

# SIMRAC

## Final Project Report

Title: THE SAFE USE OF MINE WINDING ROPES

Volume 2 : Recommendations for Changes in Rope  
Safety Factors

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**MOTIVATION FOR PROPOSED  
CHANGES TO CHAPTER 16 OF THE  
MINERALS ACT: ROPE SAFETY  
REGULATIONS FOR DRUM WINDERS**

by

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## 1. INTRODUCTION

The Steering Committee on Factors of Safety of Winder Ropes has appointed a working group to draw up a set of proposals for changing the regulations governing the required rope strength in the Minerals Act. Certain research projects have been conducted in order to substantiate the recommendations. The results of these projects have shown that a new set of regulations could be recommended for drum winder ropes even though detailed knowledge on rope deterioration was still lacking. The regulations should effectively limit the dynamic load range and the peak dynamic forces<sup>1</sup>. It was requested that static factors be specified in the regulations, however, and to make provision for dynamic winder behaviour in a code of practice.

## 2. TERMINOLOGY AND SYMBOLS

The following terms are used in this document:

**Initial breaking strength:** The as-manufactured breaking strength of the rope, i.e. before any deterioration due to ageing or actual service has taken place

**Capacity Factor:** The initial breaking strength of the rope divided by the total attached weight (i.e. the weight of the conveyance and its attachments and the full payload)

**Static Factor:** The initial breaking strength of the rope divided by the total weight (i.e. the weight of the rope plus the total attached weight)

**Peak Rope Force:** The maximum dynamic force which is the combination of the total static force plus the dynamic forces resulting from any foreseeable event such as loading and emergency braking or brakes failing on (but excluding events that are normally considered as *acts of God* such as slack rope, conveyance derailment or objects falling down the shaft)

**Dynamic Factor:** The initial breaking strength of the rope divided by the peak force acting in the rope

The following symbols are used in the calculations:

$\Delta T$	= load range
$\sigma$	= rope tensile grade
$a_p$	= peak drum acceleration
$BF$	= initial rope breaking force.
$CF$	= capacity factor

$c$	= ratio between conveyance mass and total attached mass
$DF$	= dynamic factor
$F_{\max}$	= peak dynamic rope force.
$F_{\text{stat}}$	= static rope force = $(M_p + M_c + M_r)g$
$g$	= gravitational acceleration
$M$	= total attached mass ( = $M_p + M_c$ )
$M_c$	= conveyance mass
$M_p$	= payload mass
$M_r$	= rope mass
$q$	= ratio between load range and rope strength
$r$	= rope constant
$SF$	= static factor
$z$	= length of suspended rope

### 3. SUMMARY OF DECISIONS

The working group's recommendations and individual discussions can be summarised as follows:

- In order to align the regulations with commonly accepted engineering practice, it is proposed that they should specify the rope strength at installation and not at discard.
- All winding ropes shall be inspected and discarded according to an approved code of practice for rope condition assessment (RCA). It was accepted that the contents of this code will be based on current practice and formalised with accepted discard criteria.
- Where no code of practice relating to winder performance is applied, the rope shall have a capacity factor of at least 8 and a static factor of at least 4,5.
- For vertical shafts, where a code of practice pertaining to winder performance, operation, maintenance and testing (WPOMT) is applied, in as far as it affects rope safety and deterioration, the static factor shall be not less than  $25000/(4000 + L)$ , where  $L$  is the length of the suspended rope in metres, and the dynamic factor shall not be less than 2,5.
- The initial breaking force of incline winder ropes should not be lower than the current values.

Appendix A lists the recommended regulations. Sections 3 to 5 below present the justification for the recommendations

### 4. LIMITING LOAD RANGE

It has not yet been determined to what extent the load range affects rope life or what the maximum allowable load range should be. It is accepted, however, that there is a load range

beyond which ropes may deteriorate unacceptably fast. There should thus be a limit on the load range that drum winder ropes may experience. A recent study<sup>2</sup> has shown that, under the current regulations, ropes generally experience load ranges of up to 12% of their initial breaking strength while one rope on one winder experienced a load range of 14,6%. Since the ropes on this winder attained adequate lives, it was considered appropriate to set an upper limit of 15% to allowable load ranges. Future research may show that a higher load range may also be acceptable.

#### 4.1 Limiting Load Ranges in a Regulation

There are different methods by which a regulation specifying a static factor can limit allowable dynamic load ranges. The only means by which the regulations can ensure that the load range remains limited within relatively close tolerances, however, is to enforce controlled winder dynamics and to ensure that the payload remains within limits. It was proposed that this is done by means of the WPOMT code of practice. The regulations can therefore specify a static factor and the code of practice will prescribe dynamic winder behaviour.

##### 4.1.1 Capacity factor

In order not to impose the WPOMT code of practice on all existing installations, it was proposed to retain a capacity factor regulation which, to a certain degree, will also limit the load range. Since no code of practice will apply, the capacity factor should be chosen conservatively, taking account of variations in winder dynamics and payload to conveyance mass ratios, so that a load range limit will be ensured.

##### 4.1.2 Static factor formula

A static factor that decreases with depth can be prescribed by a regulation in conjunction with WPOMT code of practice. Such a formula has been proposed<sup>3</sup>, although it was stated that "existing information on the fatigue behaviour of drum winder ropes is grossly inadequate". This formula, together with a given peak drum acceleration and a given ratio between the payload mass and the conveyance mass, results in a limited dynamic load range.

Based on the above, the working group decided on a set of proposed regulations that would limit the dynamic load range. The factors required in such regulations are derived in the following sections. Some common definitions follow here.

The dynamic load range experienced by the back end of a drum winder rope can be approximated as follows<sup>3</sup>:

$$\Delta T = M_p (g + 2 a_p) + 3 M_c a_p + 2,32 M_r a_p$$

The above equation is based on the assumption that the load variations resulting from braking at the end of the winding cycle (stopping after creep) are negligible.

A typical value for the peak drum acceleration is  $a_p = 1 \text{ m/s}^2$ . The above equation for load range can thus be approximated for a typical case by

$$\Delta T \approx 12 M_p + 3 M_c + 2 M_r$$

which shows that, for a typical peak drum acceleration, the payload has by far the highest contribution towards the load range.

If  $q$  is defined as the ratio between the load range and the rope strength, then

$$q = \frac{\Delta T}{BF}$$

## 4.2 Capacity Factor

The equation for the load range can be rewritten as

$$\Delta T = M g \left[ (1 - c) \left[ 1 + \frac{2 a_p}{g} \right] + 3 c a_p \right] + 2,32 M_r a_p$$

The capacity factor is defined as

$$CF = \frac{BF}{M g}$$

A rope constant can be defined so that

$$\frac{M_r g}{BF} = \frac{r z}{\sigma}$$

The equation for  $q$  therefore becomes

$$q = \frac{(1 - c) \left( 1 + \frac{2 a_p}{g} \right) + \frac{3 a_p c}{g}}{CF} + 2,32 \frac{a_p}{g} \frac{r z}{\sigma}, \text{ using the definitions for } CF \text{ and}$$

$r$ .

The required capacity factor is thus

$$CF = \frac{(1 - c) \left( 1 + \frac{2 a_p}{g} \right) + \frac{3 a_p c}{g}}{q - 2,32 \frac{a_p}{g} \frac{r z}{\sigma}}$$

It is assumed that the following combination of values represents the limiting case

$$c = 0,3$$

$$q = 0,15$$

$$a_p = 0,15 g$$

$$\sigma = 1800 \text{ MPa}$$

$$z = 1700 \text{ m}$$

$$r = 105,5 \text{ kN/m}^3$$

The probability of the coincidence of the above values was, however, considered to be small. Taking a peak drum acceleration of  $a_p = 0,1 g$  as an example (which is typical for most winders) the required capacity factor should be 7,3. Calculating the required capacity factor for the above values but using a conveyance ratio of  $c = 0,4$  (which is a more typical value than 0,3), the required capacity factor would be 8,3. It is therefore recommended to specify a capacity factor of 8 in the regulations.

In the unlikely event that the combination of all the values in the above list would apply the required capacity factor would have to be  $CF = 9,1$ . This would mean that there could be isolated cases where the load ranges would be somewhat higher than the recommended maximum of 15% of the initial rope strength. This could possibly lead to a shorter life. It will however not lead to a dangerous situation provided that the RCA code of practice will prescribe assessment intervals which are based on average rope lives obtained on a specific installation with a given rope. While the average life is still being determined, the assessment intervals are presumed to be relatively short and shorter rope lives will therefore not lead to an increased risk.

### 4.3 Static Factor Formula

It was shown<sup>3</sup> that the rope strength required to limit the dynamic load range can be adequately expressed by

$$BF = C_1 M g + C_2 M_r g$$

where 
$$C_1 = \frac{\frac{3 a_p}{g} + (1 - c)(1 - \frac{a_p}{g})}{q}$$

and 
$$C_2 = \frac{2,32 a_p}{q g}$$

If the peak drum accelerations are limited to  $a_p = 0,1g$  by prescribing such a value in the WPOMT code of practice and the dynamic load range is to be limited to 15% of the rope strength ( $q = 0,15$ ), then the constants (for  $c = 0,3$ ) are

$$C_1 = 6,2$$
  
and 
$$C_2 = 1,55$$

Using the previously defined rope constant, the following equation for a static factor is obtained:

$$SF = \frac{C_1}{1 + (C_1 - C_2) \frac{r Z}{\sigma}}$$

For the above values for  $C_1$  and  $C_2$  and for  $r = 105,5 \text{ kN/m}^3$  and  $\sigma = 2000 \text{ MPa}$  this becomes

$$SF = \frac{25\,258}{4\,074 + z}$$

It was suggested that this equation be approximated by

$$SF = \frac{25\,000}{4\,000 + L} \quad \text{where } L \text{ is the length of suspended rope,}$$

and that this equation be stipulated in the regulations together with a reference to the WPOMT code of practice which should, inter alia, specify a limit for  $a_p$ . It must be noted that this formula limits the load range to 15% of the rope strength only if the payload is not more than 70% of the total attached mass and if the tensile grade is not more than 2000 MPa. As in the case of the recommended capacity factor, however, the formula chosen is sufficiently conservative so that it is unlikely that a higher load range will be imposed on the rope.

## 5. PEAK LOAD LIMITS

The capacity factor and the formula suggested in the previous section were selected to ensure that the load range on drum winder ropes remains limited. In order to ensure ultimate safety of the rope, however, the peak dynamic rope loads must also be limited. It was assumed that the maximum dynamic rope forces occur during a trip-out when the emergency brakes are applied. During an investigation into dynamic rope forces<sup>4</sup> the highest forces were determined to be 32% of the initial breaking strength and a dynamic factor of 3 ( $\approx 1/0,32$ ) was therefore proposed. It was also found that the dynamic forces were up to 80% higher than the static forces. It has been reported<sup>5</sup> that the rope forces in a certain installation were as high as 37% of the initial breaking strength during trip-out tests. The ropes operating on that installation showed no abnormal deterioration during a detailed examination<sup>6</sup>. The Working Group therefore decided that a dynamic factor of 2,5 would be appropriate. This would allow rope forces of up to 40% of the breaking strength.

As in the case of dynamic load ranges, the peak dynamic load can also be limited by prescribing a conservative value for a static factor or, alternatively, by prescribing a dynamic factor in conjunction with a reference to the WPOMT code of practice which prescribes how the dynamic factor is to be determined.

### 5.1 Static Factor

The dynamic factor is defined as

$$DF = \frac{BF}{F_{\max}}$$



This equation can be rewritten as

$$DF = \frac{BF}{F_{stat}} \times \frac{F_{stat}}{F_{max}}$$

The first term in this equation is the static factor and the equation may be re-written as

$$SF = DF \times \frac{F_{max}}{F_{stat}}$$

Considering the fact that the dynamic forces can be 80% higher than the static forces, the static factor required to ensure a dynamic factor of 2,5 is therefore

$$\begin{aligned} SF &= 2,5 \times 1,8 \\ &= 4,5 \end{aligned}$$

## 5.2 Dynamic Factor

As mentioned earlier, a dynamic factor of 2,5 could be prescribed together with reference to the WPOMT code of practice which prescribes how the dynamic factor is to be determined. There are a number of options to achieve this:

- The most direct method is to measure the rope forces. This can be done using a loadcell mounted under the headsheave bearing block.
- The simplest method is to measure the conveyance accelerations and multiply the peak conveyance acceleration and the total suspended mass. This method overestimates the dynamic forces but the estimation error is only a few percent if the accelerations are fairly gentle. Where high accelerations are measured the estimation error increases but this error leads to a more conservative dynamic factor.
- Another method is to measure the deceleration profile of the winder drum and to use these measurements, together with other parameters, to calculate the rope forces. These calculations are rather complex but computer programs exist which can calculate rope forces using drum speed records as input data.

## 6. FURTHER CONSIDERATIONS

### 6.1 Incline Winders

The lowering of the factors for man winders and the change from discard factors to installation factors would effectively allow lower factors on virtually all winders. In order to force incline winders to operate at approximately the same factors as they are doing under the current regulations, the factor which addresses the vertical component of the incline was proposed to be changed from 1,05 to 1,1. This would mean that, for a static factor of 5 as prescribed by the existing regulations, the true static factor would be  $5 \times 1,05 = 5,25$

while, for a static factor of 4,5 as proposed for the new regulations, the true static factor would be  $4,5 \times 1,1 = 4,95$ . Although this is slightly lower than the true static factor of 5,25 under the existing regulations, the proposed new regulation stipulating that the strength of all ropes shall be assessed according to the RCA code of practice would ensure additional safety.

## **6.2 Gravitational Acceleration**

The gravitational acceleration at any point is a function of the latitude and altitude of that point. In South Africa the value of 9,8 is a better approximation of the gravitational acceleration than 9,81. It is therefore recommended not to change the value that is currently in the Minerals Act. Furthermore it is recommended to present this value in a definition rather than in a regulation.

## **6.3 Multi-rope Drum Winders**

The safety of conveyance-mounted compensating sheaves has been addressed in some detail<sup>1</sup>. An observation was made that lower static factors in conjunction with such devices were not justified because the free fall of the conveyance after the failure of one of the ropes would probably lead to the failure of the other rope as well.

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## APPENDIX A: PROPOSED REGULATIONS FOR DRUM WINDER ROPES

The following recommended regulations have been based on PROPOSED AMENDMENTS TO THE MINERAL ACT REGULATIONS (as tabled by Mr S Burger during the Steering Committee Meeting held on 31 March 1993). Changes and additions are printed in italics.

### A.1 Chapter 16 definitions:

- (ix) 'effective combined weight' shall mean, *in relation to the winding rope*, the static weight *in newtons which shall be calculated by multiplying the mass in kilograms of any load by 9,8* where winding is conducted in a vertical plane and it shall be *1,1* times the incline component of this static weight where winding is conducted in an incline plane;
- (x a) '*initial breaking strength*' means, *in relation to the winding rope*, the breaking strength obtained from a sample tested at an approved testing station when the rope is manufactured;
- (x b) '*peak rope force*' means the highest rope force including static and dynamic force components

### A.2 Regulations

- 16.25 A new winding rope, balance rope, tail rope or guide rope shall not be used unless the manager is in possession of a certificate showing the *initial* breaking strength, provided that a winding rope or balance rope shall *also* have a test piece cut and tested at an approved testing station immediately *before* it is installed if the certificate mentioned above is older than two years.
- 16.30 DELETE
- 16.33.1 The strength of a winding rope, balance rope or tail rope shall be assessed in accordance with an approved code of practice *which prescribes inter alia discard criteria, assessment intervals and procedures, equipment specifications and rope inspector training and qualifications* and may not be used if the breaking strength thus assessed at any point in the rope, excluding the splice or end termination, is less than nine tenths of the initial breaking strength.
- 16.33.2 *The splice or end termination shall be cut off and re-made when the discard criteria apply as prescribed in the code of practice.*
- 16.34.1 Where the winding system is such that it allows for the periodic testing of the winding rope as required by regulation 16.41 and a balance rope or tail rope is not

used, a winding rope shall have an initial breaking strength equal to or exceeding the greater of -

- (a) *eight* times the effective combined weight of the conveyance and its attachments and the maximum permitted load of persons, material, explosives or mineral, or
- (b) four and a half times the effective combined weight of the length of winding rope, the conveyance and its attachments and the maximum permitted load of persons, material, explosives or mineral.

16.34.2 *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 and a balance rope or tail rope is not used and if a mine complies with an approved code of practice pertaining to winder performance, operation, maintenance and testing, in as far as it affects rope safety and deterioration, and notwithstanding the provisions of regulations 16.34.1 and 16.37 a winding rope of a winding plant shall have an initial breaking strength equal to or exceeding the greater of -*

- (a)  $25000/(4000+L)$  times the effective combined weight of the length of winding rope, the conveyance and its attachments and the maximum permitted load of persons, material, explosives or mineral, where L is equal to the maximum length of suspended rope in metres, or
- (b) *two and a half times the peak rope force which occurs or may occur during normal operation and emergency braking.*

16.37 *Where the 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 and a balance rope or tail rope is not used and each conveyance is suspended by two or more winding ropes in conjunction with a rope-tension compensator which is constructed in such a way that the failure of one rope will not result in a momentary lowering of the force acting in any other rope, the initial breaking strength of the winding ropes shall be as specified in regulation 16.34.1(a) or 0,95 times that specified in regulation 16.34.1(b), whichever is the greatest.*

**CODE OF PRACTICE**

**PERFORMANCE, OPERATION, TESTING AND  
MAINTENANCE OF DRUM WINDERS RELATING  
TO ROPE SAFETY**

**DRAFT PREPARED BY WORKING GROUP**

The technical requirements of this code of practice are divided into the following six main categories:

- Rope selection
- Design considerations
- Monitoring and control systems
- Winding performance specifications
- Operation of the winding plant
- Inspection, testing and maintenance

The references given in square brackets, e.g. [5], refer to the normative references of the code of practice (see section 3 on p.6).

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## INTRODUCTION

The regulations in Chapter 16 of the Minerals Act (Act 50 of 1991) [1] require the following:

*16.28 The strength of a winding rope or balance rope shall be assessed in accordance with an approved safety standard and 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.*

*16.29.1 Where the winding system is such that it allows for the periodic testing of the winding rope as required by regulation 16.34.1 and a balance rope is not used, a winding rope shall have an initial breaking strength equal to or exceeding the greater of -*

*(a) eight times the effective combined weight of the conveyance and its attachments and the maximum permitted load of persons, material, explosives or mineral, or*

*(b) four and a half times the effective combined weight of the maximum suspended effective length of winding rope, the conveyance and its attachments and the maximum permitted load of persons, material, explosives or mineral.*

*16.29.2 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 16.34.1 and if the mine complies with an approved safety standard pertaining to winder performance, operation, maintenance and testing, in as far as it affects rope safety and deterioration, and notwithstanding the provisions of regulations 16.29.1 and 16.31 a winding rope of a winder shall have an initial strength equal to  $25000/(4000+L)$  times the effective combined weight of the length of winding rope, the conveyance and its attachments and the maximum permitted load of persons, material, explosives or mineral, where  $L$  is equal to the length of winding rope in metres.*

The safe use of winding ropes depends on the effectiveness of rope condition assessment strategies. This is covered by regulation 16.28 above. Continued safe usage of winder ropes can, however, only be ensured by limiting the rope deterioration between condition assessments and by avoiding overloads. Any damage that might lead to an unexpected acceleration of rope deterioration will affect the safety of the installation. This code of practice is therefore aimed at the prevention of abnormal damage to the winding rope and of excessive stresses and rates of deterioration in the rope.

This code of practice is the *approved safety standard* referred to in the regulation 16.29.2 above, and applies to drum winders operating in vertical shafts, excluding winders used for shaft sinking. It is necessary that the winding system complies with this standard at the time of installation of a rope as well as at *any time* during the life of that rope or any future rope.

Although a number of design considerations are given in this standard, it is not a detail design guide for any part of the mechanical or electrical system.



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## 1. SCOPE

This code of practice is the *approved safety standard* referred to in regulation 16.29.2 of the Minerals Act (Act 50 of 1991) [1], which applies only to drum winders operating in vertical shafts.

This code of practice aims at preventing rope overloads and damage that may lead to unexpected acceleration of rope deterioration.

The primary purpose of this code of practice is to ensure that the winding system as a whole operates such that the peak rope load will not exceed 40% of the initial breaking strength of the rope during normal winding operations and trip outs, and that the load range of any part of the rope will not exceed 15% of the initial breaking strength of the rope during a normal winding cycle.

The following areas are addressed in this safety standard:

- Rope selection criteria
- Winder design considerations
- Monitoring and control systems
- Winder performance specifications
- Operating standards
- Inspection, testing and maintenance

This code specifically addresses regulation 16.29.2 and is not a design guide for drum winders and also does not cover all operational requirements for such installations.

## **2. DEFINITIONS**

### **ACCELERATION**

Acceleration is commonly understood as being the rate of change of speed which increases the speed, whereas deceleration refers to a decrease in speed. Average acceleration is normally determined by dividing a change of speed by the time that the speed takes to change. Peak acceleration can only be measured with accelerometers or by differentiating the speed and taking very small time steps into consideration.

### **ACTUAL ROPE STRENGTH**

*See rope strength.*

### **APPOINTED ENGINEER**

The engineer appointed in terms of Regulation 2.13.1 of the Minerals Act.

### **BACK END**

That end of the rope that is attached to the drum.

### **BMR WINDER**

Blair Multi-Rope winder: A drum winder with more than one rope per conveyance.

### **BRAKE SYSTEM**

A winder brake system including the controller, all control circuits and the associated mechanical components.

### **BREAKING STRENGTH**

*See rope strength.*

### **CAPACITY FACTOR**

The *initial rope strength* divided by the maximum static load that the rope has to support at its front end (i.e. the weight of the conveyance and attachments plus the weight of the payload).

### **CATENARY**

The section of rope between the winder drum and the *headsheave*.

### **CATENARY DYNAMICS**

The whipping of the catenary.

### **CYCLE**

A winding cycle: A round or intermittent trip, starting with one conveyance, say the right hand side conveyance, at bank level and ending with the same conveyance returning to the bank level.

### **DECELERATION**

*See acceleration.*

**DEFLECTION SHEAVE**

A deflection sheave is an additional sheave wheel placed between the *headsheave* and the conveyance to suit winding compartment arrangements.

**DRUM ACCELERATION**

The linear acceleration of the rope at the drum, and calculated from the rotational acceleration of the drum and the mean rope coiling diameter.

**DRUM POSITION**

The position of the conveyance as determined from the drum, ignoring any effects of rope layering and rope stretch.

**DRUM SPEED**

The linear speed of the rope at the drum.

**DYNAMIC FACTOR (DF)**

The *initial rope strength* divided by the maximum *dynamic rope force*. (See Appendix G for typical calculations.)

**DYNAMIC ROPE FORCE**

The static rope load **plus** any dynamic components.

**D/d RATIO**

The diameter of the rope tread on a drum or sheave divided by the *nominal rope diameter*.

**FLEET ANGLE**

A graphic illustration of the fleet angles is shown on p.9.

**FRONT END**

That end of the rope that is attached to the conveyance.

**HEADSHEAVE**

This the first sheave in the headframe that the rope passes over after leaving the drum. Any dimensional requirements of the headsheaves shall also apply to *deflection sheaves*.

**INITIAL ROPE STRENGTH**

*See rope strength.*

**LAYER CROSS-OVER**

That section of the rope that lies on the transition from one layer of rope on the drum to the next.

**LENGTH OF WINDING ROPE**

That length of winding rope which causes the highest static force in the rope.

**LOAD RANGE**

The difference between the largest and smallest *dynamic rope forces* that act on a section of rope in a given period. The load range of a winder rope will vary along the length

of the rope. For the purposes of this document, load range means the highest load range that any section of the rope experiences in a given period.

**MISCOILING**

Miscoiling is the condition where a rope prematurely starts coiling on the next layer.

**NOMINAL ROPE DIAMETER**

See *rope diameter*.

**NOMINAL ROPE STRENGTH**

See *rope strength*.

**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 name for all spin resistant ropes with strands in a multi-layer construction.

**NORMAL WINDING**

Starting, running and stopping under the power of the electrical drive including cyclic terminal application of the brakes and regular events such as conveyance loading and unloading.

**RATED TORQUE**

Rated torque is the torque produced by the motor when it is operating at the rated continuous RMS power at the rated speed as detailed on the motor rating plate.

**REGIONAL DIRECTOR**

The Regional Director of the Department of Mineral and Energy Affairs.

**REPRESENTATIVE SAMPLE**

A section of the rope in the as-manufactured condition.

**ROPE DIAMETER**

**ACTUAL DIAMETER:** The diameter of the rope as measured when new and under a tensile load of 10% of the *nominal rope strength*.

**NOMINAL DIAMETER:** The rope diameter specified by the manufacturer.

**ROPE MASS PER UNIT LENGTH**

The mass of the rope per unit length, determined by weighing a *representative sample*.

**ROPE METALLIC AREA**

The sum of the cross sectional areas of all the wires in a rope.

**ROPE STRENGTH**

**ACTUAL STRENGTH:** The strength of a rope as determined by a tensile test.

**INITIAL STRENGTH:** The strength of a new rope as determined by a tensile test.

**NOMINAL STRENGTH:** The (estimated) rope strength normally specified by the rope manufacturer.



**ROPE TERMINATION**

The means by which the rope is attached to the suspended mass (e.g. hand splice, a socket, or a capel), or the connection of the rope at the drum.

**SOCKET**

A type of *rope termination*. An example of a socket is shown on p.44, section D3. The conical cavity of the socket accommodates a "brushed" rope end, and is usually filled with resin or white metal.

**SPLICE**

A type of *rope termination*, where the end of the rope is secured by interweaving the strands back into the rope. Examples of splices are shown on p.42 in section D1.

**STATIC FACTOR (SF)**

The *initial rope strength* divided by the maximum static load the rope has to carry (i.e. the weight of the maximum length of suspended rope, the weight of the conveyance and attachments and the weight of the payload). This factor is often called the safety factor.

**TRIP OUT**

Any event (e.g. power failure, overspeed, operating the emergency trip button) that leads to the controlled automatic application of the brakes.

**TURN CROSS-OVER**

In parallel coiling, that part of the rope that slants across the drum as it changes from one turn or half turn to the next.

**WEDGE TYPE CAPEL**

A mechanical friction device used as a *rope termination*. An example of a wedge type capel is shown on p.44 in section D2.

**WINDING CYCLE**

See *Cycle*.

### 3. NORMATIVE REFERENCES

- 1 The Minerals Act (Act 50 of 1991).
- 2 SABS 0208: *Code of practice for the design of structures for the mining industry.*
- 3 SABS ISO 9001 South African Standard: *Code of practice for Quality Systems - Model for quality assurance in design/development, production, installation and servicing.*
- 4 SABS xxxx:199x: South African Standard: *Code of practice: Condition assessment of steel wire ropes on mine winders.*
- 5 National Coal Board (UK): NCB 465:1965: *Rope sockets for winding ropes.*

## 4. LEGAL REQUIREMENTS

### 4.1 ROPE STRENGTH CRITERIA

Regulation 16.29.1 applies to drum winders that do **not** have to conform to this code of practice, and requires installation factors as follows:

$$\begin{array}{ll} \text{Capacity factor} & CF \geq 8,0 \\ \text{Static factor} & SF \geq 4,5 \end{array}$$

In a case where the rope force compensator of a BMR winder is such that the failure of the one rope will not result in a momentary lowering of the force acting in the other rope, Regulation 16.31 stipulates that the static factor can be reduced to:

$$SF \geq 4,275$$

Regulation 16.29.2 states that, if a winder conforms to this safety standard, the following static factor may be applied:

$$SF \geq \frac{25\,000}{4\,000 + L}$$

where  $L$  = maximum length of suspended rope in metres

### 4.2 OTHER REQUIREMENTS

The above and all other regulations that have to do with drum winders operating in vertical shafts and their ropes are listed in Appendix A.

## **5. ROPE SELECTION**

### **5.1 ROPE CONSTRUCTION**

Triangular strand, round strand, non-spin or full locked coil ropes may be used.

### **5.2 ROPE MANUFACTURING STANDARD**

Wire ropes for winders that are to conform to this code of practice shall be obtained only from manufacturers approved in terms of:

*SABS ISO 9001 South African Standard: Code of Practice for: Quality Systems - Model for quality assurance in design/development, production, installation and servicing*

### **5.3 ROPE TOLERANCES**

#### **5.3.1 Rope diameter**

The tolerance on rope diameter shall be within +5% and -1% of the nominal rope diameter. The actual diameter shall be determined by measurement under a load equal to 10% of the nominal rope strength. This measurement shall form part of the statutory test to determine the initial rope strength.

#### **5.3.2 Rope mass per unit length**

The actual rope mass shall be determined by weighing a representative sample of the rope. The mass so determined shall be used in calculating the statutory requirements each time a new rope is installed.

### **5.4 ROPE STRENGTH**

For compliance with the regulations, the initial rope strength shall be determined by an actual test at the time of manufacture. However, ropes that have aged in storage such that the breaking strength has reduced by more than 7%, shall not be used. (Also refer to Regulation 16.23 of the Minerals Act).

## 6. DESIGN CONSIDERATIONS

### 6.1 WINDING PLANT LAYOUT

#### 6.1.1 Environmental factors

Due consideration shall be given in the layout of the winding plant layout to ensure that the rope is not unnecessarily exposed to condensation, acid fumes, heat and water spray during normal winder operation and when the winder is parked.

#### 6.1.2 Fleet angles

Fleet angles are shown in the adjacent figure.

The headsheaves and the drums of winders shall be orientated such that the drum fleet angle is not more than  $2,0^\circ$  and not less than  $0,25^\circ$ . The headsheave should point at the centre of the drum.

See section 6.1.4 for deflection sheave fleet angle requirements.

#### 6.1.3 Catenary

Catenary dynamics, caused by resonance, are considered unacceptable if they could cause bad coiling, the rope to come out of the headsheave groove, or the rope to make contact with stationary objects. It is accepted that catenary resonance cannot be avoided at all times during a winding cycle; therefore:

- The catenary dynamics of a winder installation shall be analyzed in order to optimize the catenary length and winder speed so that unacceptable dynamics are avoided.
- If resonance cannot be avoided, the catenary shall be designed such that resonance does not occur at a layer crossover while the conveyance is ascending, so that these disturbances will then not influence the coiling of the rope on the drum.

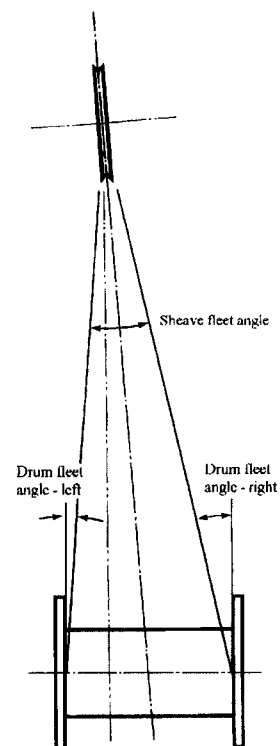
#### 6.1.4 Other plant layout considerations

The rope shall not contact any stationary object during normal winding. Intermediate sheaves and rollers are not allowed. A single deflection sheave is permissible at rope speeds less than 10 m/s. Deflection sheaves shall comply with the required minimum sheave  $D/d$  ratios of section 6.3.1. A deflection sheave shall be installed in line with the headsheave.

### 6.2 WINDER DRUMS

#### 6.2.1 Drum flange height

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.



### **6.2.2 Drum $D/d$ ratio**

The drum  $D/d$  ratio shall have a value of not less than  $D/d = 40 + 4V$

where  $V$  = rope speed in m/s

A  $D/d$  ratio of more than 140 is not required, even with high rope speeds.

Appendix B recommends an upper limit for the drum tread pressure.

### **6.2.3 Multi-layer coiling**

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

### **6.2.4 Dimensional tolerances**

The out-of-round of the rope tread surface on the drum shall be less than 0,2% of the drum diameter. The allowable size of a step at a joint shall not be greater than 1 mm and shall be smoothly blended in over a total distance of ten times the step height.

### **6.2.5 Drum stiffness**

The winder drum shall have a stiffness such that, when the full length of rope with a fully loaded conveyance is wound onto the drum, the tension in any coil of the rope on the drum is not reduced by a value that is greater than 15% of the initial rope strength. Conformity to the above can be shown by measurement or by calculation. Calculations shall use a rope elastic modulus of 140 GPa, based on the metallic area of the rope. If coiling sleeves are installed, they shall not be considered as part of the drum.

### **6.2.6 Rope coiling arrangement**

The surface of a winder drum barrel shall have rope coiling grooves, designed to avoid poor coiling and subsequent damage to the rope. The grooves may be machined directly into the drum barrel, or alternatively, the drum may be equipped with separate coiling sleeves that are rigidly attached to the drum barrel. Materials other than ferrous metals shall only be allowed with appropriate proof of satisfactory operation.

The rope coiling grooves shall be parallel with the drum flanges with two cross overs per drum turn, while a drum which will not carry more than one rope layer may have a spirally grooved surface. Appendix C contains guidelines for drum coiling patterns.

Guide rods or bars welded to the drum to simulate coiling sleeves are not allowed.

## **6.3 HEAD AND DEFLECTION SHEAVES**

The following requirements apply to headsheaves and deflection sheaves but not to conveyance mounted compensating sheaves or doubling down sheaves.

### 6.3.1 $D/d$ ratio

The  $D/d$  ratio of headsheaves and deflection sheaves shall be selected in the same way as for the drum as prescribed on p.10 in section 6.2.2.

Appendix B recommends an upper limit for the sheave tread pressure.

### 6.3.2 Inertia

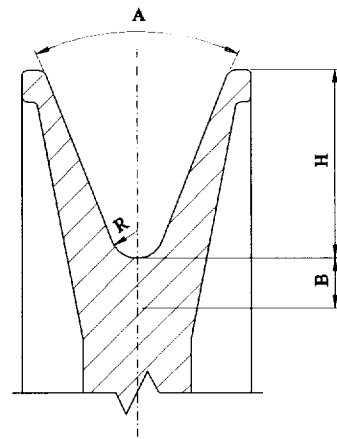
Headsheaves and deflection sheaves and their rope running surfaces shall be designed such that no relative slip shall take place between the rope and a sheave surface during emergency braking with the empty or full conveyance at any point in the shaft and in any direction of travel.

### 6.3.3 Groove radius, profile and tolerance

The headsheave and deflection sheave grooves can either be cut 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  $7 \mu\text{m}$  after machining. There must 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  
=  $45^\circ$  to  $55^\circ$
- $R$  = Root radius of the groove  
=  $0,525 d$  to  $0,55 d$
- $H$  = 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.

### 6.3.4 Ovality and eccentricity

The out-of-round of a sheave groove shall be less than 0,1% of the sheave diameter. The lateral run-out of the centre of the groove of a sheave shall not be greater than 0,1% of the diameter of the sheave.

## 6.4 ELECTRICAL DRIVE

Appendix F provides guidelines for the design of the electrical drive and control systems.

When the peak power rating of the winder motor exceeds 160% of the duty cycle requirement, a failure mode analysis shall be done to demonstrate, by calculation, that the rope forces will not exceed 60% of the initial rope strength during the malfunction of any

one element of the electrical drive and the mine shall be in possession of a document showing such calculations.

## 6.5 BRAKES

The primary requirements for winder brake systems, in terms of this code of practice, are:

- To ensure that the rope force does not exceed 40% of the initial rope strength during a trip out (i.e a dynamic factor  $\geq 2,5$ ), and
- to prevent rope failure during uncontrolled braking.

### 6.5.1 Redundancy

At least two separate and independent brake systems shall be incorporated for each winder and for each drum of electrically coupled BMR winders.

### 6.5.2 Failure mode analysis

A failure mode analysis of the complete brake system shall be done to demonstrate, by calculation, that the rope forces will not exceed 60% of the initial rope strength during the failure of any one component that leads to uncontrolled braking or brake malfunction. The highest winder deceleration that will occur during uncontrolled braking must be calculated, based on

- the type of failure being analysed,
- the degree of brake redundancy,
- variations in coefficient of friction between the brake lining and the brake path,
- the winding speed at which the failure occurs,
- the payload in the conveyances, and
- the position of the conveyances in the shaft.

The calculation of the peak dynamic rope force during uncontrolled braking shall be based on twice the above highest winder deceleration to account for the dynamic response of the system:

$$F_p = (g + 2 a_b) \times (M_r + M_c + M_p)$$

where  $F_p$  = peak dynamic rope force  
 $g$  = gravitational acceleration  
 $a_b$  = calculated drum deceleration  
 $M_r$  = rope mass  
 $M_c$  = conveyance mass  
 $M_p$  = payload mass

Alternatively, dynamic loads may be calculated using a proven mathematical model capable of simulating the actual response. The mine shall be in possession of a document showing such calculations.



## **6.6 ROPE TERMINATIONS**

The rope termination at the conveyance shall be such that the end of the rope shall not be able to rotate freely during winding. The rope termination at the conveyance shall be in accordance with one of the following:

### **6.6.1 Hand splices**

Liverpool or Admiralty type hand splices can be used. Detailed descriptions of these splices are given in Appendix D. At least seven tucks must be used with six strand round or triangular strand ropes. Nine tucks are required for non-spin ropes.

### **6.6.2 Sockets**

Sockets designed by a professional engineer or sockets in accordance with National Coal Board (UK) specification NCB 465 [5] shall be used. An example of a winding rope socket is shown on p.44, section D3. The material used for manufacture of the sockets shall be in accordance with the regulations for rope end connections. (Refer to Regulation 16.14).

### **6.6.3 Capels**

Wedge type capels may be used. The manufacturers instructions regarding assembly and maintenance shall be strictly observed. An example of a wedge type capel is shown on p.44, section D2.

### **6.6.4 Conveyance mounted compensating sheaves**

The specifications for this type of rope termination are given in section 6.7.1.

## **6.7 BMR WINDER ROPE FORCE EQUALISATION SYSTEMS**

The equalisation of rope tensions in the ropes of BMR winders can be achieved by either using a compensator on the conveyance or by a system of floating headsheaves. The amount of compensation shall allow for the rope length difference that may occur due to miscoiling; plus the effects of differences in rope stiffnesses, rope diameters, and drum diameters; plus any initial offsets such as differences in the installed rope length.

In addition to the above, the following requirements for specific types of BMR compensators:

### **6.7.1 BMR conveyance mounted compensators**

A conveyance mounted compensating system shall consist of a spirally grooved sheave wheel that can freely rotate on a spindle. Where each rope is connected to the compensating sheave, there shall at least be one and a half turns of each rope on the sheave, even after the sheave has moved to allow for compensation. The minimum diameter of the compensating sheave shall be 25 times the nominal rope diameter. The conveyance compensating system shall be designed to allow for daily examinations as required by section 10.3.1. The rope on the compensating sheave shall be adequately protected against falling objects.

### **6.7.2 BMR winder headgear mounted compensators**

A headgear mounted compensating sheave arrangement shall be designed so that it does not reach its limit of compensation/travel before the winder is brought to rest after it has been tripped out due to miscoiling. When the compensating system is hydraulically operated, an arrangement must be included to limit the peak dynamic rope force in the event of a sudden loss in hydraulic pressure.

## **6.8 CONVEYANCE GUIDING SYSTEMS**

### **6.8.1 Guide rail alignment and gauge variation tolerances**

The tolerances on guide rail alignment and on clearances between the guide rails and the conveyances shall be such that the conveyances cannot derail or become lodged in the guide rails. The mine shall be in possession of a record of such design tolerances.

### **6.8.2 Guide ropes**

The mine shall be in possession of a record of design parameters which shall include guide rope diameters, guide rope centre spacing and minimum conveyance running clearances, guide bush diameters, and guide rope tensions.

### **6.8.3 Provision for re-alignment**

Where distortion of the shaft alignment can be predicted due to geological disturbances, such as ground movement and mining of the shaft pillar, adequate provision must be made for accommodating this distortion to maintain the requirements of section 6.8.1 or 6.8.2.

## **6.9 CONVEYANCES**

The dimensions of conveyances shall comply with the tolerance requirements given in section 6.8.1.

Each conveyance shall bear a label indicating a unique serial number, the mass and the date of weighing as well as the design payload. This label shall indicate whether the mass includes any attachments or not. Where a conveyance consists of a bridle and a detachable skip or cage, each major component shall bear a separate label. Such labels shall be updated each time a conveyance is repaired or refurbished.

## **6.10 CONVEYANCE LOADING**

Any conveyance holding device shall be designed so that it does not cause slackness in the rope. A skip loading system shall be constructed in such a way that no mineral can impact the winding rope and attachments.

## **7. MONITORING AND CONTROL SYSTEM REQUIREMENTS**

### **7.1 WINDER PERFORMANCE MONITORING**

#### **7.1.1 Rope force measurement**

A winder shall be equipped with a rope force monitoring system. The rope forces shall be measured at either the conveyance end of the rope or at the headsheave. The measurement error of the rope force shall be less than 1% of the initial rope strength.

The rope force monitoring system shall sample the force at least 10 times per second, or in the case of an analogue system, it shall have a minimum frequency response of 3 Hz. The rope force monitoring system shall be equipped with an uninterruptable power supply.

#### **7.1.2 Drum speed and position**

The drum speed and drum position shall be monitored continuously. The conveyance position may be determined from drum turns and drum position, and the rope speed may be determined from the drum speed. The accuracy of the rope speed measurement shall be within  $\pm 0,5$  m/s. Conveyance position shall be determined with an accuracy as required by Appendix E.

#### **7.1.3 Determination of load range**

Either the payload and the winder acceleration or the load range shall be measured, depending on which method of monitoring load range has been selected from Appendix E.

### **7.2 ELECTRICAL DRIVE CONTROL SYSTEMS**

The electrical drive control and protection system of the winder installation shall incorporate the following categories of control:

- Primary power supply trip-out
- Safety circuit trip (emergency braking)
- Electrical stop at a controlled deceleration rate.
- Enforced reduced speed: The motor shall not be able to exceed a predetermined speed.
- End of wind lockout: The winder shall be prevented from winding after reaching the end of a wind when such action is required.
- A system whereby enforced speed reduction and end of wind lockout can only be cleared by a person with the proper authority.

Appendix F provides guidelines for the electrical drive and control systems.

### **7.3 BRAKE CONTROL**

Guidelines for the electrical brake control systems are given in sections F1 and F3 of Appendix F.

### **7.3.1 Brake control requirements**

The winder brakes shall be equipped with such control equipment which is required to achieve the performance prescribed in section 8.2.

### **7.3.2 Brake control monitoring system**

The brake control systems, including associated components, shall be monitored in such a way as to detect any malfunction in the control system where such a malfunction could cause uncontrolled braking.

## **7.4 SPECIAL REQUIREMENTS FOR BMR WINDERS**

All BMR winders shall be equipped with a rope miscoiling detector mounted at the winder drum.

Headgear mounted rope force compensating systems must be equipped with monitors to detect when the system has reached a limit where equal rope tension can no longer be ensured before the winder is brought to rest after an emergency trip out due to miscoiling.

## **7.5 PAYLOAD MEASUREMENT**

When hoisting rock, the winding installation shall be equipped with a facility to determine the average payload over any twenty winding cycles and to initiate an end-of-wind lockout if this average exceeds the licensed payload as required by section ?.

## **8. PERFORMANCE**

### **8.1 WINDER CONTROL SYSTEM**

#### **8.1.1 Normal winding**

The load ranges acting on any part of the winding ropes shall be determined for each winding cycle as required by section 7.1.3. The load range shall not exceed 15% of the initial rope strength in more than one out of ten winding cycles. Every occurrence of exceeding the allowable load range will be logged by the monitoring system.

#### **8.1.2 Non regular events (i.e. trip outs)**

The monitoring system shall log all non-regular events together with the position of the winder at that time, the peak dynamic rope force, and the winder speed.

The control system must reduce the motor torque to less than 5% of the rated torque within 200 ms after a trip-out has been initiated.

#### **8.1.3 Enforced speed reduction**

The maximum rope speed will be limited to 2 m/s when:

- A malfunction as described in section 7.3.2 is detected in the brake control system.
- The rope force has exceeded 40% of the initial rope strength.

#### **8.1.4 End of wind lockout**

An end of wind lockout will be activated when:-

- the load range has exceeded 15% of the initial rope strength in more than one out of ten successive winding cycles;
- the measured payload in any conveyance, averaged over any twenty successive winding cycles, exceeds the licensed payload; or
- the rope force has exceeded 40% of the initial rope strength.

If the control system has no means to count the number of cycles since an excessive load range or payload has occurred, the end of wind lockout must occur at the end of the winding cycle during which the event took place.

Section 9.1.1 makes provision for a procedure to be followed in the case of and end of wind lockout.

#### **8.1.5 Slack rope and tight rope**

The winder shall be tripped when the rope force at the conveyance (i.e. the rope force at the headsheave minus the weight of the suspended rope) has decreased to below 60% of the

weight of the empty conveyance. A facility shall be available to enable the driver to reset the winder immediately and recover the slack rope.

The winder shall be tripped when the rope force at the conveyance exceeds the maximum static rope force at the conveyance by 10% of the initial rope strength.

### 8.1.6 Electrical stop

When the winder is stopped with the electric drive, the deceleration rate shall be such that the generated rope forces shall not be greater than 40% of the initial rope strength.

The average deceleration rate ( $a$ ) can be calculated for any winder installation to ensure that the 40% limit is not exceeded. This is a simple calculation based on a constant deceleration rate (100% overshoot of the generated rope force), the static factor ( $SF$ ) of the installation and the minimum dynamic factor ( $DF$ ) of 2,5.

$$a = \left( \frac{SF}{DF} - 1 \right) \times \frac{10}{2}$$

For example:

$$SF = 3,5$$

$$\text{then } a = \left( \frac{3,5}{2,5} - 1 \right) \times \frac{10}{2} = 2 \text{ m/s}^2$$

## 8.2 BRAKE CONTROL

The retardation of the winder shall be controlled in such a manner that the combined electrical and mechanical brake torque will not result in slack rope or in rope forces in excess of 40% of the initial rope strength during emergency braking or when the speed control lever is set to neutral **and** the brakes are applied manually at the same time.

## 8.3 BMR ROPE MISCOILING DETECTOR

A BMR rope miscoiling detector shall be able to detect a one rope layer difference on the drum within half a drum turn.

## **9. OPERATION**

### **9.1 SPECIAL PROCEDURES**

#### **9.1.1 Procedures to be followed after the winder has tripped**

A mine shall be in possession of a procedure approved by the appointed engineer which is to be followed after any event which leads to the stoppage of the winder as prescribed in section 8.1.

#### **9.1.2 Excessive load range**

When the load range acting on any part of the rope exceeds 15% of the rope strength in more than one in ten winding cycles, the winder will have stopped (as required by section 8.1) and the cause (excessive payload, high winder accelerations or severe conveyance loading) shall be rectified.

#### **9.1.3 Excessive payload**

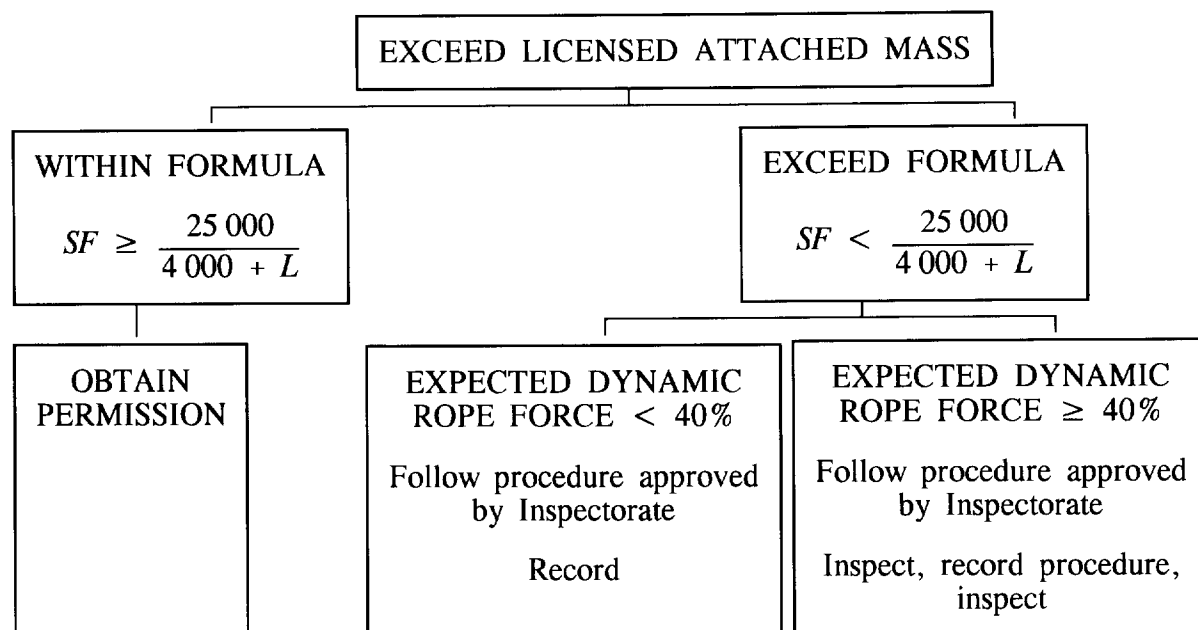
When hoisting rock and the average payload in any conveyance measured over any twenty consecutive winding cycles has exceeded the licensed payload, the winder will have stopped (as required by section 7.5) and the cause shall then be rectified.

#### **9.1.4 Excessive peak force**

When the rope force has exceeded 40% of the initial rope strength, the winder may no longer be used until the condition of the rope has been assessed in terms of the Code of Practice for Rope Condition Assessment [4].

### **9.2 HOISTING HEAVY LOADS**

On occasions it may be necessary to operate the winder with a payload that exceeds the licensed payload. The following decision tree will then apply:



### 9.2.1 Static factor according to the Regulations

If a hoisting operation is to be done with an attached mass exceeding the licensed attached mass **and** the static factor with such an attached mass is larger than the minimum required by the regulation [ $SF > 25\,000/(4\,000 + L)$ ], prior permission shall be obtained from the Regional Director.

### 9.2.2 Static factor lower than that prescribed by the Regulations

If the static factor is to be smaller than that allowed by the regulation, a procedure shall be drawn up which will ensure a minimum dynamic factor of 2,5. This could be achieved by limiting the hoisting speed so that dynamic rope forces are limited. This procedure is to be approved by the Regional Director before such hoisting may commence. The procedure shall include the listing of all operations and recording of rope forces.

If the static factor is to be less than that allowed by the regulation **and** it can be foreseen that the required dynamic factor can also not be maintained, a procedure is to be drawn up which shall be approved by the Regional Director before such hoisting may commence. The procedure shall include the assessment of the condition of the rope, according to the Code of Practice for Rope Condition Assessment [4], before **and** after the hoisting operation.

## 9.3 CRITICAL SETTINGS OF THE BRAKES

At installation and whenever any changes are made to the brake system, the critical settings of the brakes, which are required so that the brakes comply with section 8.2, shall be established by experimentation. These settings shall be recorded and displayed in the winder house. The critical settings shall typically include, but not be limited to

- settings of the retardation control system,
- brake engine operating strokes and brake application times,
- brake pressures,



- motor current required for the weekly static holding power test as required by section 10.5.2.2.

The maximum dynamic rope force allowable during a brake test, calculated as per the example shown in Appendix G, shall be displayed together with the critical settings.

## **9.4 ROPES**

### **9.4.1 Storing**

Ropes shall 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 corrosive 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.

### **9.4.2 Installing**

The headsheave and deflection sheave grooves shall be re-machined before new ropes are installed. (See section 10.12 for the sheave groove maintenance requirements). When installing ropes care must be taken to ensure that turn is not lost or introduced into the rope by the procedure.

Once the rope has been coiled on the winder drum, the dead turns shall be tensioned except when live turns will not be coiled over the dead turns. If tensioning is done by doubling the rope down the shaft, the conveyance should at least be fully loaded and doubling down sheaves and temporary deflection sheaves shall have minimum  $D/d$  ratios of 20. If another method of tensioning of the dead coils is used, the tensioning force shall be at least equal to the rope tension that would have been obtained with doubling down.

### **9.4.3 Front end cutting and re-making of the termination**

Regulation 16.34 of the Minerals Act [1] requires that a portion of the winding rope be cut at intervals for destructive testing and remaking of the end connections. This interval will not exceed six months, and where the ropes are connected to a compensating sheave on the conveyance, the interval shall not exceed three months.

Terminations shall be re-made as required by the intervals above, or at shorter intervals as may be required by the operating conditions of the winder, or by any requirements listed in section 10.2.

### **9.4.4 Back end cutting**

A suitable length of rope shall be cut from the back end of the rope to prevent excessive wear at the layer and turn cross-over points, and shall be done at intervals not exceeding 10 000 winding cycles. The dead turns on the drum shall be tensioned as prescribed in section 9.4.2.

**9.5 BMR WINDER ROPE MISCOILING DETECTION**

The winder shall be stopped automatically when miscoiling is detected. Winding can proceed again after the coiling problems have been corrected. Any occurrences of this event shall be recorded.

**9.6 BMR HEADGEAR COMPENSATOR MALFUNCTION**

The winder shall be stopped automatically when malfunctioning of the BMR headgear compensator is detected. Winding can proceed again after such problems have been corrected. Any occurrences of this event shall be recorded.

## **10. INSPECTION, TESTING AND MAINTENANCE**

The following inspections are required, over and above those required by the regulations of the Minerals Act [1].

The mine shall be in possession of a schedule of inspections, tests and maintenance as well as a detailed record of all inspections, tests and maintenance tests carried out on the winder.

### **10.1 ROPES**

The inspection of ropes on a regular basis is one of the requirements of the regulations of the Minerals Act.

#### **10.1.1 Daily examination**

The ropes shall be inspected daily to comply with Regulation 16.59(a). In addition, the complete rope, including the dead turns on the drum, shall be examined to observe the overall structure of the rope in order to determine whether there are any of the following occurrences:

- Structural damage to the rope. This would include deformation by being struck by a falling object, bird caging of the rope or strands for any reason, or any other significant feature.
- Any observable concentration of broken wires in which case any fractured wires shall be broken back.

In the event of any of the above conditions being observed, the rope shall be cleaned and examined at this place to determine its extent and magnitude. The engineer or responsible person shall be advised as soon as possible of the condition so that a decision can be made whether to discard the rope.

#### **10.1.2 Maintenance of ropes**

The rope shall be adequately protected against corrosion. Re-tensioning and pulling in of the back ends shall be done as specified in section 9.4.4.

## **10.2 ROPE TERMINATIONS**

### **10.2.1 Drum terminations**

Drum terminations shall be inspected daily. The following shall be reasons for re-making the termination:

- Any slipping of the rope in clamps or clips used in the termination.
- Any broken wires in the vicinity of the termination or at the hawse hole.

### **10.2.2 Hand splices**

The splices shall be inspected daily. The splices shall be re-made if one of the following is observed:

- Any wire fractures in the neck or throat of the splice or at the crutch of the splice;
- signs of relative movement between tucks;
- when the corrosion in the splice is greater than that of the adjacent section of the rope; and
- when the rope is not tight around the thimble.

The splice shall be adequately protected against corrosion.

### **10.2.3 Sockets**

This section on the inspection, testing, and maintenance of socket terminations is applicable to both resin filled and white metal filled sockets. Socket terminations shall be inspected daily. The socket shall be re-made if one of the following occurs:

- Any broken wires within one rope lay from the termination; and
- visible movement of the wires relative to the capping.

The rope at the socket termination shall be adequately protected against corrosion.

### **10.2.4 Wedge type capels**

Wedge type capels shall be inspected daily, and special attention shall be paid to the following:

- Rings have to be tight and in the proper as-assembled positions. Any visible sign of movement of the rings, limbs, wedges, or between the safety block and the wedge shall require the termination to be re-made.
- Broken wires at the neck shall require a re-make.

The rope at the termination shall be adequately protected against corrosion.

## **10.3 BMR WINDER ROPE FORCE EQUALISATION SYSTEMS**

### **10.3.1 Conveyance mounted compensators**

The rope force equalisation system shall be inspected daily, and any broken wires at the contact points on the compensating sheave shall require the termination to be re-made. Every time that the termination is re-made, the following shall be checked, and corrected if required:

- Any rifling of the sheave wheel;
- movement of the clamps or the cam; and
- free rotation of the sheave wheel on its bearing spindle.

The rope and the sheave wheel of the equalisation system shall be adequately protected against falling objects.

### **10.3.2 Headgear mounted compensators**

The correct operation of the malfunction detecting devices shall be checked daily.

## **10.4 BMR ROPE MISCOILING DETECTOR**

The correct operation of the tripping devices shall be checked weekly.

## **10.5 BRAKES**

A procedure for regular inspections, testing and maintenance of the brake system shall be drawn up for each winder installation. This procedure shall include, but not be limited to what follows in this section:

### **10.5.1 Brake settings**

The critical settings of the braking system shall be adjusted if necessary and maintained after completing the inspections required by section 9.3.

### **10.5.2 Weekly**

#### **10.5.2.1 Inspection of critical settings**

All critical settings are to be recorded and compared to those displayed in the winder house. If necessary, the settings are to be adjusted back to the displayed values.

#### **10.5.2.2 Static holding power test**

A test shall be conducted to prove compliance with Regulation 16.6.1 (a) of the Minerals Act. Where possible, the winder motor current or torque at which the brakes slip shall be recorded and any change in that current or torque from previous tests should be noted.

### **10.5.3 Monthly**

- (a) Weekly test and adjustments as set out above.
- (b) Three trip out tests with normal double drum winding, recording stopping distance, stopping time and peak dynamic rope force, with empty conveyances and in the following sequence:
  - (i) With a conveyance descending at  $\frac{1}{3}$  maximum licensed speed  $\frac{3}{4}$  down the shaft;
  - (ii) with a conveyance ascending at maximum licensed speed  $\frac{3}{4}$  down the shaft; and
  - (iii) with a conveyance descending at maximum licensed speed  $\frac{3}{4}$  down the shaft.

All critical functions of the braking system are to be compared with the settings determined in accordance to section 9.3. If the performance is such that the requirements given in section 8.2 may possibly not be met, a full investigation needs to be done to establish and to remedy the cause.

- (c) Review of the weekly test reports to establish whether any setting needs to be re-adjusted regularly. If this is found to be the case, the cause shall be established and a remedy shall be implemented.

#### **10.5.4 Annually**

The purpose of the annual tests is to review the critical settings and to determine the overall performance of the brakes. The tests are to be conducted by an outside authority.

A series of tests shall be conducted to verify the critical settings determined during the initial tests as required by section 9.3. The tests shall include at least one trip out with a loaded conveyance descending at the maximum licensed speed  $\frac{3}{4}$  down the shaft, and the ascending conveyance empty. During this test a speed trace and either a rope force trace or a conveyance acceleration trace shall be recorded. The dynamic factor shall be determined as per one of the examples shown in Appendix G.

#### **10.5.5 Record keeping**

The results recorded during the tests shall be available at the mine at all times. The results shall be kept for the following minimum periods of time:

<b>Test</b>	<b>Period kept</b>
Weekly	2 months
Monthly	1 year
Annual	3 years or not less than the life of two consecutive rope sets

### **10.6 ROPE FORCE MONITORING SYSTEMS**

The rope force monitoring systems have to be functional at all times. The calibration of the rope force monitoring systems shall be checked monthly.

### **10.7 ELECTRICAL DRIVE AND CONTROL SYSTEMS**

A monthly functional check shall be carried out on all critical safety devices and electrical interlocking systems.

### **10.8 CONVEYANCE GUIDING SYSTEMS**

#### **10.8.1 Guide rails**

A full alignment measurement shall be done when the shaft is commissioned and after any geological disturbance or shaft accident. The results of this measurement shall be retained. The alignment of the guide rails shall conform to the requirements specified in section 6.8.1. If necessary, the guide rails shall be re-aligned.

The guide gauge and alignment shall be checked once a year and at intervals not exceeding 18 months. If necessary, the guide rails shall be re-aligned.

### **10.8.2 Guide ropes**

The guide ropes and rubbing ropes shall be inspected as prescribed in Regulation 16.24 of the Minerals Act, with particular attention to wear, corrosion, and lubrication at attachment points and conveyance passing points.

The guide ropes and rubbing ropes shall be lubricated after each inspection.

## **10.9 CONVEYANCES**

A conveyance may only be put to use if its dimensions conform to the tolerances described in section 6.8.1. The measured dimensions and the serial number shown on the label specified in section 6.9 shall be kept together with the allowable tolerances. A trial run through the shaft shall be done with the conveyance when it is put to use for the first time and after every modification.

## **10.10 CONVEYANCE LOADING SYSTEMS**

The calibration of the mass measuring system specified in section 7.5 shall be traceable. The requirements in section ? shall be maintained.

## **10.11 FLEET ANGLES AND HEADSHEAVES**

The fleet angles between the winder drum and the headsheave, and between head and deflection sheaves shall be determined at winder and headgear installation, when a winder installation is modified to conform to this code of practice, when any modifications are done to the sheaves or their mountings, and after any other reconstruction that could have affected these angles.

The fleet angles shall be checked visually at weekly intervals. Excessive cheek rubbing and rope grease built-up on one side of the sheave groove are indicators that the fleet angles may have changed.

## **10.12 SHEAVE GROOVES**

The dimensions of the grooves of head and deflection sheaves shall be measured and recorded at three-monthly intervals and every time that the rope is changed. The grooves shall be re-machined if the allowable tolerances are exceeded, and a sheave shall be discarded if the allowable groove wear is exceeded. Section 9.4.2 requires the sheave groove to be re-machined before new ropes are installed.

A circular button may be used for machining when the groove diameter reduces to less than the maximum measured rope diameter. When the angle of flare reduces to less than 45°, the groove must be re-profiled to the greatest angle of flare possible.

### **10.13 WINDER DRUMS**

The riser and filler rings at layer cross overs shall be inspected weekly to ensure that they remain solidly attached to the drum or sleeve. Undue wear and high spots on these have to be attended to before winding will commence.

The bolts, nuts and screws that secure false flanges and coiling sleeves to the drum will be inspected weekly by tapping to ensure that they are tight. The tightening torque will be checked at intervals not exceeding six months.

Every time that the back end of the rope is pulled in or when the rope is changed, the following shall be done to ensure the integrity of the coiling system:

- The hawse hole shall be inspected visually.
- The sleeve joint gap and matching of the grooves for separately installed coiling sleeves shall be measured.
- The end fillers and risers should be inspected visually for wear, protrusions and completeness.
- Fasteners should be visually inspected for protruding heads for wear and completeness.



## 11. DOCUMENTATION AND REPORTING

In addition the documentation required by the Regulations of the Minerals Act, various sections of this code of practice require the mine to be in possession of the following documents:

<b>SECTION</b>	<b>REQUIRED DOCUMENT</b>
6.1.3	Analysis of the catenary dynamics
6.2.5	Drum stiffness calculations
6.4	Failure mode analysis of the electrical drive system (if required due to the peak motor power rating being more than 160% of the duty cycles requirement)
6.5.2	Failure mode analysis of the brake system
6.8.1	Conveyance dimensional and guide rail alignment tolerances
6.8.2	Guide rope design parameters
7.1.3	Load range calculations to establish the requirement for load range measurement
9.1.1	Procedure to be followed after the winder has tripped
9.1.4	Record of incidence and corrective action taken if an excessive peak force has occurred
9.2	Exceeding licensed attached mass
9.3	Critical brake settings
10	Schedule and records of all winder tests
10.5	Procedure for inspection, testing and maintenance of the brake system
10.5.5	Brake test results
10.8.1	Guide alignment measurement results
10.12	Sheave groove dimensions

## APPENDIX A: REGULATIONS

At the time of drafting this code, the Regulations were still being revised. **The SABS is responsible for updating this appendix immediately prior to final publication of the code.**

The following regulations are relevant to vertical drum winder installations and the ropes operating on such winders. The numbers and contents are as they appear in the proposed Chapter 16 of the Regulations of the Minerals Act (Act 50 of 1991) [1] (obtained from the Department of Mineral and Energy Affairs - Nov.1994).

The following relevant definitions were obtained from the regulations:

- 'adequate' means sufficient to meet the needs of the application or equipment to which it refers;
- 'approved testing station' means a testing station that is equipped to test winding ropes to destruction and to report on reasons for failure and on the general condition of the rope, and has been approved for the purpose by the Director-General;
- 'attached load' means everything suspended from or attached to the conveyance other than the winding rope and shall include the portion of any balance rope which contributes to load at the termination of the winding rope;
- 'attachments' shall include everything suspended from or attached to the conveyance other than the winding rope and shall include any balance rope;
- 'automatic winder' means any winder, hoist or other appliance used or intended to be used for the conveyance of persons, material, explosives or minerals by means of a conveyance in any shaft where the driving machinery is operated automatically without a driver in attendance, but shall not include any elevator or construed to have such meaning during such times such winder is operated manually;
- 'conveyance' means any appliance or combination of appliances attached directly to or suspended directly from a winding rope or ropes;
- 'degree of protection' is the available stopping distance divided by the actual stopping distance;
- 'drive' shall mean any action requiring skill whereby the controls of the winder are manipulated to control the winder;
- 'effective combined weight' shall mean the static weight resulting from the mass of any load where winding is conducted in a vertical plane and it shall be 1,05 times the incline component of this static weight where winding is conducted in an incline plane;
- 'initial breaking strength' in relation to a winder rope means the breaking strength obtained from a sample tested at an approved testing station at the time when the rope is manufactured;
- 'length of winding rope' shall mean the length between the sheave or drum in the headgear and the lowest working point of the conveyance;
- 'rope connection' means any appliance or combination of appliances together with all the associated links, pins, shackles and hooks, but excluding the top transom of the conveyance and any dead eyes or other part of which the failure is not material to safety, used for the connection of the rope or ropes to the conveyance;

The relevant regulations are:

- 16.3 The regional director may direct that specific or periodic tests or inspections of any winder be carried out.
- 16.4 In calculating the total mass of persons for the purpose of regulation 16.6 and regulations 16.29.1 to 16.33 inclusive, 75 kilograms shall be allowed for each person.
- 16.5 The winder shall be such that -
- (a) when running at various speeds with light or heavy loads it can be readily slowed and stopped and after being stopped, except after a tripout, can be restarted in either direction; and
  - (b) can lift from the bottom to the top of the shaft the maximum unbalanced load on one drum. This provision shall not apply where other means exist enabling persons employed underground to reach the top of the shaft.
- 16.6.1 Each winding drum or winding sheave shall be provided with an adequate brake(s) which shall be kept in proper working order and shall be capable of-
- (a) holding without slipping the conveyance loaded with the maximum load in the maximum out-of-balance position as allowed in the prescribed permit together with an applied torque in the direction of gravity equivalent to the torque required to lift the maximum allowable out-of-balance load; and
  - (b) stopping the winder from its permitted speed with its maximum allowable load descending, at a rate such that in conjunction with the safety devices, required in terms of regulation 16.9.1, an approved degree of protection can be maintained.
- 16.6.3 Except for friction drive or sheave type of winders, there shall not be less than 3 turns of rope upon the drum when the conveyance is at the lowest point in the shaft from which hoisting can be effected. The end of the rope where applicable shall be fastened securely.
- 16.6.10 All bolts and other fasteners upon which the safe operation of a winder depends shall be rendered secure by means of adequate locking devices.
- 16.7 In addition to any marks on the rope, or drum flange, every winder-drum shall be provided with a reliable depth indicator conveniently situated, which will at all times show clearly and accurately to the winding-engine driver at his operating position, the position of the conveyance and where a reduction in winding speed is necessary. Provided that in the case of a dial type indicator the pointer of such indicator on the right hand side shall move in a clockwise direction when lowering the conveyance. The pointer of a vertical type indicator shall move up or down as the conveyance moves up or down. Only one indicator need to be provided when the rope is driven by friction.

- 16.9.1 Every drum of a winder shall be equipped with -
- (a) at least one effective automatic upper limit and lower limit overwind prevention device, and
  - (b) an effective automatic overspeed prevention device which shall automatically cause the winder drum to be stopped if the permitted speed is exceeded by more than 15 % or if any conveyance approaches the extremities of the wind at such a speed that an approved degree of protection cannot be maintained.
- 16.9.2 Except where written permission has been granted by the regional director all conveyances shall be equipped with an effective device which shall continuously monitor any slack and tight rope condition and shall stop the winding plant if the conveyance becomes stuck in the guides.
- 16.10 Any winder with a permitted speed of over five metres per second shall be fitted with a speed indicator and a device which records the average speed of the rope against real time. The speed indicator shall be so situated that the winding speed can be easily read at all times by the winding-engine driver from his operating position.
- 16.11 Every conveyance used in any shaft where a winding plant, permitted in terms of a prescribed permit, is used shall be properly designed with calculated strength and certified as such by an appropriately qualified person registered by the Engineering Council of South Africa (Act No 114 of 1990) and shall be constructed in accordance with an approved safety standard. Details of such code shall be marked on the design drawings and a reference number shall be marked on a conspicuous place on such conveyance.
- 16.14 No rope connection shall be used for winding purposes unless it is of good quality, manufacture, of adequate calculated strength and manufactured from a class of steel approved by the Director-General.
- 16.16 At intervals of not more than six months the rope connections shall be removed, stripped, cleaned and thoroughly examined in accordance with an approved safety standard.
- 16.17 A proper record shall be kept of the examinations and working life of the rope connections referred to in regulation 16.16 and the engineer shall add to the record the report on the procedure followed in such examinations and his comments on the results. All such rope connections, and their component parts shall be marked clearly for the purpose of identification.
- 16.18 The winding rope shall be of good quality, of sound manufacture, free from visible defect, of adequate strength, and the diameter and construction shall be suited to the diameter of the sheaves and drums fitted.
- 16.19 Every winding rope shall be used and maintained in accordance with an approved safety standard.
- 16.20 A winding rope, balance rope or guide rope which has previously been in use shall not be put on anew unless the breaking strength of a specimen cut off from the end of the rope has been obtained by actual test at an approved testing station.

- 16.21 A winding rope which has previously been in use shall not be put on anew except if the engineer is in possession of the history of the working life of the rope and has satisfied himself that the rope is in a safe condition.
- 16.22 A suitable spare rope(s) for a winder(s) in use, shall be kept in reserve on the mine and shall at all times be ready for use.
- 16.23 A new winding rope, balance rope or guide rope shall not be used unless the manager is in possession of a certificate showing the breaking strength as obtained by actual test at an approved testing station provided that a winding rope or balance rope shall have a test piece cut and tested at an approved testing station immediately before it is installed if the certificate mentioned above is older than two years.
- 16.24 A winding rope, balance rope or guide rope newly put on, whether new or previously used, and the rope connections of any such rope shall be examined carefully by a competent person appointed for the purpose by the engineer and shall not be used in connection with the raising or lowering of persons until the conveyance loaded with the maximum permitted mass has been run two complete test trips down and up between the highest and lowest stopping places ordinarily in use. The result of this examination and test shall be recorded immediately in the Rope Record Book provided in terms of regulation 16.63. Such record shall be signed by the person who conducted the examination and the test.
- 16.25 When a new winding rope or balance rope is put on the particulars specified in paragraph (b) of regulation 16.63 shall be forwarded in duplicate to the regional director. When the new rope replaces a rope in service, particulars of the discarded rope, reasons for discard and life in terms of cycles and time shall also be forwarded in duplicate to the regional director: Provided that in the case of winders used exclusively for men and material, the life in terms of cycles need not be provided.
- 16.26 When a winding rope or balance rope which has previously been in use and which is put on anew, the particulars specified in paragraphs (b) and (c) of regulation 16.63 shall be forwarded in duplicate to the regional director.
- 16.27 Where a conveyance is suspended by two or more winding ropes, the ropes shall be of equal nominal size and strength. Adequate arrangements shall be made to equalize the tension in the ropes and, in calculating the breaking strength of the ropes, each rope shall be assumed to carry an equal share of the load.
- 16.28 The strength of a winding rope or balance rope shall be assessed in accordance with an approved safety standard and 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.

- 16.29.1 Where the winding system is such that it allows for the periodic testing of the winding rope as required by regulation 16.34.1 and a balance rope is not used, a winding rope shall have an initial breaking strength equal to or exceeding the greater of -
- (a) eight times the effective combined weight of the conveyance and its attachments and the maximum permitted load of persons, material, explosives or mineral, or
  - (b) four and a half times the effective combined weight of the maximum suspended effective length of winding rope, the conveyance and its attachments and the maximum permitted load of persons, material, explosives or mineral.
- 16.29.2 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 16.34.1 and if a mine complies with an approved safety standard pertaining to winder performance, operation, maintenance and testing, in as far as it affects rope safety and deterioration, and notwithstanding the provisions of regulations 16.29.1 and 16.31 a winding rope of a winder shall have an initial breaking strength equal to  $25000/(4000+L)$  times the effective combined weight of the length of winding rope, the conveyance and its attachments and the maximum permitted load of persons, material, explosives or mineral, where L is equal to the length of winding rope in metres.
- 16.31 Where the winding system operating in a vertical shaft is such that it allows for the periodic testing of the winding rope as required by regulation 16.34.1 and a balance rope or tail rope is not used and each conveyance is suspended by two or more winding rope in conjunction with a rope-tension compensator which is constructed in such a way that the failure of one rope will not result in a momentary lowering of the force acting in any other rope, the initial breaking strength of the winding ropes shall be as specified in regulation 16.29.1(a) or 0,95 times that specified in regulation 16.29.1(b), whichever is the greater.
- 16.33 A guide rope shall not be used in a winding system if the breaking strength at any point in such ropes is less than five times the effective combined weight of the rope and its tensioning weight. This provision shall not apply to any guide rope which is also used as a winding rope to raise or lower a stage, in which case the breaking force at any point in the rope shall not be less than 4,5 times the effective combined weight of the length of winding rope, and its share of the combined weight of the stage and attachments, the maximum permitted number of persons and the load of material.
- 16.34.1 Unless the winding system is such that it does not allow of the shortening of the winding rope, a portion of the winding rope shall be cut from the end attached to the conveyance as the case may be, at intervals not exceeding six months where the rope is connected directly to the conveyance and three months where the ropes are connected to a compensating sheave on the conveyance and the rope shall be re-terminated. The length of the portion so cut off shall be as specified by the approved testing station.

- 16.34.2.1 The manager shall send a sample of the rope cut off in terms of regulation 16.34.1 without delay for test to an approved testing station where the actual breaking strength and general condition shall be determined at the expense of the owner. Provided that in the case of the ropes being connected to a compensating sheave, the sample cut off the rope need only be sent for test without delay at intervals not exceeding six months.
- 16.34.2.2 The manager shall obtain a certificate from the approved testing station showing the results of the test specified in regulation 16.34.2.1.
- 16.34.2.3 If the specimen of the rope received at the approved testing station is in a condition not permitting a satisfactory test, a fresh specimen, on request, shall be forwarded by the manager.
- 16.54 No conveyance or attached load shall be allowed to be raised or lowered unless the person in charge thereof has steadied it or caused it to be steadied.
- 16.55 No conveyance shall be filled with loose rock or ground in any manner which is likely to cause spillage.
- 16.58 The manager, engineer or competent person appointed in terms of regulation, 2.13.2, as the case may be shall, appoint in writing competent persons whose duty it shall be to examine carefully, to an extent to be clearly defined in their respective letters of appointment, at least once in each week, and at intervals not exceeding 10 days, the guides or rails and the shaft compartments and equipment, including the doors, gates and barriers and ancillary equipment at stations, landing shafts and loading boxes: Provided that such equipment may be examined at intervals not exceeding 15 days if such shaft equipment is maintained in accordance with an approved code of practice.
- 16.59 The engineer or competent person appointed in terms of regulation 2.13.2, as the case may be, shall appoint in writing a competent person whose duty it shall be to examine, at the periods specified, to verify that the following equipment conforms with an approved safety standard -
- (a) at least once in each day the winding rope or the balance rope, the connection of the winding ropes to the drums, the connection referred to in regulation 16.16, the conveyance and the main members by which they are suspended and any safety catches attached thereto, the brakes, the depth indicators, the safety devices and all external parts of the winder upon the proper working of which the safety of persons depends: Provided that these examinations will not be necessary on Sundays and statutory holidays referred to in Section 9 of the Mines and Works Act, 1956, if the winder makes less than 50 trips during any such day; and
  - (b) at least once in each week the sheaves, signalling systems and safety devices used in connection therewith.

16.60 The engineer or competent person appointed in terms of regulation 2.13.2 shall examine the following equipment at the periods specified-

- (a) at least once in each week, and at intervals not exceeding 10 days, the overspeed and overwind prevention devices and the external parts of the winder;
- (b) at least once in each calendar month at intervals not exceeding 45 days the structure of the winding rope and the balance rope to assess the amount of deterioration thereof in accordance with the requirements of regulation 16.28;
- (c) by dynamically testing the automatic overwind and overspeed prevention devices in accordance with an approved code of practice at least once in every six months, at intervals not exceeding 200 days;
- (d) at least once in each year all the components of the winder as far as the operation upon which the safety of persons depend; and
- (e) after every accident or occurrence referred to in regulation 25.6(a) and before winding operations are resumed, all portions of the winding equipment affected by such accident or occurrence on which the safety of persons depends.

16.61 If any weakness or defect which may endanger the safety of persons is discovered such winder shall not be used until such weakness or defect has been remedied except in so far as may be necessary to remedy such weakness or defect.

16.62 The manager shall provide for each winder a book to be termed the Machinery Record Book in which shall be entered -

- (a) the name of each person appointed in terms of regulation 16.59 to perform the duties called for in the said regulation together with the particulars of the duties of each such person; and
- (b) a true report of every examination referred to in regulations 16.16, 16.59 and 16.60. These reports shall be recorded and signed without delay by the person making such examination. The reports made by the persons appointed in terms of regulation 16.59 shall be scrutinised and countersigned by the engineer at least once in each week.

16.63 The manager shall provide a book to be termed the Rope Record Book in which shall be entered -

- (a) the name of each person appointed in terms of regulation 16.24;
- (b) the following particulars for each winding rope and balance rope used on each winder:-
  - (i) Name of manufacturer.  
Date of manufacture.  
Coil number.



Length in metres.  
Mass per metre in kilograms.  
Diameter in millimetres.  
Construction of rope.  
Type and length of lay.  
Number of strands.  
Class of heart.  
Construction of strands.  
Number of wires or strings.  
Diameter of wires or strings in millimetres.  
Class of core.  
Tensile strength of the material in megapascals.  
Breaking force in kilonewtons.  
Rope Test Certificate number and place of test.

- (ii) Whether used for winding or balance purposes.  
Name and type of shaft.  
Designation of compartment.  
Winder Certificate number.  
Date put on;
- (iii) Dates of reterminating, shortening or turning end for end.  
Dates of testing and the breaking strength obtained at each test.  
Date taken off; and

- (c) a true report of every test or examination referred to in regulation 16.24. These reports shall be recorded and signed without delay by the person making such test or examination.

16.64 The manager shall provide for each shaft, where a winder operates for which a prescribed permit has been granted, a book to be termed the Shaft Log book in which shall be entered -

- (a) the name of each person appointed in terms of regulation 16.58 to perform duties mentioned therein together with the duties of each such person;
- (b) a true report of every examination referred to in regulation 16.58. This report shall be recorded and signed without delay by the person making such examination and the reports shall be scrutinised and countersigned by the manager and engineer or competent person appointed in terms of regulation 2.13.2, as the case may be, at least once each week.

16.65 The manager shall provide in respect of each winder a book to be termed the Drivers' Log Book, which shall be kept in the winder room and in which shall be recorded in duplicate -

- (a) a true report of the working condition of the winder, including the signalling systems, brakes, clutches, control gear, depth indicators and all other fittings used for the safe operation of the winder. Such report shall be made and signed

by the winding-engine driver for each period of charge, the time and duration of which shall be recorded;

- (b) any special instructions, effecting the safety of persons, given to the winding-engine driver and the time such instructions were given. Such entry shall be signed by the person giving the instruction and shall be countersigned by the winding-engine driver;
- (c) any warning given in terms of regulation 16.44 and the time such warning was given; and
- (d) the last signals received and given by the winding-engine driver when his relief is about to take over, and such report shall be countersigned by the winding-engine driver by whom he is relieved.

16.66 The entries in the Drivers' Log Book shall be scrutinised and countersigned daily by the persons appointed to carry out the duties specified in regulation 16.59. The duplicate shall be scrutinised and countersigned not later than the following working day by the engineer or the competent person appointed in terms of regulation 2.13.2, as the case may be, and shall be retained by him for at least 30 days.

16.70 The driver of a winder -

- (j) shall not unclutch a drum of his winder until he has assured himself beforehand by testing the brake of the drum against sufficient power of the engine that the brake is in proper condition to hold a torque to be determined by the engineer or person appointed in terms of regulation 2.13.2 as the case may be;
- (k) shall not perform clutching operations while persons are in either of the conveyance operated by his winder;

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**APPENDIX B: RECOMMENDED TREAD PRESSURE**

Drum or sheave tread pressure is defined as:

$$P_t = \frac{2F}{d \cdot D}$$

where  $P_t$  = Tread pressure  
 $F$  = Maximum static rope tension  
 $d$  = Rope diameter  
 $D$  = Drum or sheave tread diameter

No upper limit to the tread pressure is prescribed but it is recommended that a value of 3,5 MPa is not exceeded.

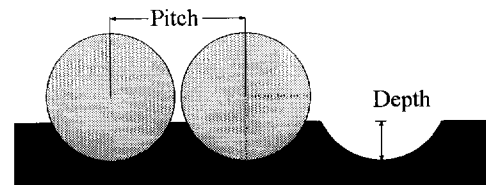
## APPENDIX C: GUIDELINES FOR DRUM COILING PATTERNS

This appendix contains guidelines on the shape and dimensions of coiling patterns on drum surfaces.

### C1. ROPE GROOVE

The groove dimensions, expressed as a fraction of the nominal diameter of the rope, should be as follows:

Radius:	0,53 to 0,54
Depth:	0,30 to 0,31
Pitch:	1,055 to 1,070.



The surface roughness of the groove after machining shall be  $7 \mu\text{m}$  or less.

### C2. HALF TURN CROSS-OVERS

All half turn cross-overs should have a length, defined as the circumferential distance between the intersections of the straight slanting line with the two parallel lines, of 12 times the nominal diameter of the rope. Transition radii between the straight line portions of a cross-over should be 120 times the nominal rope diameter.

Improved design and machining procedures that yield contours of the same transition length but with reduced rubbing and transverse acceleration of the rope will perform even better.

### C3. SLEEVE JOINT GAP

When separately manufactured sleeves are finally installed, the sleeve half joint gaps should each be between 6 and 10 mm. All groove ends should be radiused 3 mm.

### C4. MATCHING OF GROOVES

When separately manufactured sleeves are finally installed, the rope coiling grooves should align radially and axially to within  $\pm 1$  mm.

### C5. RISER AND FILLER RINGS

The riser and the filler rings should be contoured accurately to mate properly with the sleeve and to provide continuous support for the rope. All welds required for the installation of the riser and filler rings should be machined and dressed so as not to intrude into the rope space. Note that riser design requires special attention as the drum to rope size ratio increases, in order to avoid slamming between the rope and all or part of the riser during coiling.

**C6. HAWSE HOLE**

Bending radius of the rope contact groove through the hawse hole in the sleeve and/or in the drum shell must be continuous and smooth and should not be less than 15 times the nominal rope diameter. Rope support inside the drum should extend beyond the tangent to the drum shaft or hub, as the case may be.

**C7. ATTACHMENT OF COILING SLEEVES**

Components protruding into the path of the rope will lead to a rapid deterioration of the rope, and therefore, an unsafe situation. All screws, bolts, nuts, and other components required to attach coiling sleeves to drums should therefore be placed in such a position that they can regularly be inspected to ensure that they have not worked loose. The design should also be such that all the screws can be reached for tightening. All screw heads should be at least 2 mm below the rope coiling surface when installed.

## APPENDIX D: ROPE TERMINATIONS

This appendix shows examples of rope splices, wedge type capels, and sockets used for drum winder rope terminations.

### D1. TYPES OF ROPE SPLICES

A splice is a type of rope termination, where the end of the rope is secured by interweaving the strands back into the rope.

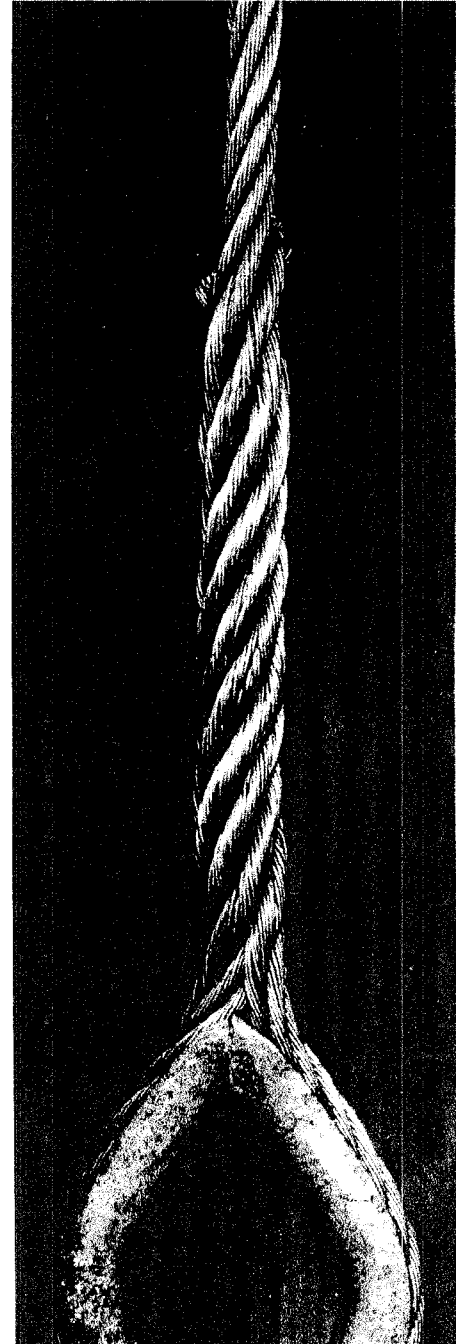
#### D1.1 Liverpool splice

A Liverpool splice is made by splicing with the lay. It is also known by the more descriptive name of "Round and Round" splice. Figure D1 shows a completed five tuck Liverpool splice. Section 6.6.1 requires that a splice on a six strand triangular strand rope should have at least seven tucks, while a splice on a non-spin rope should have at least nine tucks.

After the first series of tucks have been made each tail (or dead strand) is wrapped around one and the same strand in the main part of the rope (live strand) throughout the splice.

In the case of six strand rope, once the splice has been completed each live strand of the rope will have a dead strand wrapped around it throughout the length of the splice thus maintaining the lay of the rope. A Liverpool splice is spliced in such a way that each live strand is independent from another (the strands are not locked together) even though it has a dead strand wrapped around it. If the rope is unlayed (untwisted), the spliced portion will also unlay, which will reduce the friction between the live and dead strands and can result in the dead strands pulling out. Therefore note:

**Liverpool splices or splices made with the lay must never be used where the end of the rope is free to rotate.**



**Figure D1:** Five tuck Liverpool splice

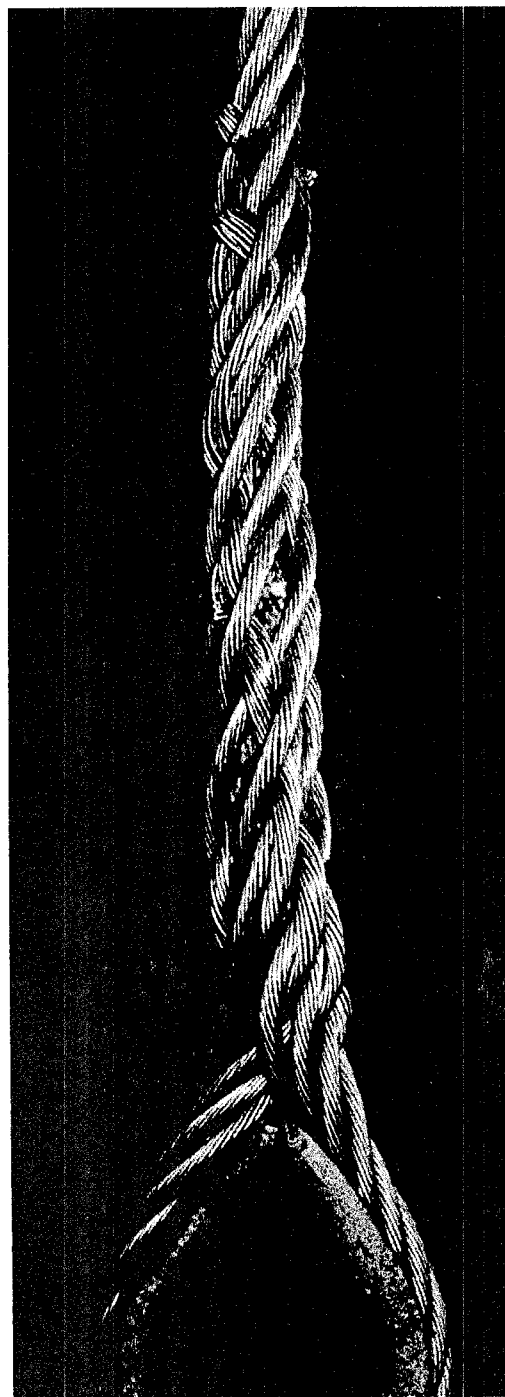
### D1.2 Admiralty splice

A cross-lay, "against-the-lay" or Admiralty splice is made by splicing against the lay. Figure D2 shows a completed five tuck Admiralty splice. Section 6.6.1 requires that a splice on a six strand triangular strand rope should have at least seven tucks, while a splice on a non-spin rope should have at least nine tucks.

After the first series of tucks have been made each tail (or dead strand) is passed over one live strand (in the main part of the rope) and then under an adjacent live strand against the lay of the rope throughout the splice. Therefore, a dead strand of a six strand rope will only be wrapped over the same live strand at every sixth tuck. In this manner each dead strand will have been interwoven with all six live strands of a six strand rope by the seventh tuck in the splice.

The dead strands move across the splice from one live strand to the next, and do not conform with the lay of the rope, thus the term "against-the-lay". This method of splicing weaves the live strands together and makes the splice a compact unit. If the rope is unlayed, the live strands in the rope will not be affected and the splice will not be weakened. Therefore note:

**Admiralty splices or splices made against the lay can be used where the end of the rope is free to rotate.**



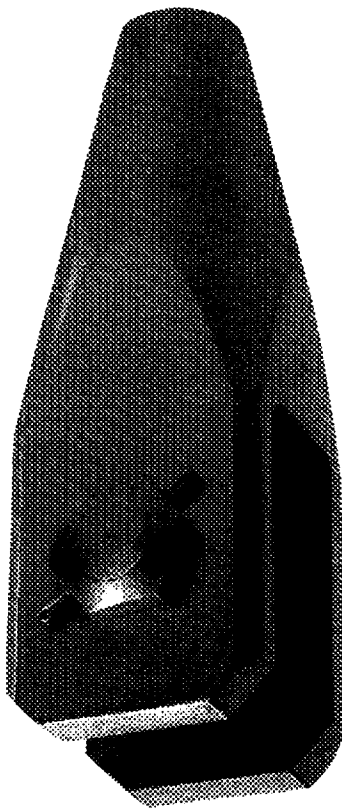
**Figure D2:** Five tuck Admiralty splice

## D2. WEDGE TYPE CAPEL

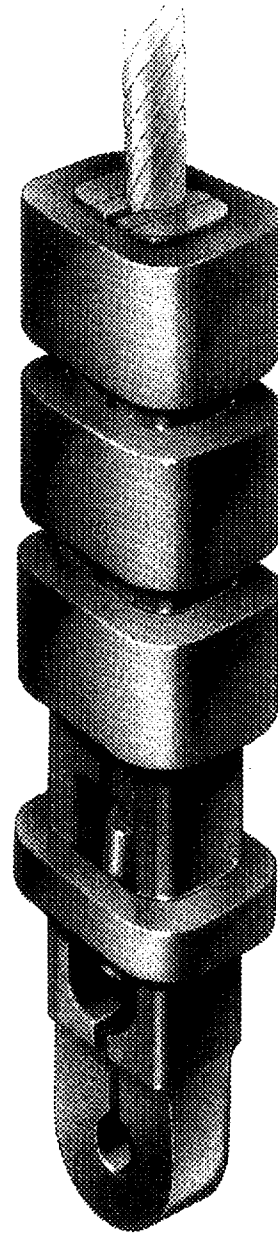
Figure D3 shows a wedge type capel. This wedge type capel grips an "un-opened" rope between two interlocking tapered wedges, which produces a "self-locking" action.

The capel bands compress the limbs of the capel frame against the wedges.

The end of the rope is fitted with a safety block, which will drive the wedges further into the frame in case of rope slippage.



**Figure D4:** A rope socket  
Illustration courtesy of Bellambie



**Figure D3:** A wedge type capel  
Illustration courtesy of Bellambie

## D3. ROPE SOCKET

Figure D4 shows a rope socket. The conical cavity of the socket accommodates a "brushed" rope end, and is usually filled with resin or white metal.



## APPENDIX E: LOAD RANGE CALCULATION

The following methods for the determination of the dynamic load range are allowed:

### E1. CALCULATED LOAD RANGE

The load range acting in a rope operating on a drum winder can be approximated as

$$\Delta T = M_p (g + 2 a_p) + 3 a_p (M_c + M_r)$$

where  $a_p$  = peak drum acceleration  
 $g$  = gravitational acceleration  
 $M_c$  = conveyance mass  
 $M_p$  = payload mass  
 $M_r$  = maximum suspended rope mass

The load range acting in the rope will therefore not exceed 15% of the initial breaking force of the rope if the payload is limited to

$$M_{p_{\max.}} = \frac{0,15 BF - 3 a_p (M_c + M_r)}{g + 2 a_p} \quad \text{where } BF = \text{rope strength}$$

If the calculated load range is used, the monitoring system shall record the peak drum accelerations and the payload. The controller shall log the allowable load range to have been exceeded each time that the peak drum acceleration exceeds the value used in the above calculations and each time the payload exceeds the maximum allowable value as calculated above.

If the winder drive employs a close loop control system and it can be proven that the maximum cyclical acceleration and deceleration will not exceed the value in the above calculations, the only the payload needs to be monitored.

#### Example:

A winder is designed to operate on a 2 000 m shaft with 54 mm 1900 MPa ropes (rope mass 12,47 kg/m, breaking force 2290 kN) and 12 tonne skips with a 19 tonne payload. The peak cyclic acceleration of the winder is 0,8 m/s<sup>2</sup>.

The required static factor is  $\frac{25\,000}{4\,000 + 2\,000} = 4,17$

The actual static factor is  $\frac{2\,290 \times 10^3}{9,8 (2\,000 \times 12,47 + 12\,000 + 19\,000)} = 4,18$

The load range can be calculated as

$$\frac{\Delta T}{BF} = \frac{19\,000 (9,81 + 2 \times 0,8) + 3 \times 0,8(12\,000 + 12,47 \times 2\,000)}{2\,290 \times 10^3} = 13,3\%$$

Under these conditions, the allowable load range will be maintained if the payload does not exceed

$$\frac{0,15 \times 2\,290 \cdot 10^3 - 3 \times 0,8 (12\,000 + 2\,000 \times 12,47)}{9,8 + 2 \times 0,8} = 22\,355 \text{ kg}$$

## **E2. LOAD RANGE CALCULATION FROM ROPE FORCES MEASURED AT THE HEADSHEAVE**

The rope force measured at the headsheave is the total force acting on the back end of the rope. It includes the weight of the conveyance, payload and suspended rope plus all dynamic rope force components. For this method, the suspended rope weight must be deducted from the total. The weight of the suspended rope is determined by the conveyance position (see Section E4 and the rope mass per unit length).

The rope force this processed must be fed into a monitoring system equipped with a peak and trough hold facility. At the start of each winding cycle, the values in the peak and trough hold memories will be reset. At the end of the winding cycle, the load range shall be calculated by subtracting the trough from the peak. If this value exceeds 15% of the initial rope breaking strength, a counter, as implied by Section 8.1.4, must be incremented.

## **E3. ALTERNATIVE METHODS**

Any other proven method of measurement and calculation may be applied to determine the load range.

## **E4. CONVEYANCE POSITION**

The conveyance position may be determined from drum turns and drum position. Conveyance position shall be determined with an accuracy of within  $\pm 0,1\%$  of the depth of the shaft.

## **APPENDIX F: GUIDELINES FOR ELECTRICAL DRIVE AND CONTROL SYSTEMS**

The behaviour of mine winder electrical equipment, i.e. the drive and control systems of a mine winder, can significantly influence the dynamic forces in winder ropes. During each winding cycle, the normal dynamic rope forces caused by acceleration, deceleration and stopping are repeated. These forces influence the load range experienced by a rope, and therefore have an influence on the deterioration of the rope. Occasionally relatively large dynamic rope forces can be generated by unusual events such as electrical motor faults. Such large forces have a direct bearing on the safety of a drum winder rope. Both the quality of equipment chosen, and the overall systems design, have an effect on the rope forces that will be generated.

This appendix provides information on characteristics of the electrical equipment and how these will influence the dynamic forces in winder ropes.

### **F1. CLOSED LOOP CONTROL (DRIVE REGULATORS) AND BRAKE CONTROL SYSTEMS**

During normal winding, the dynamic rope forces can be reduced by accurately controlling both the magnitude and the rate of change of the torque applied to the mine winder.

When peak drum accelerations of greater than  $1 \text{ m/s}^2$  are to be used during normal winding, special measures in the drive control system are essential for the reduction of the rope dynamics to acceptable levels. The drive closed loop control system, or regulator, should control the power converter system to achieve the required rate of change of torque as necessary to minimise dynamic rope loads. Similarly the brake controller controls the brake torque during emergency braking.

#### **F1.1 Analogue closed loop control systems**

Analogue closed loop control systems with very sophisticated structures are in service. However, with regard to accuracy of control, they have the following inherent disadvantages:

- Long term stability: Components such as resistors and capacitors, which are used to adjust loop parameters, age and change their characteristics with time. This makes periodical re-adjustment necessary.
- Dynamic adaptation: Although features such as acceleration ramping can be incorporated in analogue control systems, it is practically impossible to, for example, dynamically adapt the ramping time dependent on depth or payload.

#### **F1.2 Digital control systems**

Modern digital control systems offer the features that are conducive to achieve accurate drive control. Long term stability and dynamic adaptation of the control loops are possible as the control system is implemented with software algorithms. In addition, these systems generally have a multitude of internal checks and supervisions to detect and pinpoint faults as soon as they appear.

## **F2. DRIVE SYSTEMS**

### **F2.1 The type of drive**

Accurate control of both the magnitude and the rate of change of the torque applied to the mine winder during normal winding is a prerequisite to minimize dynamic rope loads. Although this is not achievable with all drive systems, there are many drive systems, including various DC or cycloconverter configurations, that can be controlled accurately.

In some drive systems the required accuracy of control is not possible because of inherent poor quality of achievable torque control. An example is a drive with wound rotor (slipping) induction motors where the torque is controlled by switching rotor resistors or by liquid controllers, coupled with phase reversal switching of the stator and DC or low frequency braking.

### **F2.2 The design of the winder motor and related power circuits**

Different types of motors have different short circuit torque characteristics. The important characteristics in this case are the magnitude and duration of the short circuit torque. It is obviously advantageous to have the short durations and relatively small magnitudes, and for short circuits to occur as rarely as possible.

Where elements of the armature circuit are exposed (e.g. the open commutator of DC motors), the risk of a short circuit is obviously higher than on AC machines where all connections are less accessible. The design of a specific motor also has a significant effect in terms of the peak value and the rate of rise of the short circuit torque.

All elements in the power circuit, which include rotating or solid state converters, circuit breakers, and fuses, as well as the supply network can affect the behaviour of a drive under fault conditions. It can also not simply be assumed that protective devices, such as loopbreakers, will of necessity assist in reducing dynamic rope loads.

The location of potential faults and that of protective devices determine the result of a short circuit. For example: A short circuit on the motor terminals will not be interrupted by a loopbreaker. It will only disconnect the power supply, and the motor will generate into the fault until it is stationary. The speed of operation of protective devices can also be critical. Unless a loopbreaker is correctly maintained, its actual tripping time after a few years of service will be substantially different to the values quoted in manufacturers specifications.

### **F2.3 The rating of the winder motor**

Although the relative peak value of the short circuit torque (i.e. a multiple of the rated torque) can be similar for different motors, the absolute value is critical with regard to peak rope forces. A motor which is overrated for the duty a winder is required to perform can therefore be a liability in that the magnitude of the short circuit torque may be too large, whereas a motor correctly rated for the winder in question will produce less severe rope forces under fault conditions.

### **F3. ELECTRICAL SYSTEMS DESIGN**

During emergency braking, the dynamic rope forces are controlled by the applied brake torque. However, whenever a fault occurs which requires emergency braking, there is an inherent delay between the safety circuit tripping and causing electrical power to be removed from the drive, and the brake control system taking over. In this transition period the winder torque is largely uncontrolled, and large dynamic rope forces could be generated. It is therefore preferable to minimise tripping the winder and applying the brakes.

Tripping is influenced by:

#### **F3.1 Reliability of equipment**

Electrical systems should be reliable since frequent failures or faults will lead to frequent tripping of the safety circuit, or will lead to rope load limits being exceeded.

#### **F3.2 Reliability of the supply network**

The systems should, as far as possible, be able to ride through supply voltage disturbances, and be immune against voltage dips and spikes. Besides measures such as surge suppression, possible measures includes battery backed-up power supplies of closed loop control and PLC systems to ensure an orderly shutdown in the event of a power failure, rather than allowing random occurrences which could be detrimental to the overall system.

#### **F3.3 Discrimination between different types of faults**

The application of brakes only when unavoidable is achieved by arranging fault signals to trip different categories of the safety circuit. These categories include application of the brakes, fast electrical stop, electrical retardation and winding at enforced reduced speed, and end of wind lockout.

#### **F3.4 Early and accurate detection of faults**

With reference to the previous point, it is of course also an advantage in this respect if the source of the fault can be determined as accurately and as early as possible. For example: Monitoring the reference and actual values of the speed controller will allow a malfunction to be detected and action to be taken before this causes the winder to overspeed and trip.

## APPENDIX G: DYNAMIC ROPE FORCE CALCULATIONS FOR BRAKE TESTS

### G1. SYMBOLS

The following symbols are used in this appendix:

- $\rho$  = rope mass per unit length
- $a_p$  = peak conveyance acceleration
- $DF$  = dynamic factor
- $F_a$  = initial rope breaking strength
- $F_d$  = dynamic rope force
- $F_s$  = static rope force
- $L$  = maximum length of suspended rope
- $g$  = gravitational acceleration = 9,8 m/s<sup>2</sup>
- $M_c$  = conveyance mass
- $M_p$  = payload mass
- $M_r$  = total rope mass =  $\rho \times L$
- $SF$  = static factor
- $z$  = depth at which the descending conveyance comes to rest after a brake test

### G2. EQUATIONS TO BE USED FOR THE CALCULATIONS

#### G2.1 Maximum allowable dynamic rope force

By definition, the static factor is

$$SF = \frac{F_a}{F_{s(\max)}}$$

where  $F_{s(\max)} = (M_c + M_p + M_r) g$

and, by definition, the dynamic factor is

$$DF = \frac{F_a}{F_{d(\max)}}$$

where  $F_{d(\max)}$  = the maximum dynamic rope force

Obviously the maximum allowable dynamic rope force under all conditions is

$$\boxed{F_{d(\max)} = \frac{F_a}{DF}}$$

## G2.2 Calculating the dynamic factor from brake test results

The dynamic factor of a winder is to be determined at installation and whenever any change is made to the hoisting system. It is left to the test personnel whether the rope forces are recorded at the headsheave or at the conveyance or whether the conveyance accelerations are recorded. This appendix provides the equations necessary for the required calculations on the basis of any of these measurements.

A brake test consists of a trip out with a fully laden conveyance descending  $\frac{3}{4}$  down the shaft. In order to obtain a value for the actual dynamic factor, it is assumed that the ratio of the dynamic force to the static force at this depth is representative for deeper positions of the laden conveyance as well. If rope forces are measured at the front end or if conveyance accelerations are measured, it is assumed that the ratio of the dynamic force to the static force is constant throughout the length of the rope.

### G2.2.1 From measured back end rope forces

$$DF = SF \times \frac{F_s}{F_d}$$

where  $F_d$  = peak dynamic rope force measured at the sheave

and  $F_s$  = static back end rope force measured at the sheave after the test or calculated by  $F_s = g \times (\rho z + M_c + M_p)$

### G2.2.2 From measured front end rope forces

$$DF = SF \times \frac{F_s}{F_d}$$

where  $F_d$  = measured peak dynamic front end rope force

and  $F_s$  = static front end rope force measured after the test or calculated by  $F_s = g \times (M_c + M_p)$

### G2.2.3 From measured conveyance accelerations

$$DF = SF \times \frac{g}{a_p + g}$$

where  $a_p$  = measured peak conveyance acceleration

## G3. EXAMPLES

### G3.1 Calculating the maximum allowable dynamic rope force

A winder is designed to operate with a maximum length of suspended rope of 3 500 m. According to the regulations, the static factor is

$$SF = \frac{25\,000}{4\,000 + L} \quad \text{with } L \text{ expressed in m}$$

For the winder in this example, the static factor is

$$\begin{aligned} SF &= \frac{25\,000}{4\,000 + 3\,500} \\ &= 3,33 \end{aligned}$$

The following basic parameters could be used for such a design:

$$\begin{aligned} F_a &= 3\,400 \text{ kN} \\ \rho &= 20 \text{ kg/m} \\ M_c &= 14\,000 \text{ kg} \\ M_p &= 20\,000 \text{ kg} \end{aligned}$$

The static factor for the above parameters is

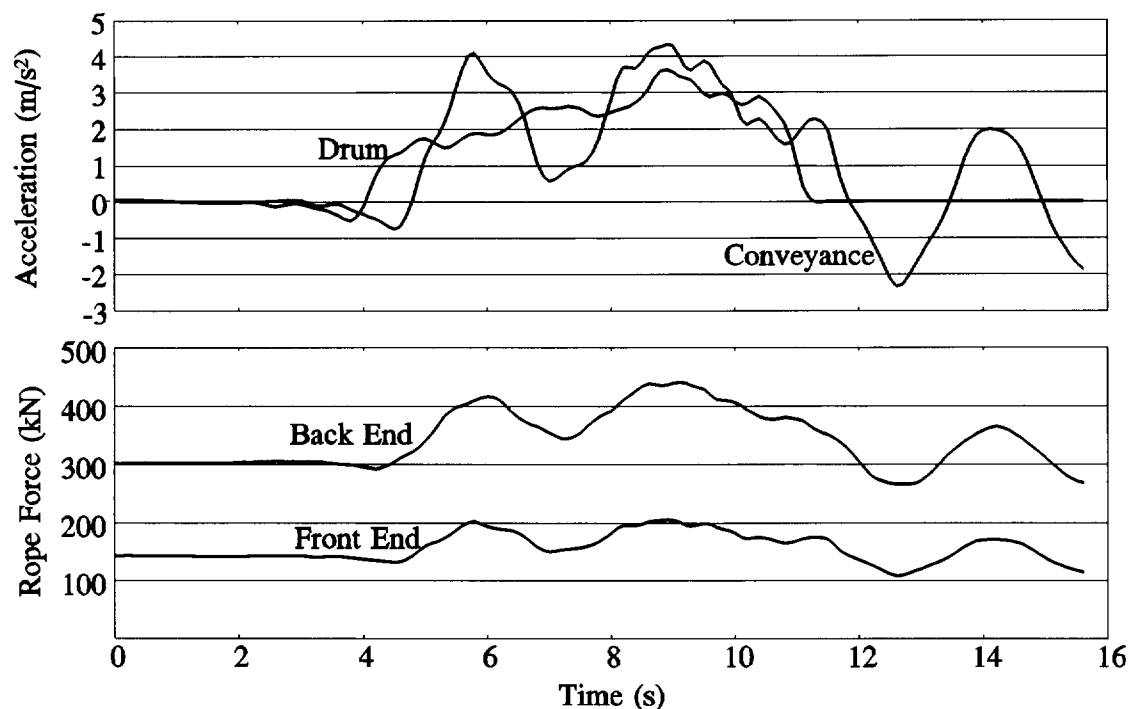
$$\begin{aligned} SF &= \frac{F_a}{g (\rho L + M_c + M_p)} \\ &= \frac{3\,400 \times 10^3}{9,8 \times (20 \times 3\,500 + 14\,000 + 20\,000)} \\ &= 3,34 \end{aligned}$$

In order to ensure a dynamic factor of at least 2,5, the dynamic rope force must be limited to

$$\begin{aligned} F_{d(\max)} &= \frac{F_a}{DF} \\ &= \frac{3\,400}{2,5} \\ &= 1\,360 \text{ kN} \end{aligned}$$



### G3.2 Calculating the dynamic factor from brake test results



**Figure G1:** Accelerations and rope forces measured at the front end and at the back end of a rope during a dynamic test

Figure G1 shows an example of a set of results of acceleration and rope force recordings for a brake test on a winder with the following parameters:

$$L = 2\,039 \text{ m}$$

$$z = 1\,635 \text{ m}$$

$$F_a = 1\,980 \text{ kN}$$

$$\rho = 10,7 \text{ kg/m}$$

$$M_c + M_p = 14\,487 \text{ kg}$$

Although the winder tripped with the descending conveyance at a depth of 1530 m, the conveyance came to rest at  $z = 1\,635 \text{ m}$ .

The figure shows all the possible measurements. Only one measurement is, however, required to calculate the dynamic factor. Using the drum acceleration curve to calculate the dynamic factor is beyond the scope of this appendix. The other measurements can be used as follows:

The static factor is calculated as follows:

rope mass:

$$\begin{aligned} M_r &= \rho \times L \\ &= 10,7 \times 2\,039 \\ &= 21\,817 \text{ kg} \end{aligned}$$

static factor:

$$\begin{aligned} SF &= \frac{F_a}{g \times (M_r + M_c + M_p)} \\ &= \frac{1\,980 \times 10^3}{9,8 \times (21\,817 + 14\,487)} \\ &= 5,57 \end{aligned}$$

The sections that follow show how the equations can be used to determine the dynamic factor from the test results. The highest dynamic factor will be obtained if rope forces measured at the headgear are used for the calculations. Lower values will be obtained if conveyance accelerations or rope forces at the conveyance are used, i.e. such calculations are a conservative estimate of the dynamic factor.

### G3.2.1 From measured back end rope forces

Static back end rope force:

$$\begin{aligned} F_s &= g \times (\rho z + M_c + M_p) \\ &= 9,8 \times (10,7 \times 1\,635 + 14\,487) \\ &= 313 \text{ kN} \end{aligned}$$

This could also have been measured after the test.

From Fig. G1 the peak dynamic rope force at the headsheave is  $F_d = 441 \text{ kN}$ .

The dynamic factor is thus

$$\begin{aligned} DF &= SF \times \frac{F_s}{F_d} \\ &= 5,57 \times \frac{313}{441} \\ &= 3,95 \end{aligned}$$

**G3.2.2** From measured front end rope forces

Static front end rope force:

$$\begin{aligned}F_s &= g \times (M_c + M_p) \\ &= 9,8 \times 14\,487 \\ &= 142 \text{ kN}\end{aligned}$$

This could also have been measured after the test.

From Fig. G1 the peak dynamic front end rope force is  $F_d = 205$  kN.  
The dynamic factor is thus

$$\begin{aligned}DF &= SF \times \frac{F_s}{F_d} \\ &= 5,57 \times \frac{142}{205} \\ &= 3,86\end{aligned}$$

**G3.2.3** From measured conveyance accelerations

From Fig. G1 the peak conveyance acceleration is  $a_p = 4,3$  m/s<sup>2</sup>.

The dynamic factor is thus

$$\begin{aligned}DF &= SF \times \frac{g}{a_p + g} \\ &= 5,57 \times \frac{9,8}{4,3 + 9,8} \\ &= 3,87\end{aligned}$$

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