 was assigned for corrosion.

Project No.: MHEAG

MST(95)MC2487
Report No.: 950131

A LITERATURE REVIEW OF THE USE OF MAGNETIC TESTING OF STEEL WIRE ROPES, WITH PARTICULAR REGARD TO ROPE DISCARD CRITERIA

by

A James

Submitted to: Safety in Mines Research Advisory Committee
Engineering Advisory Group

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Mine Hoisting Technology
DIVISION OF MATERIALS SCIENCE AND TECHNOLOGY
May 1995

Reviewed by: G F K Hecker

AJ/lc

EXECUTIVE SUMMARY

Over 100 papers and publications relating to the magnetic testing of steel wire ropes and rope discard criteria have been studied for the purpose of this literature review.

To date, only the Canadians have included statutory magnetic testing in safety and inspection regulations and have stipulated a loss of breaking strength related to the results of such tests.

Much work has been done over the years in order to achieve accurate predictions of loss of breaking strength, but this work was largely without success. Only Aimone in the USA has developed a technique, which includes the measurement of localised metal loss due to corrosion pitting, and which gives a more realistic figure.

The information in the literature review does not give any guidelines that relate the loss in rope strength to the results of magnetic testing. Furthermore, a comprehensive set of discard criteria could not be found in the publications consulted.

1. INTRODUCTION

Safety in the South African Mining Industry is of paramount importance. Since 1904, the destructive testing of mine hoisting ropes has been a statutory requirement and, according to the South African Minerals Act[1], ropes should be discarded when they have lost 10% of their original strength.

The 10% loss in strength regulation applies for all modes of rope deterioration and therefore does not differentiate between the deterioration modes.

In 1992 the Steering Committee on Factors of Safety of Winder Ropes decided to draft a Code of Practice for Rope Condition Assessment, of which magnetic testing would form an integral part. The Code of Practice was based on the inspection of triangular strand ropes operating on drum winders as the majority of deep shafts in South Africa operate using this rope construction. However, new proposed regulations were subsequently circulated for comment before the Code of Practice was completed, which changed the scope of the work as these now covered all types of rope construction. Consequently, in 1994, a new draft Code of Practice[2] was issued through the efforts of the SABS Working Group on Rope Condition Assessment. The Code contains discard criteria based on the collective knowledge of rope testers and on some experimental work.

In order to establish whether the new draft Code would meet at least the short term requirements of the Mining Industry, it would be necessary to verify the Code by conducting destructive tests on actual discarded sections of rope. The ropes would be supplied by the mines, having been discarded according to the discard criteria outlined in the Code. The discarded sections would then be tested by the CSIR and the results would indicate how well the discard criteria in the Code would meet the statutorily allowed strength reductions and what modifications would be necessary.

As a parallel thrust to the verification of the Code by destructive testing, the Safety in Mines Research Advisory Committee also decided that it would be helpful to carry out a literature study of the magnetic testing of steel wire ropes, with particular regard to the correlation between the estimated loss of breaking strength (calculated from the loss of metal area) and the actual breaking strength of the rope and, indeed, if such condition monitoring was part of any formulated discard criteria.

The draft Code of Practice[2] specifies the techniques, procedures (Section 7, p12 of the Code) and the equipment (Section 8, p24) used for the magnetic testing of steel wire ropes on mine winders. 'The apparatus is used mainly to detect the presence and location of defects and anomalies and to assist in the assessment of loss of strength. Additional measurements and visual examination are essential for further requirements when assessing the condition of a rope'. Magnetic test equipment is used for the assessment of broken wires, rope steel area and corrosion. Detailed capability specifications of magnetic test instruments are included in the Code.

2. ROPE DISCARD CRITERIA

Many of the current national standards and specifications regarding rope discard criteria cover crane ropes, elevator ropes, cableway ropes and ropes for general engineering applications. These include DIN 15020[3], ISO 4309[4], BS 6570[5] and the American Wire Users Manual[6]. A comparison of these standards by Beck[7] has shown that no single standard covers all the modes of rope deterioration and, in fact, most of the discard criteria discussed are unsuitable for mine ropes.

To date, the discard criteria for mine hoisting ropes have been specifically related to the loss in rope strength, which can be caused by a number of deterioration modes. The available mine hoist rope discard regulations of various countries are discussed below:

Australia

The discard criteria of winding ropes in Australia are legislated by the Department of Minerals and Energy, Mines Inspection Act, 1901 and General Rules (revised to 1988)[8]. The general testing requirements is that at least once every 6 months, the front end of the rope must be cut off for test. The strength discard criteria, however, vary from State to State. In Western Australia no discard criteria are specified and in Queensland only visible deterioration due to broken wires, corrosion, loss in diameter and changes in lay length are specified. In Southern Australia, Northern Territory and Victoria a 25% reduction in strength is permissible, with the added qualification in Southern Australia of visible deterioration.

The factors of safety are also an important discard criteria in Australia. No hoisting rope shall be used when the factor of safety has fallen below:

		New Ropes		
Man Winding:	5	surface to	600 m:	8
		below	600 m:	6
Rock Winding:	4,5	surface to	600 m:	6
		below	600 m:	5

Canada (Ontario)

The discard criteria of winding ropes in Ontario are covered by the Occupational Health and Safety Act and Regulations for Mines and Mining Plants[9].

No rope shall be used as a shaft rope where the breaking strength of the rope has dropped below the following:

(a)	In any part of a hoisting rope:	90%
(b)	In any part of a multi-layer, multi-strand balance rope:	90%
(c)	In any part of a single layer stranded balance rope:	85%
(d)	In any part of a guide or rubbing rope:	75%

Notwithstanding the above discard criteria, no rope shall be used as a shaft rope where,

(a) the extension of a test piece has decreased to below 60% of its original extension when tested to destruction and marked corrosion or considerable loss in wire torsion has occurred.

(b) the number of broken wires, excluding filler wires, in any section equal to one lay length exceeds 5% of the total, or

(c) the rate of stretch in a friction hoist rope shows a rapid increase over its normal stretch recorded during its service.

A 2,5 m representative sample must be tested for its breaking strength by a destructive test after 18 months of use and thereafter on a sample cut from the front end at intervals not exceeding 6 months.

There is also a magnetic test requirement in the regulations such that a shaft hoisting rope shall be tested throughout its working length by a competent person using a magnetic testing device approved by the Director:

(a) within 6 months from installation, and

(b) thereafter at regular intervals not exceeding 4 months, or

(c) at intervals shorter than 4 months, where, by interpolation of past tests, the loss in breaking strength will exceed 10% before the next test.

For balance and, where practical, guide and rubbing ropes the same conditions apply except that:

(a) is 12 months since installation

(b) is 8 month intervals (or 4 months where a test discloses a loss exceeding 5% of the breaking strength).

France

No discard criteria are specified in French regulations apart from visible deterioration due to broken wires, corrosion and changes in diameter and lay length.

Germany

The discard criteria for winding ropes in Germany are covered by the German Mining Regulations[10]. The allowable decrease in breaking strength is 15%. Marked corrosion and pitting also calls for discarding the rope.

The regulations also give specific time periods when ropes should be discarded:

Ropes travelling > 300 trips per day Sub-verticals at collieries, flat ropes, locked coil ropes, multi-strand ropes	Discard after 1 year
All other ropes, i.e. tail ropes, stage ropes, winch ropes	Discard after 2 years

Guide ropes	Discard after 5 years or when the loss in metallic area of the outer wires exceeds 40%
Sinking winders only	Cut front ends and test destructively 4 times per year

Although not part of the national regulations for rope discard criteria, the Seilprüfstelle in Bochum[11] has issued some guidelines in interpreting the effect of the combination of broken wires and wear on rope strength. The ratio of rope strength loss due to broken wires and that due to wear is 1:2 i.e. if a rope had lost 15% of its original strength due to this deterioration, 5% loss would be due to the broken wires and 10% due to the wear.

Poland

A study carried out between 1980 and 1986 indicated that more than 60% of hoisting ropes on Polish Coal mines were replaced following fatigue rupture of wires[12].

The Polish safety regulations concerning hoisting ropes subject to fatigue, classify an acceptable number of broken wires occurring over a section of 40 or 8 x rope diameter. Moreover, a rope should be replaced when the number of fractured wires suddenly increases. However, ropes are often discarded before the extreme number of broken wires is noted. The basis for the inspection procedure is the number of fractures scattered throughout the rope, which amounts to several hundred in Lang's lay ropes and reaches 2000 in regular lay ropes.

The Central Mining Institute has developed software to facilitate rope condition assessment and rope discard forecasting. The parameters include the specification of the winding machine, the rope design and strength and the number of fractured wires along the highest fatigue section of the rope.

In addition to visible broken wires on hoist ropes, there are discard criteria for maximum service life without the approval of an inspector (2 years), visible corrosion and changes in diameter and lay length.

Russia

In Russia, the allowable decrease in breaking strength of a hoisting rope is 20%. There are also requirements for the maximum number of broken wires in one rope lay (all wires), amounting to 5% of the total number of outer wires, and a 10% maximum reduction in rope diameter. The regulations also cover severe corrosion and/or pitting.

Sweden

The allowable decrease in breaking strength of a hoisting rope is also 20% in Sweden. There are also requirements for severe corrosion and/or pitting and visible deterioration due to broken wires, corrosion or a change in rope diameter and lay length.

United Kingdom

As mentioned earlier, BS 6570 is a general rope specification and of limited application to mine hoisting ropes. The Ropeman's Handbook[13] specifies that ropes should be discarded when they have lost 10% of their original rope strength. This applies to deterioration due to fatigue, corrosion-fatigue, surface embrittlement or cracked/broken wires. For corrosion and wear, a loss of 16% is permissible. Also, no rope should remain in service:

- When the Engineer considers that the factor of safety has become too low.
- When the outer wires have lost about 33⅓% of their depth as a result of any form of deterioration.
- When the outer wires are becoming loose and displaced for any reason.
- When the rope had become kinked or otherwise deformed, distorted, or damaged, and the affected part cannot be cut out.
- When examination of the rope leaves any doubt as to its safety on any grounds.
- When a rope, which is still in good condition, reaches the maximum statutory life for its type, as laid down in Regulations, or the maximum life specified by the Engineer.

USA

The Code of Federal Regulations[14] permits an allowable loss of breaking strength of 10%. It also specifies the maximum number of broken outer wires in one rope lay:

- all wires: 5%
- in one strand: 15%

The maximum loss in diameter of outer wires is given as 33⅓%, and the maximum reduction in rope diameter, 6%. The regulations also specify discard criteria for heat damage and corrosion and/or pitting.

Zambia

The Zambian safety regulations prescribe a maximum service life (without inspector approval) of 2 years and a 10% loss in breaking strength. Discard criteria for corrosion and/or pitting are also included.

Zimbabwe

The safety regulations in Zimbabwean mines are basically the same as those in Zambian mines, except that visible deterioration is an additional discard criterion.

It can be seen from the above review of available discard criteria for mine hoisting ropes that, currently, the only country to include magnetic testing as a statutory requirement is Canada. Several other countries, including South Africa, use magnetic testing to complement the normal inspection procedures.

Additional information for the rope discard review was obtained from a review of SA and foreign factors of safety by Fritz[15].

3. REVIEW OF ELECTROMAGNETIC TESTING

3.1 Background

It is beyond the scope of this report to discuss the relative merits of the methods of magnetic testing and of the various instruments used. Much of this information can be obtained from the numerous references given and also from data published by the numerous magnetic test instrument manufacturers such as Rotesco (Rotescograph), Heath and Sherwood (Magnograph), NDT Technologies (LMA-Test™) and Plessey, to name a few.

A chronological review of magnetic testing is given, with specific regard to the use of this technique for the prediction of loss of rope strength for discard rope.

3.2 Review

The first magnetic rope test instrument was developed by McCann and Colson in 1906[16]. However, it was only in the 1930's that the development had been sufficiently well advanced in Germany, specifically at the Bochum Laboratories, to be accepted as the final examination for ropes whose visual inspection left some doubt about continued usage beyond the statutory 2 years. At the time the equipment was still in an experimental phase an there was little possibility of using the equipment on site. Early accounts of the development of magnetic test techniques for wire rope inspection in Germany are given by Weischedel[17]. Similar work on magnetic test methods of testing was also carried out in England by Wall[18] and later in Canada by Cavanagh[19].

Much of the impetus for the early development of magnetic test techniques for the practical in-situ assessment of mine winder ropes was carried out in Canada following an accident at the Paymaster Gold Mine at Timmins, Ontario on February 2, 1945, in which there were 16 fatalities. The subsequent investigations and testing of the fractured rope and other discarded hoisting ropes revealed that internal corrosion existed in serious proportions in many hoisting ropes and in sections of the rope removed from the conveyance end (where the statutory test specimens were normally cut). It thus became apparent that some means of inspecting the rope throughout its length during service was desirable.

Ontario's Legislative Assembly established a Royal Commission, mandated to investigate the safety of hoisting equipment and of hoisting practices in Ontario mines and the resulting report included the recommendation "that the Department of Mines and the mining industry of Ontario continue to encourage investigation of the merits of magnetic test methods of examination of mine hoisting ropes".

The major development of the magnetic testing of winding ropes in South Africa can be attributed to Semmelink[20] who carried out extensive trials on triangular strand ropes varying in diameter from 32 mm (1¼") to 51 mm (2") and on one 38 mm (1½") diameter non-spin rope. The results indicated that the technique would be a valuable addition to the existing methods of rope examination.

On the basis of his successful work in South Africa, in 1956 Semmelink went to Canada and was immediately commissioned jointly by the Ontario Mining Association and the Ontario Department of Mines to build his equipment for investigational study. Much study and testing of various equipment had been carried out by a Canadian rope committee since 1947 but the results obtained were inconclusive and unreliable, however, over a period of four years testing the Semmelink equipment proved very successful. A directive by the Chief Engineer of Mines of Ontario in January 1963 approved the magnetic test device for use in Ontario and established testing procedures on a mandatory basis.

All round or flattened strand ropes were tested at 4 month intervals, the first test being carried out before the rope has completed 6 months of service. The previous requirement of 6 months destructive testing was waived and such testing was extended to destructive testing after 18 months service.

Such was the confidence in the equipment that magnetic test results were related to a loss in breaking strength[21] (and still is today). If the magnetic test results indicated a loss of 10% or more in breaking strength, the rope was condemned. In most cases, as the rope approaches the 10% loss it is removed from service because it was generally recognised that the magnetic test device was usually 5 to 10% low in its estimate of breaking strength. It did not take into account fatigue or broken wires unless there were a great many broken ends separated. It was reasonable to expect therefore that the actual breaking strength found by tensile testing would be considerably less than that determined by the device.

Discrepancies between predicted and actual breaking strength was also reported by Semmelink[22]. Magnetic testing of triangular strand ropes between 19 mm (¾") and 57 mm (2¼") diameter showed a close relationship between magnetic flux and breaking strength in the majority of samples. However, where external corrosion was present on the rope the variation from the value of breaking strength was appreciable. The breaking strength of such samples was considerably lower than that predicted. Tests carried out on a 6 x 31 (10/12/9)/F rope showed that the loss of strength of all outer wires must be taken into account. The relationship between actual and predicted breaking strength was found to be:

$$\text{Actual loss of breaking strength} = \frac{\text{predicted loss} \times 10}{3}$$

For internal corrosion only, there was a fairly close correlation between estimated and actual breaking strength, Figure 1.

Figure 1

Work carried out by Harvey and Kruger[23] indicated that a wide range of characteristic rope defects is recognizable from the traces on the record charts and it was now considered possible to predict the breaking strength of a rope with considerable confidence. The assessment of the strength of a rope depends directly on the multiplying factor n, and this in turn could only be obtained accurately if each wire can be examined along its full length. As this is clearly impossible without destroying the rope, the multiplying factor could only be estimated on a basis of previous experience and on a correct interpretation of the nature of the fault from the charts, and from visual examination of the rope. The most general value of the multiplying factor encountered in long faults was 3, but for short faults such as when localised corrosion is obtained, the factor may go up to 10 or more. On one instance a factor of 15 was noted.

Correlations between actual breaking load and estimated breaking load[24] are shown in Figures 2 and 3. The ropes are 44 mm (1¾") and 29 mm (1⅛") diameter respectively, flattened strand construction and Lang's lay. Both ropes were installed on a 2 layer winding.

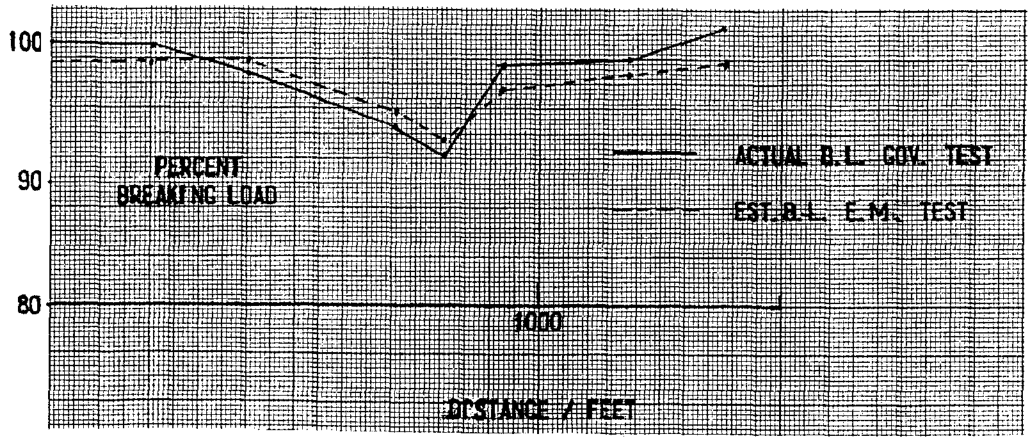

Figure 2: Graph showing the correlation between actual breaking load (BL) compared to the estimated breaking load. Examination of the test specimens from the reduced area showed the wire surface completely corroded with nicking between strands.

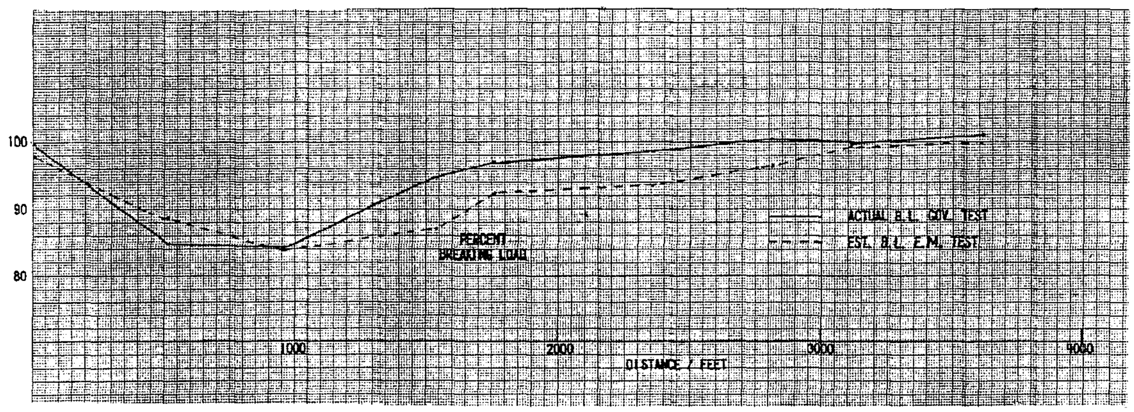

Figure 3: Graph showing the correlation between actual and estimated breaking load (BL). The specimens taken from the cross-over region of the rope were badly worn with well established pitting.

In the 1960's much research on the magnetic testing of winding ropes was being done in South Africa, North America, Australia and Europe. Harvey[25] supported the fact that good results were obtained during the magnetic testing of six strand, Lang's lay ropes that have a low steel area to rope area ratio. However, major problems were encountered with higher density ropes such as multi-strand non-spin ropes and particularly on half- and full-lock ropes.

Such difficulties were also experienced by Davis[26] who found that the degree of accuracy in determining area loss would be affected by such things as uniformity of corrosion, nicking, broken wires, work hardening and fatigue. Indeed, the value of interpretation on tests carried out on locked-coil ropes was not conclusive.

The revival of interest in the magnetic testing of winder ropes in Australia[27] was stimulated by the Australian Mineral Industries Research Association due to a number of factors. Apart from the obvious factor related to safety, there are, in addition, obvious economic reasons for retaining ropes in service for as long as possible. The third factor was the recent introduction of friction hoists on deep shafts, with consequent problems and types of rope failure not normally experienced with drum winders. Here the impossibility of cutting samples for normal destructive tests during the life of the rope was an important factor. The work concluded that, although the art of magnetic rope testing had advanced considerable over the years and had reached the stage where such testing could be used to predict the remaining strength with fair accuracy, there still remained much to be done before all the associated problems had been satisfactorily solved.

The difficulties experienced in interpreting diagrams during magnetic testing was highlighted by European workers. Work at the Bochum Rope Test Station[28] resulted in the view that magnetic testing was an extremely valuable auxiliary in assessing the condition of winding ropes, due to these difficulties. Similar difficulties were highlighted by a Working Party on the electro-magnetic examination of winding ropes[29] of various constructions. The research report also noted that no precise indication of the loss in load-carrying capacity of the rope can be obtained from the recorded charts. The work did, however, indicate that it was possible to locate major faults in ropes, to detect broken wires and to study the progress of changes in the rope. These views were supported by work on ropeways[30] but concentrated on the detection of broken and nicked wires. Local defects were examined using a calibration curve and could be noted through the particular form of the resulting impulses. The number of broken wires could be determined from applying the calibration curves i.e. the decrease of section, which is proportional to the reduction in the tensile strength.

A major advance in the development of magnetic testing equipment was announced by Aimone[31] in 1983. Basic limitations of metallic area measurements on existing equipment, i.e. the fact that major metal loss may not be fully detected if the losses are localised due to pitting corrosion, put in question the ability to predict loss of rope strength. The residual strength of a rope is related to a combination of general and localised metal loss. The severity of localized losses on different ropes or different sections of the same rope also show distinct differences on the charts. This was demonstrated by Aimone on two areas of two different ropes with approximately the same level of measured metallic area loss, shown in Figures 4 and 5.

In Figure 4, the section of the rope that showed a general metal loss of 4,8% had a strength loss of 7,4%. Corrosion was present at this part of the rope but did not produce localised patches or pitting. In Figure 5, the section of the rope that showed a 4,5% general metal loss had a strength loss of 22,3%. The reason for the difference between the strength losses is evident from the local fault traces of each sample. The local fault trace in Figure 5 is generally higher than that in Figure 4 and has 3 very large peaks around the area of maximum metal loss. This indicates localised pitting corrosion. From the results obtained, it was concluded that the loss of breaking strength in a rope is strongly associated with the size of the local fault trace. Statistical results from 70 samples taken from 13 ropes showed that a pattern emerged whereby strength loss could be modelled by using the quantitative values of the measurements of general loss in metallic area and localised faults. It was found that metal loss by itself was in general an optimistic estimator of strength loss, see Figure 6. The average error on measured metal loss was found to be 4,8%, whereas the error from the combined approach was $\pm 0,5\%$.

In the 1980's tests were still being done in the UK[32] on ropes of triangular strand construction (6/7/(7/1▵)) and further work was proposed to establish whether there was a relationship between metallic cross-section, rope diameter and tensile strength.

Recognition of the importance of measuring local faults as well as loss of metallic cross-sectional area during magnetic testing has also been discussed by Weischedel[33, 34]. With the new generation of testing equipment, simultaneous loss of metal area and local fault inspections are possible. Loss of metal area appeared to be an excelled measure of rope deterioration. Weischedel found that, in many respects, loss of metal area was a better and more reliable measure of deterioration than loss of breaking strength and proposed inspection procedures and retirement criteria to cater for this observation. Indeed, considerable efforts by the ASTM Standards Committee, the US Bureau of Mines, the Canada Centre for Mineral and Energy Technology (CANMET) and the Ontario Ministry of Labour in evaluating magnetic test instruments on ropes containing artificial defects clearly show that loss

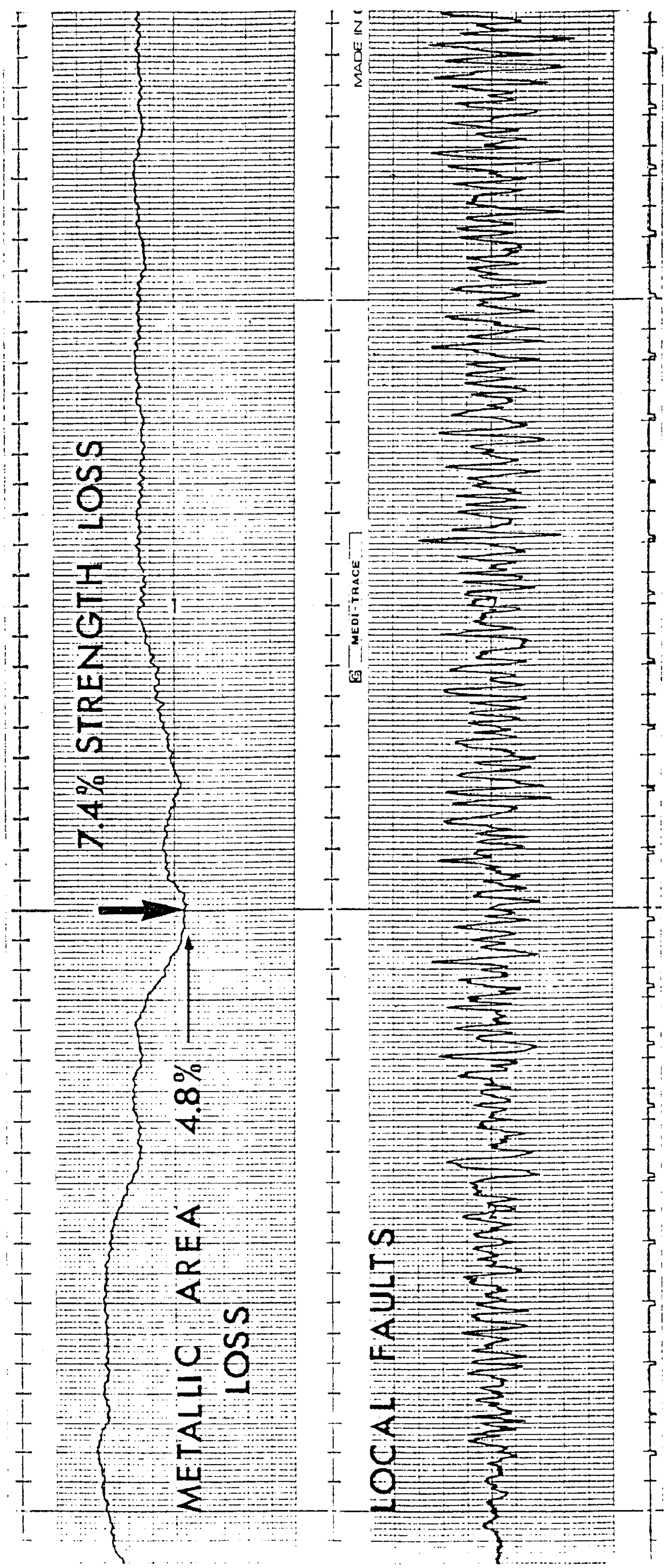

Figure 4: 1⅛" 6 x 30 rope with 4,8% measured metal loss and 7,4% strength loss.

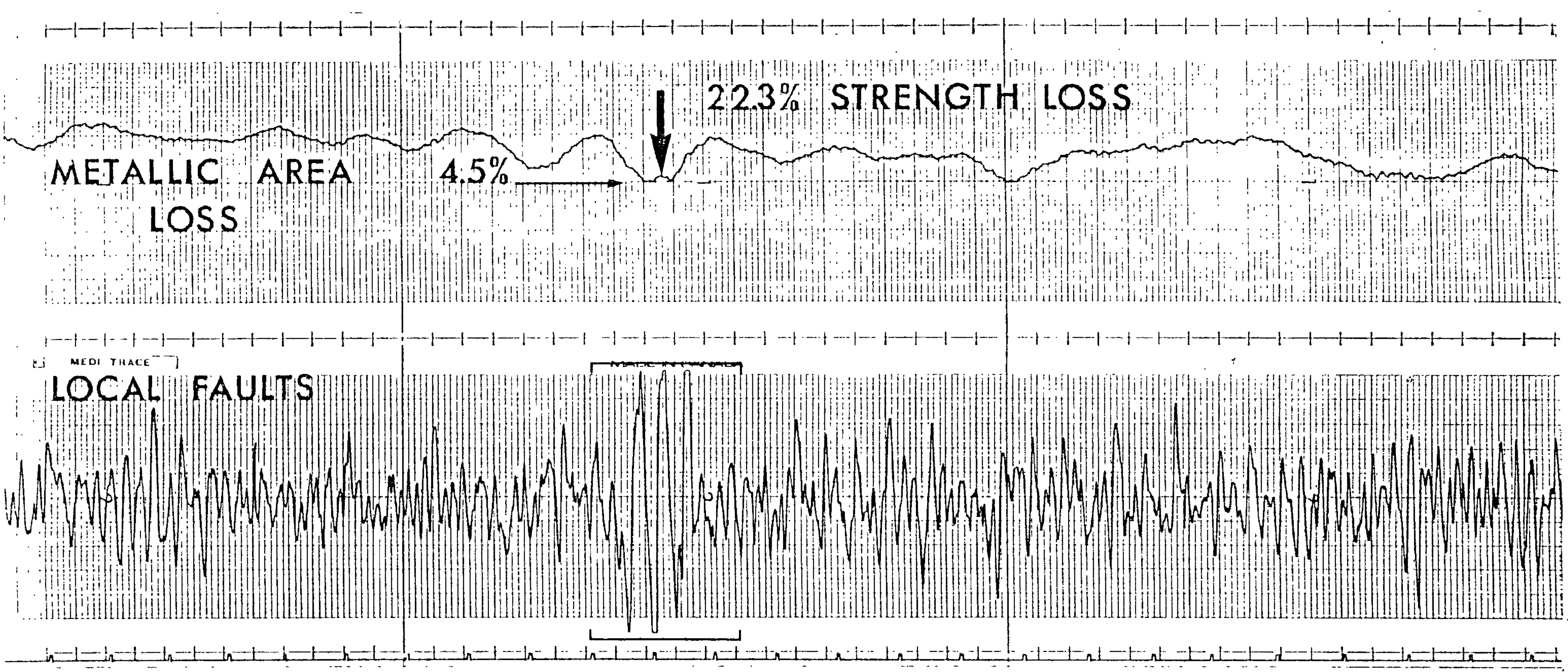

Figure 5: 1⅛" 6 x 30 rope with 4,5% measured metal loss and 22,3% strength loss due to localised corrosion.

of breaking strength is not a reliable indicator of the actual rope condition. The work also highlighted the fact that no rational method for a non-destructive prediction of loss in breaking strength exists.

The principal objective[36] of the CANMET Project was to evaluate comparatively the level of accuracy with which loss of breaking strength in mine wire ropes can be estimated, on the bases of testing with magnetic test instruments. As a result of the project it was concluded that, at the time of removal, many mine ropes had lost much more of their original breaking strength than had been estimated on the basis of magnetic testing. It was also noted that a considerable number of loss of breaking strength estimates were outside the acceptable ±4% accuracy range that is the benchmark figure included in Ontario's "Performance Requirements for magnetic Testers". The reason for the inaccurate loss of breaking strength estimates[37] was considered to be human-related, rather than hardware related. Misunderstood and nebulous processes used to convert measured local faults and loss of metal area, as obtained from the chart readings, into the loss of breaking strength estimates was the single major cause for the inaccuracies. No relevant, properly documented, algorithm was available for doing this. In fact, some service companies refused to provide loss of breaking strength estimates (contending that it is impossible to accurately predict) and others refused to disclose just exactly what research their method is based on.

It should be noted at this stage that the CANMET project specifically dealt with magnetic test instruments and the use thereof. No destructive tests were carried out to confirm the accuracy of the estimates.

Work carried out by Weischedel[38] in the early 1990's suggests that the percentage loss in aggregate strength is a more precise gauge of rope deterioration rather than percentage loss of metal area. This, however, was related to the abrasive wear of outer wires and does not consider internal defects. He also states that tensile tests cannot determine the accuracy of magnetic rope inspections. The only reliable method to access actual rope deterioration and to check the accuracy of magnetic inspections is by disassembling and visually inspecting the rope after retirement.

Recent research in Japan[39] indicates that the estimation of remaining strength of steel wire rope using magnetic testing can be aided by numerical simulation. This work was carried out on parallel wire strand ropes, however, the mechanical behaviour of the wire is far simpler than on helically wound hoisting ropes.

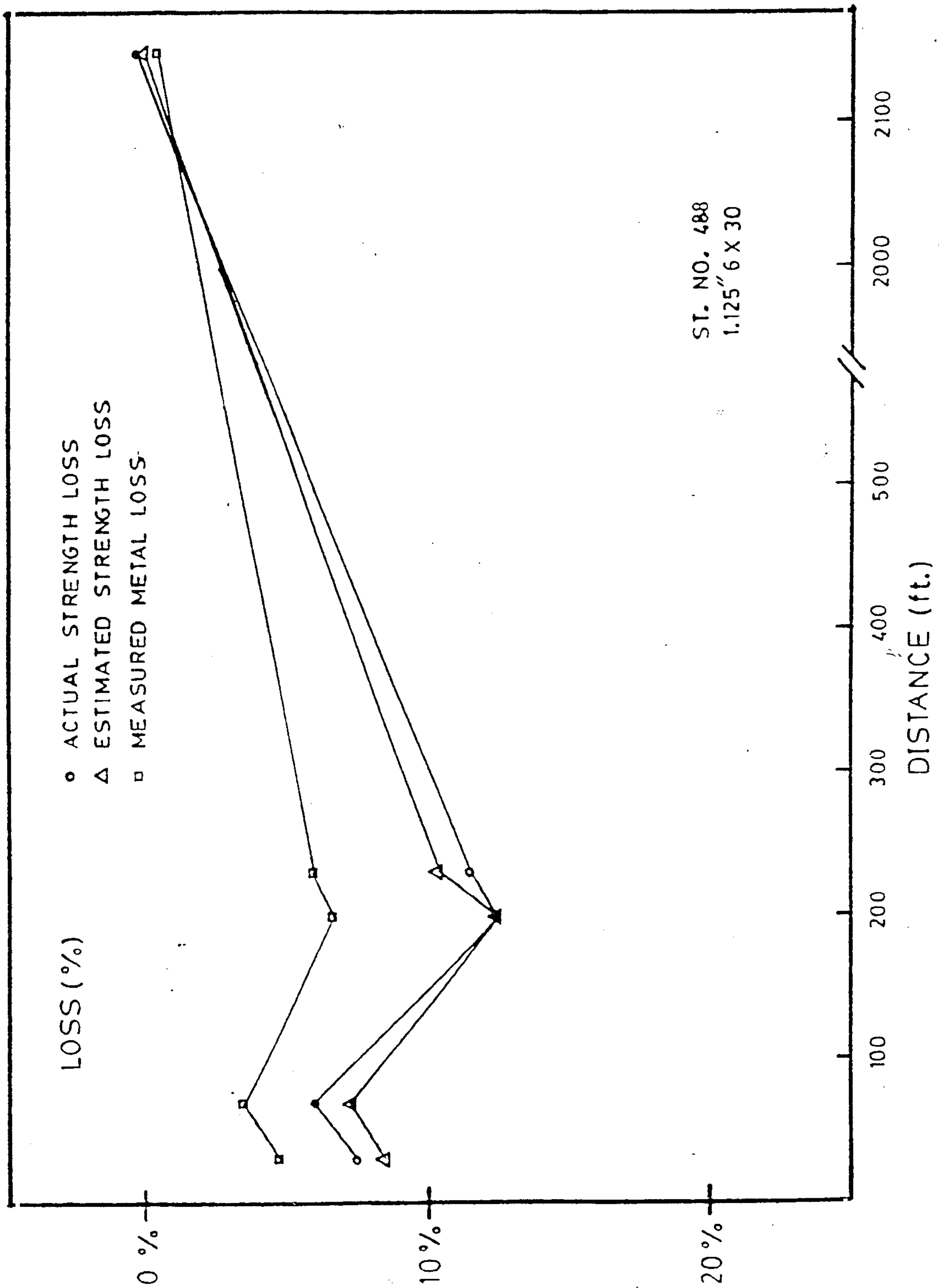
LOSS (%)
o ACTUAL STRENGTH LOSS
Δ ESTIMATED STRENGTH LOSS
□ MEASURED METAL LOSS
ST. NO. 488
1.125" 6 X 30
0 %
10 %
20 %
100
200
300
400
500
2000
2100
DISTANCE (ft.)

Figure 6

REFERENCES

1. South African Minerals Act and Regulations (Act 27 of 1956) Lex Patria Publishers, P O Box 8161, JHB, 2000, p134.

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DISCUSSION OF RESULTS OF SECOND SERIES OF TESTS ON DISCARDED ROPES IN TERMS OF THE DRAFT CODE OF PRACTICE ON ROPE CONDITION ASSESSMENT

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CONTENTS.

DISCUSSION OF RESULTS OF SECOND SERIES OF TESTS ON DISCARDED ROPES - IN TERMS OF THE DRAFT CODE OF PRACTICE ON ROPE CONDITION ASSESSMENT

1 INTRODUCTION.

In May 1995 a report was issued on an initial series of tests on discarded ropes[1] in an attempt to validate the draft SABS Code of Practice - Condition Assessment of Steel Wire Ropes on Mine Winders[2]. Recommendations contained in this report are as follows:

"Consequent on some of the comments ....there is scope for further work to improve and correct the Draft Code of Practice. These recommendations are not listed in order of importance.

1. The draft code should not be used for assessing non-spin ropes. Further work is required in interpreting electro-magnetic test traces of these ropes and combining them with revised requirements for non-spin ropes. Requirements for Koepe ropes should be different to those for non-spin ropes operating on drum winders.
2. The alternative discard factors proposed by Mr T.C. Kuun should be incorporated in a revised Draft Code of Practice.
3. Considerably more discarded rope samples should be submitted for evaluation. If possible all ropes discarded in the next two years should be assessed.
4. There is a need to provide clearer guidelines for assessing broken wires when only two to four broken wires are present in adjacent strands. The current position regarding asymmetric distribution sometimes results in discard factors in excess of 1 when rope strength has hardly been affected. Further cut wire tests in this range are required.
5. Further work is required in clarifying how corrosion is assessed. It may be that the only thing needed is more explicit instructions to rope inspectors. On the other hand adequate arrangements must be made for the various types of electro-magnetic test instrument used.
6. The importance of correct measurements and observations has been emphasised. The coordination of the work of the rope inspectors and the responsible engineer needs to be clarified and all responsible engineers should be made conversant with the code and the requirements for correct measurement."

No formal instructions have been proposed or circulated in response to these recommendations. Consequently, discarded ropes submitted for testing have been addressed in the same manner as for the previous series of tests. i.e. Ropes which have been submitted for test were examined in the laboratory before testing and on the basis of this examination, or the inspector's report on the discarded rope, a discard factor was assigned.

2 TESTS ON DISCARDED ROPES.

A second series of ropes which had been discarded for a variety of reasons were submitted for test. In many cases more than one sample from the same rope were submitted for evaluation. In many cases the information was required by the EM Test technician for comparative purposes in assessing the results of EM tests.

The discarded samples exhibited the following deterioration or defects:

- Wear, both abrasive and plastic deformation.
- Reduction in rope diameter.
- Corrosion.
- Broken wires.
- Split wires.
- Damage.
- Kinks.
- Waves.

Rope constructions varied from the normal triangular strand drum winder ropes to round strand ropes used on Koepe winders and non-spin Koepe head-ropes and tail-ropes.

2.1 PROCEDURE.

On receipt of the rope sample and the rope inspector's report, if any, the sample was carefully inspected to establish the rope condition and conformance with the report. The position of all broken and split wires was measured and recorded. The visual amount of corrosion was recorded and the rope diameter measured, while tensioned to 10 % of the initial breaking force.

After the tensile test to destruction, the rope was examined in accordance with normal test procedures and a test certificate produced.

In many cases the rope inspector involved wished to witness the test. Generally the rope inspector's report had not been submitted and sometimes very little interest was shown in the test.

2.2 RESULTS.

In some cases samples were received but without details or an application form. In a few other cases information and/or application forms were received but no samples. A total of 50 samples have been received and tested. The results have been presented in graphical form and also incorporated in the graphs illustrating the results of the first series of tests.

Many non-spin rope samples were cut from ropes in such poor condition that it was obvious that the strength would be well down. Useful data for assessing discard criteria for non-spin ropes was therefore not obtained from these samples.

Concise details of test results and the pre-test examination are to be found in the appendix at the end of this document. All the ropes tested in this series of tests are listed. It must be noted that the serial numbers are not all consecutive because in many cases although advice of test samples was received the samples themselves did not arrive. These have all been omitted from the appendix.

3 CORRELATION WITH CODE OF PRACTICE.

Not enough information was submitted with each sample for test to enable direct comparisons to be made between the discard criteria and the appearance of the rope in the field. In no case was there a comprehensive rope inspector's report detailing the observations and explaining how discard factors were arrived at. In only two cases was a discard factor indicated.

Because of this lack of information, it was decided to assign discard factors based on the pre-test inspection of each sample. The basis for assigning these factors was as follows:

1. If an inspector's report was available with an actual diameter measured on site, this measurement was used. In the absence of this information the measurement made by the CSIR under a 10 % tensile load was used. Based on reports and observations of symmetrical or asymmetrical wear, discard factors were calculated in terms of the Code of Practice and the highest value, obtained from either source, was used. In the absence of diameter measurements taken soon after installation of the rope it was not possible to do a comparative assessment of the two bases for calculation, the nominal rope diameter was used as the initial diameter for calculation.

2. The number and exact position of broken wires was determined, care being taken to identify any wires which had broken more than once in the sample. On the basis of numbers of broken wires, distribution and rope construction the code was applied to produce a discard factor for broken wires.

3. The assessment of discard factors for corrosion presented some difficulty. When the CSIR pre-test inspection indicated "excessive corrosion" a discard factor of 1 was assigned, except in some cases where the external corrosion was so severe that a greater factor was appropriate. There were no cases submitted where internal corrosion was indicated by the inspector.

4. A discard factor of 1 was automatically assigned for kinks.

5. There were ropes which were found to be wavy when examined by the CSIR. No details of measurements such as depth of wave were given. Consequently it was assumed that these ropes had been discarded due to the wave and a discard factor of 1 was assigned.

On the basis that mandatory discard of ropes with kinks or wavy ropes with a certain depth of wave is required, because of expected rapid deterioration of the rope and not necessarily because of loss in strength, test results are considered in various groups:

- Triangular strand and round strand ropes discarded due to wear, corrosion or broken wires.
- Kinked ropes.
- Wavy ropes.
- Triangular strand and round strand ropes discarded due to wear only.
- Non-spin ropes.

3.1 DISCARD IN CONFORMANCE WITH THE CODE.

The 50 samples submitted and tested in the second series were cut from 33 discarded ropes. The percentage loss in strength of these ropes varied from nil to a maximum of 48,7 %. The distribution of strength loss with respect to the number of ropes discarded is shown in Figure 1 on page 5. It can be seen that only 4 ropes of the 33 were discarded where the loss in strength at discard was below the regulation requirement of 10 % but more than 5 %, which was an appropriate lower value for discard.

This discard pattern is regarded as abnormal because not all discarded ropes had been submitted for test and greater interest has often been shown for the results of tests on ropes which exhibit an interesting anomaly. The true pattern of rope discard can only be ascertained when all discarded ropes are submitted for evaluation.

Figure 2 on page 5 shows the distribution of strength loss with respect to the number of ropes discarded for the 10 non-spin ropes tested. This pattern is completely abnormal and is regarded as an indication of the extent to which this program is being exploited to satisfy morbid curiosity regarding the strength of ropes which should obviously have been discarded before reaching such dangerous levels of deterioration.

Figure 3 on page 6 incorporates the information in Figure 1 into the distribution chart of the first report. It can be seen that the distribution pattern has not been altered to any extent and illustrates that too much emphasis has been placed on submitting discard samples with serious defects, because nearly half of the discarded rope samples had a loss in strength in excess of 10 %.

Figure 4 on page 6 shows the distribution of all the samples tested (both series of tests) which have been assigned a discard factor. The patterns shown are very much the same as in Figure 1, but illustrate considerable discrepancies with respect to the discard factors which need to be evaluated and explained. In particular, there is one sample where the assigned discard factor was less than 1 but where the loss in strength was more than 10 %. This anomaly is associated with difficulties experienced in assessing corrosion and wear in non-spin compact strand ropes. In addition, this global approach gives an inappropriate correlation pattern due to discard requirements which cater for such aspects as the possibility of rapid deterioration due to distortion or other factors.

The Code of Practice - "Condition Assessment of Steel Wire Ropes on Mine Winders" is designed to provide a means for combining relationships relating to various deterioration patterns on a "go/no-go" basis. Relationships for the various parameters have been determined and methods for combining the information, in an intelligible manner, provided. The effectiveness of the Code is evaluated and discussed in the remainder of this report.

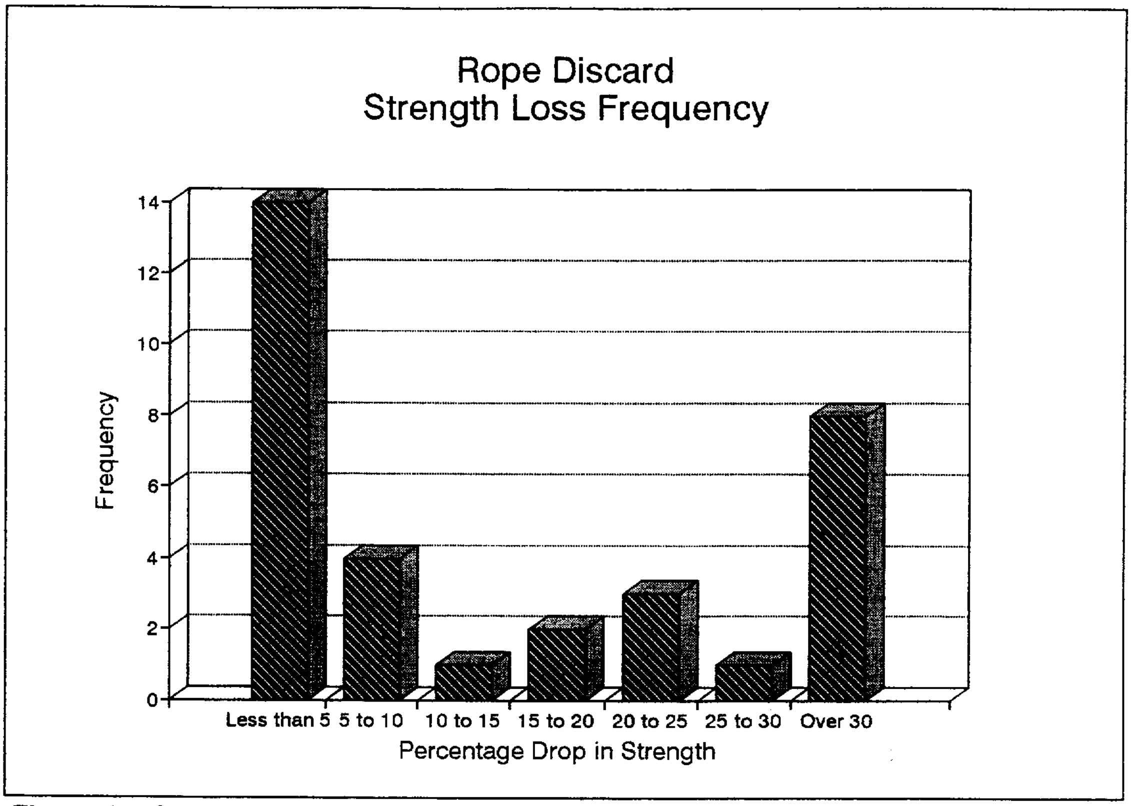

Figure 1 Strength Loss Frequency for All Discarded Ropes.

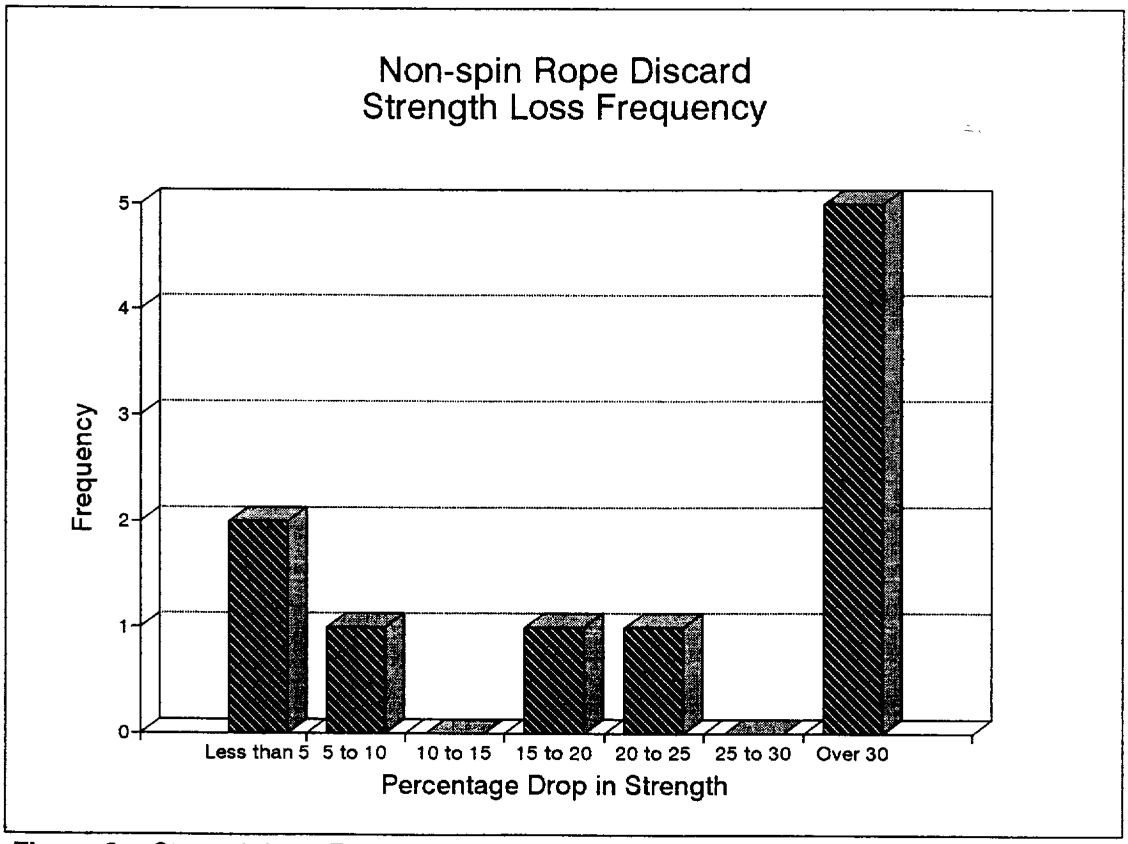

Figure 2 Strength Loss Frequency for Discarded Non-spin Ropes.

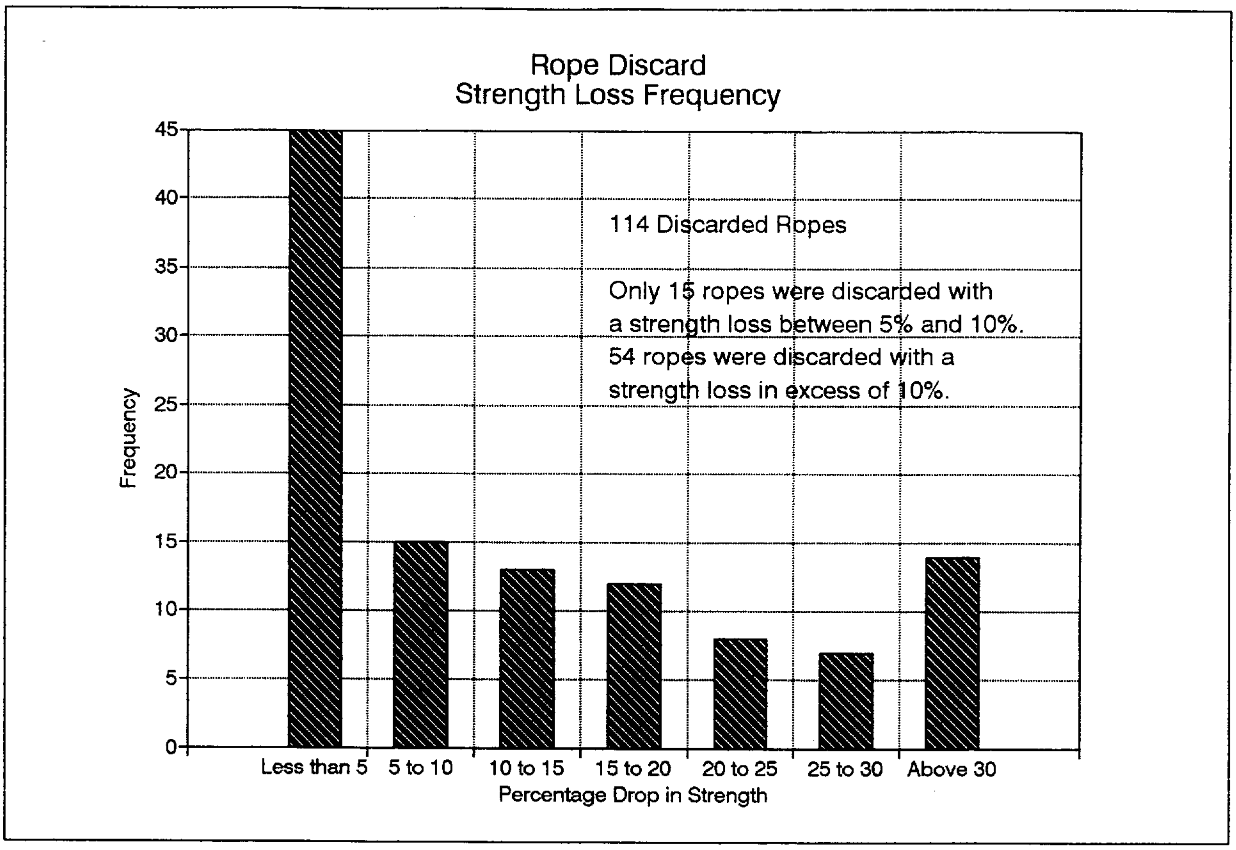

Figure 3 Frequency Distribution of Loss in Strength for Discarded Ropes of Both Series. (based on sample which is assumed to be the reason for discard)

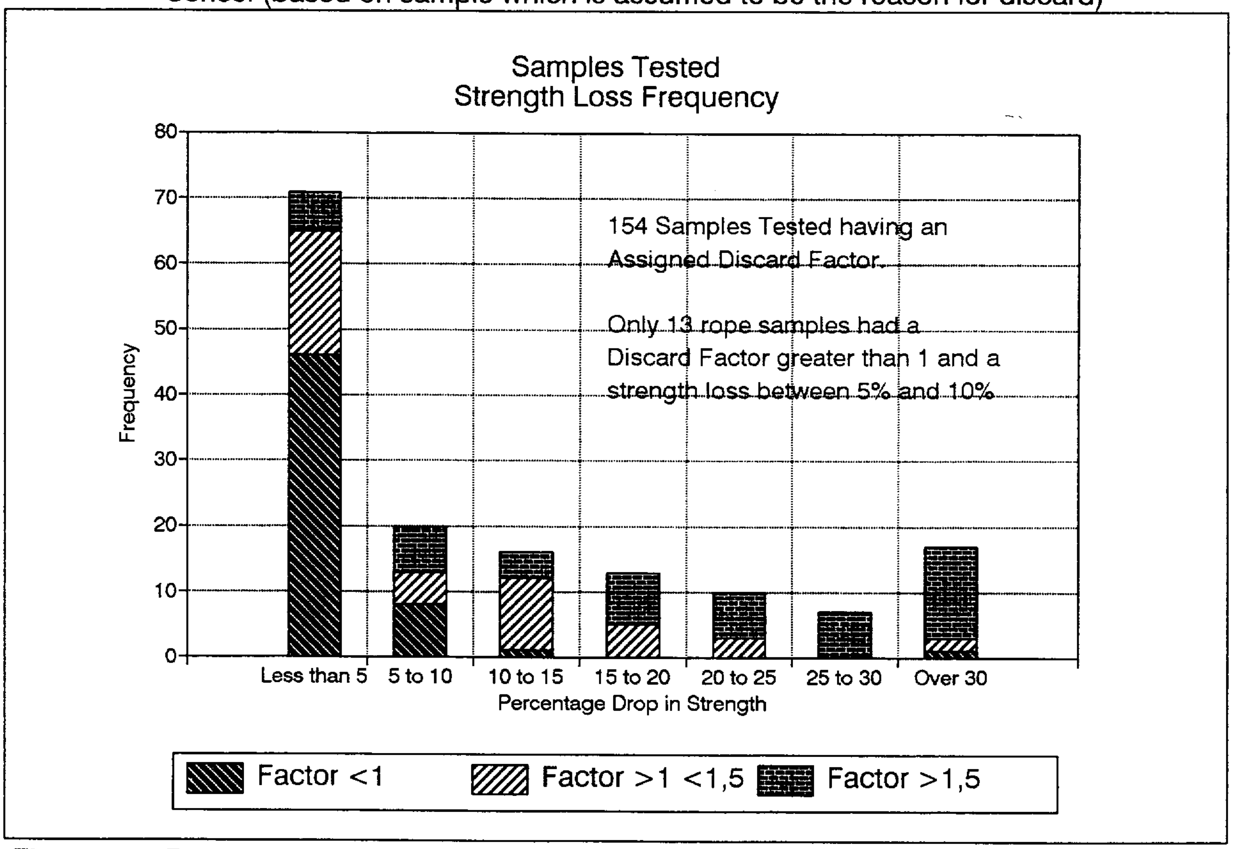

Figure 4 Frequency Distribution of Loss in Strength for Samples of Both Series - Discard Factors Below 1, Between 1 and 1,5 and Above 1,5

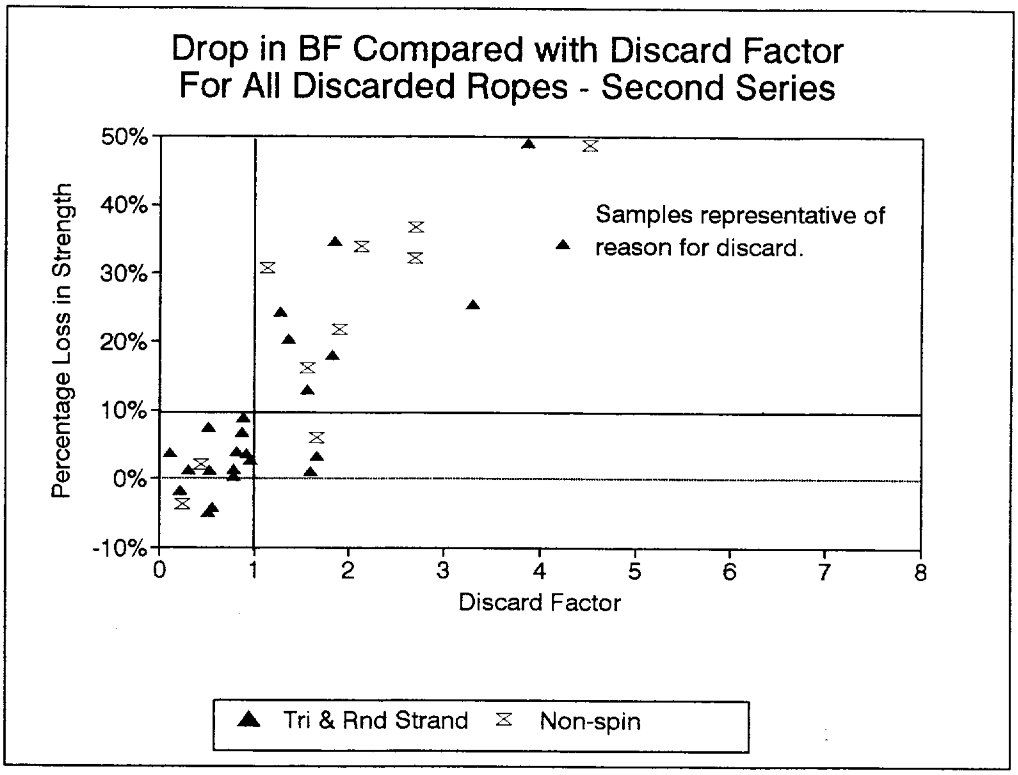

Figure 5 Percentage Drop in Strength Compared with Discard Factor for All Rope Samples Representative of Reason for Discard in Second Series.

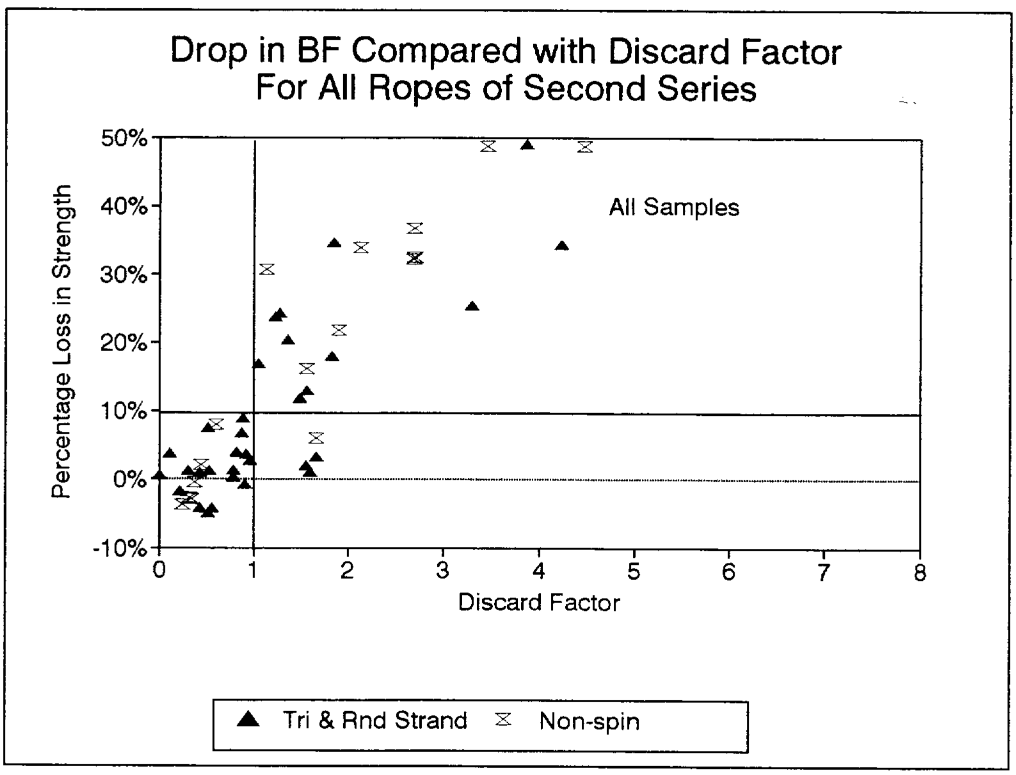

Figure 6 Percentage Drop in Strength Compared with Discard Factor for All Samples Submitted in Second Series.

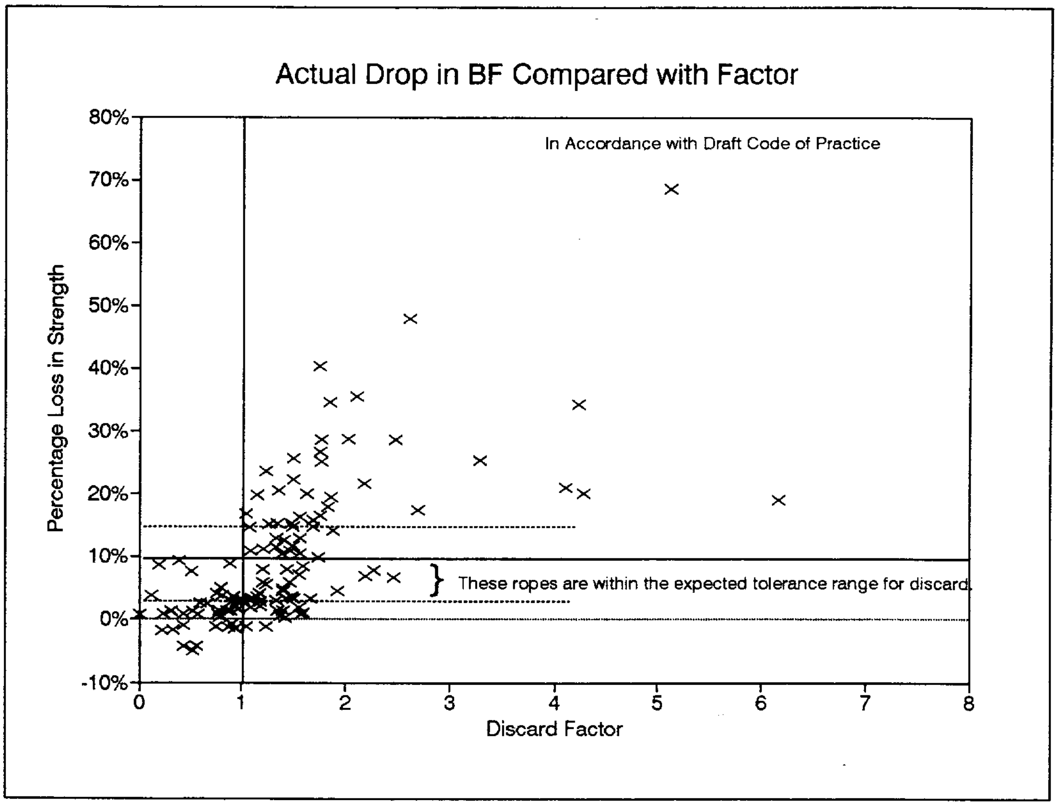

Figure 7 Loss in Strength Compared with Assessed Discard Factor for All Samples of Both Series.

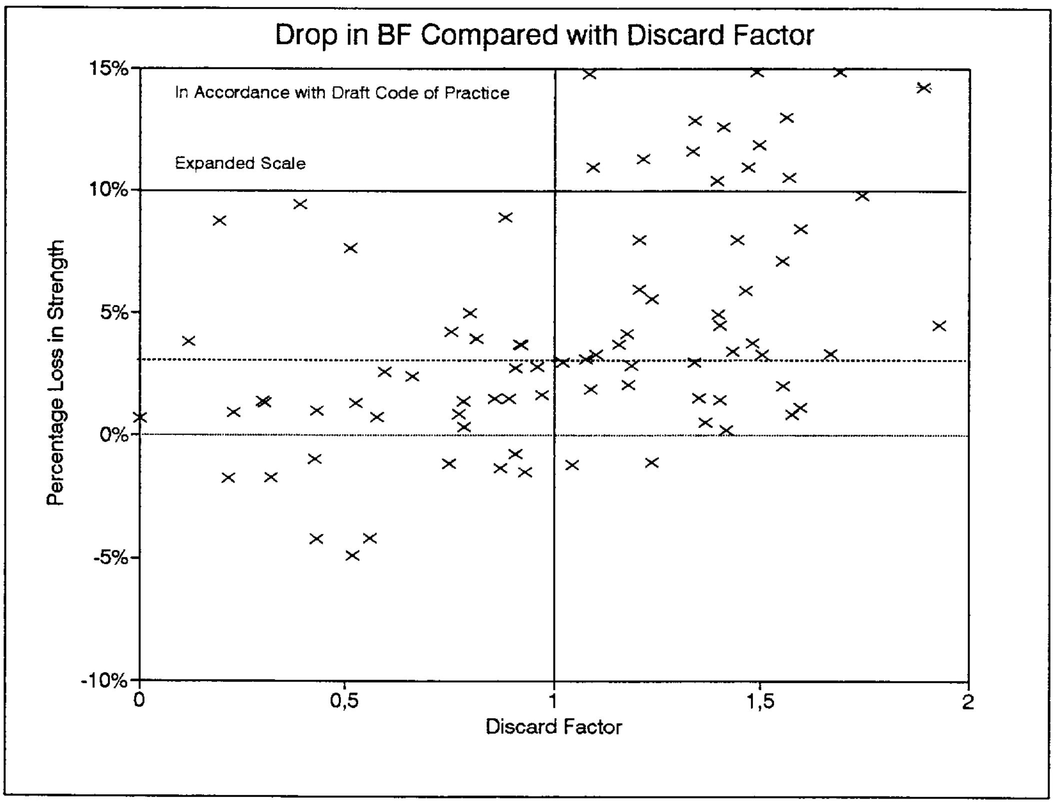

Figure 8 Portion of Figure 7 with Expanded Scale

3.2 ALL ROPES.

Scatter graphs for series 2 ropes are shown in Figures 5 and 6 on page 7. Figure 5 shows the results for samples which are assumed to be representative of the reason for discard of the rope, (in the absence of adequate reports from the mines in question), and Figure 6 shows the results for all the ropes tested. Many of the samples submitted were control samples to establish the general condition of the rope, but in some cases the sample was sufficiently deteriorated to give similar results as the representative sample. It can be seen that in most cases valid information has been obtained, although a few discrepancies need to be explained.

Figures 7 and 8 on page 8 show the combined results for both series of tests.

3.3 TRIANGULAR STRAND AND ROUND STRAND ROPES.

3.3.1 All Reasons for Discard.

Scatter graphs showing the percentage drop in breaking strength, for all samples of triangular strand and round strand ropes tested (in the second series), plotted for the corresponding discard factor are shown in Figure 9 on page 10. The discard factor has been assessed in terms of the code of practice and is the sum of individual factors for broken wires, loss in rope diameter and corrosion, including results for wavy and kinked ropes.

It can be seen that in most cases the discard criterion of 1 makes an appropriate cut-off for discard. The five samples which had an assigned factor and broke with a strength of less than 5 % were either wavy samples or were ropes which only had a reduced diameter. These will be discussed in the appropriate places.

3.3.2 Discard Due to Broken Wires.

Figure 10 on page 10 shows the relationship (for the second series of tests) between the assigned discard factor and the loss in breaking strength for the triangular strand and round strand ropes which were representative of the reason for discard. It must be noted that four of these ropes had strength loss in excess of 20 %. The condition of the ropes in question made it obvious that excessive loss in strength could be expected, so the testing of these ropes did not make any significant contribution to the objective of this program. However, one case is of interest; a sample was submitted with a large number of visible broken wires which on detailed examination resulted in an assessment of two wires broken in many places. This occurrence highlights the importance of the method described in the code for determining the number and distribution of broken wires.

At the other end of the scale, when there are only one or two broken wires in a rope the code appears to emphasize the effect so that discard factors slightly higher than appropriate are assigned. However when considering the results this effect is not regarded as a serious disadvantage and is unlikely to result in the premature discard of ropes when they are still in a safe condition.

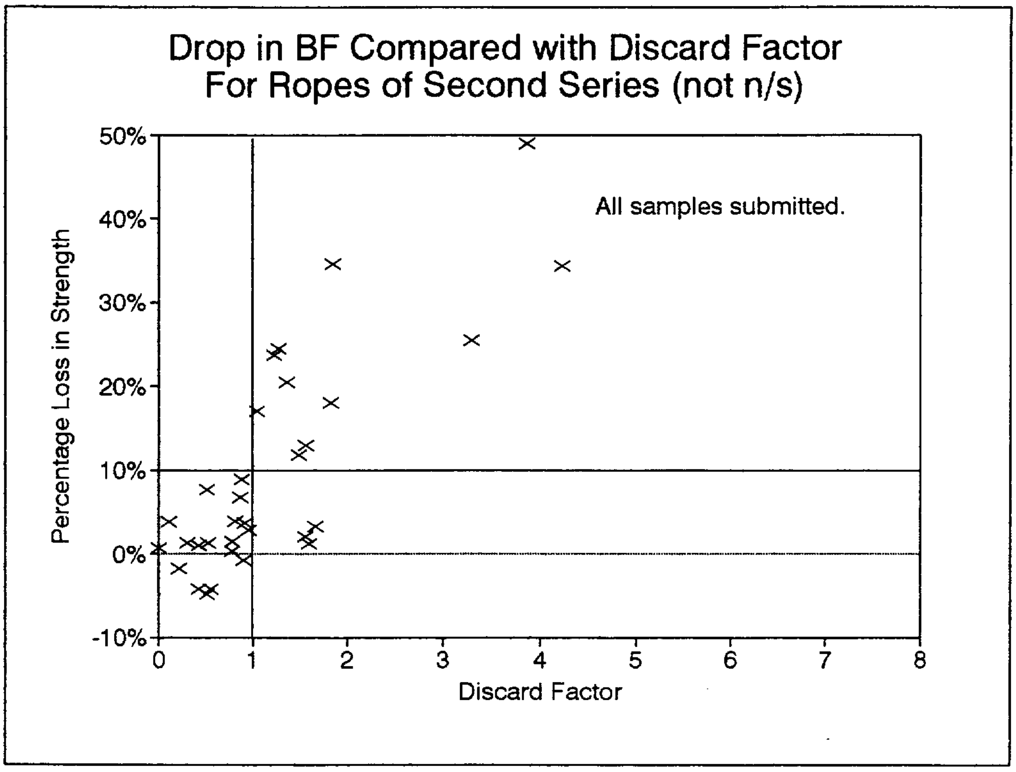

Figure 9 Percentage Drop in Strength Compared with Discard Factor for Triangular Strand and Round Strand Ropes of Second Series.

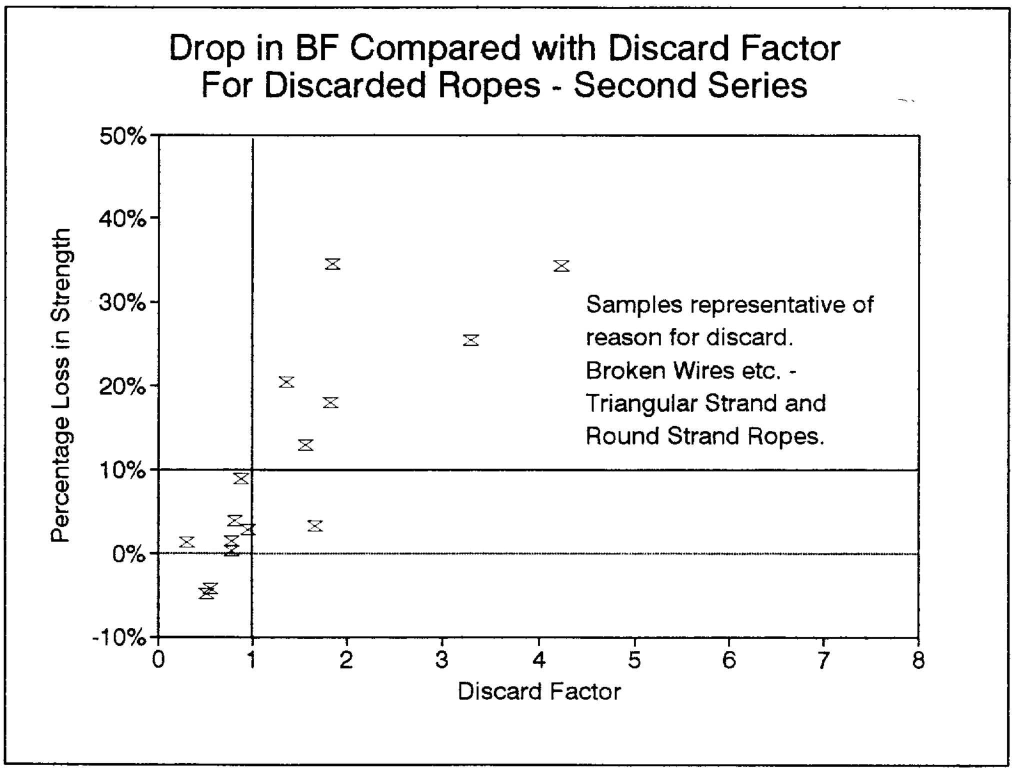

Figure 10 Percentage Drop in Strength Compared with Discard Factor for Triangular Strand and Round Strand Ropes of Second Series with Wire Breaks.

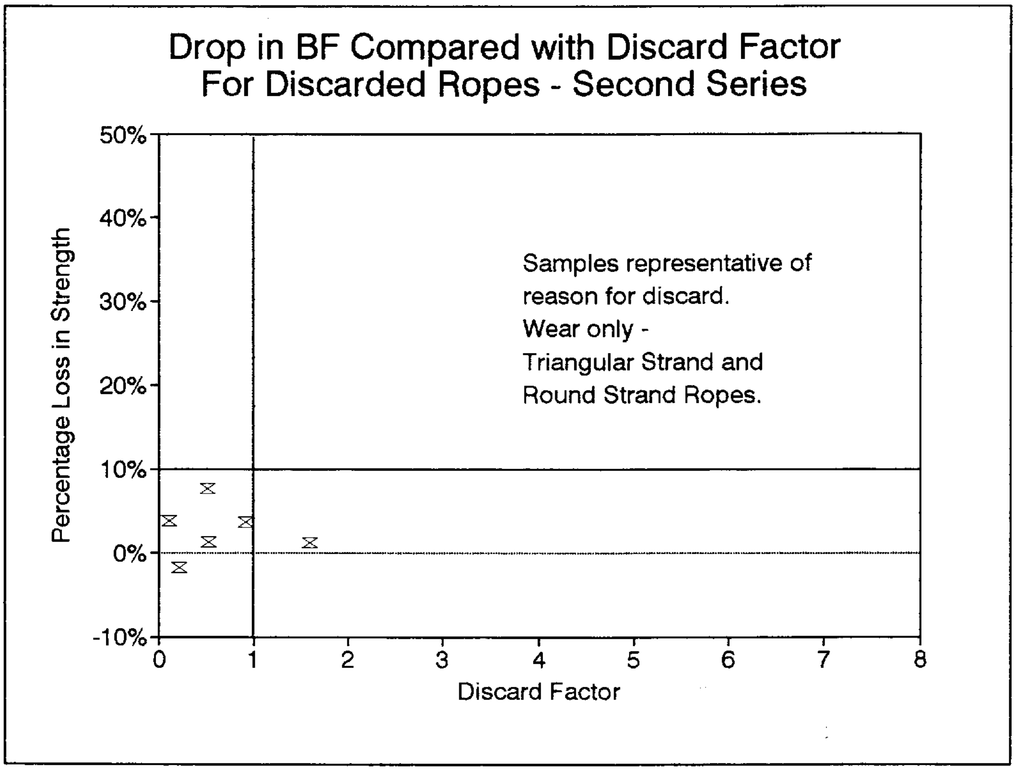

Figure 11 Percentage Drop in Strength Compared with Discard Factor for Triangular Strand and Round Strand Ropes of Second Series Due to Wear.

In view of these results and considering the above comments it can be confirmed that the method for calculating the discard factor for triangular strand and round strand ropes with respect to broken wires is appropriate and leads to a safe assessment of the rope condition.

3.3.3 Discard Due to Wear.

Figure 11, on this page, shows ropes discarded for only wear and/or corrosion. In the second series of tests there were no corroded samples of triangular or round strand ropes so comments relate specifically to discard due to wear.

The scatter graph only includes ropes which were discarded due to reduced rope diameter in service. In some cases the visible amount of wear or plastic deformation was slight, but because the rope diameter had reduced considerably the rope was discarded, however, in these cases no report was received from the mine. In all other cases the amount of wear and plastic deformation of the wires was severe to considerable.

Two of these samples were accompanied by reports from the mine. In the one case the rope was discarded due to being wavy with a reduced diameter. This is the only wavy rope submitted which was not associated with a kink so it was included in this section for comment.

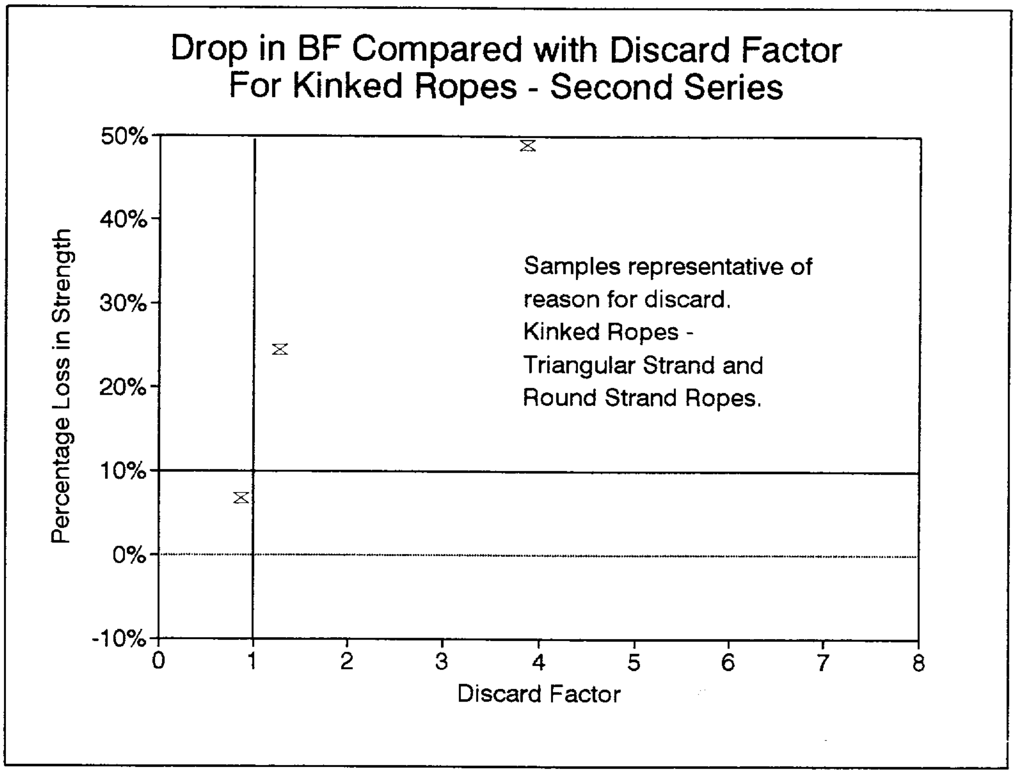

Figure 12 Percentage Drop in Strength Compared with Discard Factor for Triangular Strand and Round Strand Ropes of Second Series Due to Kinks.

Although most of these samples exhibited a considerable amount of plastic wear the actual strength loss was lower than should be expected from the discard factor calculated in accordance with the code. In view of this, consideration should be given to modifying the code so that the reduction in diameter is compared with the actual measured diameter of the rope soon after installation and not with the nominal rope diameter.

3.3.4 Discard Due to Kinks.

Three ropes of the second series were discarded due to being kinked. In one case the kink had remained in service and outer wires of the rope had worn away. As can be seen in Figure 12, the loss in strength of this sample was nearly 50 %. In the case where the strength loss was below 10 % there was no wear of the rope and no broken wires. These features confirm the importance of discarding kinked ropes (or cutting off the damaged portion) as soon as the kink is discovered.

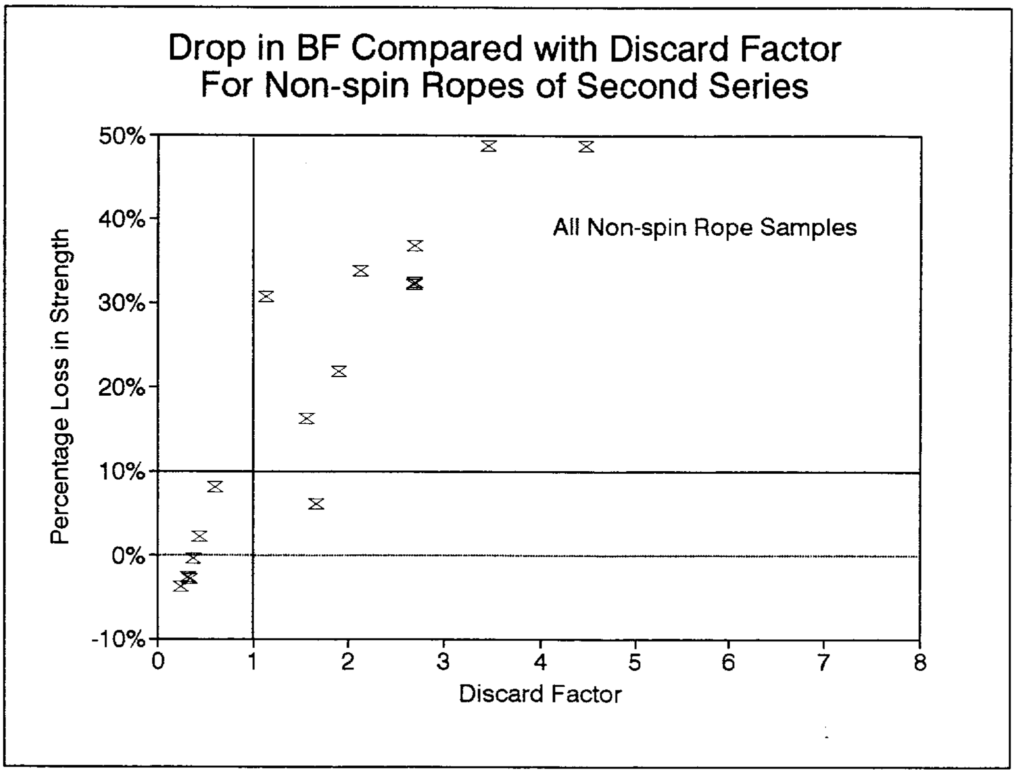

Figure 13 Percentage Drop in Strength Compared with Discard Factor for All Non-spin Rope Samples of Second Series.

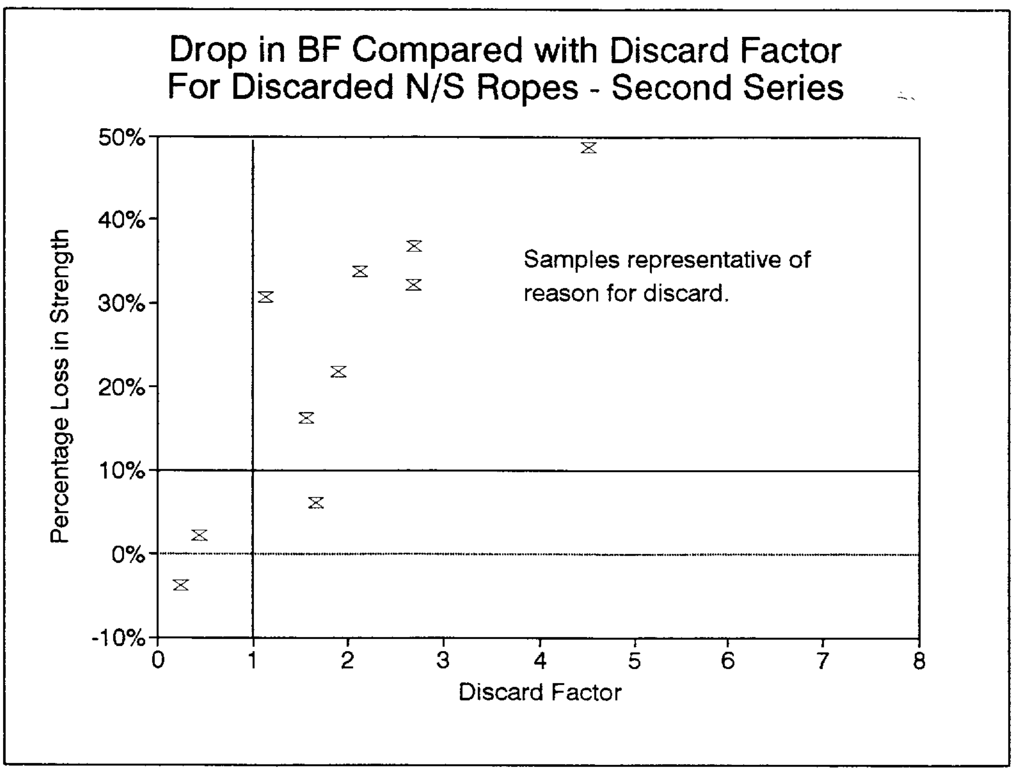

Figure 14 Percentage Drop in Strength Compared with Discard Factor for Non-spin Rope Samples of Second Series Representative of Reason for Discard.

3.4 NON-SPIN ROPES.

Scatter graphs for non-spin ropes which were submitted for examination and test in the second series are shown in Figure 13 and Figure 14 on page 13. Figure 13 gives the results of all the samples tested, many of which were required by the rope inspector for comparative control purposes. This is appropriate as much work must be done to develop the electro-magnetic examination of these ropes into a reliable means of determining the rope's condition.

Figure 14 on page 13 is the scatter graph for the samples regarded as the reason for discard. Only two of the samples were discarded due to internal anomalies identified by EM testing. In the other samples the external condition of the ropes was so bad that it was obvious that the strength would be significantly reduced. However in one case the test resulted in a strength loss of 6,1 % which is within the expected tolerance for discard.

Unfortunately although this graph has the appearance that the code can be used satisfactorily, there is still the need to develop a code for the discard of non-spins. 8 of the samples tested had a reduction in strength in excess of 20 %. All of these samples were chosen because of severe corrosion, damage or other obvious reasons. For this reason it was easy to assign an appropriate discard factor. The difficulty with this type of rope is to identify when the rope strength has reduced by the permitted amount due to internal deterioration. Although test personnel probably had appropriate EM test observations and interpretation, not sufficient information was supplied to enable recommendations to be made for changes to the code.

4 CONCLUSIONS.

The range of deterioration patterns of the ropes submitted has been wide enough for an initial assessment of the Code of Practice. However there have been insufficient test samples submitted which have been discarded at an appropriate time and with a normal amount of deterioration. Rope inspector's reports, or reports by the mine, have either not been submitted with the samples or have been inadequate in many details which could help in refining the code.

The results using assessed discard factors have shown that the discard criteria in the Draft Code of Practice are generally satisfactory for round strand and triangular strand ropes. The discard criteria are completely inappropriate for assessing non-spin ropes, especially those used on Koepe winders.

It is apparent that engineers having responsibility for winding ropes are not sufficiently aware of the code or have not been advised of the importance of submitting suitable discarded rope samples for the purpose of improving the Code. It was reported by one engineer that he had been requested to submit samples of *interest*. This is obviously not an appropriate method for selecting samples which are required to refine the code. In no case was any report, or information, supplied directly by the mine, especially where recommendations for discard were not necessarily made by the rope inspector and the discard was decided by the responsible engineer. It should be brought to the attention of the responsible engineers that discard reports and measurements are required to ensure an effective program.

REFERENCES.

1. WAINWRIGHT E. J. "Discussion of Results of Tests on Discarded Ropes - In Terms of the Draft Code of Practice on Rope Condition Assessment." Prepared for Mine Hoisting Technology, Division of Materials Science and Technology, CSIR and submitted to Safety in Mines Research Advisory Committee, Engineering Advisory Group.

2. SOUTH AFRICAN BUREAU OF STANDARDS. "Code of Practice - Condition Assessment of Steel Wire Ropes on Mine Winders." SABS xxxx:199x.

APPENDIX.

Abbreviated details of samples submitted for test, inspectors report (when submitted), CSIR examination of samples and discard values assigned, based on the CSIR examination, are listed in the following pages.

Winder Certificate No: 3991

SAMPLE NO: B001		*Mine:* West Driefontein		*Group:* Goldfields	
Coil No: 108972	*Rope Dia:* 43 mm	*Rope Construction:* 18 str Fishback		*Tensile Strength:* 1800 MPa	
Initial BF: 1470 kN		*Discard BF:* 972,4 kN		*Percentage Loss:* 33,9%	

Discard Criteria		**Inspectors Report**			
Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:					
Other Comments:					

Discard Criteria		**CSIR Pre Test Assessment**			
Rope Dia: 42,5 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:* 0	*1 Lay:* 0	*1 Lay, 1 Strand:* 0	*5 Lays:* 0	*Sym/asym:*
Corrosion:	Excessive external				
Other Comments:	Sample slightly slack				

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,13	0	2,0		2,13

No report on discard condition or criteria received from the mine.

Winder Certificate No: 3991

SAMPLE NO: B002		*Mine:* West Driefontein		*Group:* Goldfields	
Coil No: 108971	*Rope Dia:* 43 mm	*Rope Construction:* 18 str Fishback		*Tensile Strength:* 1800 MPa	
Initial BF: 1470 kN		*Discard BF:* 1018,4 kN		*Percentage Loss:* 30,7%	
Discard Criteria		**Inspectors Report**			
Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:					
Other Comments:					
Discard Criteria		**CSIR Pre Test Assessment**			
Rope Dia: 42,5 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:* 0	*1 Lay, 1 Strand:* 0	*5 Lays:* 0	*Sym/asym:*
Corrosion:	Excessive external				
Other Comments:					
Assigned Discard Factors					
Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*	
0,13	0	1		1,13	

No report received from the mine. Corrosion discard factor assigned on the basis of the visual examination at the laboratory.

Winder Certificate No: 4128

SAMPLE NO: B005		*Mine:* West Driefontein		*Group:* Goldfields	
Coil No: 027046	*Rope Dia:* 50 mm	*Rope Construction:* 6x32T		*Tensile Strength:* 1900 MPa	
Initial BF: 1950 kN		*Discard BF:* 1885,2 kN		*Percentage Loss:* 3,3%	

Discard Criteria — **Inspectors Report**

Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria — **CSIR Pre Test Assessment**

Rope Dia: 48,8 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:* 5	*1 Lay:* 5	*1 Lay, 1 Strand:* 5	*5 Lays:* 5	*Sym/asym:* Asym.

Corrosion: Nil

Other Comments: The rope has been crushed in the area of the broken wires. At this place the ovality is 47,5 mm x 58,9 mm.

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,34	1,32			1,67

No report received from the mine.

Winder Certificate No: Unlic.

Sample No: B008		*Mine:* Beatrix		*Group:* Genmin	
Coil No: 135358001	*Rope Dia:* 25 mm	*Rope Construction:* 6x13Br		*Tensile Strength:* 1800 MPa	
Initial BF: 474 kN		*Discard BF:* 358,2 kN		*Percentage Loss:* 24,4%	
Discard Criteria		**Inspectors Report**			
Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:					
Other Comments:					
Discard Criteria		**CSIR Pre Test Assessment**			
Rope Dia: 25,5 mm	*Wear/Plastic Deformation:* Heavy plastic wear.				
Broken Wires	*Total:* 0	*1 Lay:* 0	*1 Lay, 1 Strand:* 0	*5 Lays:* 0	*Sym/asym:*
Corrosion:	Nil				
Other Comments:	Sample has a kink				
Assigned Discard Factors					
Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*	
-0,22	0	0	1,5	1,28	

The factor of 1,5 was assigned due to the severity of the kink.

Winder Certificate No: 0078A

SAMPLE No: B009		*Mine:* Consolidated Murchison		*Group:* JCI	
Coil No: 117843001	*Rope Dia:* 41 mm	*Rope Construction:* 6x29T		*Tensile Strength:* 1800 MPa	
Initial BF: 1270 kN		*Discard BF:* 1332,0 kN		*Percentage Loss:* -4,9%	

Discard Criteria		**Inspectors Report**			
Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:					
Other Comments:					

Discard Criteria		**CSIR Pre Test Assessment**			
Rope Dia: 40,4 mm	*Wear/Plastic Deformation:* Normal				
Broken Wires	*Total:* 1	*1 Lay:* 1	*1 Lay, 1 Strand:* 1	*5 Lays:* 1	*Sym/asym:*
Corrosion:	Nil				
Other Comments:					

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,16	0,35			0,52

No report on discard condition or criteria received from the mine.

Winder Certificate No: 3948

Sample No: B010		*Mine:* Blyvooruitzicht	*Group:* Randgold
Coil No: 127774001	*Rope Dia:* 36 mm	*Rope Construction:* 6x27T	*Tensile Strength:* 1800 MPa
Initial BF: 991 kN		*Discard BF:* 873,6 kN	*Percentage Loss:* 11,8%

Discard Criteria — **Inspectors Report**

Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria — **CSIR Pre Test Assessment**

Rope Dia: 34,4 mm	*Wear/Plastic Deformation:* Severe				
Broken Wires	*Total:* 0	*1 Lay:* 0	*1 Lay, 1 Strand:* 0	*5 Lays:* 0	*Sym/asym:*

Corrosion: Nil

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,49	0		1	1,49

Rope has a wave.

Winder Certificate No: 3948

SAMPLE NO: B011		*Mine:* Blyvooruitzicht		*Group:* Randgold	
Coil No: 127774001	*Rope Dia:* 36 mm	*Rope Construction:* 6x27T		*Tensile Strength:* 1800 MPa	
Initial BF: 991 kN		*Discard BF:* 505,4 kN		*Percentage Loss:* 49,0%	

Discard Criteria		**Inspectors Report**			
Rope Dia: 35,5 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:* 5	*1 Lay:* 5	*1 Lay, 1 Strand:* 3	*5 Lays:* 5	*Sym/asym:*
Corrosion:					
Other Comments:	Angular bend. Summation of combined effects - 2,648				

Discard Criteria		**CSIR Pre Test Assessment**			
Rope Dia: 34,5 mm	*Wear/Plastic Deformation:* Severe				
Broken Wires	*Total:* 6	*1 Lay:* 6	*1 Lay, 1 Strand:* 3	*5 Lays:* 6	*Sym/asym:* Asym.
Corrosion:	Nil				
Other Comments:	Kink and wavy rope.				

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,46	1,9		1,5	3,86

A discard factor of 1,5 was assigned due to the severity of the kink.

Winder Certificate No: 3534

SAMPLE NO: B012		*Mine:* Wildebeestfontein North		*Group:* Genmin	
Coil No: 134479001	*Rope Dia:* 49 mm	*Rope Construction:* 6x32T		*Tensile Strength:* 1900 MPa	
Initial BF: 1861 kN		*Discard BF:* 1808,8 kN		*Percentage Loss:* 2,8%	

Discard Criteria | **Inspectors Report**

Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:					
Other Comments:					

Discard Criteria | **CSIR Pre Test Assessment**

Rope Dia: 48,3 mm	*Wear/Plastic Deformation:* Heavy				
Broken Wires	*Total:* 3	*1 Lay:* 3	*1 Lay, 1 Strand:* 3	*5 Lays:* 3	*Sym/asym:* Asym.
Corrosion:	Nil				
Other Comments:					

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,16	0,8			0,96

Winder Certificate No: 3971

Sample No: B013		*Mine:* Doornfontein		*Group:* Goldfields	
Coil No: 129031001	*Rope Dia:* 47 mm	*Rope Construction:* 15 str Fishback		*Tensile Strength:* 1800 MPa	
Initial BF: 1782 kN		*Discard BF:* 1206,8 kN		*Percentage Loss:* 32,3%	
Discard Criteria		**Inspectors Report**			
Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:					
Other Comments:					
Discard Criteria		**CSIR Pre Test Assessment**			
Rope Dia: 44,1 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:	Excessive				
Other Comments:	Rope outer strands slack.				
Assigned Discard Factors					
Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*	
0,69	0	2		2,69	

No report on discard condition or criteria received from the mine. The discard factor for corrosion was assigned on the basis of the visual examination in the laboratory.

Winder Certificate No: 3971

Sample No: B014		*Mine:* Doornfontein		*Group:* Goldfields	
Coil No: 129031002	*Rope Dia:* 47 mm	*Rope Construction:* 15 str Fishback		*Tensile Strength:* 1800 MPa	
Initial BF: 1766 kN		*Discard BF:* 1658,4 kN		*Percentage Loss:* 6,1%	

Discard Criteria — **Inspectors Report**

Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria — **CSIR Pre Test Assessment**

Rope Dia: 48,8 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:* 0	*1 Lay:* 0	*1 Lay, 1 Strand:* 0	*5 Lays:* 0	*Sym/asym:*

Corrosion: Excessive

Other Comments: Sample slightly slack - large gaps between outer strands.

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
-0,33	0	2		1,67

No report on discard condition or criteria received from the mine. The discard factor for corrosion was assigned on the basis if the visual examination in the laboratory.

Winder Certificate No:

SAMPLE NO: B016		*Mine:* Doornfontein		*Group:* Goldfields	
Coil No: 131229001	*Rope Dia:* 41 mm	*Rope Construction:* 18 str Fishback		*Tensile Strength:* 1800 MPa	
Initial BF: 1330 kN		*Discard BF:* 897,8 kN		*Percentage Loss:* 32,5%	

Discard Criteria **Inspectors Report**

Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 39,9 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:* 9	*1 Lay:* 5	*1 Lay, 1 Strand:* 2	*5 Lays:* 3	*Sym/asym:* Sym.

Corrosion: Excessive

Other Comments: Corrosion has caused the broken wires.

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
3972	No report on discard condition or criteria received from the mine.			

Winder Certificate No: 3972

SAMPLE No: B016A		*Mine:* Doornfontein		*Group:* Goldfields	
Coil No: 131229001	*Rope Dia:* 41 mm	*Rope Construction:* 18 str Fishback		*Tensile Strength:* 1800 MPa	
Initial BF: 1330 kN		*Discard BF:* 840,6 kN		*Percentage Loss:* 36,8%	
Discard Criteria		**Inspectors Report**			
Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:					
Other Comments:					
Discard Criteria		**CSIR Pre Test Assessment**			
Rope Dia: 39,8 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:* 3	*1 Lay:* 3	*1 Lay, 1 Strand:* 1	*5 Lays:* 3	*Sym/asym:* Asym.
Corrosion:	Excessive				
Other Comments:	Excessive localised corrosion at 2280 mm from end of rope sample.				
Assigned Discard Factors					
Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*	
0,42	0,28	2		2,69	

No report on discard condition or criteria received from the mine. The discard factor for corrosion was assigned on the basis of the visual examination in the laboratory.

Winder Certificate No: 3972

Sample No: B017		*Mine:* Doornfontein		*Group:* Goldfields	
Coil No: 131229002	*Rope Dia:* 41 mm	*Rope Construction:* 18 str Fishback		*Tensile Strength:* 1800 MPa	
Initial BF: 1330 kN		*Discard BF:* 682,6 kN		*Percentage Loss:* 48,6%	

Discard Criteria **Inspectors Report**

Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 40,2 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:* 35	*1 Lay:* 20	*1 Lay, 1 Strand:* 8	*5 Lays:* 35	*Sym/asym:* Sym.

Corrosion: Excessive

Other Comments: All outer wires of all outer strands are either slack or broken.

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,22	1,23	2		3,45

No report on discard condition or criteria received from the mine. The discard factor for corrosion was assigned on the basis of the visual examination in the laboratory.

Winder Certificate No: 3972

Sample No: B017A		*Mine:* Doornfontein	*Group:* Goldfields
Coil No: 131229002	*Rope Dia:* 41 mm	*Rope Construction:* 18 str Fishback	*Tensile Strength:* 1800 MPa
Initial BF: 1330 kN		*Discard BF:* 682,4 kN	*Percentage Loss:* 48,7%

Discard Criteria **Inspectors Report**

Rope Dia: mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 40,4 mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	48	40	8	48	Sym.

Corrosion: Excessive

Other Comments: All outer wires of all outer strands are either slack or broken.

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,16	2,31	2		4,47

No report on discard condition or criteria received from the mine. The discard factor for corrosion was assigned on the basis of the visual examination in the laboratory.

Winder Certificate No: 8528B

SAMPLE NO: B019		*Mine:* Winkelhaak		*Group:* Genmin	
Coil No: 131005002	*Rope Dia:* 36 mm	*Rope Construction:* 6x27T		*Tensile Strength:* 1800 MPa	
Initial BF: 998 kN		*Discard BF:* 655,2 kN		*Percentage Loss:* 34,3%	

Discard Criteria — **Inspectors Report**

Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria — **CSIR Pre Test Assessment**

Rope Dia: 35,6 mm	*Wear/Plastic Deformation:* Slight				
Broken Wires	*Total:* 13	*1 Lay:* 13	*1 Lay, 1 Strand:* 5	*5 Lays:* 13	*Sym/asym:* Asym.

Corrosion: Nil

Other Comments: Rope has a wave.

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,12	4,11			4,23

No report on discard condition or criteria received from the mine.

Winder Certificate No: 8528B

SAMPLE No: B019A		*Mine:* Winkelhaak	*Group:* Genmin
Coil No: 131005002	*Rope Dia:* 36 mm	*Rope Construction:* 6x27T	*Tensile Strength:* 1800 MPa
Initial BF: 998 kN		*Discard BF:* 1023,0 kN	*Percentage Loss:* -2,5%

Discard Criteria **Inspectors Report**

Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 36,4 mm	*Wear/Plastic Deformation:* Slight				
Broken Wires	*Total:* 0	*1 Lay:* 0	*1 Lay, 1 Strand:* 0	*5 Lays:* 0	*Sym/asym:*

Corrosion: Nil

Other Comments: Rope has a wave.

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
-0,12	0			-0,12

No report on discard condition or criteria received from the mine.

Winder Certificate No: 2884

SAMPLE NO: B035		*Mine:* Karee Mine		*Group:* Western Platinum	
Coil No: 120254002	*Rope Dia:* 34 mm	*Rope Construction:* 6x27T		*Tensile Strength:* 1750 MPa	
Initial BF: 860 kN		*Discard BF:* 826,2 kN		*Percentage Loss:* 3,9%	
Discard Criteria		**Inspectors Report**			
Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:					
Other Comments:					
Discard Criteria		**CSIR Pre Test Assessment**			
Rope Dia: 33,1 mm	*Wear/Plastic Deformation:* Severe				
Broken Wires	*Total:* 1	*1 Lay:* 1	*1 Lay, 1 Strand:* 1	*5 Lays:* 1	*Sym/asym:*
Corrosion:	Nil				
Other Comments:					
Assigned Discard Factors					
Rope Dia: 0,29	*Broken Wires:* 0,52	*Corrosion:*	*Other:*	*Total Factor:* 0,81	

No report on discard condition or criteria received from the mine.

Winder Certificate No: 2884

SAMPLE No: B036		*Mine:* Karee Mine		*Group:* Western Platinum	
Coil No: 120254002	*Rope Dia:* 34 mm	*Rope Construction:* 6x27T		*Tensile Strength:* 1750 MPa	
Initial BF: 860 kN		*Discard BF:* 903,2 kN		*Percentage Loss:* -5,0%	

Discard Criteria **Inspectors Report**

Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 34,7 mm	*Wear/Plastic Deformation:* Minimal				
Broken Wires	*Total:* 0	*1 Lay:* 0	*1 Lay, 1 Strand:* 0	*5 Lays:* 0	*Sym/asym:*

Corrosion: Nil

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
-0,23	0			-0,23

No report on discard condition or criteria received from the mine.

Winder Certificate No: 3975

SAMPLE NO: B041		*Mine:* Western Deep Levels		*Group:* Anglo American	
Coil No: 130214001	*Rope Dia:* 45 mm	*Rope Construction:* 17 str n/s		*Tensile Strength:* 1600 MPa	
Initial BF: 1260 kN		*Discard BF:* 1232,8 kN		*Percentage Loss:* 2,2%	

Discard Criteria		**Inspectors Report**			
Rope Dia: 44,2 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:					
Other Comments:	Clusters of internal broken wires. WMC failure.				

Discard Criteria		**CSIR Pre Test Assessment**			
Rope Dia: 43,2 mm	*Wear/Plastic Deformation:* Slight				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:	Nil				
Other Comments:	No visible broken wires.				

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,44				0,44

There was not enough information given to assign a discard factor for internal broken wires.

Winder Certificate No: 3975

SAMPLE NO: B041A		*Mine:* Western Deep Levels		*Group:* Anglo American	
Coil No: 130214001	*Rope Dia:* 45 mm	*Rope Construction:* 17 str n/s		*Tensile Strength:* 1600 MPa	
Initial BF: 1260 kN		*Discard BF:* 1296,0 kN		*Percentage Loss:* -2,9%	

Discard Criteria — **Inspectors Report**

Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:					
Other Comments:	Control sample				

Discard Criteria — **CSIR Pre Test Assessment**

Rope Dia: 43,6 mm	*Wear/Plastic Deformation:* Slight				
Broken Wires	*Total:* 0	*1 Lay:* 0	*1 Lay, 1 Strand:* 0	*5 Lays:* 0	*Sym/asym:*
Corrosion:	Nil				
Other Comments:					

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,35	0			0,35

Winder Certificate No: 3975

Sample No: B042		*Mine:* Western Deep Levels		*Group:* Anglo American	
Coil No: 130214001	*Rope Dia:* 45 mm	*Rope Construction:* 17 str n/s		*Tensile Strength:* 1600 MPa	
Initial BF: 1260 kN		*Discard BF:* 1265,6 kN		*Percentage Loss:* -0,4%	

Discard Criteria — **Inspectors Report**

Rope Dia: 44,2 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments: Clusters of internal broken wires. WMC failure.

Discard Criteria — **CSIR Pre Test Assessment**

Rope Dia: 43,5 mm	*Wear/Plastic Deformation:* Slight				
Broken Wires	*Total:* 0	*1 Lay:* 0	*1 Lay, 1 Strand:* 0	*5 Lays:* 0	*Sym/asym:*

Corrosion: Nil

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,37	0			0,37

Label indicated 350 m below east skip. There was not enough information given to assign a discard factor for internal broken wires.

Winder Certificate No: 3975

Sample No: B042A		*Mine:* Western Deep Levels		*Group:* Anglo American	
Coil No: 130214001	*Rope Dia:* 45 mm	*Rope Construction:* 17 str n/s		*Tensile Strength:* 1600 MPa	
Initial BF: 1260 kN		*Discard BF:* 1293,2 kN		*Percentage Loss:* -2,6%	

Discard Criteria **Inspectors Report**

Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:					

Other Comments: Control sample.

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 43,7 mm	*Wear/Plastic Deformation:* Slight				
Broken Wires	*Total:* 0	*1 Lay:* 0	*1 Lay, 1 Strand:* 0	*5 Lays:* 0	*Sym/asym:*
Corrosion:	Nil				

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,32	0			0,32

Winder Certificate No: 6623

SAMPLE NO: B043		*Mine:* Vaal Reefs	*Group:* Anglo American
Coil No: 124997002	*Rope Dia:* 62 mm	*Rope Construction:* 6x34T	*Tensile Strength:* 1800 MPa
Initial BF: 2890 kN		*Discard BF:* 2850,0 kN	*Percentage Loss:* 1,4%

Discard Criteria **Inspectors Report**

Rope Dia: 59,4 mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	4	3	3	4	Asym.

Corrosion:

Other Comments: Summation of combined effects - 0,62. Reason for discard due to U/L rope, this spot for evaluation only.

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 62,0 mm *Wear/Plastic Deformation:* Severe

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	8	6	3	8	Asym.

Corrosion: More than slight

Other Comments: Four broken wires in one strand (3 in one place) and 4 slack wires in other strands. There is localised wear and plastic flow due to cross-over wear.

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0	0,78			0,78

Winder Certificate No: 6623

SAMPLE NO: B043A		*Mine:* Vaal Reefs	*Group:* Anglo American
Coil No: 124997002	*Rope Dia:* 62 mm	*Rope Construction:* 6x34T	*Tensile Strength:* 1800 MPa
Initial BF: 2890 kN		*Discard BF:* 3012,0 kN	*Percentage Loss:* -4,2%

Discard Criteria **Inspectors Report**

Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments: See comments for sample B043.

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 62,5 mm	*Wear/Plastic Deformation:* Severe				
Broken Wires	*Total:* 4	*1 Lay:* 4	*1 Lay, 1 Strand:* 1	*5 Lays:* 4	*Sym/asym:* Asym.

Corrosion: More than slight

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
-0,09	0,52			0,43

Winder Certificate No: 3884

SAMPLE NO: B044		*Mine:* Doornfontein	*Group:* Goldfields
Coil No: 124014001	*Rope Dia:* 49 mm	*Rope Construction:* 6x33T	*Tensile Strength:* 1800 MPa
Initial BF: 1817 kN		*Discard BF:* 1489,2 kN	*Percentage Loss:* 18,0%

Discard Criteria **Inspectors Report**

Rope Dia: mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 48,8 mm

Wear/Plastic Deformation: Slight

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	6	6	2	6	Asym.

Corrosion: Nil

Other Comments: Severe localised wear along a plane as though in contact with an overlaying turn of rope. Rope wavy.

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,06	0,77		1	1,83

No report on discard condition or criteria received from the mine.

Winder Certificate No: 3884

SAMPLE NO: B045		*Mine:* Doornfontein		*Group:* Goldfields	
Coil No: 129017002	*Rope Dia:* 49 mm	*Rope Construction:* 6x33T		*Tensile Strength:* 1800 MPa	
Initial BF: 1817 kN		*Discard BF:* 1830,4 kN		*Percentage Loss:* -0.7%	
Discard Criteria		**Inspectors Report**			
Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:					
Other Comments:					
Discard Criteria		**CSIR Pre Test Assessment**			
Rope Dia: 49,4 mm	*Wear/Plastic Deformation:* Slight				
Broken Wires	*Total:* 0	*1 Lay:* 0	*1 Lay, 1 Strand:* 0	*5 Lays:* 0	*Sym/asym:*
Corrosion:	Nil				
Other Comments:	The specimen was corkscrewed over the full test length.				
Assigned Discard Factors					
Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*	
-0,09	0		1	0,91	

Application form stated that rope had a corkscrew caused by slack rope condition. No report on discard condition or criteria received from the mine.

Winder Certificate No: 3527

SAMPLE NO: B047		*Mine:* Rust. Plats. Rustenburg Section	*Group:* JCI
Coil No: 114827001	*Rope Dia:* 51 mm	*Rope Construction:* 6x32T	*Tensile Strength:* 1800 MPa
Initial BF: 1970 kN		*Discard BF:* 1469,6 kN	*Percentage Loss:* 25,4%

Discard Criteria **Inspectors Report**

Rope Dia: mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 50,3 mm *Wear/Plastic Deformation:* Slight

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	11	11	6	11	Asym.

Corrosion: Nil

Other Comments: Rope crushed in area of broken wires. Ovality of rope at this place 49,2 mm x 55,0 mm. Rope wavy.

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,5	1,79		1	3,29

No report on discard condition or criteria received from the mine.

Winder Certificate No: 0634

SAMPLE No: B048		*Mine:* Vaal Reefs	*Group:* Anglo American
Coil No: 124536001	*Rope Dia:* 45 mm	*Rope Construction:* 17 str n/s	*Tensile Strength:* 1600 MPa
Initial BF: 1180 kN		*Discard BF:* 1224,4 kN	*Percentage Loss:* -3,8%

Discard Criteria **Inspectors Report**

Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments: Rapid increase of internal broken wires and loose outer strands reason for discard.

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 44,0 mm	*Wear/Plastic Deformation:* Slight				
Broken Wires	*Total:* 0	*1 Lay:* 0	*1 Lay, 1 Strand:* 0	*5 Lays:* 0	*Sym/asym:*

Corrosion: Nil

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,25	0			0,25

Winder Certificate No: 3567

Sample No: B049		*Mine:* Zondereinder/Northam Platinum	*Group:* Goldfields
Coil No: 129658002	*Rope Dia:* 51 mm	*Rope Construction:* 6x33T	*Tensile Strength:* 1950 MPa
Initial BF: 1986 kN		*Discard BF:* 2069,2 kN	*Percentage Loss:* -4,2%

Discard Criteria **Inspectors Report**

Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 49,6 mm	*Wear/Plastic Deformation:* Severe				
Broken Wires	*Total:* 2	*1 Lay:* 2	*1 Lay, 1 Strand:* 1	*5 Lays:* 2	*Sym/asym:* Asym.

Corrosion: Nil

Other Comments: The same wire broken several times along length of specimen.

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,31	0,25			0,56

No report on discard condition or criteria received from the mine.

Winder Certificate No: 5100A

SAMPLE No: B050		*Mine:* Freddies		*Group:* Anglo American	
Coil No: 124635002	*Rope Dia:* 56 mm	*Rope Construction:* 6x32T		*Tensile Strength:* 1900 MPa	
Initial BF: 2460 kN		*Discard BF:* 2366,4 kN		*Percentage Loss:* 3,8%	

Discard Criteria		**Inspectors Report**			
Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:					
Other Comments:					

Discard Criteria		**CSIR Pre Test Assessment**			
Rope Dia: 55,4 mm	*Wear/Plastic Deformation:* Slight				
Broken Wires	*Total:* 0	*1 Lay:* 0	*1 Lay, 1 Strand:* 0	*5 Lays:* 0	*Sym/asym:*
Corrosion:	Nil				
Other Comments:					

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,12	0			0,12

No report on discard condition or criteria received from the mine.

Winder Certificate No: 5100A

SAMPLE No: B051		*Mine:* Freddies		*Group:* Anglo American	
Coil No: 124635001	*Rope Dia:* 56 mm	*Rope Construction:* 6x32T		*Tensile Strength:* 1900 MPa	
Initial BF: 2470 kN		*Discard BF:* 2437,2 kN		*Percentage Loss:* 1,3%	

Discard Criteria **Inspectors Report**

Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 55,8 mm	*Wear/Plastic Deformation:* Slight				
Broken Wires	*Total:* 1	*1 Lay:* 1	*1 Lay, 1 Strand:* 1	*5 Lays:* 1	*Sym/asym:* Asym.

Corrosion: Nil

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,04	0,27			0,31

No report on discard condition or criteria received from the mine.

Winder Certificate No: 5536A

SAMPLE No: B054		*Mine:* President Brand		*Group:* Anglo American	
Coil No: 133846001	*Rope Dia:* 63 mm	*Rope Construction:* 6x34T		*Tensile Strength:* 1950 MPa	
Initial BF: 3153 kN		*Discard BF:* 2743,0 kN		*Percentage Loss:* 13,0%	

Discard Criteria — **Inspectors Report**

Rope Dia: 60,9 mm	*Wear/Plastic Deformation:* Asym.				
Broken Wires	*Total:* 5	*1 Lay:* 5	*1 Lay, 1 Strand:* 5	*5 Lays:* 5	*Sym/asym:* Asym.
Corrosion:	None				

Other Comments: Reason for discard - 4 broken wires and 1 cracked wire in one strand.

Discard Criteria — **CSIR Pre Test Assessment**

Rope Dia: 62,4 mm	*Wear/Plastic Deformation:* Severe				
Broken Wires	*Total:* 6	*1 Lay:* 6	*1 Lay, 1 Strand:* 5	*5 Lays:* 6	*Sym/asym:* Asym.
Corrosion:	Nil				

Other Comments: Localised wear due to cross-over wear.

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,48	1,08			1,56

Winder Certificate No: 8529

SAMPLE NO: B055		*Mine:* Kinross		*Group:* Genmin	
Coil No: 130339003	*Rope Dia:* 46 mm	*Rope Construction:* 6x30T		*Tensile Strength:* 1950 MPa	
Initial BF: 1790 kN		*Discard BF:* 1821,2 kN		*Percentage Loss:* -1,7%	

Discard Criteria		**Inspectors Report**			
Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:					
Other Comments:					

Discard Criteria		**CSIR Pre Test Assessment**			
Rope Dia: 45,1 mm	*Wear/Plastic Deformation:* Severe				
Broken Wires	*Total:* 0	*1 Lay:* 0	*1 Lay, 1 Strand:* 0	*5 Lays:* 0	*Sym/asym:*
Corrosion:	Nil				
Other Comments:					

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,22	0			0,22

No report on discard condition or criteria received from the mine.

Winder Certificate No: 3979

SAMPLE No: B057		*Mine:* Western Deep Levels		*Group:* Anglo American
Coil No: 134038002	*Rope Dia:* 45 mm	*Rope Construction:* 17 str n/s		*Tensile Strength:* 1600 MPa
Initial BF: 1274 kN		*Discard BF:* 995,2 kN		*Percentage Loss:* 21,9%

Discard Criteria — **Inspectors Report**

Rope Dia: 44,5 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:* 12	*1 Lay:* 12	*1 Lay, 1 Strand:* 10	*5 Lays:* 12	*Sym/asym:*

Corrosion:

Other Comments: Reason for discard - damage to rope.

Discard Criteria — **CSIR Pre Test Assessment**

Rope Dia: 43,8 mm	*Wear/Plastic Deformation:* None				
Broken Wires	*Total:* 12	*1 Lay:* 12	*1 Lay, 1 Strand:* 10	*5 Lays:* 12	*Sym/asym:* Asym.

Corrosion: Nil

Other Comments: Rope indented at area of broken wires with 3 strands damaged.

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,3	1,6			1,9

Winder Certificate No: 2283

SAMPLE NO: B058		*Mine:* Finsch		*Group:* Anglo American	
Coil No: 131917002	*Rope Dia:* 50 mm	*Rope Construction:* 6x36/F		*Tensile Strength:* 1800 MPa	
Initial BF: 1731 kN		*Discard BF:* 1576,5 kN		*Percentage Loss:* 8,9%	

Discard Criteria **Inspectors Report**

Rope Dia: 48,5 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:* 11	*1 Lay:* 7	*1 Lay, 1 Strand:* 4	*5 Lays:* 11	*Sym/asym:*
Corrosion:	Nil				

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 50,0 mm	*Wear/Plastic Deformation:* None				
Broken Wires	*Total:* 11	*1 Lay:* 7	*1 Lay, 1 Strand:* 4	*5 Lays:* 11	*Sym/asym:* Asym.
Corrosion:	Nil				

Other Comments: Plastic deformation at broken wires (damage) in one of the strands.

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0	0,88			0,88

Winder Certificate No: 2283

SAMPLE NO: B059		*Mine:* Finsch		*Group:* Anglo American	
Coil No: 131917002	*Rope Dia:* 50 mm	*Rope Construction:* 6x36/F		*Tensile Strength:* 1800 MPa	
Initial BF: 1731 kN		*Discard BF:* 1718,8 kN		*Percentage Loss:* 0,7%	

Discard Criteria		**Inspectors Report**			
Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:					
Other Comments:	Control sample cut next to discard section.				

Discard Criteria		**CSIR Pre Test Assessment**			
Rope Dia: 50,0 mm	*Wear/Plastic Deformation:* None				
Broken Wires	*Total:* 0	*1 Lay:* 0	*1 Lay, 1 Strand:* 0	*5 Lays:* 0	*Sym/asym:*
Corrosion:	Nil				
Other Comments:					

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0	0			0

Winder Certificate No: 3791A

SAMPLE NO: B062		*Mine:* Blyvooruitzicht	*Group:* Randgold
Coil No: 125147002	*Rope Dia:* 36 mm	*Rope Construction:* 6x27T	*Tensile Strength:* 1800 MPa
Initial BF: 994 kN		*Discard BF:* 982,6 kN	*Percentage Loss:* 1,1%

Discard Criteria **Inspectors Report**

Rope Dia: 34,8 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments: Waviness: 7,5 % of nominal diameter.

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 34,5 mm

Wear/Plastic Deformation: Severe

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: Nil

Other Comments: Rope has a dark brown colour, as though it has been heated. Severe wear and plastic flow on 5 strands. The 6th strand has about 50 % less wear than the other strands.

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,6	0		1	1,6

Winder Certificate No: 3791A

SAMPLE No: B063		*Mine:* Blyvooruitzicht		*Group:* Randgold	
Coil No: 125147002	*Rope Dia:* 36 mm	*Rope Construction:* 6x27T		*Tensile Strength:* 1800 MPa	
Initial BF: 994 kN		*Discard BF:* 973,8 kN		*Percentage Loss:* 2,0%	

Discard Criteria **Inspectors Report**

Rope Dia: 34,8 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments: Waviness: 7,5 % of nominal diameter.

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 34,6 mm	*Wear/Plastic Deformation:* Severe				
Broken Wires	*Total:* 0	*1 Lay:* 0	*1 Lay, 1 Strand:* 0	*5 Lays:* 0	*Sym/asym:*

Corrosion: Nil

Other Comments: Rope has a dark brown colour, as though it has been heated. Rope has a permanent radius of about 10 m. Severe wear and plastic flow on 5 strands, but the 6th strand has less.

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,56	0		1	1,56

Winder Certificate No: 3791A

SAMPLE No: B064		*Mine:* Blyvooruitzicht		*Group:* Randgold	
Coil No: 125147001	*Rope Dia:* 36 mm	*Rope Construction:* 6x27T		*Tensile Strength:* 1800 MPa	
Initial BF: 994 kN		*Discard BF:* 980,8 kN		*Percentage Loss:* 1,3%	

Discard Criteria **Inspectors Report**

Rope Dia: 35,2 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:					

Other Comments: Waviness: 13,8 % of nominal rope diameter.

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 34,3 mm	*Wear/Plastic Deformation:* Severe				
Broken Wires	*Total:* 0	*1 Lay:* 0	*1 Lay, 1 Strand:* 0	*5 Lays:* 0	*Sym/asym:*
Corrosion:	Nil				

Other Comments: Rope has a dark brown colour, as though it has been heated. The rope is evenly worn.

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,52	0		1	1,52

Winder Certificate No: 3791A

Sample No: B065		*Mine:* Blyvooruitzicht	*Group:* Randgold	
Coil No: 125147001	*Rope Dia:* 36 mm	*Rope Construction:* 6x27T	*Tensile Strength:* 1800 MPa	
Initial BF: 994 kN		*Discard BF:* 984,0 kN	*Percentage Loss:* 1,0%	

Discard Criteria **Inspectors Report**

Rope Dia: 35,2 mm

Wear/Plastic Deformation:

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion:

Other Comments: Waviness: 13,8 % of nominal rope diameter.

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 34,6 mm

Wear/Plastic Deformation: Severe

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	0	0	0	0	

Corrosion: Nil

Other Comments: Rope has a dark brown colour, as though it has been heated. Rope is evenly worn.

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,43	0		1	1,43

Winder Certificate No: 3544

Sample No: B066		*Mine:* Zondereinder/Northam Platinum		*Group:* Goldfields	
Coil No: 127897002	*Rope Dia:* 51 mm	*Rope Construction:* 6x32T		*Tensile Strength:* 1900 MPa	
Initial BF: 2027 kN		*Discard BF:* 1888,8 kN		*Percentage Loss:* 6,8%	
Discard Criteria		**Inspectors Report**			
Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:					
Other Comments:					
Discard Criteria		**CSIR Pre Test Assessment**			
Rope Dia: 51,6 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:* 0	*1 Lay:* 0	*1 Lay, 1 Strand:* 0	*5 Lays:* 0	*Sym/asym:*
Corrosion:	Nil				
Other Comments:	Kink which had pulled tight.				
Assigned Discard Factors					
Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*	
-0,13	0		1	0,87	

No report on discard condition or criteria received from the mine.

Winder Certificate No: 3558

Sample No: B067		*Mine:* Rust. Plats. Amandelbult Sect.	*Group:* JCI
Coil No: 127745001	*Rope Dia:* 54 mm	*Rope Construction:* 6x34T	*Tensile Strength:* 2100 MPa
Initial BF: 2442 kN		*Discard BF:* 2027,6 kN	*Percentage Loss:* 17,0%

Discard Criteria **Inspectors Report**

Rope Dia: mm *Wear/Plastic Deformation:*

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 54,1 mm *Wear/Plastic Deformation:* Heavy

Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
	6	6	5	6	Asym.

Corrosion: Nil

Other Comments: Sample had a slight increase in diameter in area between the broken wires - measured 56,5 mm.

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
-0,02	1,07			1,04

No report on discard condition or criteria received from the mine.

Winder Certificate No: 3558

SAMPLE NO: B068		*Mine:* Rust. Plats. Amandelbult Sect.		*Group:* JCI	
Coil No: 127745001	*Rope Dia:* 54 mm	*Rope Construction:* 6x34T		*Tensile Strength:* 2100 MPa	
Initial BF: 2442 kN		*Discard BF:* 1942,0 kN		*Percentage Loss:* 20,5%	

Discard Criteria **Inspectors Report**

Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 53,6 mm	*Wear/Plastic Deformation:* Heavy				
Broken Wires	*Total:* 10	*1 Lay:* 10	*1 Lay, 1 Strand:* 5	*5 Lays:* 10	*Sym/asym:* Asym.

Corrosion: Nil

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,08	1,28			1,36

No report on discard condition or criteria received from the mine.

Winder Certificate No: 2158A

SAMPLE NO: B070		*Mine:* Loraine		*Group:* Anglovaal
Coil No: 75857	*Rope Dia:* 46 mm	*Rope Construction:* 6x31T		*Tensile Strength:* 1800 MPa
Initial BF: 1640 kN		*Discard BF:* 1578,8 kN		*Percentage Loss:* 3,7%

Discard Criteria **Inspectors Report**

Rope Dia: 42,2 mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments: Reason for discard - reduction in diameter.

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 44,1 mm	*Wear/Plastic Deformation:* Very severe				
Broken Wires	*Total:* 0	*1 Lay:* 0	*1 Lay, 1 Strand:* 0	*5 Lays:* 0	*Sym/asym:*

Corrosion: Nil

Other Comments: Wear and plastic deformation uniform along specimen.

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,92	0			0,92

Winder Certificate No: 4553B

SAMPLE NO: B071		*Mine:* East Driefontein		*Group:* Goldfields	
Coil No: 122187002	*Rope Dia:* 30 mm	*Rope Construction:* 15 str n/s (O09)		*Tensile Strength:* 1800 MPa	
Initial BF: 688,0 kN		*Discard BF:* 575,9 kN		*Percentage Loss:* 16,3%	

Discard Criteria **Inspectors Report**

Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:					
Other Comments:					

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 29,4 mm	*Wear/Plastic Deformation:* Minimal				
Broken Wires	*Total:* 7	*1 Lay:* 5	*1 Lay, 1 Strand:* 4	*5 Lays:* 7	*Sym/asym:* Asym.
Corrosion:	Nil				
Other Comments:					

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,22	1,34			1,56

No report on discard condition or criteria received from the mine.

Winder Certificate No: 4553B

SAMPLE NO: B071A		*Mine:* East Driefontein		*Group:* Goldfields	
Coil No: 122187002	*Rope Dia:* 30 mm	*Rope Construction:* 15 str n/s (O09)		*Tensile Strength:* 1800 MPa	
Initial BF: 688,0 kN		*Discard BF:* 632,5 kN		*Percentage Loss:* 8,1%	

Discard Criteria **Inspectors Report**

Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 30,0 mm	*Wear/Plastic Deformation:* Minimal				
Broken Wires	*Total:* 4	*1 Lay:* 3	*1 Lay, 1 Strand:* 1	*5 Lays:* 4	*Sym/asym:* Asym.

Corrosion: Nil

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0	0,6			0,6

No report on discard condition or criteria received from the mine.

Winder Certificate No: 3539

SAMPLE No: B073		*Mine:* Wildebeestfontein South		*Group:* Genmin	
Coil No: 131451001	*Rope Dia:* 49 mm	*Rope Construction:* 6x32T		*Tensile Strength:* 2050 MPa	
Initial BF: 2019 kN		*Discard BF:* 1540 kN		*Percentage Loss:* 23,7%	

Discard Criteria **Inspectors Report**

Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*
Corrosion:					
Other Comments:					

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 47,8 mm	*Wear/Plastic Deformation:* Heavy				
Broken Wires	*Total:* 6	*1 Lay:* 6	*1 Lay, 1 Strand:* 2	*5 Lays:* 6	*Sym/asym:* Asym.
Corrosion:	Nil				
Other Comments:					

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,27	0,96			1,23

No report on discard condition or criteria received from the mine.

Winder Certificate No: 3539

SAMPLE No: B074		*Mine:* Wildebeestfontein South		*Group:* Genmin	
Coil No: 131451001	*Rope Dia:* 49 mm	*Rope Construction:* 6x32T		*Tensile Strength:* 2050 MPa	
Initial BF: 2019 kN		*Discard BF:* 1320 kN		*Percentage Loss:* 34,6%	

Discard Criteria **Inspectors Report**

Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 47,9 mm	*Wear/Plastic Deformation:* Heavy				
Broken Wires	*Total:* 10	*1 Lay:* 10	*1 Lay, 1 Strand:* 5	*5 Lays:* 10	*Sym/asym:* Asym.

Corrosion: Nil

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,25	1,60			1,85

No report on discard condition or criteria received from the mine.

Winder Certificate No: 1735

Sample No: B075		*Mine:* ERPM		*Group:* Randgold	
Coil No: 124822001	*Rope Dia:* 46 mm	*Rope Construction:* 6x31T		*Tensile Strength:* 1800 MPa	
Initial BF: 1600 kN		*Discard BF:* 1594,4 kN		*Percentage Loss:* 0,3%	

Discard Criteria — **Inspectors Report**

Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria — **CSIR Pre Test Assessment**

Rope Dia: 44,0 mm	*Wear/Plastic Deformation:* Severe				
Broken Wires	*Total:* 1	*1 Lay:* 1	*1 Lay, 1 Strand:* 1	*5 Lays:* 1	*Sym/asym:* Asym.

Corrosion: Nil

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,48	0,3			0,79

No report on discard condition or criteria received from the mine.

Winder Certificate No: -

Sample No: B079		*Mine:* Rust. Plats. Rustenburg Sect.	*Group:* JCI
Coil No: 209118001	*Rope Dia:* 26 mm	*Rope Construction:* 6x19(9/9/1)/F	*Tensile Strength:* 1800 MPa
Initial BF: 423 kN		*Discard BF:* 390,6 kN	*Percentage Loss:* 7,7%

Discard Criteria **Inspectors Report**

Rope Dia: mm	*Wear/Plastic Deformation:*				
Broken Wires	*Total:*	*1 Lay:*	*1 Lay, 1 Strand:*	*5 Lays:*	*Sym/asym:*

Corrosion:

Other Comments:

Discard Criteria **CSIR Pre Test Assessment**

Rope Dia: 24,8 mm	*Wear/Plastic Deformation:* Slight				
Broken Wires	*Total:* 0	*1 Lay:* 0	*1 Lay, 1 Strand:* 0	*5 Lays:* 0	*Sym/asym:*

Corrosion: Superficial rust

Other Comments:

Assigned Discard Factors

Rope Dia:	*Broken Wires:*	*Corrosion:*	*Other:*	*Total Factor:*
0,51	0			0,51

No report on discard condition or criteria received from the mine.

Project No.: MHEAG Ref: Mattek 49

FURTHER TESTS TO STUDY THE EFFECT OF CUT WIRES ON THE STRENGTH OF WINDING ROPES

by

G F K Hecker and T C Kuun

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Job No.: MST(95)MC0000
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CONTENTS

1. INTRODUCTION

Representatives of the South African mining industry have drafted a code of practice for mine winder rope condition assessment. The discard criteria are central to this code of practice and have largely been based on experience. The allowable number of broken wires, however, has been based on work done by Harvey and Kruger[1]. Further work by Borello and Kuun[2] has shown that the presence of broken wires has a different effect to that reported by Harvey and Kruger. They suggested that the broken wire discard criteria may need to be amended, subject to the results of further work.

The results of such further work are presented in this report. A final recommendation is made for changing the allowable number of broken wires in the discard criteria for triangular strand and round strand ropes.

2. SCOPE OF TESTS

Borello and Kuun reported on a comprehensive set of tests done on samples obtained from a 48 mm triangular strand rope. They recommended that further tests be done to study the effect of broken wires on the strength of ropes of different sizes and tensile grades. When it came to do the tests, however, it soon became evident that the required samples would not be available in the time allocated to the project. The scope of the tests was therefore altered to suit the availability of specimens.

The samples can be divided into three major categories:

- An assortment of samples with different tensile grades, diameters and constructions. These samples were supplied by Messrs Haggie Rand Ltd. They were obtained from their sample store according to a list of requests supplied by the CSIR.
- A length of discarded 62 mm triangular strand rope supplied by Mr H van Rooyen of Anglo American Corporation.
- A length of 41 mm triangular strand rope purchased for this series of tests.

The above categories were subdivided into smaller categories for analysing the results.

3. TEST PROCEDURE

As far as possible, the same procedure was followed as that described by Borello and Kuun so that comparable results could be obtained. Specimen preparation entailed

- providing the specimen with white metal endcaps,
- subjecting the specimen to 500 load cycles with a range of 5% to 25% of the new rope breaking strength, and
- cutting the desired number of wires with an angle grinder.

The set of tests on 41 mm rope specimens was repeated, but with on set of specimens subjected to cycling *after* the wires were cut and the other set of specimens with no cycling done before the test.

After this preparation, the specimens were tensile tested to destruction to obtain their breaking strength.

The results of the tests are shown in tables in the sections that follow. Although these tables show samples with increasing number of broken wires, this has been done to improve readability and does not reflect the sequence of the test. The actual test sequence was done randomly for each category of samples in an attempt to exclude any gradual effect of sample preparation.

4. ANALYSIS OF RESULTS

For each set of results, the reduction in rope area (X) due to the cut wires and the loss in rope strength (Y) were calculated as percentages. Constants B and Q of the regression equation $Y = X + BX^Q$ were derived for the minimum sum of the squares of the deviations.

Each section that follows contains an abbreviated title that is the name of the data set used in the analyses. The sections describe the specimens, list the test results and table the results of the analyses.

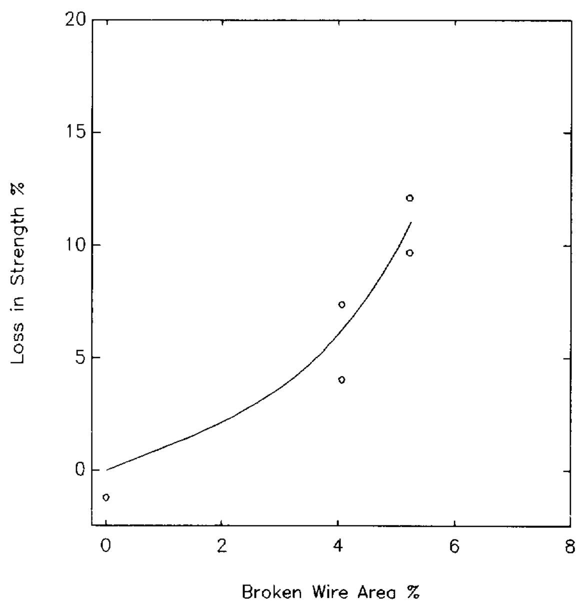
4.1 NEW62

Diameter: 62 mm
Construction: Compound Triangular Strand 34(16/12/6+3T)
Tensile grade: 1 800 MPa

Number of cut wires	Reduction in area (%)	New breaking strength (kN)	Breaking strength (kN)	Reduction in breaking strength (%)
0	0,00	3020	3057	-1,23
7	4,06	2890	2677	7,37
7	4,06	2979	2828	5,07
9	5,22	2990	2701	9,67
9	5,22	2999	2636	12,10

B = 0,01
Q = 3,84

These samples were obtained from Haggie Rand's sample store. Since the samples were cut from ropes with different coil numbers, no proper zero reference could be obtained.



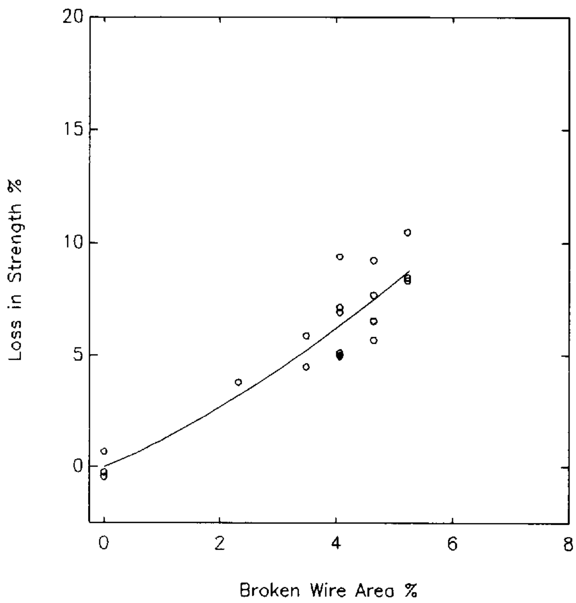
4.2 DISC62

Diameter: 62 mm
Construction: Compound Triangular Strand 34(16/12/6+3T)
Tensile grade: 1 800 MPa

Number of cut wires	Reduction in area (%)	New breaking strength (kN)*	Breaking strength (kN)	Reduction in breaking strength (%)
0	0,00	3025,7	3039	-0,44
0	0,00	3025,7	3005	0,68
0	0,00	3025,7	3033	-0,24
4	2,32	3025,7	2911	3,79
6	3,48	3025,7	2890	4,48
6	3,48	3025,7	2848	5,87
7	4,06	3025,7	2871	5,11
7	4,06	3025,7	2874	5,01
7	4,06	3025,7	2742	9,38
7	4,06	3025,7	2810	7,13
7	4,06	3025,7	2817	6,90
7	4,06	3025,7	2876	4,95
8	4,46	3025,7	2829	6,50
8	4,64	3025,7	2828	6,53
8	4,64	3025,7	2794	7,66
8	4,64	3025,7	2747	9,21
8	4,64	3025,7	2854	5,67
9	5,22	3025,7	2774	8,32
9	5,22	3025,7	2770	8,45
9	5,22	3025,7	2709	10,47

* The new rope breaking strength was set to the average breaking strength of the first three samples without cut wires

B = 0,21
Q = 1,7



These samples were obtained from Messrs Vaal Reefs Exploration and Mining Co Ltd. Two lengths of discarded 62 mm rope were supplied and the samples were cut from sections that showed normal deterioration. Sections that seemed to have suffered from handling (e.g. samples with loose strands) were not used for the tests.

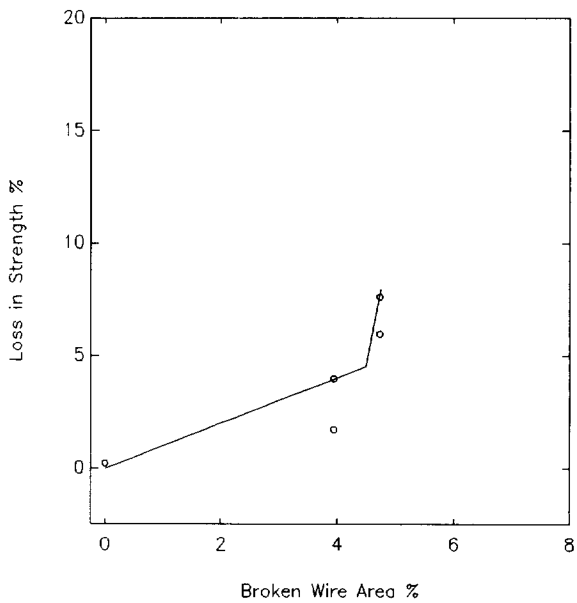
Only three tests on samples with zero cut wires were done. The average breaking force obtained from these three tests was taken as the reference breaking strength for both ropes. The average breaking strength was 3,2% higher than the new rope breaking strength while the new rope breaking strengths were within 0,2% of each other.

4.3 Y48R

Diameter: 48 mm
Construction: Round Strand 25(12/6+6/1)
Tensile grade: EIPS

Number of cut wires	Reduction in area (%)	New breaking strength (kN)	Breaking strength (kN)	Reduction in breaking strength (%)
0	0,00	1710	1706	0,23
5	3,49	1700	1671	1,71
5	3,49	1716	1648	3,96
6	4,73	1699	1598	5,94
6	4,73	1722	1591	7,61

$B = 1{,}2 \times 10^{-70}$
$Q = 104$



These samples were obtained from Haggie Rand's sample store. Since the samples were cut from ropes with different coil numbers, no proper zero reference could be obtained.

Constant B is very small and Q is very large. This results in the definite kink in the fitted curve. Such a ridiculous curve is an example of the results an analysis of too few data points. Other curves can be fitted that produce smaller residuals, but they cannot be justified because such curves violate the assumption that the percentage loss in breaking strength is at least equal to the percentage area loss.

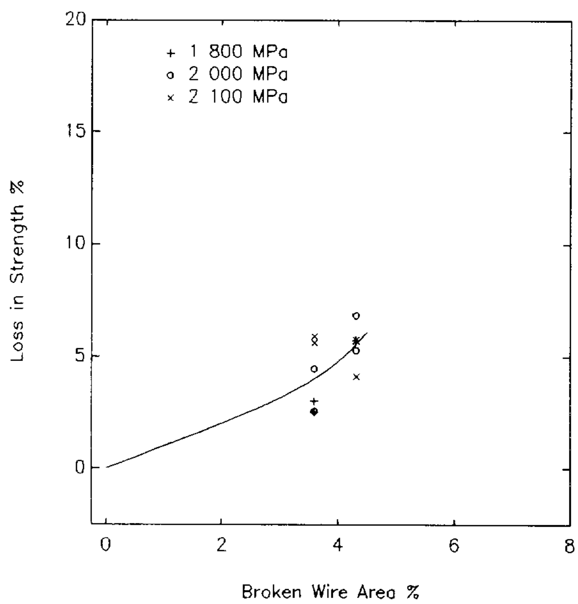
Results from such a small population cannot support statistical treatment. They should be ignored so that one is not tempted to reach invalid conclusions.

4.4 AL48T

Diameter: 48 mm
Construction: Compound Triangular Strand 32(14/12/6+3T)
Tensile grade: 1 800, 2 000 and 2 100 MPa

Number of cut wires	Reduction in area (%)	New breaking strength (kN)	Breaking strength (kN)	Reduction in breaking strength (%)
+ 5	3,59	1750	1706	2,51
5	3,59	1730	1678	3,01
6	4,31	1720	1622	5,70
o 5	3,59	1957	1870	4,45
5	3,59	1884	1836	2,55
6	4,31	1962	1828	6,83
6	4,31	1898	1798	5,27
× 5	3,59	2028	1914	5,62
5	3,59	1983	1866	5,90
6	4,31	2031	1915	5,71
6	4,31	1978	1897	4,10

$B = 2{,}4 \times 10^{-4}$
$Q = 5{,}8$



These samples were obtained from Haggie Rand's sample store. Since the samples were cut from ropes with different coil numbers, no proper zero reference could be obtained.

The first sample in the above table was cut from the rope used in the 1994 tests. This sample was prepared by Mr M Borello to show CSIR staff how the previous samples were prepared. This was done so that there would be continuity in the preparation procedure. The reference breaking strength of this sample was taken as the breaking strength of the new rope, thus keeping the reference method the same for all ropes. Since the 1994 tests were based on a reference breaking strength of 1 817,5 kN, however, its reduction in breaking strength would have been calculated as 6,13%.

4.5 AL32

Diameter: 32 mm
Construction: Compound Triangular Strand 26(8/12/6+3T)
Tensile grade: 1 800 and 1 900 MPa

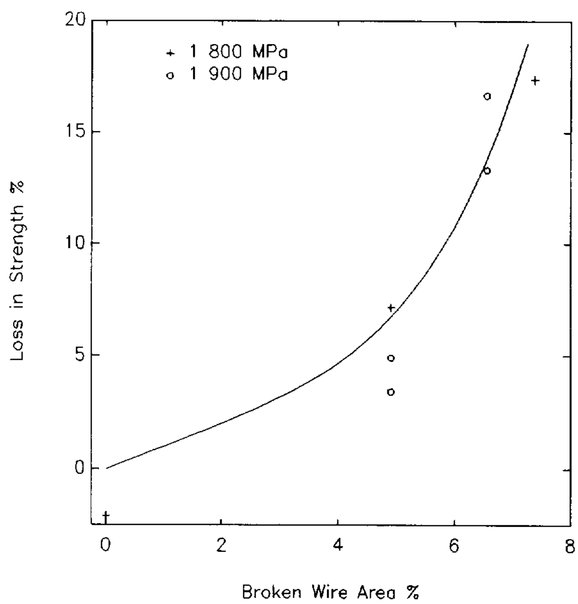
Number of cut wires	Reduction in area (%)	New breaking strength (kN)	Breaking strength (kN)	Reduction in breaking strength (%)
+ 0*	0,00	765	781	-2,09
3	4,91	784	728	7,14
4,5**	7,37	755	624	17,35
o 3	4,91	794	755	4,91
3	4,91	792	765	3,41
4	6,55	751	651	13,32
4	6,55	799	666	16,65

* The result with zero cut wires has not been taken into account during the analysis and is only shown for completeness

** Apart from the four cut wires, one wire was damaged before the test. The approximation of 4,5 broken wires was made rather than to exclude the result from the analyses

$B = 9{,}1 \times 10^{-4}$
$Q = 4{,}8$

These samples were obtained from Haggie Rand's sample store. Since the samples were cut from ropes with different coil numbers, no proper zero reference could be obtained. The one test result without wires cut seems to suggest that different results would be obtained if a proper zero reference was established.



4.6 AL41

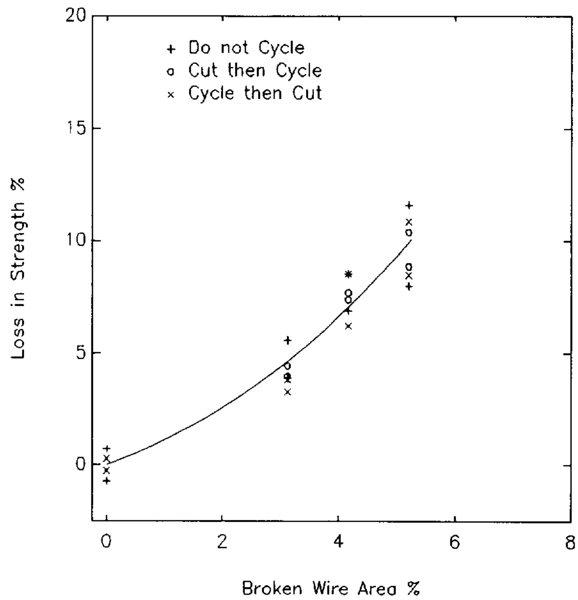
Diameter: 41 mm
Construction: Compound Triangular Strand 29(11/12/6+3T)
Tensile grade: 1 800 MPa

Number of cut wires	Reduction in area (%)	Reference breaking strength (kN)	Breaking strength (kN)	Reduction in breaking strength (%)
+ 0	0,00	1300,5*	1310	-0,73
0	0,00		1291	0,73
3	3,12		1228	5,57
3	3,12		1250	3,88
4	4,16		1190	8,50
4	4,16		1211	6,88
5	5,20		1197	7,96
5	5,20		1150	11,57
○ 3	3,12	1296,5**	1239	4,44
3	3,12		1245	3,97
4	4,16		1201	7,37
4	4,16		1197	7,68
5	5,20		1162	10,37
5	5,20		1182	8,83
× 0	0,00	1296,5	1300	-0,27
0	0,00		1293	0,27
3	3,12		1247	3,82
3	3,12		1254	3,28
4	4,16		1216	6,21
4	4,16		1186	8,25
5	5,20		1156	10,84
5	5,20		1187	8,45

* The reference breaking strength was taken as the average of the two ropes that had no wires cut and were not cycled before the tensile test

** The reference breaking strength was taken as the average of the two ropes that had no wires cut and were cycled before the tensile test

B = 0,13
Q = 2,2

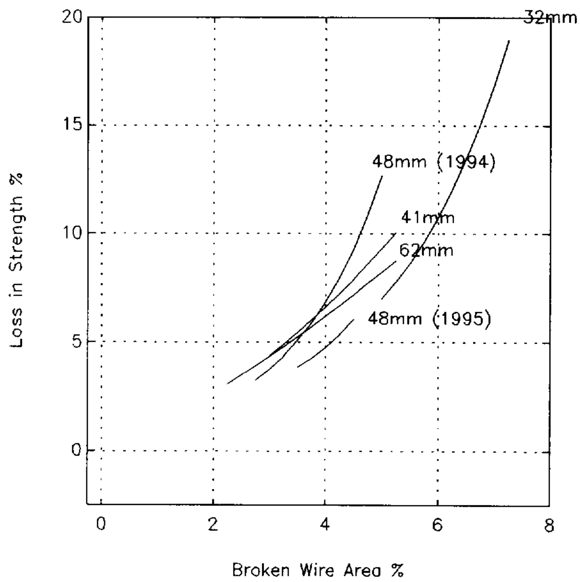


These samples were cut from a single rope purchased for these tests. The difference in the two reference breaking strengths is 0,3%. Considering the fact that the repeatability of rope tensile tests is within 1%, this difference is considered negligible. This is in contradiction with the findings reported by Borello and Kuun[2] where the average breaking strength of the rope after cycling was 3,9% higher than the breaking strength of the new rope. It must also be mentioned that, with the tests done by Borello and Kuun, the reference breaking strength (after cycling) was done more than five years after the test on the new rope was done. The effect of cycling is therefore not yet fully understood. The only effect of cycling that can be observed from the current tests seems to be: The largest difference between the results from identical tests is obtained if the specimens are not cycled at all and the smallest difference is obtained when the wires are cut before the specimens are cycled.

5. DISCUSSION

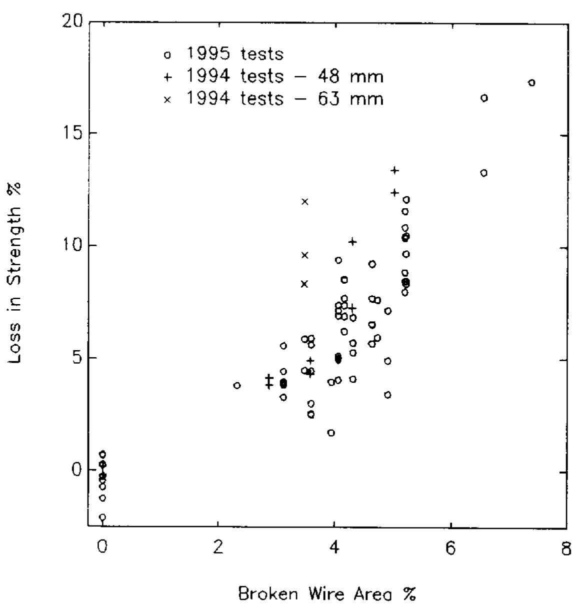
Limited test results (fewer than six data points and no proper reference) do not represent their population reliably and can cause bizarre interpretations. Included in this category are the 48 mm round strand (see remarks on p.6) and the new 62 mm data sets.

The results of the regression analyses are all shown in this figure so that comparisons can be made. Apparently the 32 mm ropes and the 48 mm ropes tested in 1995 have a lower loss in breaking strength than the other sets. As mentioned before, however, no proper reference strength has been obtained for these ropes. Only one test was done on a 32 mm rope without cutting a wire (see p. 8) and this test showed an increase in strength of ~2%. No significance should be attached to the result of a single test, however.



For a reduction in area of less than about 4%, no rope size effect is apparent in this graph. Beyond this range the curves diverge, but it is not certain that rope size is the determining factor: The 48 mm data of 1994 were produced by a different team while the 62 mm samples were cut from a discarded rope that had been in service for some time.

The adjacent graph shows all the results from the 1995 tests, the results from tests of single strand cut wires in 1994 and three tests on 63 mm ropes done in 1994. The test results from the 63 mm ropes clearly are outliers and no explanation could be found for this.



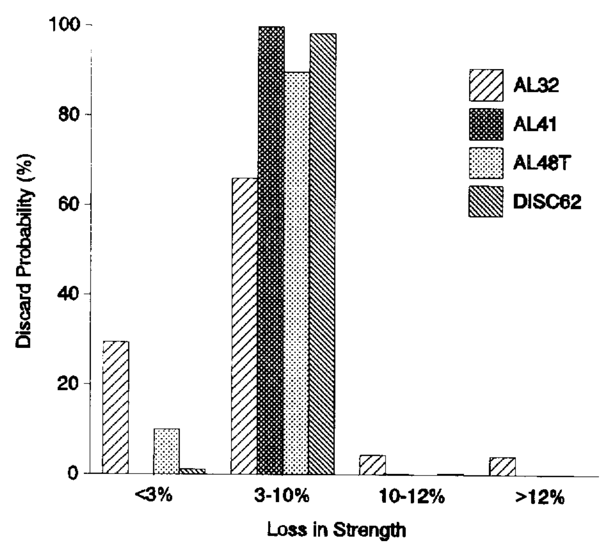
The comments on 1995 tests regarding sample size and reference strengths also apply to these three results. They gave rise to a recommendation that further tests be done with ropes of different diameters and tensile grades. As will be seen, the results of the 1995 tests did not lead to recommendations that differ from those based on the 1994 tests.

The table below shows a summary of the results of the regression analyses. Details of the analysis strategy can be found in reference 2. For each data set, a broken wire discard criterion varying from 3,5% to 5,0% was chosen. The loss in strength, as calculated by the regression equation $Y = X + BX^Q$, is shown for each discard criterion as well as the probability of various losses in rope strength at discard.

Data Set and Regression Result	Area loss X	Strength loss Y	Probability (%) of loss in strength			
			<3%	>10%	>12%	>15%
AL32	3,5	3,9	39,1	2,5	0,5	
$Y = X + 9{,}1 \times 10^{-4} X^{4{,}8}$	4,0	4,7	29,5	4,4	4,2	<0,1
	4,5	5,7	19,4	8,4	2,2	0,1
	5,0	7,0	10,1	16,7	5,4	0,5
AL41	3,5	5,5	1,7	<0,1		
$Y = X + 0{,}125X^{2{,}2}$	4,0	6,6	0,1	0,2	<0,1	
	4,5	7,9	<0,1	3,7	<0,1	
	5,0	9,3	<0,1	27,6	1,0	<0,1
AL48T	3,5	3,9	26,9	<0,1		
$Y = X + 2{,}4 \times 10^{-4} X^{5{,}8}$	4,0	4,8	10,1	<0,1		
	4,5	6,1	1,4	0,2	<0,1	
	5,0	7,9	<0,1	6,5	0,2	<0,1
DISC62	3,5	5,3	5,6	<0,1		
$Y = X + 0{,}21X^{1{,}7}$	4,0	6,2	1,2	0,4	>0,1	
	4,5	7,2	0,2	2,5	<0,1	
	5,0	8,2	<0,1	10,8	0,4	<0,1

X = Area loss due to broken wires, expressed as a percentage of rope area
Y = Strength loss due to broken wires, expressed as a percentage of rope strength

Based on this table, the discard criterion of 4% has been chosen. The probability distributions for this discard criterion are shown in this figure. Data set AL32 shows the largest scatter. This can be attributed to the lack of a proper zero reference and the very small number of samples (see comments on p.8).



6. RECOMMENDATIONS

Based on the 1994 48 mm and the present 41 and 62 mm specimen test results, the probability of a loss in strength greater than 10% is 0,4%, 0,2% and 0,4% respectively, for a reduction in area of 4%. A reduction in area of 4,5% increases the probability to 28%, 4% and 2% respectively. There is clearly no reason to deviate from the 1994 recommendation that loss in rope area due to broken wires in one strand over one lay length of the rope must not exceed 4%. (As shown in the 1994 report, the same requirement applies to cases where more than one half of the total number of broken wires over one lay length is contained in two adjacent stands.)

REFERENCES

1. Harvey, T and Kruger, H.W. *The theory and practice of electronic testing of winding ropes* Trans. Inst. Elect. Eng., June 1959

2. Borello, M. and Kuun, T.C. *The effect of cut wires on the strength of winding ropes* CSIR Contract Report MST(94)MC2333 No. 940286, December 1994