SAFETY IN MINES RESEARCH ADVISORY COMMITTEE

SIMRAC

FINAL REPORT

Title: CATALOGUE OF BEST PRACTICES FOR THE ROPES AND WINDERS OF DEEP SHAFT SINKING OPERATIONS

AUTHOR/S: MIKE VAN ZYL
FRIEDER HECKER

RESEARCH AGENCY : MATTEK/ MININGTEK, CSIR

Project No: GAP 418

Date: November 1998

Executive summary

At the time of compiling this report, the statutory rope strength requirements in South Africa limited shaft sinking depths with conventional methods to approximately 3 000 m. Deeper shafts can only be sunk if an exemption is granted by the Department of Minerals and Energy.

Such an exemption will be granted if the sinking operation adheres to a code of practice that is based on the contents of the addendum to this report, which is a catalogue of best practices for the ropes and winders of shaft sinking operations.

The minimum static rope load factors allowed by the Regulations are:

Stage winder ropes:	A static factor of 4,5
Kibble winder ropes:	A capacity factor of 8 A static factor of 4,5

The minimum rope load factors that will be allowed by an exemption:

Stage winder ropes:	A static factor of 3
Kibble winder ropes:	A capacity factor of 8 A dynamic factor of 2,5

The primary purpose of the catalogue of best practices is to ensure the safety of the winding ropes. It therefore addresses aspects that will influence rope loads, rope strength, rope deterioration and the condition assessment of the winding ropes. Other aspects of the stage and kibble winders that could influence the safety of personnel conveyed in kibbles and personnel working on the stage are included, e.g. the required braking capacities of winders.

General consensus was reached amongst members of the shaft sinking and mining industries, and the Department of Minerals and Energy on the contents of the catalogue of best practices. The first mine, and only one in the near future, that will have to apply for exemption to continue sinking will be the South Deep Project of JCI-Western Areas Limited. The requirements for exemption may have to be reviewed once the sinking of the shafts at South Deep has been completed.

Acknowledgements

The following persons contributed in one way or the other from the start of the initial investigations until the catalogue of best practices was completed. The authors of this report acknowledge their contributions.

- Schalk Burger, Fred Wilmans, Ian Paterson, Vern Botes (Department of Minerals and Energy)
- Jan Botha (Amplats)
- Dr Keith Wainwright, Martin Dohm (Anglo American Corporation)
- Piet Laubscher (ex-Gold Fields, Gencor and Billiton)
- Richard Gundersen (Gold Fields)
- Warrick Morley-Jepson, Les Cox (JCI)
- Stuart Allan (Project Manager, South Deep), André van Zyl (JCI Projects)
- Colin Swanepoel (Construction Manager, South Deep)
- Tim Wakefield, Ian Wallace, Piet Davidtsz, Alastair Douglas, Allan du Plessis (Cementation Mining - Sinking at South Deep)
- Brian Brasher (Brian Brasher Consulting Services, ex-Shaft Sinkers, Avgold)
- Trevor van Dyk, Jannie Mostert (Shaft Sinkers)
- Martin Hamer (West Driefontein)
- Barnie Berghard, Errol Drake, Piet Louw (ex-Vaal Reefs 11 Shaft)
- Mike Borello, Duncan MacDonald (Haggie Rand)
- Errol Sparg (Fuller Vecor)
- John Lock (CEGELEC)
- John Wainwright (ex-Haggie Rand)
- Len Atkinson (ex-Winder Controls)
- Peter Collins (Hatch Africa)

Table of contents

1 Introduction

At the time of compiling this report, the statutory rope strength requirements in South Africa limited shaft sinking depths with conventional methods to approximately 3 000 m. Deeper shafts can only be sunk if an exemption is granted by the Department of Minerals and Energy.

Such an exemption will be granted if the sinking operation adheres to a code of practice that is based on the contents of the addendum to this report, which is a catalogue of best practices for the ropes and winders of shaft sinking operations.

This report summarises the investigations and methods followed to produce the catalogue of best practices.

2 Methodology

2.1 Initial investigations

Proposing minimum rope load factors for deep shaft sinking operations has to take actual rope loads into account. The rope loads that were generated in both kibble and stage ropes during different sinking operations were measured as the initial part of the investigation, because very little information was available on such rope loads.

During the latter part of 1995, these measurements were carried out at three shaft sinking installations as part of SIMRAC Project GAP054.[1,2,3]

2.2 Overview report

A subsequent report[4] explored the scope of further work on the requirements of the safe use of stage and kibble winder ropes. That report was largely based on information accumulated through interviews with members of the shaft sinking industry, visits to shaft sinking sites and observations made while measuring the rope loads during the initial investigation.

2.3 Subsequent investigations

In order to motivate and propose suitable rope load factors for deep shaft sinking operations, and to include appropriate requirements in a "code of practice", three investigations were undertaken during 1996:

- The rope loads that could be generated in kibble winder ropes in the event of brake failure were analysed.[5]

- The load ranges and the rope loads during emergency braking that would be experienced by the kibble winder ropes of deep shafts were analysed in order to propose rope load factors for ropes operating in such shafts.[6]

- The rope loads of deep shaft stages, as well as the "safety factors" for other industries that use ropes in a quasi-static fashion, were analysed in order to propose load factors for the stage ropes of very deep shafts.[7]

Appropriate rope factors and associated requirements for the "code of practice" were proposed and motivated for stage and kibble winder ropes in the mentioned reports.[6,7]

2.4 Catalogue of best practices

The reports mentioned in the previous section, together with the proposed rope factors for deep shaft sinking operations, were then discussed with the concerned parties, which consisted of representatives from the shaft sinking industry, mines and mining houses, the Department of Minerals and Energy, and suppliers of winders and winding equipment.

The results of these discussion were used together with the contents of the *winder code of practice*[8] to produce the first draft of the catalogue of best practices for deep shaft sinking operations. This draft was issued in January 1998.

Although not part of the original plan, a section on the capacity of kibble winder brakes was included in the "catalogue" because it will be required by one of the kibble winders at South Deep. Granting exemption for that winder to sink to the required depths would then only require complying with the requirements of one document.

After the concerned parties were given ample time to study the draft document, queries, comments, suggestions and concerns were collected and compiled into one document. These were discussed at a one day workshop with the concerned parties. General consensus was reached on all the issues.

The catalogue of best practices for deep shaft sinking operations was revised and is attached to this report as a separate addendum, complete with its own table of contents and introduction in order to be a stand-alone document.

3 Conclusions

The first mine, and only one in the near future, that will have to apply for exemption to continue sinking will be South Deep. The requirements for exemption may have to be reviewed once the sinking of the shafts at South Deep has been completed.

4 References

1. **Van Zyl, Mike.** Rope force measurements during shaft sinking operations at Vaal Reefs 11 Shaft. *First issued in December 1995, published in Volume 7 of the SIMRAC report GAP054, April 1996.*

2. **Van Zyl, Mike.** Rope force measurements during shaft sinking operations at West Driefontein 10 Shaft. *First issued in January 1996, published in Volume 7 of the SIMRAC report GAP054, April 1996.*

3. **Van Zyl, Mike.** Rope force measurements during shaft sinking operations at West Driefontein 9 Shaft. *First issued in February 1996, published in Volume 7 of the SIMRAC report GAP054, April 1996.*

4. **Van Zyl, Mike.** Overview of the winding rope requirements for deep shaft sinking operations. *First issued in April 1996, published in Volume 2 of the SIMRAC report GAP324, November 1997.*

5. **Van Zyl, Mike.** Rope forces generated after brake control failure on kibble winders. *First issued in December 1996, published in Volume 2 of the SIMRAC report GAP324, November 1997.*

6. **Van Zyl, Mike.** Load ranges acting in kibble winder ropes and proposals for new kibble winder rope regulations. *First issued in November 1996, published in Volume 2 of the SIMRAC report GAP324, November 1997.*

7. **Van Zyl, Mike.** Stage rope factors for deep shaft sinking operations. *First issued in January 1997, published in Volume 2 of the SIMRAC report GAP324, November 1997.*

8. **SABS.** Code of Practice: Performance, operation, testing and maintenance of drum winders relating to rope safety. *To be published by the SABS.*

Addendum to SIMRAC GAP418 Final Project Report

The pages that follow is the stand-alone document:

Catalogue of best practices for the ropes and winders of deep shaft sinking operations

SAFETY IN MINES RESEARCH ADVISORY COMMITTEE

SIMRAC

ADDENDUM

GAP 418

Catalogue of best practices for the ropes and winders of deep shaft sinking operations

AUTHORS: MN Van Zyl
F Hecker

RESEARCH AGENCY: Mattek/ Miningtek
CSIR

Safety in Mines Research Advisory Committee Project GAP418

CATALOGUE OF BEST PRACTICES FOR THE ROPES AND WINDERS OF DEEP SHAFT SINKING OPERATIONS

PREAMBLE

At the time of compiling this document, the statutory rope strength requirements in South Africa limited shaft sinking depths to approximately 3 000 m. Deeper shafts can only be sunk if an exemption is granted by the Department of Minerals and Energy.

Such an exemption will be granted if the sinking operation adheres to a code of practice that is based on the contents of this document.

The static rope load factors allowed by the Regulations are:

Stage winder ropes:	A static factor of 4,5
Kibble winder ropes:	A capacity factor of 8 A static factor of 4,5.

The rope load factors of this document:

Stage winder ropes:	A static factor of 3
Kibble winder ropes:	A capacity factor of 8 A dynamic factor of 2,5 i.e. the maximum rope loads shall not exceed 40% of the initial breaking strength of the rope.

The primary purpose of this document is to ensure the safety of the winding ropes, i.e. rope loads, rope deterioration and the condition assessment of the winding ropes. Aspects of the stage and kibble winders that could influence the safety of personnel conveyed in kibbles and personnel working on the stage are included.

November 1998

CONTENTS

1. INTRODUCTION

Complying with the requirements of this document will allow kibble and stage winders to operate at depths greater than those allowed by the current Regulations.

The primary purpose of this document is the safety of the winding ropes, i.e. rope loads, rope deterioration, the condition of new ropes, and the condition assessment of the winding ropes in service. This document also includes aspects of the stage and kibble winders that could influence winding safety in general, such as the brake systems of the sinking winders, and procedures that will ensure the safety of personnel conveyed in kibbles and personnel working on the stage.

2. DEFINITIONS

Some of the terms used in this document are defined as follows:

Front end: That end of the rope attached to the kibble or the conveyance, or the section of rope near the front end of the rope.

Live back end: That end of the rope at or near the drum when the kibble is at its lowest position in the shaft. As a shaft gets deeper, the live back end position on a kibble rope changes.

Transition depth: The shaft depth at which the *static factor* for the stage ropes and the kibble ropes will have a value of 4,5 i.e. the shaft depth at which a stage winder or kibble winder installation has to comply with the requirements of this document.

Initial breaking strength: The actual breaking strength of a rope when new (Reg. 16.30.1).

Nominal rope mass: The rope mass from the manufacturers catalogued.

Actual rope mass: The rope mass determined by weighing a representative sample of the rope.

Nominal rope diameter: The rope diameter specified by the manufacturer (Reg. 16.30.1)

Non-spin rope: A rope consisting of multiple layers of strands in which the strand layers are laid in opposite directions to achieve opposing torques under load and reduce the torque produced by the rope under load. Non-spin rope is a generic na,e for all spin resistant ropes with strands in a multi-layer construction.

Capacity factor: The initial strength of the rope divided by the maximum static load the rope has to support at its front end.

Static factor: The initial strength of the rope divided by the maximum static load it has to carry (i.e. the maximum weight that it has to support at its front end plus the weight of the maximum length of the suspended rope). This factor decreases for stage and kibble winder ropes as the depth of the shaft increases.

Rope selection factors: The *capacity factor* and *static factor* defined above are static rope factors, and are also referred to as rope selection factors.

Heavy load: A heavy load is anything with a weight greater than one eight of the initial breaking strength of the kibble winder rope, i.e. a heavy load will have a capacity factor of less than 8.

Winding cycle: A winding cycle for the kibble winder is a round or intermittent trip, starting with the kibble (or the rope front end or crosshead), at bank level and ending with the same kibble returning to the bank level (Reg. 16.30.1).

Load range: This is the difference between the largest and smallest rope load that occurred in any section of a kibble rope during one winding cycle. When the static rope loads are used to determine the load range it will be referred to as the static load range, and when actual (dynamic) rope loads are used it will be referred to as the dynamic load range or just the load range.

Load range ratio: This refers to the load range expressed as a percentage or fraction of the initial breaking strength of a rope.

Permanent installations: Permanent installations refer to those winding systems that operate in shafts after sinking and equipping of a shaft have been completed.

Sinking installations: This term refers to those winding systems used for shaft sinking and operating as such until shaft equipping has been completed.

Kibble winder: The drum winder used for kibble winding during shaft sinking operations. Although this winder is often the permanent winder, the term "kibble winder" is used to distinguish between the operations of a winder and its ropes during shaft sinking operations and their use as a permanent installation.

***D/d* ratio:** The diameter of the rope tread on a drum or sheave divided by the nominal rope diameter.

Rope condition assessment code of practice: SABS0293:1996: Condition assessment of steel wire ropes on mine winders.

Winder code of practice: An abbreviation for the Code of Practice: Performance, operation, testing and maintenance of drum winders relating to rope safety (to be published by the SABS).

Rope load measurement and rope load monitoring: An example of "rope load measurement" is the loadcell systems and readouts currently employed at most stage winders. Continuous "rope load monitoring" will require the measured rope loads to be monitored by, for example, a computerised data acquisition system.

3. THE REGULATIONS AND ROPE SELECTION FACTORS

The static rope factors in this section are all based on the initial breaking strength of a rope, and are generally referred to as installation factors. The minimum new rope breaking strengths are determined by the specified factors, and ropes are then allowed to deteriorate to a maximum 10% reduction in strength.

3.1 Rope discard

Regulation 16.33 requires that:

> *The strength of a winding rope or balance rope must be assessed in accordance with an approved safety standard and the rope may not be used if the breaking strength thus assessed at any point in the rope, is less than nine-tenths of the initial breaking strength.*

The approved safety standard is the *Rope condition assessment code of practice: SABS0293:1996.*

In its current form, SABS0293:1996 does not specify how and at what intervals kibble and stage ropes should be inspected. The discard criteria for non-spin ropes are also not final yet. Until such a time that SABS0293 is updated, discard criteria, inspection intervals, and the sections of rope to be inspected are included in Part I (section I.6.3, p. 9) in this document.

3.2 Kibble winder ropes

The strength of the ropes of kibble winders is currently determined by the same regulations that apply to permanent drum winder installations, because a kibble winder also "allows for the periodic testing of the winding rope". *Regulation 16.34.1* reads:

> *Where a winding system operating in a vertical shaft is such that it allows for the periodic testing of the winding rope as required by regulation 16.41.1.1, and a balance rope is not used, a winding rope must have a breaking strength at installation not less than -*
>
> *(a) eight times the attached load; and*
> *(b) four and a half times the suspended load.*

Regulation 16.30.1 defines:

> *attached load* means everything suspended from or attached to the winding rope and includes the portion of any balance rope and one half of any tail carriage and sheave which contributes to load at the termination of the winding rope;
> *suspended load* means the sum of the attached load and the mass of the effective length of winding rope;
> *effective length* of rope means the length of rope between the centre of the sheave or drum in the headgear and the lowest working point of the conveyance.

When the shaft has reached a depth that is such that the kibble winder ropes cannot comply with the 4,5 rope static factor requirement (the "transition depth"), *the kibble winder ropes will still be required to have a capacity factor of 8, and shall then comply with the kibble winder requirements in this document.*

See section I.2.2, p. 7, for notes on the calculation of kibble winder rope selection factors.

3.3 Stage ropes

The strength of a stage rope is determined by *Regulation 16.40.2* on stage rope selection factors:

> *Any rope which is used to raise or lower a stage in a shaft, must have a breaking strength of not less than 4,5 times the combined weight of the effective length of rope and its share of the attached load.*

Although not stated explicitly, the minimum static factor of 4,5 required for the stage ropes is an installation factor, calculated on the initial breaking strength of the stage ropes.

Stage ropes do not require a given capacity factor.

When the shaft has reached a depth that is such that the stage ropes cannot comply with the 4,5 rope static factor requirement, *the stage winder and ropes shall comply with the relevant requirements in this document. A minimum static factor of 3 shall be allowed for the stage ropes if the stage winder and its ropes comply with the requirements in this document.*

See section I.2.1, p. 7, for notes on the calculation of the static factor for stage winder ropes.

4. OTHER REQUIREMENTS INCLUDED IN THIS DOCUMENT

This section gives an overview of the requirements and specifications included in this document.

4.1 ROPES

Apart from starter ropes on the kibbles and perhaps the stage winder(s), very deep shafts may also require intermediate rope sets. If a rope set will eventually be used at static factors less than 4,5 the winder installation will have to comply with the requirements of this document from the time that such a rope set is installed.

The other rope requirements in this document concern rope construction, dimensions and mechanical properties, spare ropes, used ropes, rope inspection and maintenance procedures, and rope terminations.

The sinking winder rope requirements are detailed in Part I.

4.2 STAGE WINDERS AND THE STAGE

The stage winder and stage requirements are detailed in Part II. They include stage winder layouts, *D/d* ratios for the stage winder drums and the sheaves of the stage ropes, and stage rope load measurement.

4.3 KIBBLE WINDERS

The maximum rope load during (normal) controlled emergency braking shall not exceed 40% of the initial rope breaking strength:

> This measure, together with other winder brake and brake control requirements, will ensure that a reasonable safety margin on the ropes exists during emergency braking operations and in case of brake malfunction that will lead to uncontrolled braking.
>
> The actual brake control strategy that has to be employed to ensure that the rope loads remain less than 40% of the rope breaking strength is not specified in this document. It is left to the user to decide how this is to be achieved.

The (dynamic) load range during a winding cycle shall not exceed 15% of the initial rope breaking strength of the kibble winder rope.

Kibble rope load monitoring is required by this document:

> Kibble rope load monitoring will effectively determine whether the kibble winder brake control system operates properly, and whether the loads conveyed by the kibble winder remain within acceptable limits.

The other requirements for kibble winders include allowable *D/d* ratios for the winder drums and headgear sheaves.

The kibble winder requirements are detailed in Part III.

Appendix A lists equations with which the dynamic kibble winder rope loads can be estimated.

4.4 MONITORING AND CONTROL

The monitoring and control requirements of this document are summarised in Part IV.

4.5 INSPECTION, TESTING AND MAINTENANCE

The inspection, testing and maintenance requirements of this document are summarised in Part V.

5. EXAMPLE CALCULATIONS

Example calculations of various requirements of this document (e.g. dynamic rope loads, brake capacities) are included in Appendix F.

6. SUMMARY

A summary of the data required to determine whether a stage or kibble winder installation will comply with the requirements of this document are given in Appendix G.

7. RECOMMENDED PRACTICES

Appendix H lists some recommendations. These recommendations do not concern rope safety or the safety of the winder installations. A sinking installation therefore does not have to comply with the listed recommendations in order to be given exemption to operate at the rope selection factors given in this document.

PART I: ROPES

This part includes requirements and procedures for rope selection, storage, installation, rope terminations, and rope inspection procedures and rope discard criteria.

I.1. ROPE SELECTION

I.1.1 Rope manufacturing standard

Regulation 16.20 requires that the winding ropes for the stage and kibble winders must be manufactured by a manufacturer approved in terms of:

> *ISO 9001: Code of practice for: Quality Systems - Model for quality assurance in design/development, production, installation and servicing.*

I.1.2 Rope strength

The initial rope strength shall be determined by an actual test at the time of manufacture (Regulation 16.30.1 (iv)).

I.1.3 Rope mass

The nominal rope mass shall be used for the calculation of static rope factors, except if required otherwise in this document.

I.1.4 Rope diameter

The actual rope diameter shall be within +5% and -1% of the nominal rope diameter.

I.2. CALCULATION OF ROPE SELECTION FACTORS

I.2.1 Stage ropes

The calculation of the static factors for stage ropes shall use the (actual) initial breaking strength of the rope and the measured stage rope load.

Should the initial strengths of the individual stage ropes differ, the lowest rope strength shall be used in the above calculations. Should the stage rope load measurements for the stage ropes differ, the highest measured value shall be used in the above calculations.

See section II.6, p 13, for the requirements for stage rope load measurements.

I.2.2 Kibble ropes

The calculation of the capacity and static factors for kibble ropes shall use the (actual) initial breaking strength of the rope, the catalogued rope mass and the licensed (allowable) masses.

I.3. SPARE ROPES

Spare ropes will be stored in dry conditions with suitable arrangements to ensure that the ropes will not come into contact with the floor. Ropes shall never be stored on cinder or ash floors and there shall be no risk of damage due to corrosion or other fumes. Ropes shall be protected from the weather and shall be stored in such a manner that they will not be exposed to direct sunlight and that the rope temperature is never above the ambient air temperature.

I.4. USED ROPES

Used ropes will be allowed for winders that have to comply with the requirements of this document. See Regulations 16.23a and 16.23b for the *use of old ropes*.

I.5. ROPE TERMINATIONS

I.5.1 At the front end of the kibble rope

Rope sockets (resin or white metal) shall be used at the front end termination of the kibble rope. Rope splices and capels are not allowed. Sockets designed by a Professional Engineer or sockets in accordance with National Coal Board (UK) specification NCB 456 shall be used.

I.5.2 Stage rope

Rope sockets (resin or white metal) or wedge type wire rope clamps shall be used for the termination of a stage rope. Sockets will be to the same specifications as for section I.5.1.

I.6. ROPE INSPECTION PROCEDURES

The Regulations require that the condition of all winder ropes be assessed in accordance with SABS0293, and not only the ropes of the winder installations that have to comply with the requirements of this document. The requirements of this section will therefore be applicable to any rope in the shaft system.

Apart from rope condition assessment in accordance with SABS0293, the requirements for daily, weekly and monthly examinations are given in this section.

I.6.1 Kibble ropes

I.6.1.1 Daily examination

Every kibble rope must be examined visually along its operating length to ascertain if there are any distortions, loose strands or any obviously damaged or broken wires. In addition the visible dead turns on the drum, when the crosshead is at the bottom of the shaft, must be examined to establish if the dead turns are still tight, that there are no obviously broken wires or strands and that there is no indication of the rope bird-caging in any of the dead turns. Loose dead turns shall be re-tensioned as specified in section I.7. The front end rope termination and attachments shall also be examined visually to determine if there are any anomalies, damage or broken wires.

I.6.1.2 Weekly examination

In addition to the requirements of the daily inspection, the device which engages the crosshead must also be examined.

I.6.1.3 Monthly examination

Monthly examination of the kibble ropes is required by the regulations.

I.6.2 Stage ropes

In the event of anything falling down the shaft this visual examination must made (from the kibble) of all falls of the stage ropes. In the event of crosshead separation, a visual examination shall be carried out of the guide ropes on which the crosshead separation occurred.

I.6.2.1 Monthly examination

The rope from the storage drum to the stage winder must be examined to ensure that the rope is not developing birdcages or any other distortion.

The guide parts of the stage ropes must be examined visually while travelling in the kibble to the shaft bottom to ascertain that there are no distortions which could cause the crosshead to hang up.

The guide rope sections of the stage ropes must be cleaned and examined at regular intervals. If the part of the stage rope with the end termination is used as a guide sections special care must be taken in examining this fall of rope over the life of the rope, because the section nearest to the end termination will be subjected to the greatest amount of wear. The end termination should also be examined for broken wires or any other defects. If for any reason it is found that the crosshead guide bushes have worn out and the metal of the crosshead has run on the guide section a detailed examination of that fall must be made to establish if there has been any excessive wear of the rope.

I.6.3 Rope condition assessment of kibble and stage ropes

Rope condition assessments shall be carried out in accordance with SABS0293:1996. Where SABS0293 does not clearly state what is required for stage and kibble winder ropes, the procedures of Appendix B shall be followed.

I.7. ROPE INSTALLATION PROCEDURES

All kibble rope sheave grooves shall be inspected before the installation of a kibble rope, and if necessary shall be re-machined to match the rope diameter.

After installation of a kibble winder rope, the rope shall be doubled down so that all the dead turns are tensioned. The mass attached to the doubling down sheave shall have a value of at least 100% of the sum of the allowable rock mass plus (empty) kibble mass. The diameter of the doubling down sheave shall at least be 32 rope diameters.

I.8. ROPE MAINTENANCE PROCEDURES

The lubrication of all sinking ropes shall be maintained.

The dead coils of the kibble winder ropes shall be re-tensioned by doubling down, as specified in section I.7, and at intervals not exceeding six months. The pulling in of back-ends shall be based on the assessment of the condition of the ropes (see section I.6.3 and Appendix B) and inspection of the dead turns when doubling down.

PART II: STAGE WINDER AND STAGE

II.1. THE STAGE WINDER LAYOUT

II.1.1 General

The major components of a friction stage winder are shown in Fig. II.1.

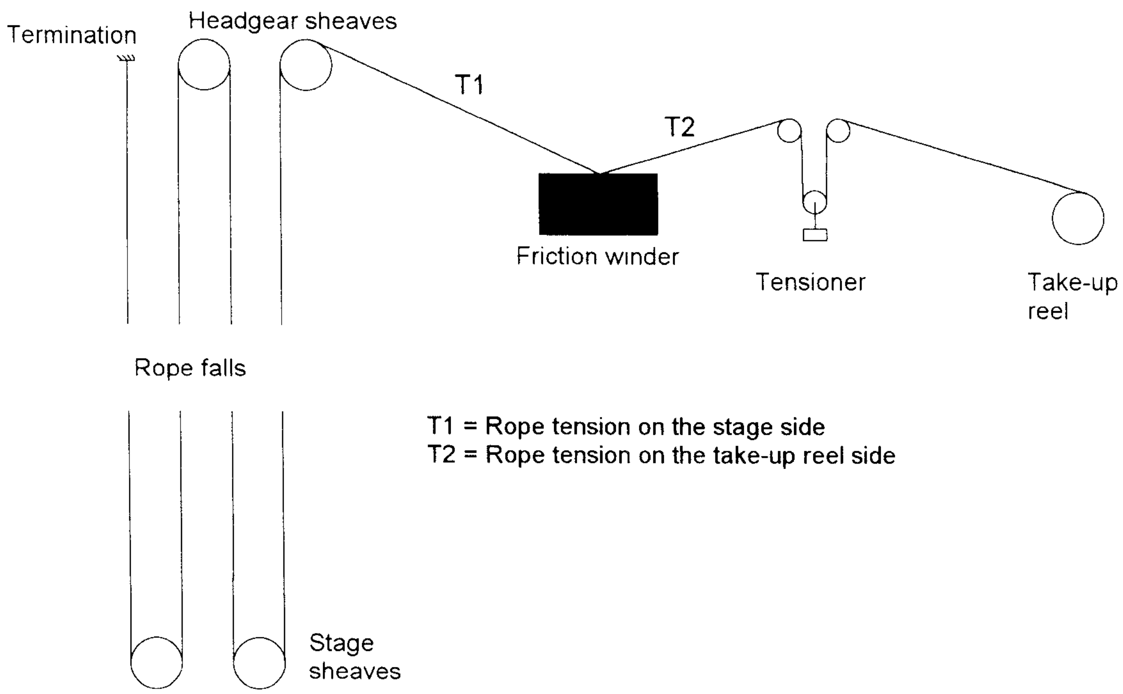


Figure II.1: Components of a friction type stage winder

The design of the stage winder and the tensioning weights shall be such that:

- one stage rope of a two rope stage winder will be able to support the stage without slipping at final shaft depth, or
- three ropes of a four rope stage winder will be able to support the stage without slipping at final shaft depth.

The stage winder drum(s) for each of the stage ropes shall be equipped with brakes. The minimum holding power of the brakes shall match the rope tension specified in the preceding paragraph.

II.1.2 The drum

The *D/d* ratio of the winder drum shall be at least 40.

The diameter of the rope grooves of a stage winder drum with individual rope grooves shall at least be 1,05 times the nominal rope diameter. The tread diameter of all the grooves on grooved stage winder drums shall be within ±0,1% of the mean groove diameter.

Each side of the winder shall be equipped with brakes. The holding power of the brake(s) on each drum side shall be at least twice the maximum rope pull that will be experienced.

II.1.3 The tensioner

The *D/d* ratios of the sheaves of the tensioner shall be at least 40.

The general design of the tensioner shall be such that the stage rope shall not be damaged if the tensioner accidentally runs into its travelling limits. Over-travel limit switches shall be provided to stop the winder in the event of any over-travel.

Any form of sheave wheel braking in the tensioning tower is not allowed.

II.1.4 The take-up reel

The *D/d* ratio of a take-up reel shall be at least 40.

Each take-up reel shall be equipped with two separate and independent brake systems. Each of the two brakes shall have a capacity of at least 20% greater than rope tension produced by the tensioning weight in the tensioning tower.

A take-up reel shall have a miscoiling detector.

II.1.5 Motor power

The peak torque of the stage winder motor shall be limited such that the stage winder shall not be able to generate rope loads greater than 40% of the initial stage rope breaking strength. For this calculation it will be assumed that all stage ropes will carry equal loads.

II.2. HEADGEAR SPECIFICATIONS

The *D/d* ratios of all stage rope sheaves in the headgear shall be at least 40.

II.3. STAGE SPECIFICATIONS

The *D/d* ratios of all stage rope sheaves on the stage shall be at least 40.

Protection for the stage ropes at the stage sheaves shall be provided to prevent objects being trapped between the stage ropes and the sheaves.

II.4. STAGE ROPE SHEAVE GROOVES

The shape of the grooves of all the sheaves of the stage ropes shall be as specified in section III.3, p. 14.

II.5. STAGE ROPE TERMINATIONS

See section I.5, p. 8.

II.6. STAGE ROPE LOAD MEASUREMENT

The load in each individual stage rope shall be measured with loadcells installed in the headgear of the shaft. The measured rope loads shall be displayed in the banksman's cabin and at the stage winder driver controls. The stage rope load measurements shall have an accuracy of 1% of the breaking strength of the stage ropes.

The layout of the stage rope loadcells shall be such that the load on the loadcells can be removed to obtain "zero load" measurements at any time. Zero load readings shall be taken every three months in order to check the integrity of the loadcell system. The calibration of the loadcells shall be verified annually. The calibration of the loadcells shall be traceable.

The measured stage rope loads shall be used for the calculation of the rope static factors as specified in section I.2, p. 7.

II.7. KIBBLE CROSSHEAD GUIDES

The material of the kibble crosshead guide bushes shall be of such a nature that the bushes will not damage the stage ropes.

PART III: KIBBLE WINDER

III.1. WINDER DRUM

The *D/d* ratio of the kibble winder drum shall have a value of not less than 100.

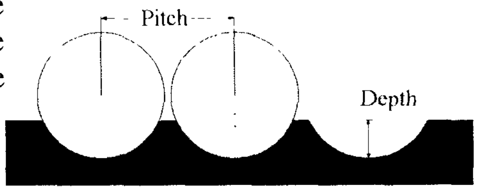
The winder shall not be operated with more than six rope layers on the drum.

The flange of the winder drum shall be at least 2,5 rope diameters higher than the top of the top rope layer when the rope is fully wound.

III.2. DRUM COILING PATTERN

The surface of the drum barrel shall have rope coiling grooves, designed to avoid poor coiling and subsequent damage to the rope. The rope coiling grooves shall be parallel with the drum flanges, with two cross-overs per drum turn. Guide rods or bars welded to the drum to simulate coiling grooves are not allowed.

The minimum diameter and pitch of the grooves shall be 1,05 times the nominal diameter of the rope. The groove depth shall be of the order of 0,3 times the nominal rope diameter.



The surface roughness of the groove, after machining, should be 7 μm or less.

III.3. HEADGEAR SHEAVES

The *headsheave* is the last sheave that the kibble winder rope encounters before it goes down the shaft. All other sheaves in the headgear will be referred to as deflection sheaves. The *D/d* ratio of the *headsheave* shall have a value of not less than 100.

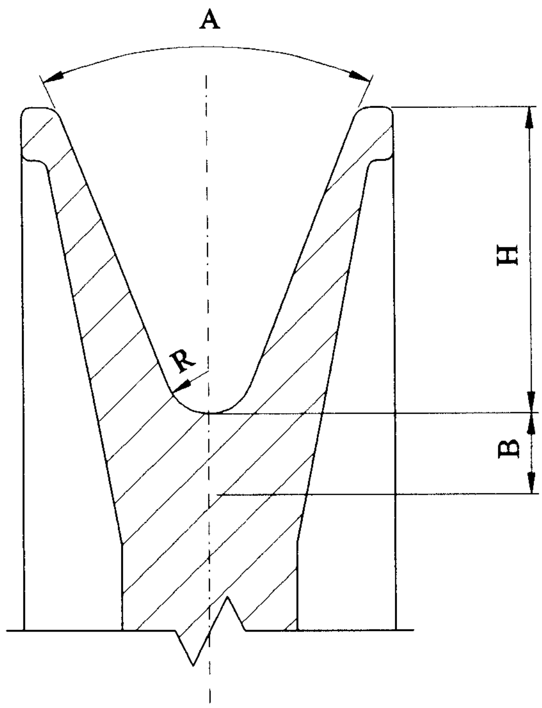
Any deflection sheave in the headgear shall have a *D/d* ratio of not less than 100 if the wrap angle of the rope on that deflection sheave is equal or greater than 45°. For wrap angles less than 45°, the *D/d* ratio shall not be less than 60.

Positioning deflection sheaves may be used between the drum and the headgear. These sheaves shall have the same *D/d* ratio as the *headsheave*. Only one positioning sheave per rope is allowed and care must be taken to ensure that fleet angles do not exceed 1½°.

The grooves of the headsheave and any deflection sheave can either be machined into the sheave wheel or can be formed through non-metallic inserts.

If the groove is machined into the sheave, the surface roughness of the groove shall be less than 15 μm after machining. There shall be no steps or shoulders at the junction of the groove and the flange faces.

The dimensions of the sheave wheel groove shown in the figure shall have values as follows:



A	=	Angle of flare
	=	45° to 55°
R	=	Root radius of the groove
	=	minimum of *0,525 d*
H	=	Minimum height of the groove
	=	*2,5 d*
B	=	Maximum allowable groove wear
d	=	Nominal rope diameter

The minimum flange thickness and the maximum allowable groove wear shall be specified by the manufacturer of the sheave.

III.4. CROSS-HEAD AND GUIDES

The minimum height to width ratio of the crosshead shall be 1,5.

The specifications for the materials of the rope guide bushes are given in section II.7, p. 13.

III.5. ROPE TERMINATIONS

Kibble rope terminations as specified in section I.5, p. 8.

III.6. NORMAL WINDING AND WINDER MOTOR CONTROL

The load range acting on any part of the rope shall be determined for each winding rope cycle. The load range shall remain within 15% of the initial rope strength.

Every occurrence of exceeding the allowable load range shall be logged by the kibble winder rope load monitoring system.

If the 15% load range limit is exceeded more than one out of ten winding cycles, the winder shall be stopped and the problem corrected.

III.7. WINDER BRAKES AND WINDER BRAKE CONTROL

III.7.1 General requirements

With regards to safety, brake specifications for kibble winders are important for the following reasons:

- The winder must be able to stop when required.
- The rope loads resulting from controlled emergency braking must not damage the winding ropes. The rope loads that are generated during controlled emergency braking shall not exceed 40% of the initial breaking strength of the rope.
- The winder brake(s) must function when required, especially when one drum of a double drum winder is unclutched.
- Excessive rope loads must not be generated during uncontrolled braking.
- The drum deceleration during uncontrolled braking must be within limits so that severe slack rope situations are avoided.

The specifications and requirements for the kibble winder brakes and the brake control systems are detailed in Appendix C.

III.7.2 Exceeding the rope load limit

If the 40% of initial rope breaking strength limit is exceeded on a kibble rope, it will be allowed that the kibble or the load attached at the front end be returned to bank level/tip and the load removed. After that, no loads greater than an empty kibble will be allowed on that rope until:

- The condition of the rope is assessed as required by section I.6.3, p. 9, and is found to be acceptable in terms of the discard criteria of that section.
- It has been established that no laylength changes occurred in the rope.

Every occurrence of exceeding the allowable rope load limit shall be logged by the kibble winder rope load monitoring system.

III.7.3 Testing and maintenance

A procedure for the regular inspection, testing and maintenance of the brake system shall be drawn up for the kibble winder. This procedure shall include the following:

- Critical brake settings.
- Weekly inspection procedures, which will include testing the holding power of the brakes.
- Monthly and annual inspection and testing procedures.

- Record keeping.
- Dynamic brake testing procedures.

III.8. KIBBLE WINDER ROPE LOAD MONITORING

The loads in the kibble winder ropes shall be measured in the headgear by appropriate devices at the headgear sheaves. The measured signals shall be monitored continuously to ensure that the rope loads remain within the specified limits.

Detailed requirements of the kibble winder rope load monitoring system are given in Appendix D. The determination of load range requires that the kibble positions, or kibble rope front end positions, be determined as part of the rope load monitoring.

III.9. DETERMINING THE CYCLIC LOAD RANGE RATIO

Determining the maximum cyclic load range ratio from the measured rope loads and the suspended length of rope in the shaft is detailed in Appendix E.

III.10. TRANSPORTING HEAVY LOADS

A heavy load is anything with a weight greater than one eight of the initial breaking strength of the kibble winder rope, i.e. a heavy load will have a capacity factor of less than 8.

A heavy load shall be suitably counterweighted on the other winding rope so that the maximum out of balance at the maximum winding depth will not be greater than 80% of the capacity of the remaining winder brakes if one brake fails to be applied during braking.

Using the definitions of Appendix C, the above requires that the maximum out of balance mass be limited to:

$$Max.\ out\ of\ balance\ mass = 80\% \ \frac{(n-1)\ T_{brake}\ D_{drum}}{2\ g} \qquad \textbf{(1)}$$

where T_{brake} = minimum brake torque of *one winder brake*
n = number of winder brakes
g = gravitational acceleration (= 9,8 m/s^2)
D_{drum} = drum diameter (bottom rope layer)

The winding speed during the transportation of heavy loads shall be in accordance with the requirements of section C4.3, p. 30.

The mine shall be in possession of a procedure and calculations for transporting heavy loads on the kibble ropes. This procedure shall include the following:

- The winding speed for the heavy load.
- The rope loads that will be generated during emergency braking with the heavy load.

PART IV: MONITORING AND CONTROL

IV.1. REQUIREMENTS INCLUDED IN OTHER PARTS OF THIS DOCUMENT

The following monitor and control requirements and specifications are included in other parts of this document as indicated:

Stage winder motor control: See section II.1.5, p. 12.
Stage rope load measurement: See section II.6, p. 13.
Operation of the stage winder: See section ?, p. ?.

Kibble winder motor control: See section III.6, p. 15.
Kibble winder brake control: See section III.7.1, p. 16, and Appendix C, p. 26.
Kibble rope load monitoring: See section III.8, p. 17, and Appendix D, p. 32.

Determining the kibble winder cyclic load range:
See section III.9, p. 17, and Appendix E, p. 36.

PART V: INSPECTION, TESTING AND MAINTENANCE

V.1. REQUIREMENTS INCLUDED IN OTHER PARTS OF THIS DOCUMENT

The following inspection and maintenance requirements and specifications are included in other parts of this document as indicated:

Daily and monthly rope inspections and rope condition assessment:
See section I.6, p. 8, and Appendix B, p. 23.

Tensioning of the dead turns of the kibble winder during installation:
See section I.7, p. 9.
Re-tensioning of the dead turns:
See section I.8, p. 10.

Stage rope load measurement: Calibration and checking: See section II.6, p. 13.

Kibble crosshead guide bushes: See section II.7, p. 13.

Testing and maintenance of the kibble winder brakes: See section III.7.3, p. 16.

Kibble winder rope load monitoring: Calibration and checking: See section D4, p. 33.

APPENDIX A: EQUATIONS FOR THE ESTIMATION OF KIBBLE WINDER ROPE LOADS

Equations with which the dynamic rope loads of the kibble winder can be calculated, are given in this appendix.

Example calculations, using these equations, are included in Appendix F.

A1. PEAK ROPE LOADS

The peak (maximum) rope load, F_{peak}, generated when a winder with a rope and attached mass is accelerated upwards (or decelerated while the conveyance descends) is:

$$F_{peak} = m_{total}\left[g + a(1 + \alpha)\right] \quad \textbf{(A1)}$$

with:

m_{total} = the total suspended mass (rope plus attached mass)
g = gravitational acceleration (= 9,8 m/s²)
a = constant (average) winder acceleration (actually, linear rope acceleration)
α = dynamic amplification factor

Acceleration will increase the winding speed, and deceleration will reduce the winding speed. When the winder is decelerated while ascending (or accelerated while descending), a will have a negative value.

The dynamic factor, α, will have a value of 0,85 if the acceleration (or deceleration) is applied instantaneously (e.g. "bang-bang" application of the emergency brakes). Most winder motors take a least one second to reach constant acceleration, for which a value of 0,80 is more appropriate.

Time is required for the rope loads to reach the peak value (it could be a number of seconds for very long ropes). If a conveyance does not travel fast enough, the rope load will not reach the peak value given by the equation above during deceleration, because the winder drum will come to a halt before the peak is reached.

The acceleration or deceleration of a winder, during normal winding or emergency braking, can be "ramped". Ramping will reduce the dynamic amplification. By matching the ramp time to the natural period of oscillation of the winding system, rope dynamics can be eliminated (α = 0).

A2. MAXIMUM ROPE LOADS

The maximum rope load will occur when emergency braking takes place at maximum shaft depth with the maximum allowable load attached to the rope. Although braking will take place some distance away from shaft bottom, the difference for deep shafts will be small. The following equation gives the maximum rope load that could be generated when a winder with a rope and attached mass is decelerated while descending:

$$F_{max} = m_{total} [g + a(1 + \alpha)] \tag{A2}$$

with:
F_{max} = maximum rope load
m_{total} = rope mass plus maximum allowable attached mass
g = gravitational acceleration (= 9,8 m/s²)
a = constant deceleration at the drum end
α = dynamic amplification factor

$$m_{total} = m_{attach} + r_{mass} L \tag{A3}$$

with:
m_{attach} = maximum allowable attached mass including the crosshead
r_{mass} = the rope mass per unit length
L = (maximum) length of suspended rope

Limiting the maximum rope load to a certain fraction of the rope breaking strength gives:

$$F_{max} = \Delta F_{break} \tag{A4}$$

with:
F_{break} = the breaking strength of the rope
Δ = allowable fraction of rope breaking strength (40% max.)

The static rope factor (f_{SF}) is by definition:

$$f_{SF} = \frac{F_{break}}{m_{total}\, g} \tag{A5}$$

Substituting the two equations above into the first equation, and rearranging, gives the maximum rope load as a fraction of the rope breaking strength and in terms of the static factor and the winder dynamics during emergency braking:

$$\Delta = \frac{1}{f_{SF}} \left[1 + \frac{a}{g}(1 + \alpha) \right] \tag{A6}$$

For a given, or allowable fraction, the equation can be rearranged to give a required rope static factor:

$$f_{SF} = \frac{1}{\Delta} \left[1 + \frac{a}{g}(1 + \alpha) \right] \tag{A7}$$

The permissable winder deceleration can also be expressed in terms of the winder dynamic behaviour, rope static factor, and allowable fraction:

$$a = \frac{g}{1 + \alpha} \left(f_{SF}\, \Delta - 1 \right) \tag{A8}$$

The above equations can also be written in terms of the capacity factor (f_{CF}) using the following relationship between the static factor (f_{SF}) and capacity factor:

$$f_{SF} = f_{CF} \frac{m_{attach}}{m_{attach} + r_{mass} L} \qquad \textbf{(A9)}$$

A3. LOAD RANGE

The live back end of a kibble winder rope normally experiences the largest load range. The estimation of the load range of a kibble winder rope can then be carried out as shown in this section.

By definition of load range, the load range of the live back end of a kibble winder rope, for a shaft depth (length of suspended rope), L, will be:

$$R_{range} = F_{peak} - r_{mass} L g \qquad \textbf{(A10)}$$

The peak rope load will be experienced during the acceleration of the winder from shaft bottom at an acceleration of a. Substituting peak load from Eqn A1 gives:

$$\begin{aligned} R_{range} &= m_{total} \left(g + a(1 + \alpha)\right) - r_{mass} L g \\ &= \left(m_{attach} + r_{mass} L\right)\left(g + a(1 + \alpha)\right) - r_{mass} L g \end{aligned} \qquad \textbf{(A11)}$$

The load range ratio is obtained by expressing the load range as a fraction of the initial rope breaking strength:

$$R_{ratio} = \frac{R_{range\text{-}\max}}{F_{break}} \qquad \textbf{(A12)}$$

With the static factor known for a given shaft depth, load range ratio can be expressed in terms of static factor, capacity factor and winder acceleration as follows:

$$R_{ratio} = \frac{1}{f_{CF}} + \frac{1}{f_{SF}} \left[\frac{a}{g} (1 + \alpha) \right] \qquad \textbf{(A13)}$$

The equation above shows that the load range ratio cannot be less than the reciprocal of the capacity factor, which is the static load range ratio. The dynamic component of the load range ratio can be reduced by reducing the normal winder acceleration (a), and/or by reducing the winder dynamics (α).

APPENDIX B: ROPE CONDITION ASSESSMENT

This appendix is referred to in the part on ropes (Part I, section I.6.3, p. 9).

The Regulations require that the condition of all winder ropes be assessed in accordance with SABS0293:1996, and not only the ropes of the winder installations that have to comply with the requirements in this document. Therefore, the requirements of this appendix will be applicable to the ropes of all shaft sinking installations.

Where SABS0293 does not clearly state what is required for stage and kibble winder ropes, the procedures of this appendix shall be followed.

This appendix specifically addresses the intervals at which the condition of the stage and kibble winder ropes shall be assessed, the sections of the ropes that shall be assessed, and the discard criteria for the ropes. The discard criteria in this appendix only consider broken wires, rope diameter reductions and laylength changes. All the other discard criteria of SABS0293 shall still be adhered to.

Specifications reprinted from SABS0293 are all preceded by "SABS0293: ".

B1. STAGE ROPES

The condition of the sections of the stage ropes that are used as guide ropes for the kibble crossheads shall be assessed within one month after the installation of the stage ropes. After that, the condition of these sections of the stage ropes shall be assessed at intervals not exceeding six months.

The complete length of the guide rope sections, from the tip to the top of the stage, shall be assessed.

The requirement for the first inspection, one month after installation of the ropes, shall not apply to the first rope set installed at the start of the shaft sinking operation.

B2. KIBBLE WINDER ROPES

The condition of the kibble winder ropes shall be assessed within one month after installation, and then at intervals not exceeding three months. The length of rope between the shaft collar and when the kibble is at shaft bottom shall be assessed. The dead turns on the drum shall be assessed at intervals not exceeding sixth months, i.e. when the ropes are doubled down.

The requirement for the first inspection, one month after installation of the ropes, shall not apply to the first rope set installed at the start of the shaft sinking operation.

B3. ROPE DISCARD CRITERIA

The discard criteria for triangular strand ropes of SABS0293 are repeated here for the sake of completeness and for comparison with non-spin rope constructions.

B3.1 Broken wires

SABS0293: The number of visible broken wires in a single strand over one rope laylength shall not exceed 40% of the total number of outer wires in the strand.

One laylength for a non-spin rope shall be a laylength of the outer strand layer of the rope.

B3.1.1 Triangular strand ropes

SABS0293: The maximum allowable reduction in steel area due to visible broken wires are:

7% if the broken wires are distributed symmetrically in one laylength
4% if the broken wires are distributed asymmetrically
Double these amounts are allowed over five laylengths

If more than half of the visible broken wires are in two adjacent strands the broken wire distribution will be termed asymmetrical.

B3.1.2 Non-spin ropes

The discard criteria for broken wires on non-spin ropes, and effectiveness of magnetic rope testing instruments to detect broken wires in non-spin ropes will be published in 1999 in the reports on SIMRAC projects GAP502 and GAP503.

Until the mentioned report are published, the following discard criteria shall be used:

> The broken wires in a rope shall be assessed by visual inspection and the aid of magnetic rope testing instruments. The rope shall be discarded if the assessed cross-sectional steel area of the broken wires in one laylength is greater than 10% of the total cross-sectional steel area of the rope.

B3.2 Changes in rope diameter

B3.2.1 Abrasive wear only

Abrasive wear could occur on those stage rope sections used as guide ropes for the kibbles, and will be the result of poor crosshead guide bushes. The following reductions in rope diameter (as a percentage of the nominal rope diameter) are reason for discard:

SABS0293: Triangular strand ropes:
7% if the wear is symmetrical
5% if the wear is asymmetrical

Non-spin ropes:
5% if the wear is symmetrical
4% if the wear is asymmetrical

B3.2.2 Wear and plastic deformation

The ropes of drum winders in vertical shafts generally experience this combined type of surface damage. The following reductions in rope diameter (as a percentage of the nominal rope diameter) are reason for discard:

SABS0293: Triangular strand ropes:
- 9% if the wear is symmetrical
- 7% if the wear is asymmetrical

Non-spin ropes:
- 6% if the wear is symmetrical
- 5% if the wear is asymmetrical

B3.3 Laylength changes

SABS0293:

Local variation:

Triangular strand ropes: Any local laylength increase or decrease that exceeds 12% of the average of the laylengths on the unaffected sections on both sides of the anomaly shall be reason for discard.

Non-spin ropes: Any local laylength increase or decrease that exceeds 5% of the average of the laylengths on the unaffected sections on both sides of the anomaly shall be reason for discard.

Slack strands:

Any slack strand(s) and also any relative strand movement of more than one strand diameter or strand altitude shall be reason for discard.

Note: The above requirement on slack strands shall not be applicable to the front end of a kibble winder rope used for shaft sinking.

General variation:

Triangular strand ropes: Any laylength decrease that exceeds 30% of the nominal laylength of the rope and any laylength increase that exceeds 100% of the nominal laylength of the rope shall be reason for discard.

Non-spin ropes: Any laylength decrease that exceeds 12% of the nominal laylength of the rope and any laylength increase that exceeds 12% of the nominal laylength of the rope shall be reason for discard.

APPENDIX C: KIBBLE WINDER BRAKES

This appendix is referred to in the part on kibble winders (Part III, section III.7, p. 16).

With regards to safety, brake specifications for kibble winders are important for the following reasons:

- The winder must be able to stop when required.
- The rope loads resulting from controlled emergency braking must not damage the winding ropes.
- The winder brake(s) must function when required, especially when one drum of a double drum winder is unclutched.
- Excessive rope loads must not be generated during uncontrolled braking.
- The winder drum deceleration during uncontrolled braking must remain within limits so that severe slack rope situations are avoided, and that personnel being conveyed in the kibble are not exposed to the risk of injury.

Any failure in the brake and brake control system that will lead to either uncontrolled application of the brakes or not applying a brake at all will simply be referred to as *brake control failure*. Brake and brake control failure will be defined as the failure of any *one* component of the emergency brake system.

The failure of items such as the connecting rod between the two brake callipers are not considered. Such items fall into the same category as, for example, a conveyance drawbar. Their failure can be prevented by proper design, manufacture and inspection procedures.

The simultaneous failure of more than one item in the brake control system is improbable, and is not considered in this document. An example is a burst pipe on one brake and a control valve getting stuck on the other brake at the same time.

The winder brake capacity required by this document is such that a winder shall be able to stop in the normal controlled way when one of the winder brakes fails to be applied during emergency braking. The maximum brake capacity is also limited to prevent excessive slack rope at the front end of the rope when brake control failure occurs.

C1. BRAKE DEFINITIONS

C1.1 A winder brake

A mechanical brake unit is that part of the brake system that physically applies a braking force to the winder drum. The hydraulic brake engine together with the spring nest arrangement is considered part of the mechanical brake unit.

Any number of mechanical brake units which are controlled by a single and separate brake control unit will be considered as *one winder brake*. Examples are:

- A single drum winder with a calliper brake unit at each end of a drum, and an independent brake control unit for each brake, will be considered as having *two* winder brakes. If both the brake units are controlled by a single unit, it will be considered that the winder only has *one* winder brake.

- A double drum winder with two brake discs and twelve brake units, coupled to three separate brake control units will be considered to have *three* winder brakes. Further: If the disc units are divided such that all three brakes operate on each of the two drum brake discs, then it will be considered that the winder has *three* winder brakes when one drum is unclutched.
- A double drum winder with a calliper brake unit on each drum, and an independent brake control unit for each brake, will be considered as having *two* winder brakes. When one drum is unclutched, the moving drum will only have *one* winder brake.
- A mechanically coupled BMR with two calliper brakes per drum, and four independent brake control systems (each coupled to a separate brake) will be considered as having *four* winder brakes. In the unclutched condition, the moving drum will have *two* winder brakes. If a BMR has only two brake control systems with the two brakes of a drum connected to one system, the winder will be considered to have *two* winder brakes, and only *one* winder brake when the a drum is unclutched.
- An electrically coupled BMR is considered as two separate single drum winders.

Mechanical brake units are considered to be coupled hydraulically if the hydraulic brake engines are directly linked through a hydraulic pipe, i.e. loss of pressure in one unit will lead to pressure loss in the other(s). Any number of mechanical brake units coupled together hydraulically will be considered as *one winder brake*, irrespective of the number of separate brake control units.

C1.2 A brake control unit

A basic brake control system consists of a drum speed sensor, an electronic control unit, and the hydraulic system of the brake(s).

A drum speed sensing unit that is such that failure of any one component in the unit will not lead to the loss of the speed signal to the brake control unit(s) is considered as an *independent drum speed sensing unit.*

If two or more brake control units receive a speed input signal from an *independent drum speed sensing unit*, they are considered as separate brake control units.

C2. NUMBER OF WINDER BRAKES

A (mechanically coupled) double drum winder shall have at least two winder brakes. A single drum winder shall have at least two winder brakes.

C3. BRAKE CONTROL PROCEDURES

The brakes of the winder shall be controlled in such a manner that the rope loads will not exceed 40% of the initial breaking strength of the winding ropes. (For the estimation of maximum kibble winder rope loads, see section A2, p. 20, and the example in section F3.1, p. 38.)

The brake control system of a winder shall be such that it will not be possible to apply all the winder brakes in full if the winding speed is greater than creep speed (1,5 m/s max.).

The winding speed of a mechanically coupled double drum winder with one winder brake per drum (two winder brakes in total) shall not exceed creep speed when one drum is unclutched.

The brake system of a mechanically coupled double drum winder with one winder brake per drum shall be such that the winder driver will be able to apply the brake of the moving drum manually and in full.

Failure of any component in the brake and brake control system shall not lead to the application of more than one winder brake in full, nor shall it lead to the non-application of more than one winder brake.

C4. BRAKE CAPACITY

C4.1 Required brake capacity

The winder brakes shall each have a capacity such that the winder will be able to stop in the normal (controlled) way if one of the brakes fails to be applied.

If a double drum winder has *n* winder brakes, the holding power, T_{brake}, of *one winder brake* (see section C1.1) shall have a design value of at least:

$$T_{brake} = \frac{T_{rot} + T_{lin} + T_{OoB}}{n - 1} \qquad \textbf{(C1)}$$

with

$$T_{rot} = \frac{2\,a}{D_{drum}} \left(I_{drum} + I_{motor} + I_{sheave} \right) \qquad \textbf{(C2)}$$

$$T_{lin} = \frac{a\,D_{drum}}{2} \left(2\, r_{mass} L_{rope} + M_{att} + 2\, M_{xh} \right) \qquad \textbf{(C3)}$$

$$T_{OoB} = \frac{g\,D_{drum}}{2} \left(r_{mass} L_{final} + M_{att} \right) \qquad \textbf{(C4)}$$

where T_{brake} = required brake torque of *one winder brake*
T_{rot} = brake torque required to decelerate the rotating winder parts
T_{lin} = brake torque required to decelerate the ropes and attached mass
T_{OoB} = brake torque required to overcome the maximum winder out-of-balance
I_{drum} = Total drum inertia (both sides for a double drum)
I_{motor} = Total motor inertia (two motors for a mechanically coupled BMR)
I_{sheave} = Sum of the inertias of two headgear sheaves
n = number of winder brakes
a = required (maximum) winder deceleration (in m/s²)
g = gravitational acceleration (= 9,8 m/s²)

L_{rope} = the length of each of the two kibble ropes
L_{final} = the final depth of the shaft that is being sunk
M_{att} = maximum allowable rope front end load (excluding the crosshead)
M_{xh} = mass of the crosshead
r_{mass} = rope mass per unit length
D_{drum} = drum diameter (bottom rope layer)

The winder deceleration, a, is the maximum deceleration required during emergency braking and is the "constant" or "average" deceleration during emergency braking. The deceleration normally has a value between 2,2 m/s² and 2,5 m/s². For winding depths greater than 3 000 m, lower deceleration rates or "ramped" brake control will be required (see section A2, and the example in section F3.1.

Normally drum winder brakes are designed with a capacity of around 10% greater than the value calculated with the Eqn C1 above.

For a single drum winder with n winder brakes, the parts of Eqn C1 are calculated as follows:

$$T_{rot} = \frac{2\,a}{D_{drum}} \left(I_{drum} + I_{motor} + I_{sheave} \right) \qquad \textbf{(C5)}$$

$$T_{lin} = \frac{a\,D_{drum}}{2} \left(r_{mass} L_{rope} + M_{att} + M_{xh} \right) \qquad \textbf{(C6)}$$

$$T_{OoB} = \frac{g\,D_{drum}}{2} \left(r_{mass} L_{final} + M_{att} + M_{xh} \right) \qquad \textbf{(C7)}$$

The variables have the same meanings as before, except that I_{sheave} will be the inertia of one headgear sheave only.

The Regulations for drum winder brakes require that (bracketed parts added):

> Each (of the two) brakes on a (double) drum winder shall have a holding power of twice the maximum (unclutched) out-of-balance (at final shaft depth).

If the regulation is to be interpreted that n-1 winder brakes should have a holding power of twice the maximum out-of-balance load (at final shaft depth), the required holding power of each brake is as follows:

$$T_{brake} = \frac{D_{drum}\, g \left(M_{\max} + L_{final}\, m_{rope} \right)}{n - 1} \qquad \textbf{(C8)}$$

where T_{brake} = minimum brake torque of *one winder brake*
n = number of winder brakes
L_{final} = the final depth of the shaft that is being sunk
M_{max} = maximum allowable rope front end load (including the crosshead)
m_{rope} = rope mass per unit length

D_{drum} = drum diameter (bottom rope layer)
g = gravitational acceleration (= 9,8 m/s²)

For double drum winders with two brakes, the brake capacity calculated in this way will be of the same order as that calculated with Eqn C1.

Minimum brake capacities calculated with Eqn C1 will ensure that a winder will be able to stop in the normal required way if one brake fails to be applied during emergency braking.

C4.2 Maximum brake capacity

The maximum brake capacity of each *winder brake* shall be limited to minimise the adverse effects of brake control failure, i.e. the maximum rope loads and the degree of slack rope that will be generated.

The maximum (design) capacity of each winder brake, $T_{brake\text{-}max}$, shall not be greater than:

$$T_{brake\text{-}max} = 1{,}3\,(T_{rot} + T_{lin} + T_{OoB}) \qquad \textbf{(C9)}$$

The variables in Eqn C9 have the same meanings as for Eqn C1.

C4.3 Exceptions

Should the brake torque of one winder brake be less than that required by Eqn C1, the winder brakes are classified as "under-powered", and the procedures of this section shall be followed.

The requirements of this section consider descending loads. "Descending loads" are all situations where the mass attached to the descending side of the winder is greater than that attached to the ascending side. The calculations required by the procedures that follow assume that only the crosshead is attached to the ascending side of the winder.

The minimum (design) capacity of each winder brake, $T_{brake\text{-}min}$, shall not be less than:

$$T_{brake\text{-}min} = \frac{1{,}25}{n-1}\,\frac{g\,D_{drum}}{2}\,(r_{mass}L_{final} + M_{att} + M_{xh}) \qquad \textbf{(C10)}$$

The variables in Eqn C10 have the same meanings as for Eqn C1. The minimum brake capacity (for under-powered brakes) is such that if one brake fails to be applied, the remaining brake(s) will have a combined holding power 25% greater than the maximum out-of-balance of the winder at final shaft depth.

The procedures that have to be followed for under-powered brakes are:

1. Determine the maximum shaft depth at which n-1 winder brakes will decelerate and stop the winder in the normal and required way when the maximum allowable load is attached at the descending side. The rest of the listed procedures shall then be applicable from that shaft depth.

2. Determine the heaviest load that can be stopped with *n*-1 winder brakes in the normal way from full speed descending at final (maximum) shaft depth. The rest of the listed procedures shall then be applicable for lowering all loads that are heavier than the determined load.

3. Determine the winder deceleration that can be achieved with *n*-1 winder brakes when the maximum allowable load is descending at final shaft depth.

4. Determine the winding speed that will give the same stopping distance at the winder deceleration of #3 than for normal deceleration at full winding speed. This calculated "reduced winding speed" shall then be the allowable speed at which loads heavier than that determined in #2 are allowed to descend when the shaft is deeper than that determined in #1.

5. Determine the temperature rise of the brake path(s) of the *n*-1 winder brake(s) when the maximum allowable load is stopped from the "reduced winding speed" at final shaft depth. A brake path surface temperature rise of 100°C will be allowed to prevent the remaining brakes "fading" in the event of one brake not being applied. If the temperature rise is greater than 100°C, the winding speed shall be adjusted accordingly. The mine shall be in possession of the calculations of the brake path temperature increases.

Example calculations of kibble winder brake capacities are given in section F4, p. 39, of Appendix F.

APPENDIX D: KIBBLE WINDER ROPE LOAD MONITORING

This appendix is referred to in the Part III, section III.8, p. 17.

D1. OBJECTIVES

The loads in the kibble winder ropes have to be monitored to determine if and when:

- The rope loads exceed 40% of the initial breaking strength of a rope.
- The load range during one winding cycle exceeds 15% of the initial breaking strength of a rope.

D2. MINIMUM SYSTEM REQUIREMENTS

The kibble rope loads shall be measured at the headsheave or at a deflection sheave in the headgear.

The rope loads are normally measured with loadcells or by strain gauges installed on the sheave wheel stool structure. Any other type of measuring system with which the required accuracy can be achieved shall be allowed. Any removable rope load measuring device in the headgear will be referred to as a loadcell.

The load acting in a kibble rope shall be measured on both sides of the headsheave. If the sheave wheel stool structure is such that the loads on both sides of the sheave are combined mechanically, a single load measuring system shall be allowed. If two individual signals are obtained for a rope load, the signals may be combined electrically.

The calculation of the cyclic load range for a rope requires that the suspended length of the rope in the shaft has to be known at the time of every rope load measurement. This required kibble rope front end position measurement does not have to be more accurate than one winder drum rotation. The length of suspended rope in the shaft may therefore be determined by simply counting the drum rotations. Separate drum rotation counting is required for each of the two sides of a double drum winder.

The monitoring system has to be able to determine when a winding cycle is completed. The user can decide how this is to be achieved.

The monitoring system shall sample (digitise) each rope load signal and the rope front end position at least at a rate of 10 samples per second.

The monitoring system shall have a display for the winder driver. The following information shall be displayed for each rope or drum side:

- The load range ratio of the last completed winding cycle.
- The number of times that the 15% load range ratio limit was exceeded in the last 10 winding cycles.

- The highest rope load of the last completed winding cycle, expressed as a percentage of the initial breaking strength of the rope.
- The highest rope load of the last 100 completed winding cycles.

The following information, for at least the last six months, shall be stored by the monitoring system for retrieval at any time:

- All occurrences of exceeding the 15% load range ratio limit, together with the date and time of the occurrence.
- All occurrences of exceeding the 40% of initial rope breaking strength limit, together with the date and time of the occurrence.

The complete kibble winder rope load monitoring system shall remain operational for at least five minutes after a power failure.

D3. ACCURACY OF THE ROPE LOAD MEASUREMENTS

The accuracy with which the rope load monitoring systems measures the rope loads shall be determined. Non-linearity, creep, hysteresis, temperature drift, and output change with temperature shall be taken into account. The accuracy of the data acquisition system of the rope load monitoring system can also influence the accuracy of the rope load measurements, and this shall also be taken into account.

The accuracy of any rope load reading (measurement) shall be within 1% of the breaking strength of the rope. The mine shall be in possession of proof of the accuracy of an installed system.

If the assessed accuracy is within 2% of the breaking strength of the rope, the allowable rope load limits shall be 39% of the breaking strength of the rope, and a 14% load range ratio.

D4. CALIBRATION AND PERFORMANCE CHECKING

D4.1 Loadcells

Loadcells shall be calibrated in an appropriate machine where known forces can be applied. If a mine is in possession of documentation that shows how the kibble rope load is translated to the forces measured by the loadcells, no other calibration procedures will be required.

The calibration of loadcells shall be checked annually.

The performance of the loadcell system shall be checked, as described in section D4.3, at intervals not exceeding three months. A loadcell based system may also be calibrated using the method in the following section.

D4.2 Other systems

Systems that do not use (removable) loadcells shall be calibrated using the procedures in this section.

The following known masses are required:

- A fully loaded kibble with a mass determined to within $\pm 1\%$.
- An empty kibble with a mass determined to within $\pm 4\%$.
- The cross-head mass determined to within $\pm 10\%$.

The length of rope between the kibble winder headsheave and when the kibble is at the bank has to be known.

Perform the calibration on each of the ropes as follows:

- Pick up the loaded kibble from the bank.
- Wind the kibble to shaft bottom, stopping every 20 drum turns.
- Park the kibble at shaft bottom and release the load.
- Pick up the kibble from shaft bottom.
- Wind the kibble to the bank, stopping at the same positions as on the way down.
- Release the kibble load at bank level.

- Repeat the above procedure.

- Repeat the above procedure with the empty kibble.

- Tip the (loaded or empty) kibble to obtain an approximate zero rope load reading.

The order of the calibration procedure may be altered.

The accuracy, linearity and (short term) repeatability of the rope load measurements shall be established from the data recorded by the monitoring system during the calibration procedure. The data of every calibration shall be kept.

The calibration procedure uses the mass of the suspended kibble rope as well as the predetermined masses to establish the calibration of the load measurement system. The rope mass, determined from a representative rope sample, will be more appropriate than the catalogued mass for the calculation of the calibration factors.

The described calibration procedure for systems that do not use (removable) loadcells shall be carried out at intervals not exceeding six months.

D4.3 Operational checks

The performance of the kibble rope load monitoring system shall be checked at intervals not exceeding three months and as follows:

The measured rope load at or near bank level with only the crosshead attached to the front end of the rope shall be close to zero load.
The measured rope load with a kibble or other known mass (the jumbo drilling rig for example) at or near shaft bottom shall agree with the actual (calculated) rope load within the accuracy limits of the rope load monitoring system.

D5. NON-OPERATION OF THE SYSTEM

The winder may not be operated for a period of longer than seven days without rope load monitoring, and then only if the winder speed is recorded during that period.

APPENDIX E: DETERMINING THE LOAD RANGE

The maximum load range during a winding rope cycle of a kibble winder rope is calculated by subtracting the weight of the suspended rope length at any point during the winding rope cycle from the measured rope load (in the headgear), and determining the maximum of these results for the complete winding rope cycle. The maximum load range ratio is determined by dividing the maximum load range by the breaking strength of the rope. The position of the front end of the rope in the shaft needs to be recorded together with the rope load at the headgear sheave for the determination of the load range of kibble winder ropes.

In equation form, load range and load range ratio are:

$$R_{range\text{-}\max} = MAX\ [\ F(t)\ -\ z(t)\ r_{mass}\ g\ ] \qquad t_{start\ of\ cycle} \leq t \leq t_{end\ of\ cycle} \tag{E1}$$

$$R_{ratio} = \frac{R_{range\text{-}\max}}{F_{break}} \tag{E2}$$

$R_{range\text{-}max}$ = maximum cyclic load range (expressed as a force)
R_{ratio} = load range ratio (load range as a fraction of the rope breaking strength)
F_{break} = the breaking strength of the rope
$F(t)$ = Rope load measured in the headgear at a given time, t
$z(t)$ = length of rope suspended in the shaft at a given time, t
r_{mass} = the rope mass per unit length
g = gravitational acceleration (= 9,8 m/s^2)

At any time, t, during a winding rope cycle, the rope load and the length of suspended rope are measured. The weight of the rope is calculated and subtracted from the measured (headgear) rope load. The maximum of the resulting values for a winding rope cycle is determined, which is the maximum load range. By dividing the maximum load range by the initial rope breaking strength, the load range ratio is obtained. Load range ratio can be expressed as a percentage of the rope breaking strength by multiplying the result by 100.

APPENDIX F: EXAMPLE CALCULATIONS

Example calculations of the following are included in this appendix:

- Static rope factors for the stage and kibble winder ropes, and transition depths where an installation has to comply with the requirements in this document.
- Rope dynamics: Maximum rope loads, and load range.
- Required brake capacity and winders with "under-powered" brakes

In all of the examples "shaft depth" will mean the length of the rope suspended in the shaft.

F1. STAGE WINDER TRANSITION DEPTH

Assume that a stage has an all up mass of 120 000 kg, and uses six rope falls in total of a 43 mm non-spin rope with a breaking strength of 1 500 kN and a mass of 7,8 kg/m.

The ropes will have static factor of 4,5 at a depth of 1 800 m. The stage winder will therefore only have to comply with the requirements in this document from a shaft depth of 1 800 m, or from the time that the rope set that will go past 1 800 m is installed.

At a depth of 3 975 m, the static factor of the ropes will be equal to 3. This will be the maximum shaft depth allowed for the given stage mass. At that depth, the "rope pull" at the stage winder will be 500 kN.

F2. KIBBLE WINDER TRANSITION DEPTH

Assume the following parameters for the kibble winder and its ropes:

Empty kibble mass	4 000 kg
Crosshead mass	1 500 kg
Maximum payload (rock)	15 000 kg
Rope diameter	47 mm
Rope mass	10,4 kg/m
Breaking strength	1 900 kN

The kibble winder ropes will have a capacity factor of 9,46.

At a depth of 2 170 m, the kibble winder ropes will have a static factor of 4,5. The kibble winder installation will therefore have to comply with the requirements in this document from that shaft depth, or from the time that the kibble rope set that will go past 2 170 m is installed.

F3. KIBBLE WINDER ROPE DYNAMICS

F3.1 Maximum rope load

Assume the same kibble winder and rope parameters as in section F2 above. Further assume that the (constant) deceleration during emergency braking is controlled at 2,5 m/s², and that the brakes are applied instantaneously ("bang-bang"). Also assume that the jumbo drilling rig weighs as much as a fully loaded kibble, i.e. 19 000 kg. Together with the crosshead, the attached mass will be 20 500 kg.

The static factor at which the dynamic rope load will reach 40% of the breaking strength of the kibble rope during emergency braking can be calculated using Eqn A7, p. 21.

$$f_{SF} = \frac{1}{\Delta}\left[1 + \frac{a}{g}(1 + \alpha)\right]$$

Substituting:

g = 9,8 m/s²
a = 2,5 m/s² (constant deceleration at the drum end)
α = 0,85 (dynamic amplification factor)
Δ = 0,40 (40% of rope breaking strength allowed)

gives a static factor (f_{SF}) of:

$$f_{SF} = 3{,}68$$

For the example case, a static factor of 3,68 will be reached with the jumbo rig at a depth of 3 095 m. During emergency braking at greater shaft depths with the assumed jumbo mass, the rope load will be greater than the allowable 40% of the rope breaking strength. To keep the rope loads within limits, the deceleration of the winder during emergency braking will have to be reduced, and/or the application of the brakes have to be controlled in such a way that the dynamic factor is reduced.

At a shaft depth of 4 000 m, the static factor will be 3,12. In order to keep the rope loads less than 40% of the breaking strength of the rope, the following can be calculated from the equation above:

$$a(1 + \alpha) = 2{,}44$$

This means that if the application of the brakes can be controlled such that all rope dynamics are eliminated, a winder deceleration of 2,44 m/s² at a depth of 4 000 m will result in a peak rope load equal to 40% of the breaking strength of the rope. If the brakes are applied instantaneously ($\alpha = 0{,}85$), the winder deceleration should be limited to 1,32 m/s². A winder deceleration of 2,0 m/s² requires the brake control system to reduce the dynamic factor, α, to 0,22.

The rope loads can also be reduced by limiting the winding speed to such a degree that the peak rope load cannot develop fully before the winder drum comes to a halt (see Appendix ?, and the example of section ?).

F3.2 Load range

Assume the same kibble winder and rope parameters as in section F2. Further assume that the winder motor accelerates the winder at 0,75 m/s², and that the dynamic factor is 0,80.

At a shaft depth of 4 000 m the static factor will be 3,12. Substituting the following values into Eqn A13, p. 22

$$R_{ratio} = \frac{1}{f_{CF}} + \frac{1}{f_{SF}} \left[\frac{a}{g} (1 + \alpha) \right]$$

f_{CF} = 9,46
f_{SF} = 3,12
g = 9,80 m/s²
a = 0,75 m/s²
α = 0,80

gives a load range ratio, R_{ratio}, of 15%, which is on the limit of the requirements of this document.

At shallower depths, the load range ratio will be lower.

F4. KIBBLE WINDER BRAKES

Assume the following winder and rope parameters for a double drum kibble winder for the brake calculations of this section:

Empty kibble mass	2 500 kg
Crosshead mass	1 500 kg
Maximum payload (rock)	12 000 kg
Rope diameter	43 mm
Rope mass	8,4 kg/m
Breaking strength	1 550 kN
Length of a kibble rope	3 300 m
Maximum shaft depth	3 000 m
Capacity factor	9,89
Static factor (at 3 000 m)	3,84
Transition depth	2 280 m
Drum diameter	4,9 m
Total rotating inertia (excluding ropes)	700 000 kg m²

Required emergency braking deceleration	2,3 m/s²
Number of brakes	2

The total (allowable) mass at the front end of the rope is therefore 16 000 kg. The same mass is assumed for the jumbo drilling rig plus crosshead.

F4.1 Required brake capacity

With the brake capacity required by this document, the winder will be able to stop in the normal way when one brake fails to be applied. If a winder has n winder brakes, the minimum torque capacity, T_{brake}, of *one winder brake* (see section C1.1, p. 26) shall have a design value given by Eqn C1, p. 28:

$$T_{brake} = \frac{T_{rot} + T_{lin} + T_{OoB}}{n - 1}$$

with

$$T_{rot} = \frac{2a}{D_{drum}} (I_{drum} + I_{motor} + I_{sheave})$$

$$T_{lin} = \frac{a D_{drum}}{2} (2 r_{mass} L_{rope} + M_{att} + 2 M_{xh})$$

$$T_{OoB} = \frac{g D_{drum}}{2} (r_{mass} L_{final} + M_{att})$$

where, for this example, the variables have the following values and meanings:

T_{rot} = brake torque required to decelerate the rotating winder parts
T_{lin} = brake torque required to decelerate the ropes and attached mass
T_{OoB} = brake torque required to overcome the maximum winder out-of-balance

I_{drum} = Total drum inertia
I_{motor} = Total motor inertia
I_{sheave} = Sum of the inertias of two headgear sheaves

The above three values are added together as the total rotating inertia, which is 700 000 kg m².

n = 2: number of winder brakes
a = 2,3 m/s²: required (maximum) winder deceleration
g = 9,8 m/s²: gravitational acceleration

L_{rope} = 3 300 m: the length of each of the two kibble ropes

L_{final} = 3 000 m: the final depth of the shaft that is being sunk
M_{att} = 14 500 kg: maximum rope front end load (excl. crosshead)
M_{xh} = 1 500 kg: mass of the crosshead
r_{mass} = 8,4 kg/m: rope mass per unit length
D_{drum} = 4,9 m: drum diameter (bottom rope layer)

The following values are given by the different equations:

T_{rot} = 657 kNm
T_{lin} = 411 kNm
T_{OoB} = 953 kNm

and T_{brake} = 2 021 kNm

If the winder has a brake capacity less than the value above, the stopping distance of the winder will be greater than normal if one brake fails to be applied during emergency braking, close to the bottom of the shaft, at final shaft depth, and with a full load descending. For the same situation, but for a full load ascending, only 6% of the brake capacity of one brake will be required to retard the winder at the required rate.

For a comparison, a twice out-of-balance requirement (see Eqn C8, p. 29, of section C4.1, p. 28) gives a torque of one brake as 1 978 kNm (which is 2% less than the value required by this document. This close correspondence of the values is coincidental.)

The transition depth, from where the example winder has to comply with the requirements of this document is 2 280 m. Say that on this installation it was decided to use a starter/intermediate rope set to a depth of 2 200 m, and that each rope length was 2 400 m. For this situation the following were calculated:

A twice out-of-balance at 2 200 m requires a brake torque of 1 656 kNm per brake.

The brake torque per brake required for the given depth (2 200 m) and rope length (2 400 m) is 1 775 kNm.

The required brake torque of 2 021 kNm for the final shaft depth will most probably only be available if the (normally) larger permanent winder is used for kibble winding duties. Such a brake torque will also only be required at final shaft depth. This document therefore makes provision for winders with "under-powered" brakes, i.e. brake capacities less than required.

F4.2 Under-powered brakes

F4.2.1 Brake capacity of 1 800 kNm

If the design brake torque of one brake of the example winder is 1 800 kNm, the brake capacity will be less than required.

The steps that should be followed then are outlined in section C4.3, p. 30, and are as follows: (The calculation of stopping distances assumed instantaneous application of the winder deceleration.)

1. Determine the maximum shaft depth at which n-1 winder brakes will decelerate and stop the winder in the normal and required way when the maximum allowable load is attached at the descending side. The rest of the listed procedures shall then be applicable from that shaft depth.

   The value of L_{final} has to be adjusted in the calculations of the previous section so that the required brake torque is equal to the actual brake torque. The rope length, L_{rope}, for the final rope set will be 3 300 m. For the example case, and for a brake capacity of 1 800 kNm, this shaft depth will be 1 900 m.

   > In comparison, the twice out-of-balance specification will still be met at a shaft depth of 2 550 m. If the allowed winding speed is 15 m/s for this example, the stopping distance during normal emergency braking will be 50 m. If one brake fails to be applied near shaft bottom for a shaft depth of 2 550 m, the winder deceleration for a descending full load will be 2,09 m/s^2, which will result in a stopping distance of 54 m.

   From the time that the final rope set is installed, the winder will have to comply with the requirements of this document. When the shaft depth, with the final rope set, reaches 1 900 m, the rest of the procedures listed here shall be applicable.

2. Determine the heaviest load that can be stopped with n-1 winder brakes in the normal way from full speed descending at final (maximum) shaft depth. The rest of the listed procedures shall then be applicable for lowering all loads that are heavier than the determined load.

   Adjust the value for M_{att} in the equations so that the required brake capacity equals 1 800 kNm. This value for the attached mass is 7 000 kg (excluding the crosshead).

   Therefore: With the final rope set installed, the winder can be used normally till a depth of 1 900 m. From that depth to final shaft depth, loads of up to 7 000 kg can be lowered in the normal way. For heavier loads, the rest of the procedures will apply.

3. Determine the winder deceleration that can be achieved with *n-1* winder brakes when the maximum allowable load is descending at final shaft depth.

   For the example, the winder will decelerate at 1,89 m/s^2 with a full load descending near shaft bottom at final shaft depth when one brake fails to be applied.

4. Determine the winding speed that will give the same stopping distance, at the winder deceleration of #3, as for normal deceleration at full winding speed. This calculated "reduced winding speed" shall then be the allowable speed at which loads heavier than that determined in #2 are allowed to descend when the shaft is deeper than that determined in #1.

   The normal stopping distance of 50 m will be achieved at a winding speed of 13,5 m/s.

5. Determine the temperature rise of the brake path(s) of the n-1 winder brake(s) when the maximum allowable load is stopped from the "reduced winding speed" at final shaft depth. A temperature rise of 100°C will be allowed to prevent the remaining brakes "fading" in the event of one brake not being applied. If the temperature rise is greater than 100°C, the winding speed shall be adjusted accordingly.

F4.2.2 Brake capacity of 1 600 kNm

If the design brake torque of one brake of the example winder is 1 600 kNm, the situation will be as follows:

For the starter/intermediate rope set of section F4.1 above, it was shown that this winder will (very nearly) meet a twice out-of-balance brake capacity specification. The regulations will therefore allow this winder to operate to a shaft depth of 2 200 m, although at this shaft depth, the winder deceleration will be 1,89 m/s^2 when one brake fails to be applied with maximum load descending near the shaft bottom. This will result in the stopping distance increasing from the expected 50 m to 60 m.

After the (long) final rope set is installed, the winder will have a greater inertia, the stopping distance for one brake failing with a full load descending for a shaft depth of 2 200 m will now increase to 62 m (1,80 m/s^2 deceleration).

The procedures of the previous section for under-powered brakes (and one brake fails to be applied), for this example are:

1. The maximum shaft depth for full load descending is 1 095 m. (In the example the shaft is already deeper, therefore proceed to #2.)

2. The maximum load that can be attached for full speed descending at final shaft depth is only 300 kg (less than an empty kibble). All loads that can be attached will be greater than this value, therefore proceed to #3.

3. The winder deceleration that can be achieved for maximum load descending near shaft bottom for final shaft depth is 1,4 m/s^2. (From 15 m/s, the stopping distance will be 80 m at this deceleration.)

4. To achieve the normal stopping distance of 50 m during emergency braking, the winding speed for all descending loads will have to be reduced to 11,5 m/s, for shaft depths greater than 1 095 m.

F4.2.3 Absolute minimum brake capacity

See section C4.3, p. 30, and Eqn 10, p. 30.

For the example winder, the out-of-balance of the maximum rope load at final shaft depth is just less than 1 000 kNm (see section F4.1). The capacity of a winder brake has to be greater than this value, otherwise the winder will not be able to hold the loads during clutching operations.

For a brake capacity of 1 200 kNm (25 % greater than maximum out-of-balance), the example winder will decelerate at 0,53 m/s^2 at maximum shaft depth and maximum load. To achieve the normal stopping distance of 50 m (for this example case) the winding speed has to be reduced to 7 m/s.

A minimum brake capacity of 25 % greater than the maximum out-of-balance at maximum shaft depth can therefore be permitted.

APPENDIX G: DATA REQUIRED

The winder, rope and loading data that are required to determine whether stage and kibble winder installations comply with the requirements of this document are:

Stage winder:

Number of ropes
Number of rope falls
Number of stage winders

Rope diameter
Rope mass
Rope tensile grade
Rope strength(s)

Stage mass
Final shaft depth (or licensed depth)
Transition depth

Diameter of stage winder drums
Diameter of all stage rope sheave wheels

Stage winder speed
Stage winder power
Maximum stage winder pull
Stage winder brake capacities
Take up reel brake capacity

Required tensioning weight

Kibble winder(s):

Rope diameter
Rope mass (catalogued and actual)
Rope tensile grade
Rope strength(s)

Crosshead mass
Kibble mass
Allowable loads (rock, material, personnel)
Mass of jumbo drilling rig

Final shaft depth (or licensed depth)
Transition depth

Drum diameter
All kibble rope sheave diameters

Number of kibble winder brakes
Design capacity of each brake
Brake control layout

Winding speed
Deceleration during emergency braking

APPENDIX H: RECOMMENDED PRACTICES

The recommendations listed in this appendix do not concern rope safety or the safety of the winder installations. A sinking installation therefore does not have to comply with these recommendations in order to be given exemption to operate at the rope factors given in this document.

Stage winder ropes: Where possible, a stage rope diameter of 43 mm is recommended in order to standardise on these long ropes. Where an equal number of individual stage ropes are used, they should be of opposite hand of lay to ensure that the net torque generated by the stage ropes on the stage is minimised.

The **stage layout** should be such that the rope fall which is a deadleg (a fall terminated in the headgear) or a fall terminated at the stage is not be used as a guide rope for a kibble.

Stage friction winder rope tension calculations may be based on a **friction coefficient** of 0,07 between the rope and the winder drum.

The required minimum **doubling down sheave** *D/d* ratio for the kibble winder ropes is 32. It is recommended that a doubling down sheave should be as large as possible.

Kibble winder **drum coiling pattern**: The turn cross-over transition should have a length of 12 times the nominal rope diameter. Transition radii of the turn crossover should be 120 times the nominal rope diameter.

The installation of **deflection sheaves** for kibble ropes should be avoided.

If available, the rope supplier should provide a **magnetic trace** of a new rope. For used ropes, previous magnetic traces should be obtained.

The monitoring of the **kibble winder rope speed** is recommended as part of the kibble winder rope load monitoring system.

It is recommended that a **winding cycle** should be considered as complete when the front end of the overlay rope passes the shaft collar/bank while ascending. The direction of travel can be determined by monitoring the winding (rope) speed.

It is recommended that, once the **kibble rope load monitoring system** is installed, the rope loads be monitored and stored continuously for a period of at least 5 days. The overall accuracy of the system can then be evaluated from the acquired data.

It is recommended that the **calibration method** of section D4.2, p. 33, at least be used once on a loadcell system to verify the overall performance of such a kibble rope load monitoring system.