
Guideline for Design, Commissioning and Maintenance of Drum Winders

Incorporates reference to requirements of Coal Mines Regulation Act 1982 as amended

MDG 33

Produced by Mine Safety Operations Division,
New South Wales Department of
Primary Industries

October 1998



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FOREWORD

Mine winders are important items of infrastructure in the underground mining industry and there are many installations operating in the NSW coal mining industry. These installations comprise many variations of design ranging from single rope drum vertical shaft and drift slope haulage systems and vertical shaft friction winder systems.

The application of mine winders range from those designed for personnel transport only to those designed for both personnel and materials transport duty and to those designed solely for the purpose of coal haulage. These winders are permanent items of the operational mine's infrastructure. In addition there are shaft sinking winders required for relatively short term projects associated with the development of new or extension of existing underground mines.

The purpose of this guideline is to cover the range of drum winder types used in the coal mining industry only. Guidelines for friction winders are detailed in MDG 12.

This guideline has been prepared to assist those involved with the design, commissioning and maintenance of drum winders. It is a guide and as such it is not intended that it comprehensively covers all safety related aspects for this type of equipment as it should be recognised that predominately each design is unique.

The guideline makes reference to the suite of Australian Standards that have been developed over the past few years for mine winding ropes, shaft attachments and furnishings. This document together with these standards provide a complete dossier of reference material which has never previously been available. Adoption of this technical information and the appropriate use of risk assessment techniques should foster "Safe Drum Winding Practices".

The Coal Mining Inspectorate is indebted to Mr Les Melane for the development of this guideline. He has many years of experience in the design, assessment and commissioning of drum winders and he has brought these experiences together in this document so that it is available for the benefit of others.

The preparation of the document involved input and support from Messrs. G.Jervis and L.Roberts (Department of Mineral Resources). Contributions were received from representatives of coal mines and equipment manufacturers/suppliers and these are gratefully acknowledged.

It would be expected that from time to time the document should be reviewed to reflect current safety issues. Comments on any aspect of this guideline should be submitted in writing to:

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1 SCOPE AND DEFINITIONS

1.1 Reference Documents

1.1.1 Australian Standards

The following Australian Standards should be used as reference documents for this guideline:

AS1403	Design of Rotating Steel Shafts for Fatigue
AS1426	Steel wire ropes for mines
AS1554	Structural Steel Welding
AS1554.1	Part 1:Welding of steel structures
AS1554.4	Part 4:Welding of High Strength Q&T steels
AS1554.5	Part 5:Welding of steel structures subject to high levels of fatigue loading
AS1654	Limits and Fits for Engineering
AS1657	Fixed platforms, walkways, stairways and ladders in design, construction, and installation
AS1318	Colours-Safety Marking
AS1710	Non-Destructive testing of carbon and low alloy steel plate-test methods and quality classification.
AS2012	Part 2: Acoustics - Measurement of airborne noise emitted by earth-moving machinery and agricultural tractors
AS2080	Safety Glass for land vehicles
AS3637	Underground Mining - Winding Suspension Equipment
AS3637.1	Part 1: General Requirements
AS3637.2	Part 2: Detaching Hooks
AS3637.3	Part 3: Rope Cappings
AS3637.5	Part 5: Rope Swivels and Swivel Hooks
AS3637.6	Part 6: Shackles and Chains
AS3751	Couplings and Drawbars

AS3785	Underground Mining - Shaft Equipment
AS3785.1	Part 1: Overwind Safety Catch Systems
AS3785.3	Part 3: Drum Winding Gripper Systems
AS3785.4	Part 4: Conveyances for Vertical Shafts
AS3785.5	Part 5: Headframes
AS3785.6	Part 6: Guides & Rubbing Ropes for Conveyances
AS3785.7	Part 7: Sheaves
AS3785.8	Part 8: Personnel Conveyances in other than Vertical Shafts

AS3990 Steelwork for Engineering Applications

AS4100 Steel Structures Code

AS4360 Risk Management

- 1.1.2 Safe Manriding in Mines parts 1A and 1B, parts 2A and 2B being the first and second report of the National Committee for Safety of Manriding in shafts and Unwalkable Outlets.
- 1.1.3 Coal Mines Regulation Act, 1982 No 67
- 1.1.4 Occupational Health & Safety Act 1983 No 20
- 1.1.5 NCB Codes and Rules
Minimum Standards of Fencing and Guarding
- 1.1.6 Department of Mineral Resources MDG 26 - Guideline for Examination, Testing and Retirement of Mine Winder Ropes
- 1.1.7 Department of Mineral Resources MDG 1010 - "Risk Management Handbook for Mining Industry"

1.2 Scope

1.2.1 The Guide

This guide is intended to assist designers and manufacturers of drum winders by indicating parameters which will be considered in the assessment for approval of equipment, as referred to in 1.2.1.1, 1.2.1.2 and 1.2.1.3.

1.2.1.1 Clause 7 of the Coal Mines Regulation (Shafts and Roadways - Underground Mines) Regulation 1984, requires that a mechanically operated winding apparatus or mechanically operated rope haulage apparatus used at a mine for transporting persons through any shaft or roadway be approved by the Chief Inspector.

1.2.1.2 Clause 9(1) and Clause 11 of the Coal Mines Regulation (Shafts and Roadways - Underground Mines) Regulation 1984, requires that conveyances used at a coal mine for transporting persons through a shaft or roadway, be of a type which has been approved for the purpose by the Chief Inspector.

1.2.1.3 Clause 6(6) of the Coal Mines Regulation (Approval of Items) Regulation by way of notice requires that all slope drift rope haulage systems be approved by the Chief Inspector. (refer Appendix B - Notice F34).

1.2.1.4 This guide is not intended to restrict innovative design. Where specific values or test procedures are required in addition to, or as alternatives to those included in this document, advice should be sought from Inspectors of Mechanical Engineering, Coal Mining Inspectorate and Engineering Branch of the Department of Mineral Resources.

1.2.1.5 When specified "shall" means the requirement is mandatory if required under existing legislation or as determined by the Chief Inspector. When specified "should" means the requirement is recommended.

1.2.1.6 Unless otherwise specified the appropriate Australian Standards shall apply.

1.2.1.7 Where reference is made to a design standard, the current published version shall be used. Where the intent of the design standard generates a substantive difference with this Code, the advice of the local Inspector of Mechanical Engineering should be sought.

1.2.1.8 This guide does not in any way negate the requirements of the Coal Mines Regulation Act 67, 1982, nor the Occupational Health and Safety Act, 1983, No 20.

1.3 Approval Procedures

1.3.1 Requirements

In order to gain approval for a new design, modification to existing design, replacement or change to original approval, a formal written application to the Chief Inspector will be required.

1.3.2 New or Existing Winders

Whilst primarily intended for the use with new drum winders, the guidelines, where applicable, will be used as an integral part of the application assessment process for approval of variations to existing approved drum winders (refer to **Appendix B**).

1.3.3 Risk Assessment Report

Any application for primary or supplementary approval must be supported by a creditable Risk Assessment report. The risk assessment should be based on the document AS4360 - Risk Management and MDG 1010 "Risk Management Handbook."

1.3.3.1 In general the Risk Assessment will cover situations or areas where there are no codes or standards or where variations to codes or standards are required.

1.3.3.2 This document may be used as an aid in identifying hazards, but should not be solely relied on for that purpose.

1.3.3.3 The application should contain a brief statement of compliance, variation, or reason for non-compliance with each item mentioned in this guide.

1.3.3.4 The application should contain results of tests and a statement of compliance with all requirements in accordance with Australian or other relevant standards, codes, or methods used.

1.3.3.5 The application should contain any further information, calculations, drawings or other documentation considered to be appropriate in supporting the application.

1.3.3.6 Full details covering electrical and control aspects will be required including as may be detailed by other guidelines, codes and standards.

1.3.3.7 Information as detailed in MDG 1010 shall be supplied.

1.4 Definitions

1.4.1 **Drum winder**

A shaft winding system in which conveyances, skips, kibbles, or stages are raised and lowered by means of a single rope attached directly and winding onto a cylindrical drum, or drums in the case of double drum winding.

1.4.2 **Conveyance**

Any car, carriage, cage, skip, kibble, or stage in which persons, minerals or materials are wound through a shaft or any counterweight.

1.4.2.1 **Skip**

A container attached to the end of rope and operating in a shaft in which materials are transported.

1.4.2.2 **Cage**

A container attached to the end of rope and operating in a shaft in which personnel are transported. In some shafts a skip and cage combination may be used.

1.4.2.3 **Kibble (or Bucket)**

A container attached to the end of rope attachments and operating in a shaft for the purposes of transporting materials and personnel. It is usually circular in shape. This term is commonly associated with shaft sinking operations.

1.4.2.4 **Stage**

A structure attached to the end of rope attachments operating in a shaft and supported by multiple ropes used to create a movable working platform or platforms (usually for shaft sinking operations).

1.4.2.5 **Attachments**

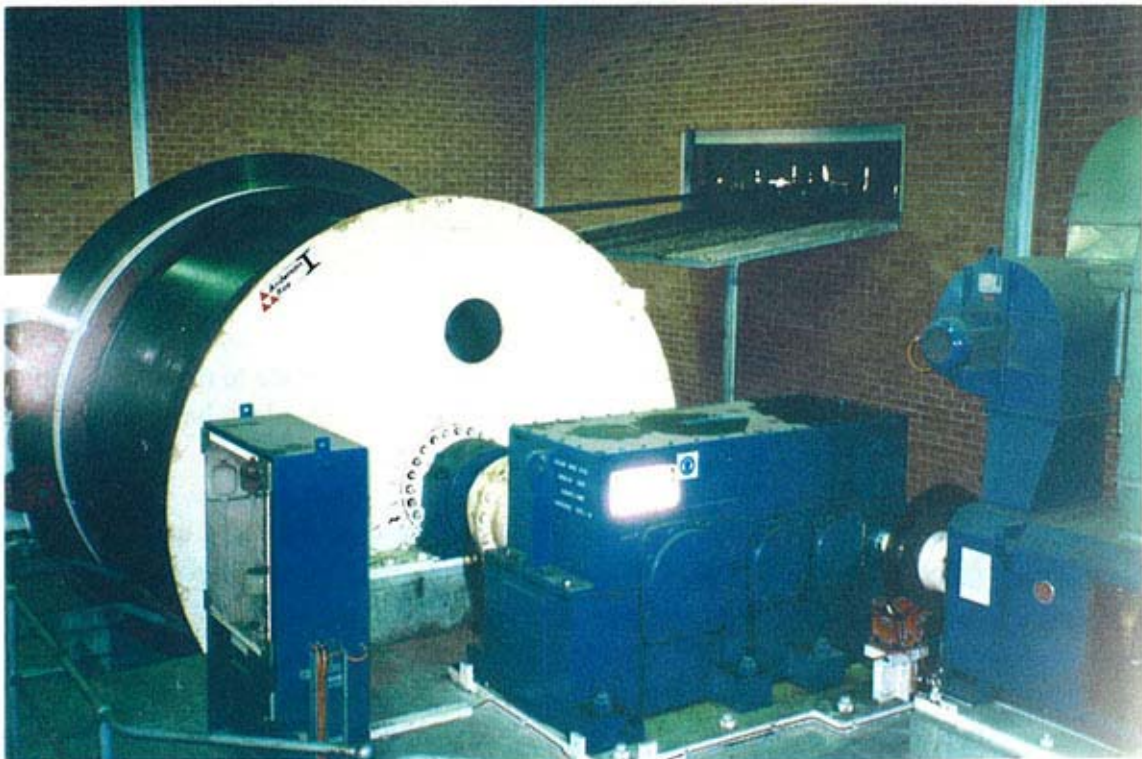
Components used to connect the conveyance to the end of rope. The components may include capels, pins, couplers, bars, etc.

1.4.3 **Mechanical Brakes**

All brakes other than electrical braking by motor control used to decelerate, stop and hold a drum winder.



Modern Drift Winder Surface Assembled Manriding Conveyances



Modern Drift Winder Haulage Engine

2 ROPES

OVERVIEW

2.1 Rope Factors of Safety and Retirement

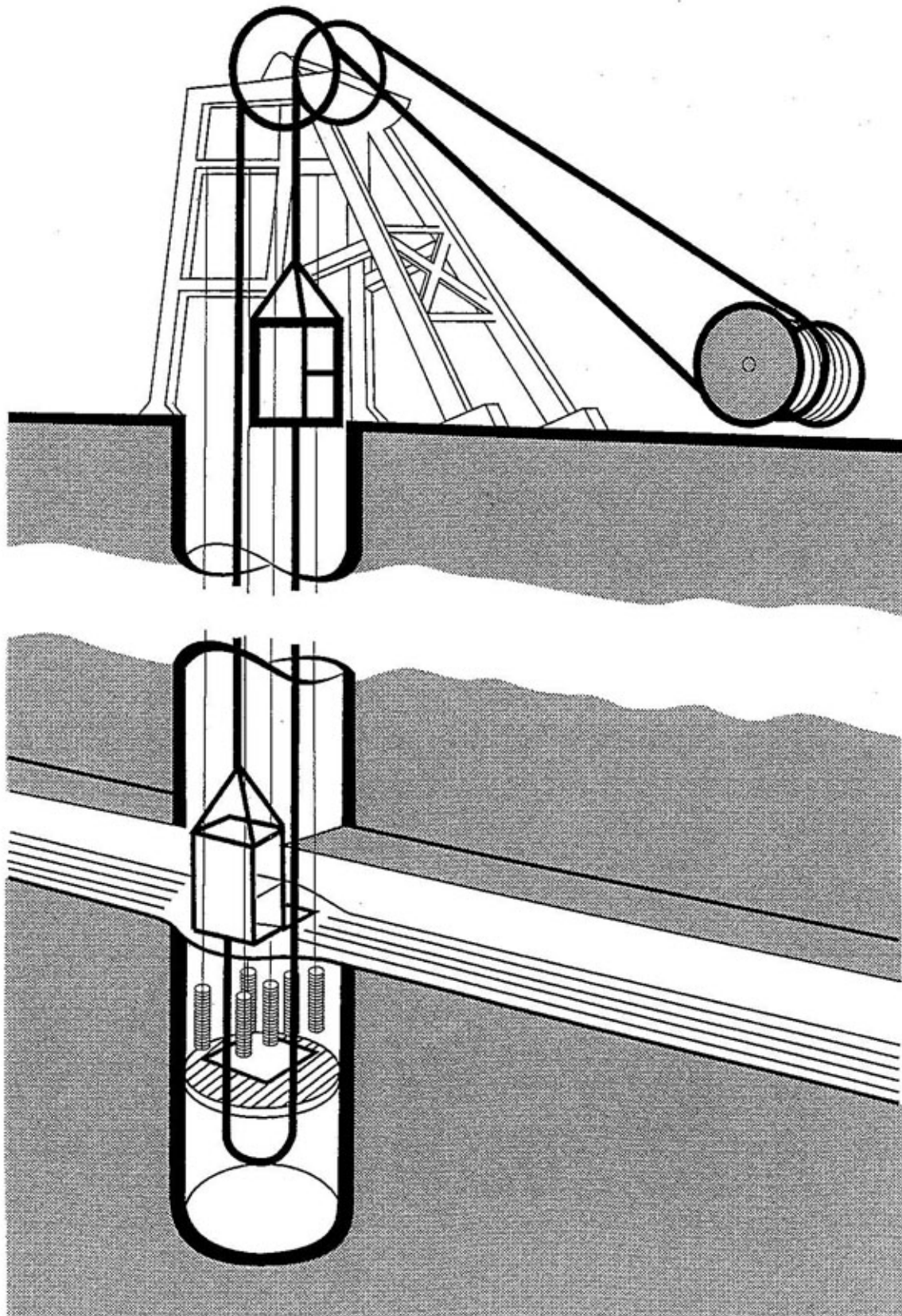
2.2 General Rope Requirements

2.3 Winding Ropes

2.4 Guide and Rubbing Ropes

2.5 Rope Attachments

2.6 Conveyance Attachments



Vertical Shaft Layout - Double Drum Winder

Fig 2.1

2. ROPES

2.1 Rope Factors Of Safety And Retirement

For rope factors of safety and winder rope retirement as required by the Coal Mines Regulation Act refer to MDG 26 - Guideline for Examination, Testing and Retirement of Mine Winder Ropes.

2.1.1 Winding Rope

2.1.1.1 For drum winders the Factor of Safety for the transport of personnel "when newly installed shall not be less than 10" (See MDG 26 for calculation method).

2.1.1.2 A rope other than newly installed shall not be used for the transport of men if its Factor of Safety falls below 8.

2.1.1.3 For drum winders the Factor of Safety for the transport of materials "when newly installed shall not be less than 8".

2.1.1.4 A rope other than newly installed shall not be used for the transport of materials if its Factor of Safety falls below 6.

2.1.2 Balance Ropes

When used with drum winders the Factor of Safety for balance ropes shall not be less than 6.

2.1.3 Stage or Scaffold Ropes

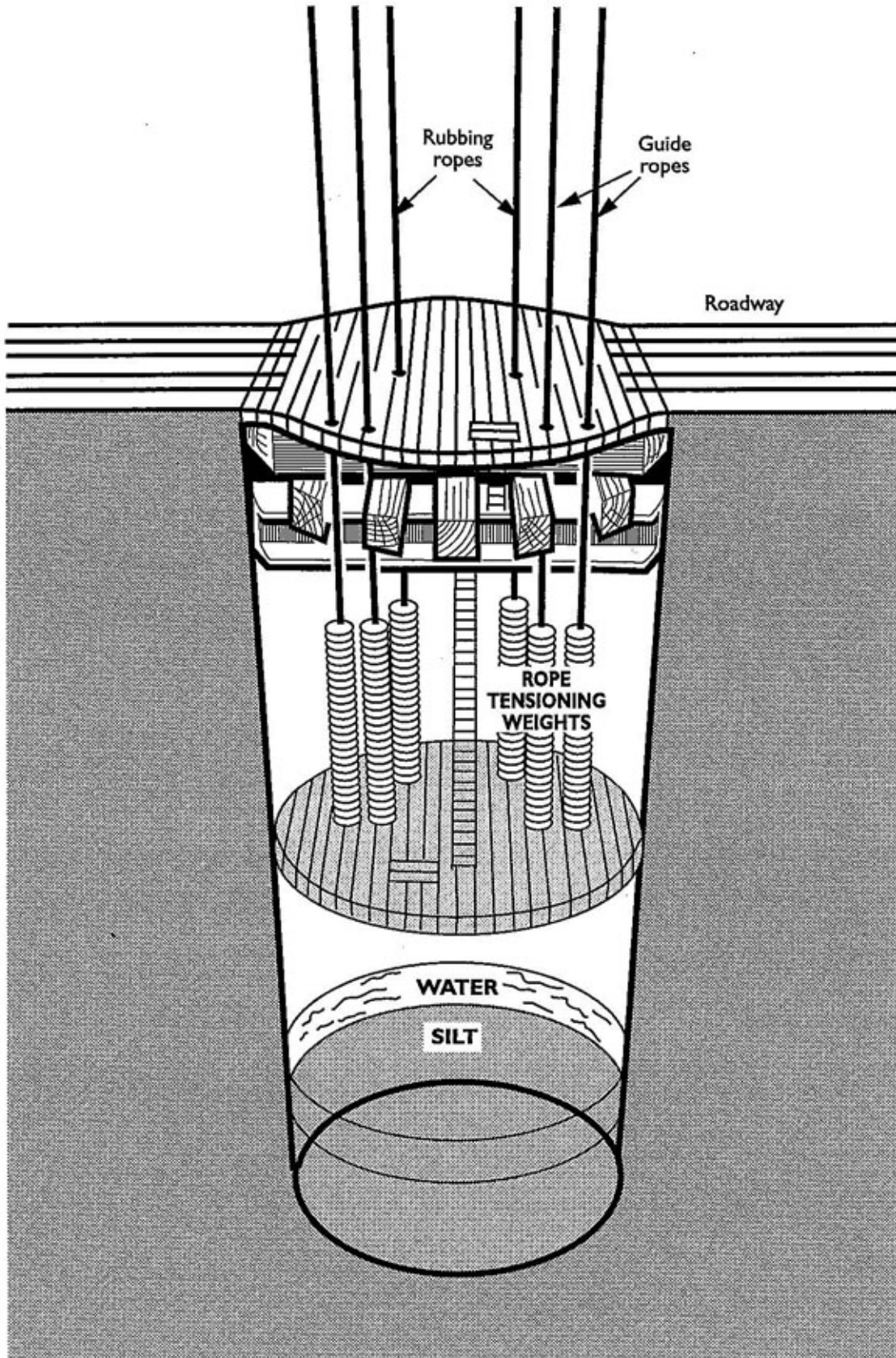
For ropes used with stage drum winders the Factor of Safety for stage ropes shall not be less than 6.

2.1.4 Guide Ropes - Factors of Safety

For ropes used as guides in vertical shafts with drum winders the Factor of Safety shall not be less than 5.

2.1.5 Rubbing or Buffer Ropes

For ropes used as safety ropes between two conveyances or between a conveyance and counterweight (known as rubbing or buffer ropes), and used with drum winders the Factor of Safety shall not be less than 5.



Layout Of Rope Tensioning Weights In Shaft Sump
Fig 2.2

2.2 General Rope Requirements

2.2.1 **Rope for Use in Mine Winding Systems**

No rope that has been joined or spliced shall be used as a winding, balance or guide rope.

2.2.1.1 All ropes shall be attached to conveyances with attachments complying with Australian Standards (see AS3637.3 - Rope Cappings).

2.2.1.2 When attaching the winding rope to the winder drum a minimum of three (3) complete dead coils shall be retained on the drum at all times.

2.2.1.3 The winder rope shall be anchored to the winder drum with a suitable clamping device or system. The Factor of Safety of the clamping device or system shall be not less than the rope Factor of Safety. Spare rope stored on the drum shall not be considered as reducing the load on the anchorage.

2.2.1.4 Sufficient allowance on the total length of winding rope must be made for cutting rope samples for destructive testing.

2.2.1.5 For drift haulage winders it is recommended that at least 100 metres of additional rope be provided to allow removal of damaged rope during its service life.

2.2.1.6 For construction of typical ropes used in mine winding systems refer to Section 2.3 of this guideline. (See also AS1426 - Steel wire ropes for mines).

2.3 Winding Ropes

Winding ropes are classified as those ropes supporting the conveyance and directly carrying the man and/or materials load.

These guidelines do not in any way negate the requirements of the Coal Mines Regulation (Shafts and Roadways - Underground Mines) Regulation, 1984. For typical winding Ropes refer to Figures 2.3 and 2.4.

2.3.1 **Vertical Shaft Winding Rope**

For vertical shafts the rope construction should be based on the type of conveyance guides.

2.3.1.1 For vertical shafts with **fixed wooden or steel guides** guiding the conveyance for the complete depth of the shaft, the winding rope should be a preformed triangular (flattened) strand rope. These ropes are highly resistant to crushing and wear, have good strength to diameter ratio properties and a good strength to weight ratio.

2.3.1.2 For vertical shafts with **rope guides**, the winding rope should be Non-Spin (locked coil) or "Fishback" Non-Spin construction for depths exceeding 300 metres.

2.3.1.3 In all cases the rope construction for the particular application should be referred to the rope manufacturer for final recommendation.

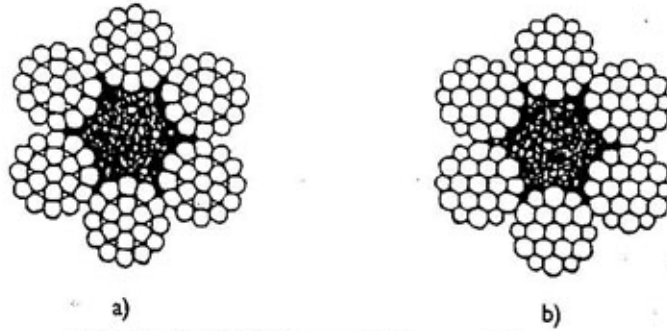
2.3.2 (2.3.2 not used)

2.3.3 **Drift Haulage Rope**

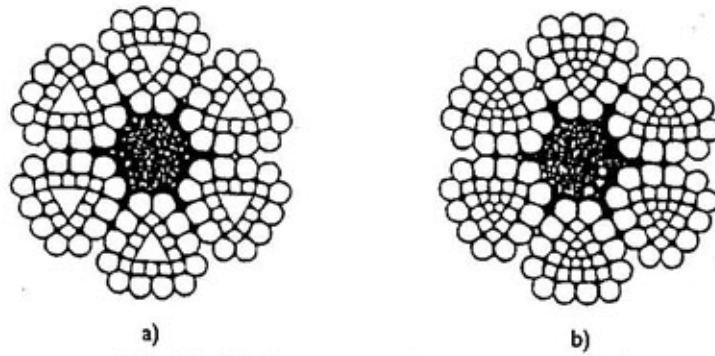
The generally accepted standard for drift haulage rope construction is preformed triangular (flattened) strand rope of grade 1770 MPa wire. If higher strength rope is to be used the special consideration should be given to bend radii such as the vertical crest radius, turnout radius and rope control rollers, crest roller diameters, etc.

2.3.4 **Head Sheave Diameters**

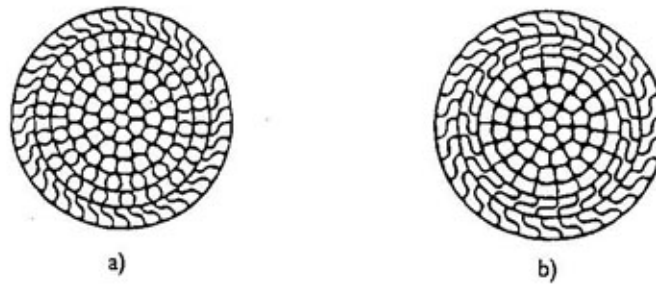
Head sheaves shall be designed to suit the winding rope strength and diameter and construction used. Refer to AS3785.7 - Underground mining - Shaft Equipment - Part 7: Sheaves.



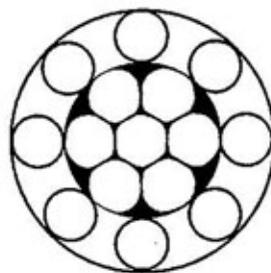
Typical 6*19 Round Strand Ropes



Typical Flattened Strand Ropes



Typical Locked Coil Ropes



Typical Half Locked Coil Rope

**Construction of Typical Winding Ropes
Fig 2.3**

2.3.5 Winding Drum Construction

Winding drums should be constructed to provide storage for the rope, and to ensure that the rope coils and uncoils safely and correctly to the drum.

2.3.5.1 The correct Drum to rope ratio (D/d Ratio) will depend on the rope speed and wire tensile strength. For rope speeds up to 6 Metres/second a minimum D/d ratio of 70:1 is a good guide for most winding drums using flattened strand rope. For locked coil rope a D/d ratio of 100:1 is recommended.

2.3.5.2 The correct fleet angle from the winding drum to the head sheave should be maintained. For grooved drums this angle should be a maximum of 1.5 degrees and a minimum of 0.25 degrees. This provision is to ensure the rope will scroll away from the drum flange. (Note that the fleet angle is the angle formed by a line from the centre of the drum to the centre of the head sheave and a line from the drum rope flange to the centre of the head sheave. See Fig 2.5). Refer to section 4.2.3 for further information.

2.3.5.3 For permanent drum winders the drum shell should be grooved to suit the rope. For rope speeds up to 6 metres/second parallel grooving with a rope cross-over section is recommended.

2.3.5.4 Refer to 2.2.1.3 for requirements of drum/rope anchor attachment.

2.3.5.5 The drum/rope anchor attachment shall be readily accessible for routine inspections.

2.3.5.6 A harmonic analysis should be carried out to ensure that fundamental vibrations do not coincide with the rope/drum crossover frequency (See Section 4.2.6).

2.3.5.7 Parallel rope grooves should have a pitch spacing of Nominal Rope Diameter plus 4%.

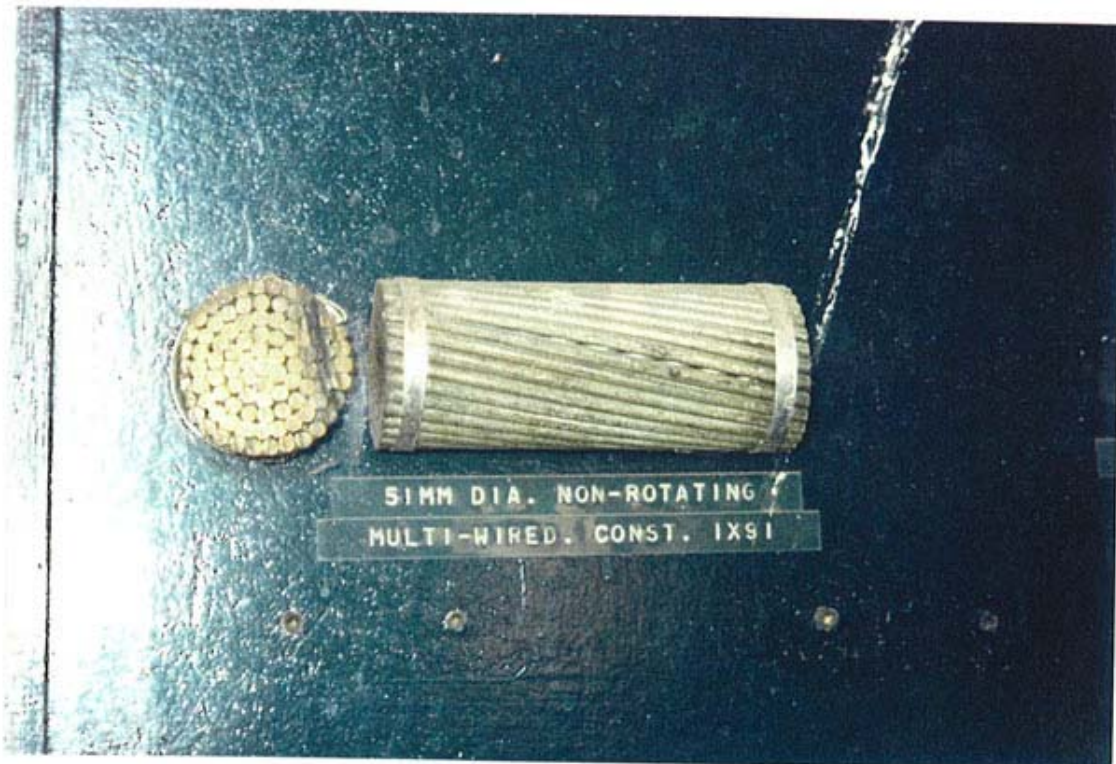
2.3.5.8 Parallel rope grooves should have a groove radius of Nominal Radius of Rope plus 5%.

2.3.5.9 Parallel rope grooves should have a groove depth of no more than 10% of the rope diameter.

2.3.5.10 For parallel grooved drums the rope cross-over section should be machined to the bottom of the grooves for a length of not less than 20 times the rope diameter.



Typical Winding Ropes
Fig 2.4



Typical Winding Ropes (contd.)
Fig 2.4



Typical Winding Ropes (contd.)
Fig 2.4

2.3.5.11 For the correct coiling of multi-layering rope on the drum, the position of the hawse hole, wedges and riser dimensions must be precisely selected.

2.3.5.12 To ensure the rope is protected from nicks, all sharp edges should be carefully removed.

2.3.6 Rope Installation

When installing new rope on the drum, the dead coils on the drum should be tensioned to at least 50% of the working rope tension.

2.3.7 Rope Flanges

A minimum rope flange height of total rope depth plus two and a half (2.5) full rope diameters should be maintained. This is to ensure that should two coils pile up on the drum flange they will not fall off.

2.3.8 Rope Overcoiling Protection

To ensure that the rope always scrolls correctly, the drum should be fitted with a device that stops the winder (by emergency braking) if the coils do not scroll back from the drum flanges. This device is usually a beam located across the drum which operates a switching device should the rope coil above its maximum number of layers.

2.3.9 Rope Lubrication

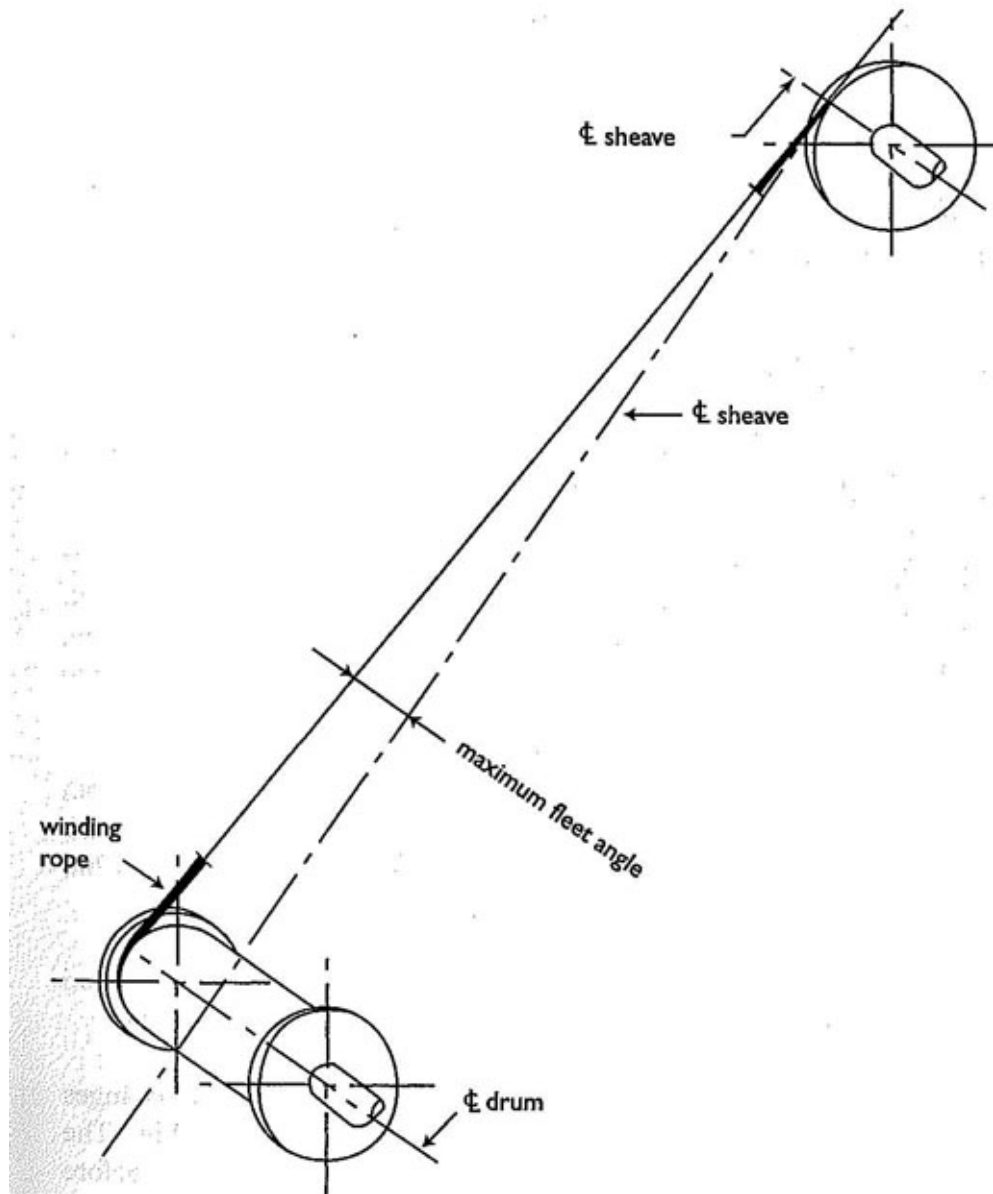
Winding ropes are delivered with the rope internals lubricated. Close attention should be paid to this lubrication process.

2.3.10 Slack Rope Protection

Slack rope can be dangerous to both personnel and equipment. It forms when the conveyance no longer exerts a tension force on the rope allowing the rope to become slack. This could happen if the conveyance is not freely moving, jams, derails or malfunctions or the winder overwinds. Devices shall be provided to detect the formation of slack rope.

2.3.11 Multi-Layer Coiling

The maximum number of rope layers should be limited to five (5) layers.



Winding Drum and Headsheave Fleet Angle
Fig 2.5

2.4 Guide And Rubbing Ropes

In vertical shafts guide ropes shall be anchored at one end and tensioned by a suitable means at the other. The tensioning device must be capable of exerting a constant tension to the rope due to variations of rope stretch, temperature variations and ground movements.

In general tensioning will be by dead weights positioned in the shaft sump, or by spring loading the rope at the top or bottom ends. Other arrangements or combinations of tensioning the ropes may be used.

(Ref: AS3785: Part 6 - "Guides and rubbing ropes for conveyances")

2.4.1 Guide Rope Tensioning

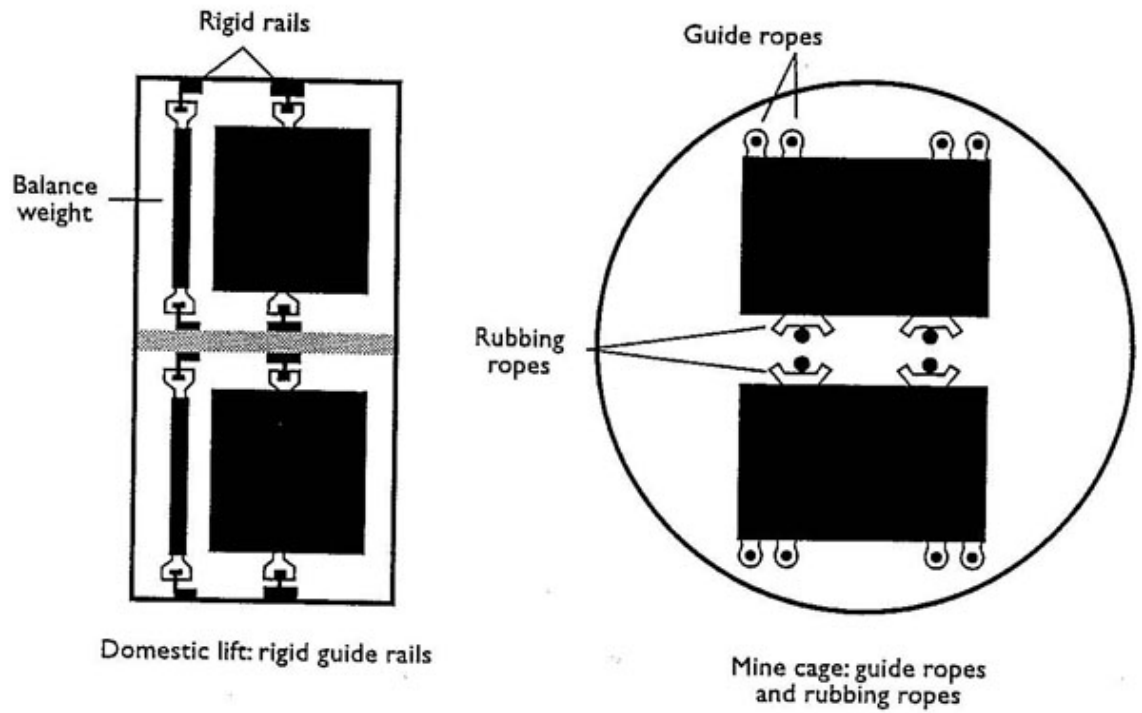
2.4.1.1 In all cases, the tension in the ropes must be capable of being measured and adjusted to maintain the correct tension.

2.4.1.2 In general, the selection of guide ropes is based on experience. If guide ropes are not correctly positioned and tensioned, high frequency forces of low magnitude are imparted to the winding rope. The smoothest running conditions are obtained with four (4) guide ropes fitted to one side of the cage with staggered tension weights.

2.4.1.3 Correct tensioning of the guide ropes has been learnt from experience. The tension required is nominally 1 Tonne per 100 metres of shaft depth up to 500 metres. Over 500 metres to 1200 metres a linear increase to 9 Tonnes.

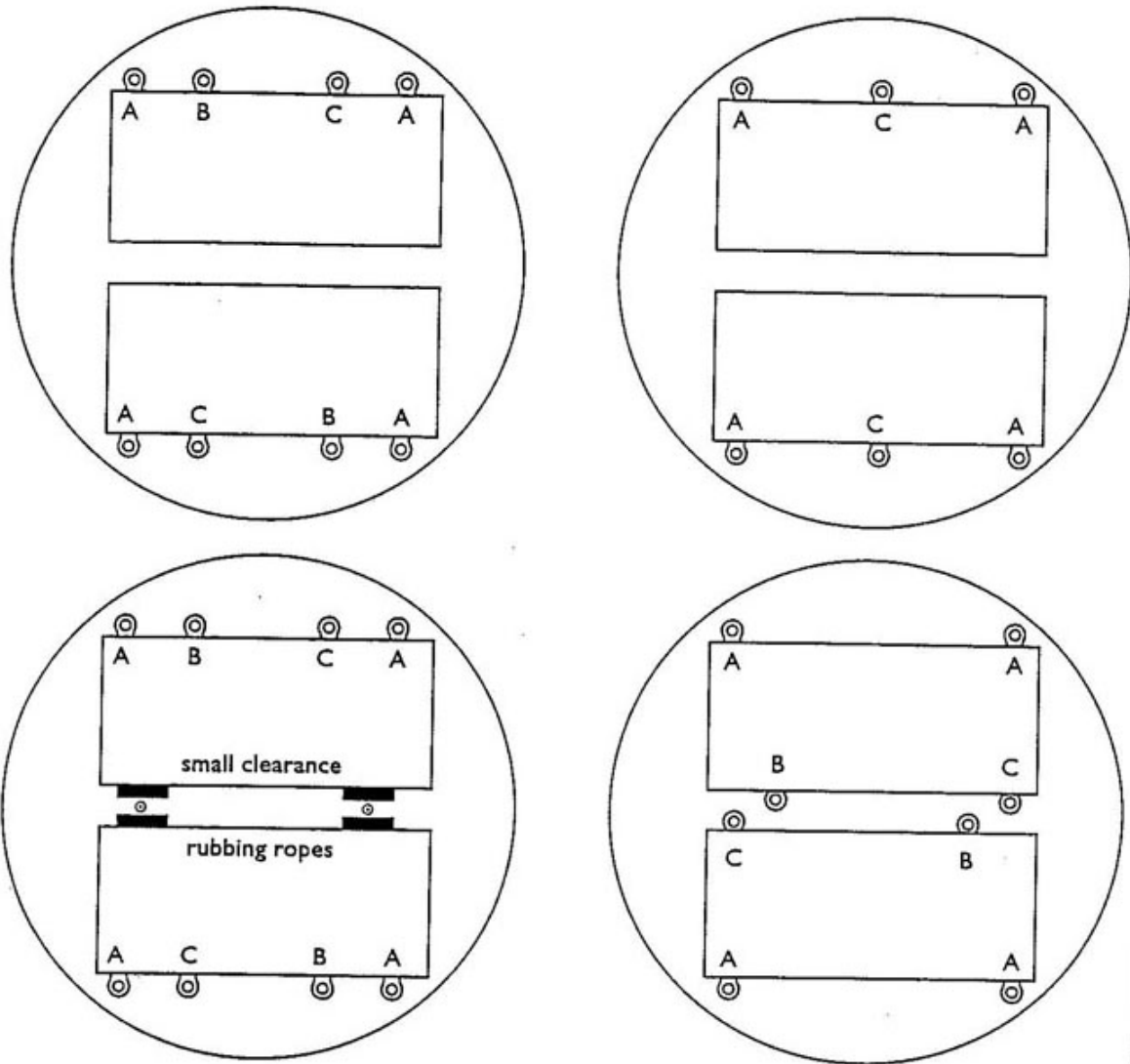
2.4.1.4 Generally, rope guide diameters should be maintained at 40mm minimum to 1200 metres and 50mm diameter over 1200 metres.

2.4.1.5 In some shafts the variations in shaft depth due to moisture changes make the use of spring loaded guide ropes unacceptable. The geotechnical conditions of the shaft should be investigated before the selection of the tensioning device is finalised.



Guide Methods Used For Conveyances

Fig 2.6



Typical Guide Rope Layouts

Fig. 2.7

Depth of Shaft (Metres)	Size of Guide Ropes (mm)	Guide Weight (Min. Tonnes)		
		A	B	C
0-200	30	3.0	2.5	2.0
200-400	34	4.0	3.5	3.0
400-600	38	5.0	4.5	4.0
600-800	42	6.0	5.5	5.0
800-1000	44	7.0	6.5	6.0

2.4.2 Number of Guide Ropes

In general, the number of guide ropes has been found to depend on the depth of the shaft.

Up to 200 metres, 2 guide ropes per cage.

From 200 to 500 metres, 3 guide ropes per cage.

Over 500 metres, 4 guide ropes per cage.

2.4.3 Type of Guide Rope

In general, guide and rubbing ropes should be half locked or locked coil construction rope. It is essential that the outer wires are large to avoid frequent replacement due to wear, and it is preferable that all wires are rust resistant.

2.4.4 Guide Rope Clearances

As a general rule the clearance between conveyances and the conveyances and shaft walls should be no less than 300mm.

2.4.4.1 Should lesser clearance be required rubbing ropes should be used between the conveyances when the clearance is between 100m to 300m.

2.4.5 Guide Rope Inspection and Rotation

Guide and rubbing ropes should be periodically examined for wear and general condition. They should be cleaned, examined and measured at all points liable to deterioration, and other selected positions along their length, including those sections above and below the top and bottom landings.

2.4.5.1 The interval between these examinations should not exceed 12 months. A record should be maintained of all measurements and the inspection and assessment comments.

2.4.5.2 Guide ropes tend to wear unevenly owing to the rubbing action of conveyance shoes at positions where the lateral movement is greatest (eg., entrances to the fixed guides, top and bottom landings). Where uneven wear occurs it is usual practice to rotate the guide ropes at intervals in order to equalise.

2.4.5.3 To minimise the effect of fatigue at a point where vibration is arrested (at the gland), the ropes should be lifted at appropriate intervals (through a distance of not less than 1.5 times the length within the capping or gland) and the termination remade.

2.4.5.4 Any rotation or lifting of the guide or rubbing ropes should be recorded in the guide rope documentation.

2.4.6 Guide Rope Lubrication

A wire rope needs lubrication both during manufacture and throughout its working life. It also often needs a preservative, and the grease and oil used serves both of these purposes. Once the rope has been made it is extremely difficult to lubricate the interior. Therefore it is important that the lubrication or greasing carried out during manufacture should be thorough.

2.4.6.1 Rope wear can be reduced to a minimum by the use of anti-wear materials for guide slippers, and well lubricated rope.

2.4.6.2 Corrosion can be kept to a minimum by efficient lubrication, the most susceptible being the fixing points at top and bottom. The use of galvanised wires generally assists to overcome corrosion problems.

2.4.6.3 Where corrosion in a shaft is considered to be a problem, the use of half-locked coil ropes have advantages in that the resistance to corrosion is greater since the clearances through which moisture can penetrate are smaller.

2.5 Rope Attachments

When selecting attachments expert guidance should be sought from reputable manufacturers and AS3637 "Underground Mining - Winding Suspension Equipment" as a reference.

2.5.1 Wedge Type Capels

Wedge type capels are commonly used as attachments for attaching the rope to the conveyance or guide weights used in vertical shafts (refer to Figure 2.8).

2.5.1.1 Special care should be given to the lubrication and assembly of capels. Only lubricant recommended by the manufacturer should be used.

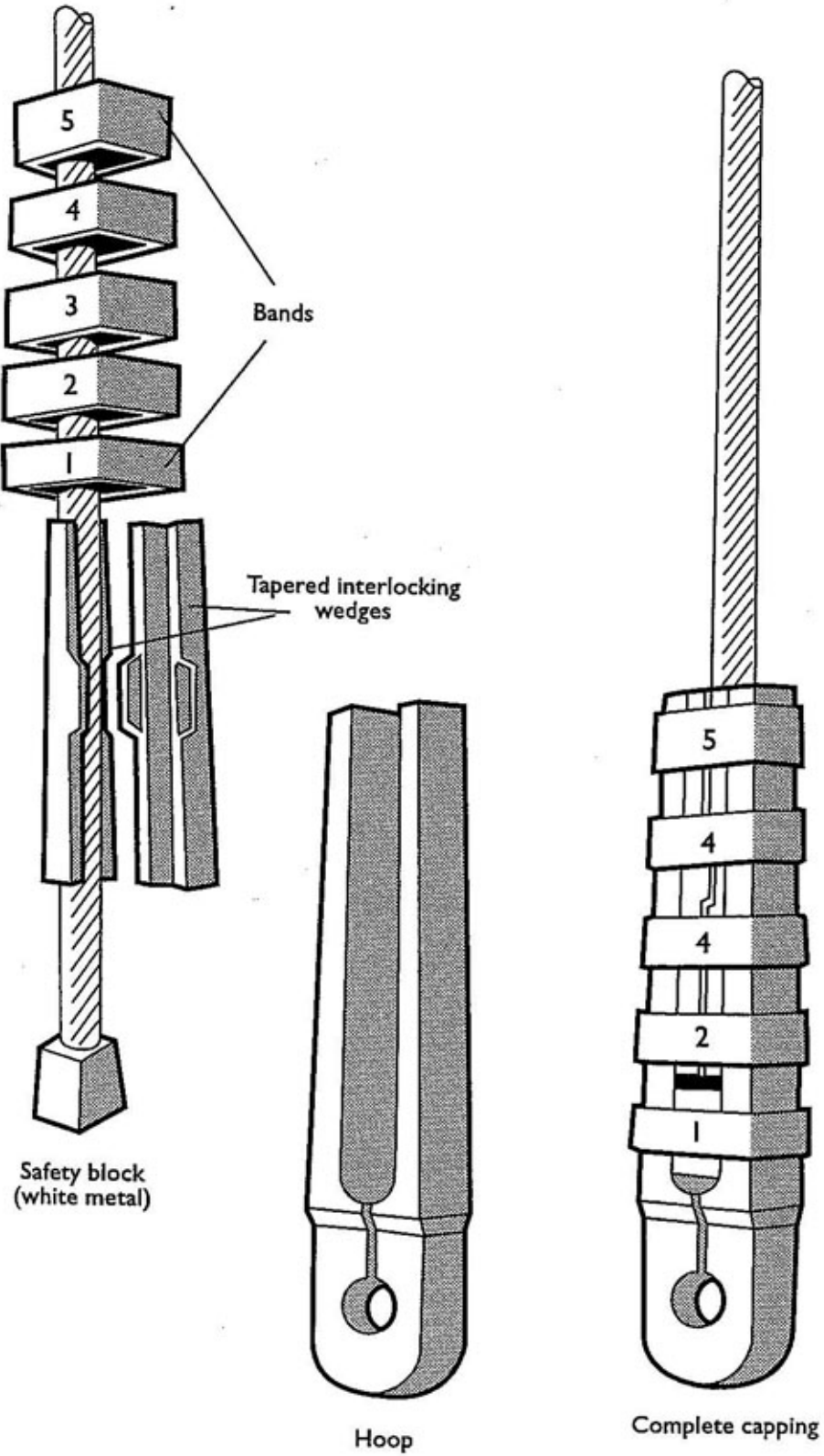
2.5.2 Rope Sockets

Fluted plug and tail and white metal filled type rope (see Figure 2.9) sockets are the preferred method of attaching the conveyance to the rope for both slope haulage and underlay shaft winder systems.

2.5.3 Rope Attachment Suspension Arrangement

Typical arrangements of rope attachment suspension systems are shown in Figures 2.10 and 2.11.

(Note: Figure 2.11 represents a multi-rope arrangement eg. a friction winder but is included for completeness)



Wedge Type Rope Capel
Fig 2.8

2.6 Conveyance Attachments

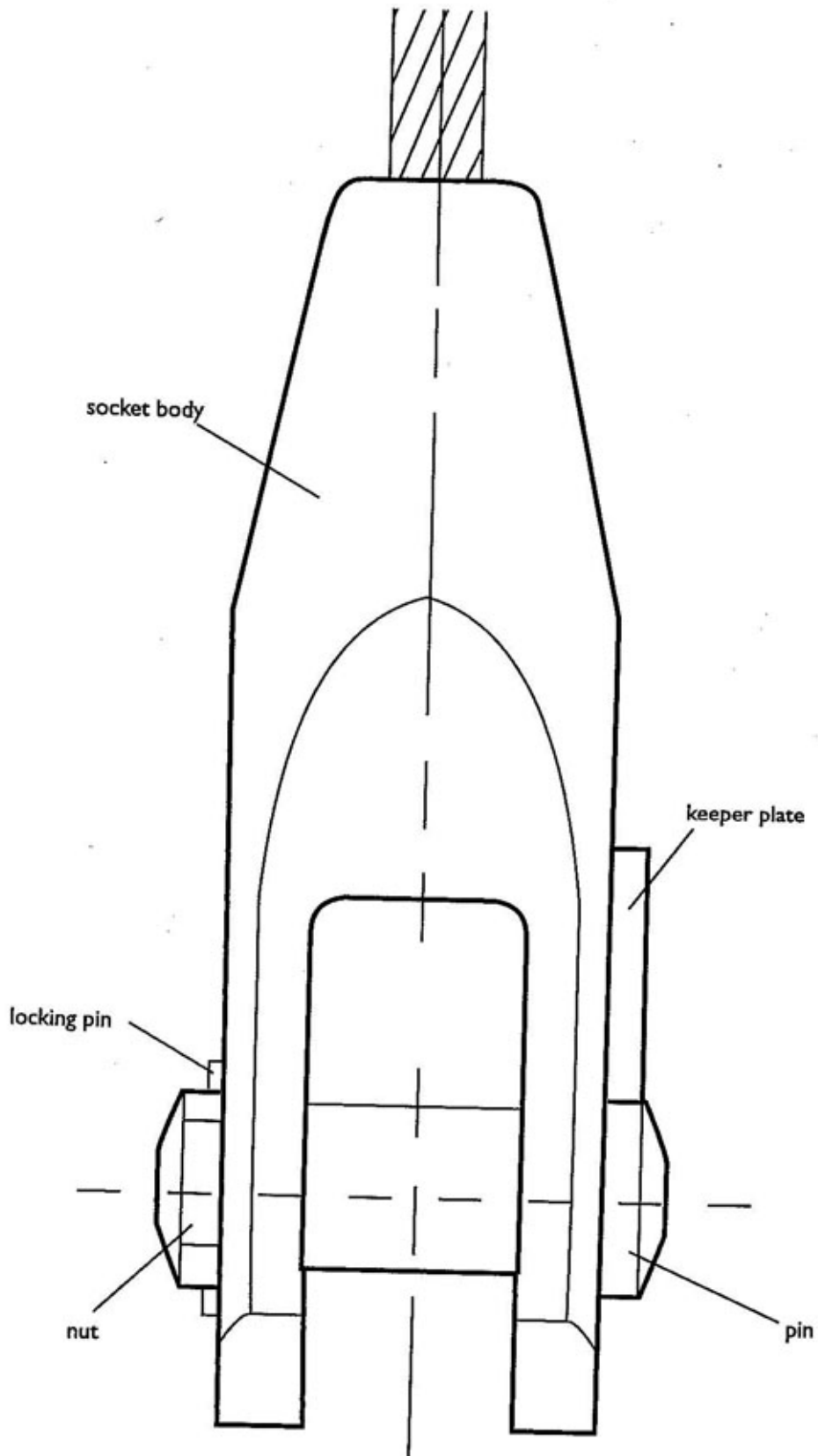
When selecting attachments expert guidance should be sought from reputable manufacturers.

2.6.1 Vertical Shaft

Refer to AS3637 “Underground Mining- Shaft Equipment” Part 4 - Conveyances for Vertical Shafts.

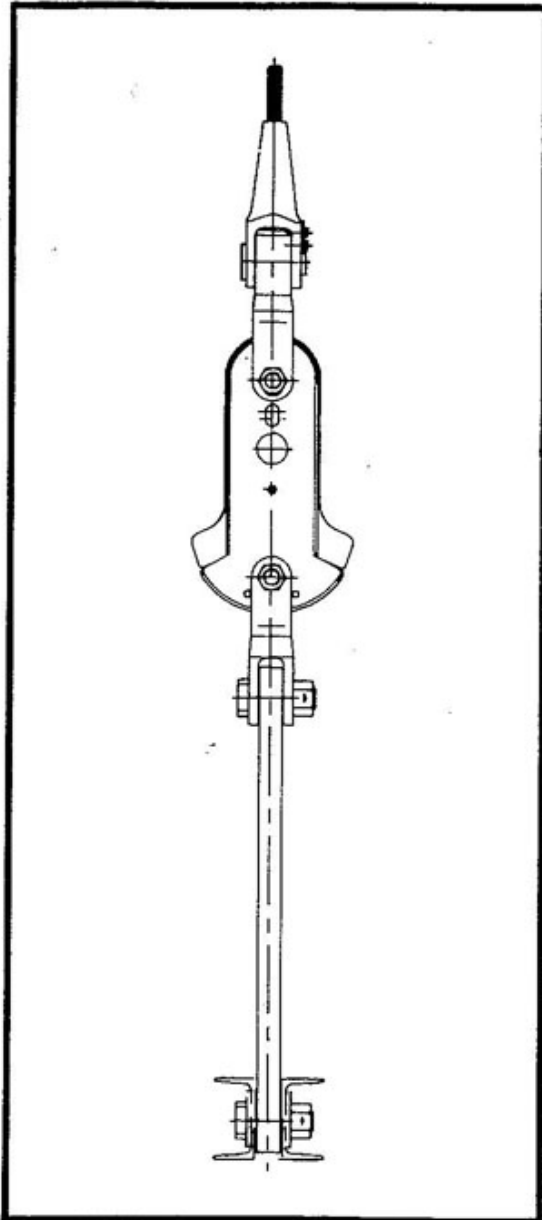
2.6.2 Drift Haulage:

Refer to Section 5.6.3.11 and AS3637 - “Underground Mining - Shaft Equipment” Part 8 - Personnel Conveyances in other than vertical shafts” and AS3751 - “Couplings and Drawbars.”

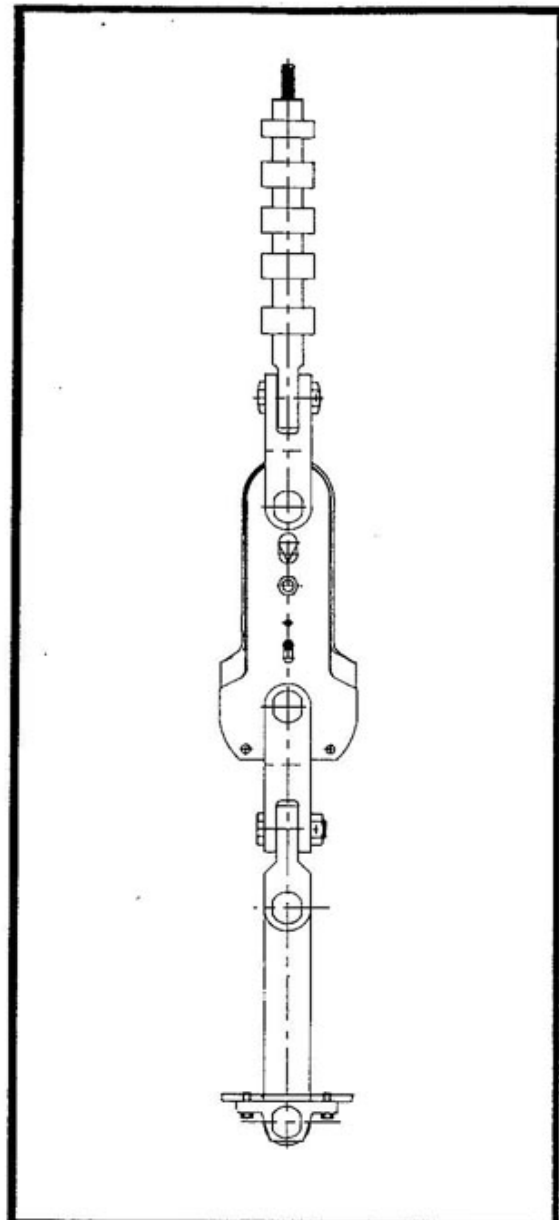


White Metal Filled Rope Socket

Fig 2.9

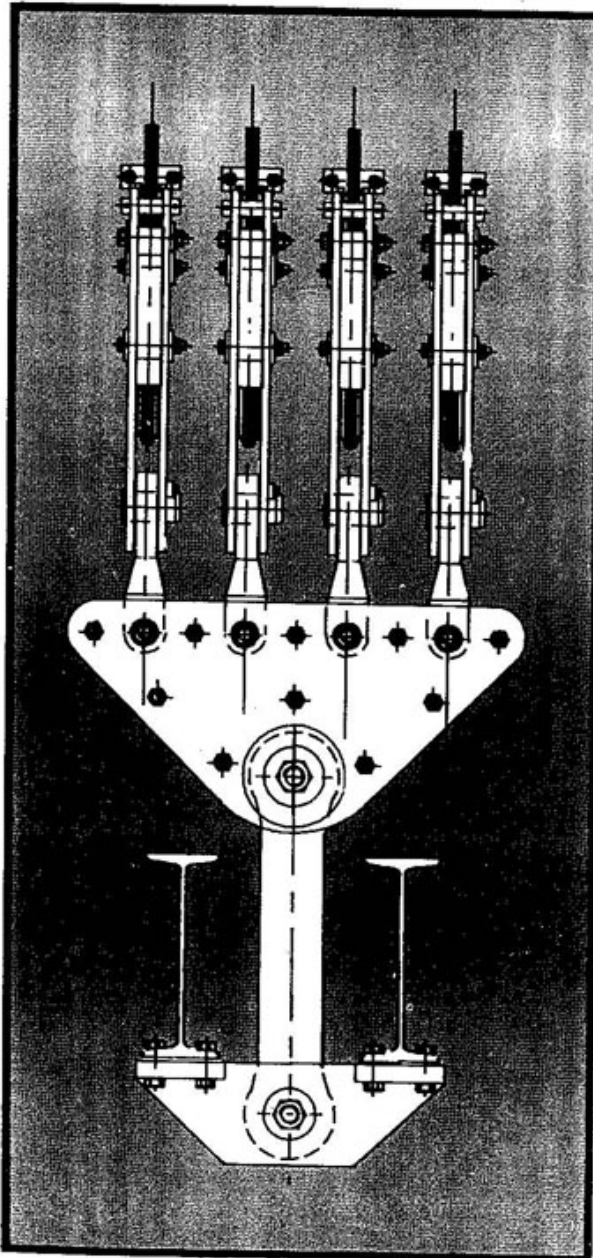


Head Rope Suspension arrangement consisting of Inserted Cone and Tail Socket, Humble Type Detaching Hook, Drawbar and Transom Support.

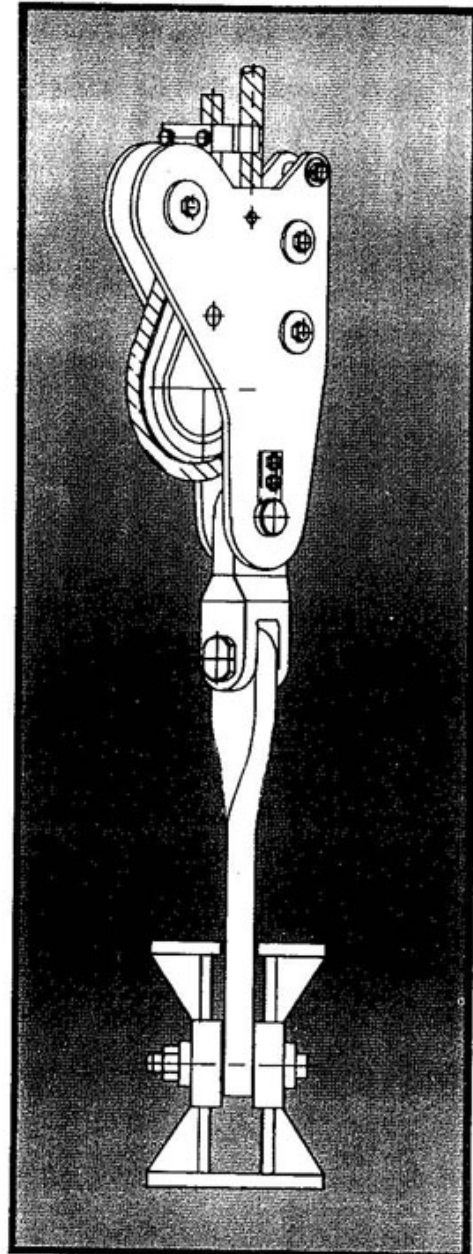


Wedge Type Capel connected to a King Type Detaching Hook, Drawbar and Suspension Pedestal Support.

Examples of Single Rope Suspension Systems
Fig.2.10



A four rope suspension system showing the thimble capel connection to an equalising plate. A draw bar connects the equalising plate to a transom underframe support.



Side view showing a thimble capel, right angle chase block, and draw-bar connected to conveyance transom. The draw bar is twisted to ensure the thimble capel clears shaft furnishings.

Examples of Multi Rope Suspension Systems

Fig.2.11

3 BRAKES AND BRAKING SYSTEMS

OVERVIEW

3.1 Design and Performance

3.2 Operation and Maintenance

3.3 Calculations

3.4 General Comments

3. BRAKES AND BRAKING SYSTEMS

3.1 Design And Performance

General Principle

The principle which should be adopted for all winders is that the **mechanical brakes** shall be the ultimate means of retarding the winding system. The objective is that this principle should apply even in the event of the failure of any one component.

New mechanical brakes should be arranged so that they contain no single line component, the failure of which would prevent application of the brake, either directly by the winder, or by a safety device. All critical connecting pins must be secured using split pins or similar means. Grub screws are not acceptable.

3.1.1 Performance Criteria

Mine winder drum brakes must meet the following statutory performance requirements:

- There shall be two independent mechanical braking systems. At least one shall act directly on the winder drum.
- If one mechanical brake fails, the other shall be able to retard and stop the winder safely before the descending conveyance, carrying the rated load, reaches any obstruction.
- When all brakes apply, decelerations should not be so violent (greater than 0.5 g) that personnel travelling in the conveyance are injured.
- The brakes shall not overheat or fade during an emergency stop.

3.1.2 Brake Function

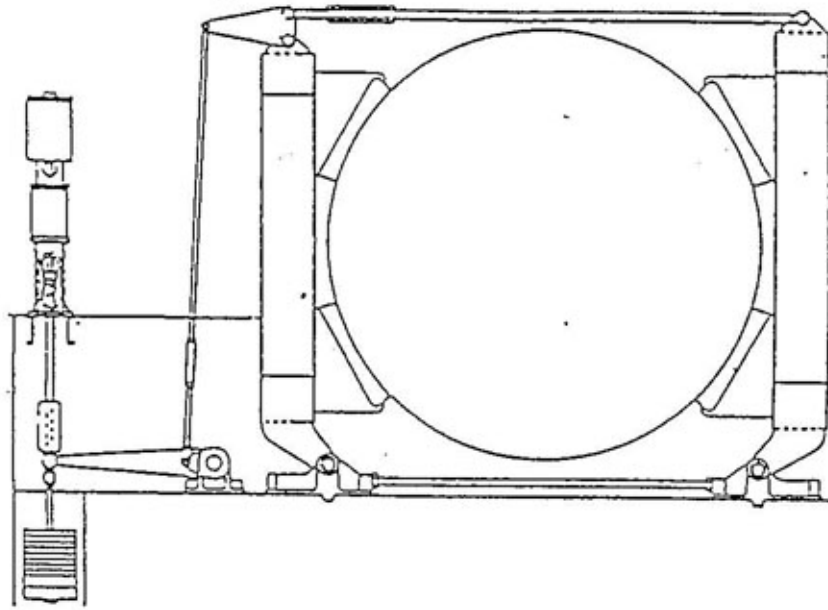
Mine winder drum brakes perform three prime functions:

- service braking
- parking braking
- emergency braking.

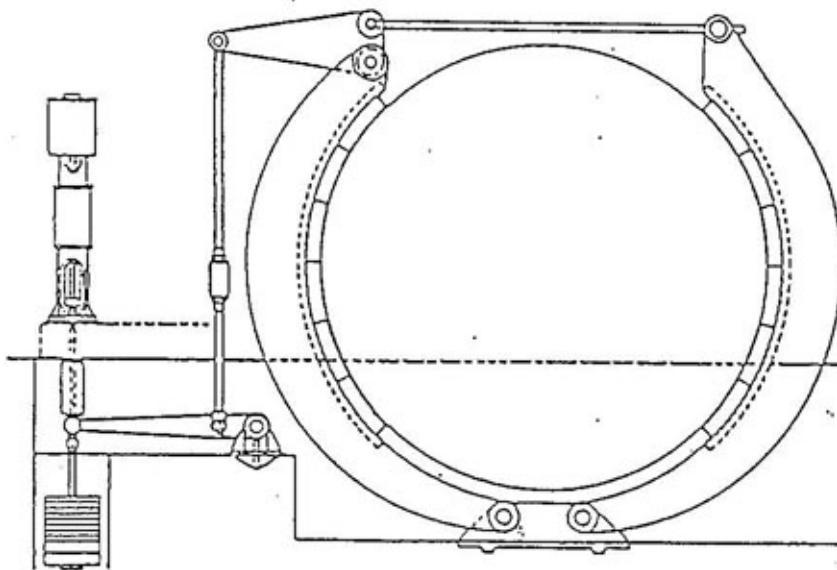
Modern winders almost exclusively use electrical motor control for service braking.

3.1.2.1 Service braking involves retarding or restraining the speed as required by the operator or automatic controls.

3.1.2.2 Parking braking involves holding the load safely when the wind is completed, or when power is disconnected for servicing or standing.



POST BRAKE



CALIPER BRAKE

Typical drum winder brake configurations
Fig 3.1

3.1.2.3 Emergency braking results in slowing and stopping the winder before the conveyance, skip, kibble or stage, reaches the limits of travel. It will occur when:

- the controls malfunction or control is lost
- power is lost
- an emergency stop is instigated by either personnel intervention or some protective device signalling an operating fault.

3.1.3 Brake Types

Drum winders may have drum shoe caliper brakes of various configurations (see Figs 3.1, 3.2 and 3.3), operating on a cylindrical brake drum, and incorporating a dead weight or spring applied system of brake force; or a system employing one or more disk calipers operating on a disk which incorporates hydraulic pressure to lift the brakes and spring force to apply the brakes.

3.1.3.1 The preferred system is multiple disc caliper brakes (See 3.1.9, 3.1.19 and Section 4.6.)

3.1.4 Brake Application

In every case brake application shall be "fail to safety".

3.1.5 Single Drum Winder Brakes

For single drum winders where persons are carried at any time, two (2) independent braking systems shall be installed, one of which shall operate on a brake path attached directly to the drum.

3.1.5.1 The second brake system shall not use the same brake path or disk used by the first system.

3.1.5.2 The brake system attached directly to the drum shall always apply to stop the winder before any second brake system applies.

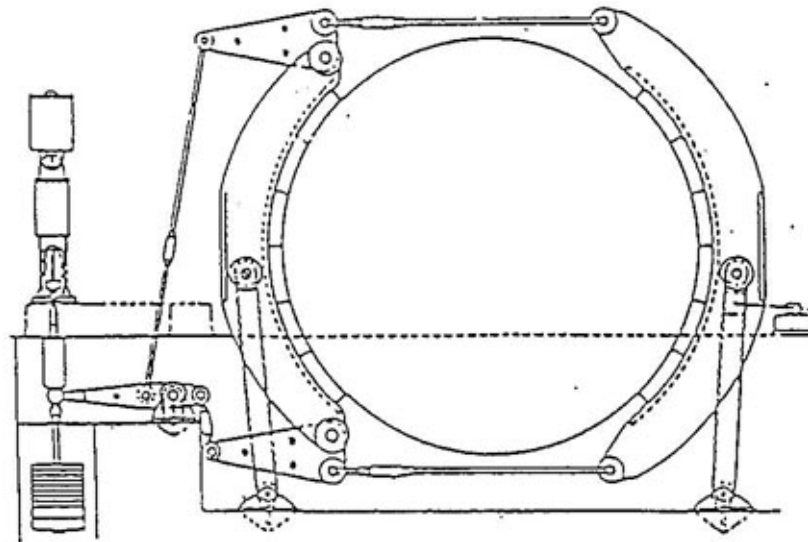
3.1.5.3 Hydraulic control systems for the brake may be incorporated into an integrated control unit provided such a unit fails to safety.

3.1.6 Double Drum Winder Brakes

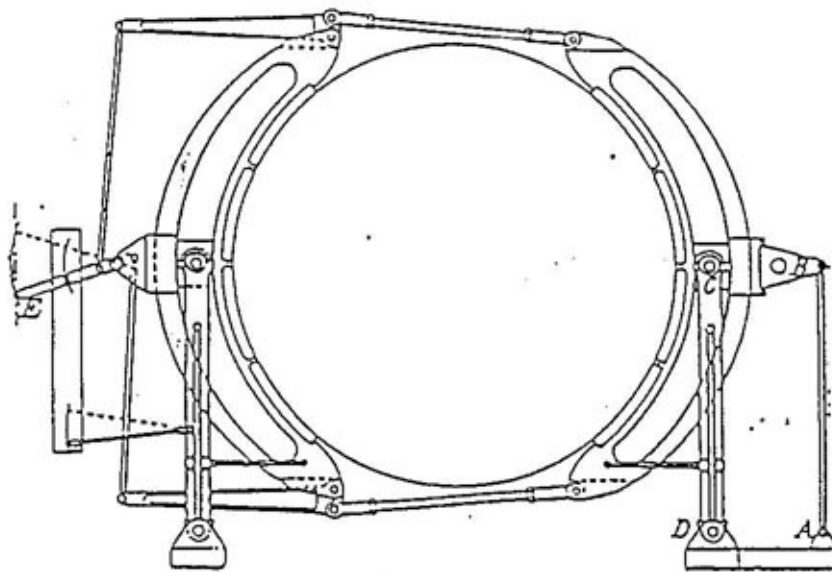
When a double drum winder is used, and personnel are to be transported at any time in the conveyance attached to one drum when the other drum is de-clutched, both drums shall have a mechanical brake attached directly to each drum.

3.1.6.1 The winder shall have a third brake which must be coordinated with the main drum brakes.

3.1.6.2 The third brake system shall not use the same brake path or disk used by the main drum brakes.



SUSPENDED POST BRAKE



PARALLEL MOTION BRAKE

Typical drum winder brake configurations (cont'd)

Fig 3.2

3.1.6.3 The brake systems attached directly to the drum shall always apply to stop the winder before any third brake system applies.

3.1.6.4 When the drums of a double drum winder are clutched the brakes should be capable of holding the drums stationary when the loads are balanced and the normal maximum torque is applied in either direction by the winding motor. In the declutched condition each drum brake should be capable of stopping the winder.

3.1.6.5 When a drum of a double drum winder is declutched, that drum shall not be capable of rotating. An interlocking system between brake and clutch should ensure that the brake cannot be removed from a declutched drum.

3.1.7 Brake Locking

All winders shall be provided with an effective means of locking the mechanical brakes in position when they are fully engaged, and these means should be set to operate automatically in the event of the loss of power.

3.1.8 Brake Component Factors of Safety

Wherever possible, single line components should not be used for brake linkages. When single line components are used, a minimum factor of safety of 10 shall apply to all brake components, except in the case of screwed threads. In this case a minimum factor of safety of 15, based on the root diameter of the thread, shall apply.

3.1.9 Disk Caliper Brakes

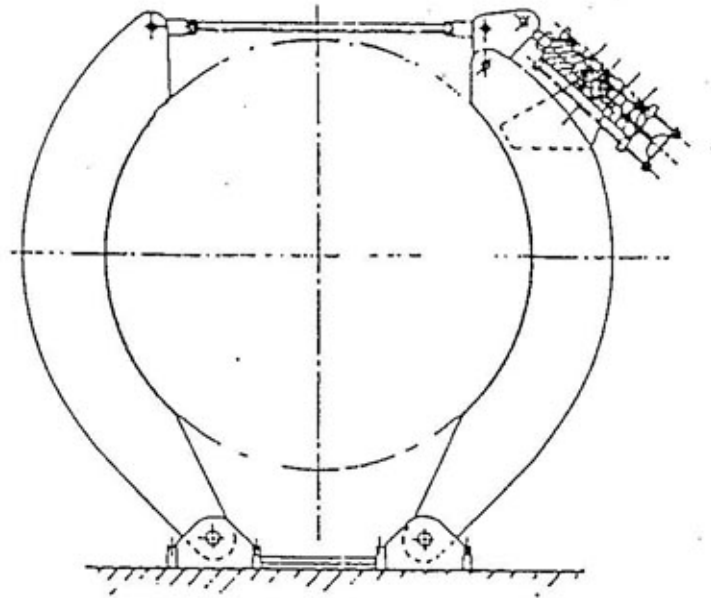
When disk calipers are used to brake the winder, multiple calipers should be used on the disk whenever possible. When selecting the type of caliper to be used, the expected braking cycles during the life of the winder should be taken into consideration.

3.1.10 Brake Capacity

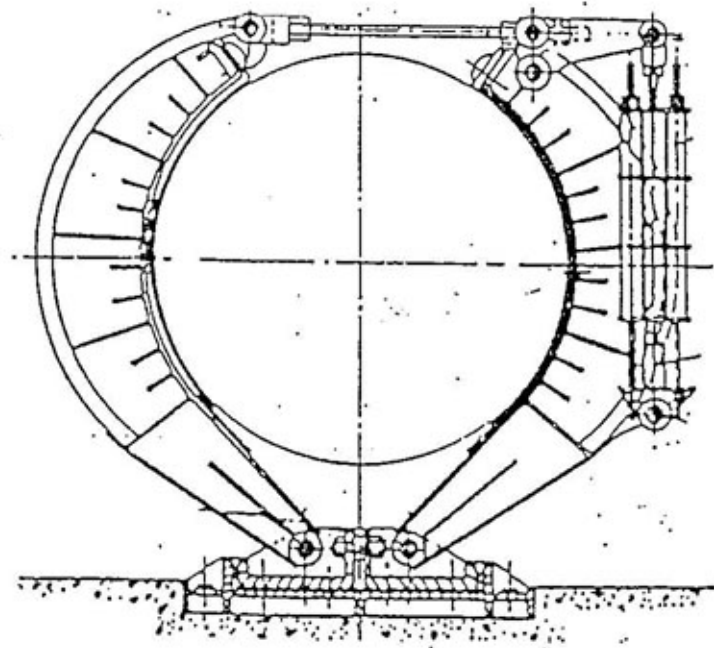
The braking system shall be designed to bring the winder to a halt from an overspeed emergency trip condition without damage or injury to personnel or materials. The brake system should be designed with a margin of safety that allows for possible deterioration of performance.

3.1.10.1 For drift haulage systems, each brake system on the winder, when new, shall have a minimum capacity of 175% on maximum static torque.

3.1.10.2 For vertical shaft winding, each brake system on the winder, when new, shall have a minimum capacity of 200% on maximum static torque.



High pressure, pressure applied spring backup Caliper Brake



High pressure spring applied Caliper Brake

Typical drum winder brake configurations (cont'd)

Fig.3.3

- 3.1.10.3** When considering the application of braking effort, the protection of personnel being transported is a prime concern. For emergency braking the deceleration rate shall not be greater than 0.5g (4.9 m/s²) and not less than 1.0 m/s².
- 3.1.10.4** When winders are used to transport both personnel and heavy loads, brakes must be designed to maintain deceleration rates within the minimum to maximum load range.
- 3.1.10.5** The total Braking System must ensure that a multiplication of brake effort from multiple brake systems cannot cause damage or injury.
- 3.1.10.6** For every winder transporting personnel, or being used where personnel are working in the vicinity of the operation, brake capacity testing and recording shall be undertaken to a pre-determined schedule. The testing shall consist of both static and dynamic tests of all brake systems. Records must be kept and be available to an Inspector upon request.
- 3.1.10.7** The brakes shall not overheat or fade during an emergency stop to such an extent that will cause the brakes to fail.
- 3.1.10.8** The brakes shall be able to retard to rest at least twice in succession, a descending conveyance, approaching the lower limits of travel, carrying full rated load, and travelling at the maximum speed permitted by the overspeed device.

3.1.11 Brake Operation

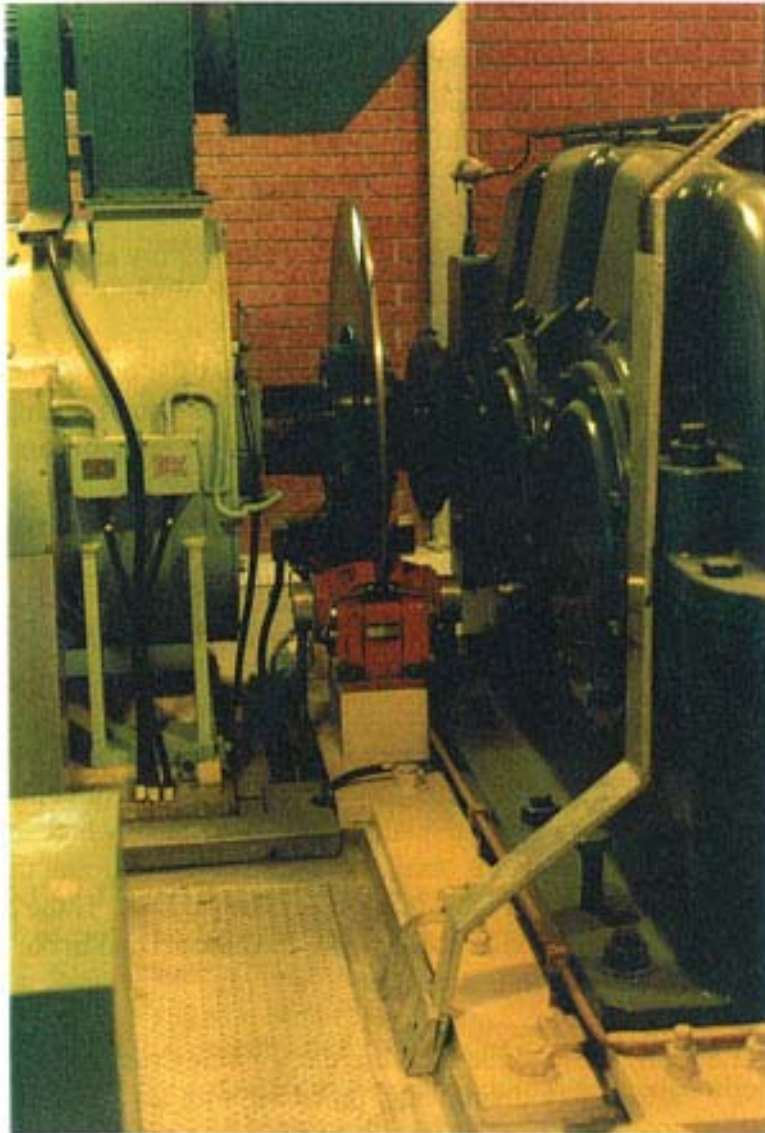
Mechanical brakes shall automatically apply on:

- (a) power failure
- (b) overspeed on ramp control
- (c) overspeed of haulage drum
- (d) overspeed of conveyance
- (e) overwind through limits
- (f) slack rope indication
- (g) rope overcoiling on drum
- (h) conveyance dump brake pressure loss (Drift application)
- (I) derailment of conveyance (Drift application)
- (j) lost motion on gear drive train
- (k) loss of system pressure in the brake control system
- (l) high level drum pit flood alarm
- (m) Emergency stop buttons at any station

Mechanical brakes shall also apply if initiated by a normal control stop by driver or the control system.



Modern drift haulage winder drum fitted with disk caliper brake arrangement



Modern drift haulage drive fitted with high speed disk caliper brake arrangement

- 3.1.11.1** The brake control system shall be designed to ensure that, in the event of a control failure or malfunction, the system will fail to safety. The brake control circuit shall allow the winder to complete its cycle, but not recommence a new cycle if any of the following occurs:
- (a) brake wear indication
 - (b) faulty or stuck valve indication
 - (c) low hydraulic oil level
 - (d) low system pressure
 - (e) earth leakage alarm
 - (f) high temperature alarms including fire alarms
 - (g) low level drum pit flood alarm
- 3.1.11.2** If a hydraulic unit is used to control the brake system it should be located and constructed so as to avoid contaminating the brake paths if a spillage, leakage, burst pipe, or oil spray occurs. Oil spray from any hydraulic leak on one brake system shall not be able to contaminate the brake path nor affect the effectiveness of the other brake systems.
- 3.1.11.3** All hydraulic lines should be shielded to provide maximum protection to the brake path (disk) from contamination in the event of a pipe or connection failure.
- 3.1.11.4** The brake path (disk) shall be protected from contamination due to flooding. If the path (disk) is located where contamination is possible, alarms shall be installed to indicate that flooding has occurred, and the winder should be stopped. If the brake path (disk) is in a pit which could flood, then the second brake system shall not be located in that pit.
- 3.1.11.5** Any pit required to house the winding drum and brake path shall be adequately drained and protected with an alarm system. If natural drainage is unavailable because of the adjacent land levels, or other reasons, the pit should be fitted with an automatic pump-out system and alarms.
- 3.1.11.6** The foundations should be constructed such that the floor level of the winder house is at least 150mm above the local ground level. Where the winder house is not fully enclosed, provision should be made to drain water away from any pit.

3.1.12 Brake Operation - Post Caliper Brakes

- 3.1.12.1** New linings fitted to brake shoes shall be of asbestos free material and should have a coefficient of friction within the range of 0.30 to 0.43. Linings used for this purpose must be a type generally acceptable, and approved for this use by the brake lining manufacturer.
- 3.1.12.2** Brake engines or cylinders shall be fitted with indicators, visible for daily inspections, to show clearly that the cylinder piston is operating within the range of the cylinder. This indicator should work on a safety margin of at least 10% of the cylinder stroke.
- 3.1.12.3** Brake engines or cylinders and their control systems should be of such proportion and construction as to allow the brake application time, from receipt of emergency stop signal to full brake application, to be less than one (1) second.

3.1.13 Brake Operation - Disk Calipers

- 3.1.13.1** Each brake caliper shall be fitted with indicating and alarm devices to detect brake pad wear and brake pad lift failure.
- 3.1.13.2** All brake caliper attachment bolts, stands and mounting posts shall have a factor of safety of 10 or greater. Multiple bolts shall be used for all attachment and foundation requirements.
- 3.1.13.3** Brake disk design should ensure that heating or expansion of the disk caused by brake applications does not reduce the braking capacity.

3.1.14 Brake Path Condensation Contamination

Where climatic conditions are likely to cause condensation on the brake path of winder installations, provision should be made to prevent such contamination. This can be achieved by heating the winder house or by fan heating the brake path.

3.1.15 Hydraulic Power Units

A hydraulic control unit for activating the brakes shall be a fail-to-safety type system. The control system shall be designed to ensure that, in the event of a malfunction, the winder shall be brought to an emergency stop.

- 3.1.15.1** The hydraulic brake unit should include:
- (a) duplicated main control valves
 - (b) duplicated exhaust lines from control valves to reservoir
 - (c) faulty control valve operation alarm
 - (d) low level hydraulic fluid alarm
 - (e) low oil pressure alarm
 - (f) high oil temperature alarm
 - (g) full flow filters of a size to ensure contaminants do not lead to seizure of valves
 - (h) visual means of monitoring the power supply to individual solenoids
- 3.1.15.2** The brake control circuit should allow the winder to complete its cycle (return to ramp or docking position), but not commence a new cycle, if any of the following events occurs during the cycle:
- (a) faulty or stuck valve indication
 - (b) low hydraulic oil level
 - (c) low hydraulic oil pressure
 - (d) high oil temperature
- 3.1.15.3** Spool type main control valves should not be used in the design of hydraulic power units. Hydraulic valves shall be designed to minimise the potential for seizure.
- 3.1.15.4** The unit should be designed to confine within the unit construction, any oil spillage, leakage, or spray, due to pipes, seals or joints rupturing. Any collecting tray or container used for this purpose should be easily removable.
- 3.1.15.5** The oil reservoir should be large enough to allow the completion of a cycle after a low oil level alarm has been activated.
- 3.1.15.6** Dual oil supply pumps should allow either pump to be isolated for removal and servicing.
- 3.1.15.7** Flow valves or other application components should be such as to accurately set the necessary brake application times for the winder to achieve the required deceleration rates. Once set, the components should have the capacity to lock the timing in place.
- 3.1.15.8** The hydraulic system circuits should have all components clearly identified. The final "as manufactured and installed" drawing should include all brake timings set at commissioning.
- 3.1.15.9** To maintain security of the hydraulic unit, the control system should be designed to be enclosed in a lockable cabinet.

3.1.16 Air control of brakes

An air pressure control unit for activating the brakes shall be a fail-to-safety type system. The control system shall be designed to ensure that, in the event of a malfunction, the winder shall be brought to an emergency stop.

3.1.17 Electro-mechanical actuators

3.1.17.1 When electro-mechanical actuators are used for activating the brakes, the system shall be a fail-to-safety type. The control system shall be designed to ensure that, in the event of a malfunction, the winder shall be brought to an emergency stop.

3.1.17.2 Thrusters should be fitted with time delays to accurately control the brake application.

3.1.17.3 The selected thruster actuated shoe brakes should dissipate the heat energy from at least two (2) repeated emergency stops, without brake fade.

3.1.18 Brake Caliper Posts

When brake calipers are mounted on brake mounting posts designed for the purpose of stacking brake calipers, a Factor of Safety of 10 on failure, when based on the worst brake load case, shall be used for the post design and mounting bolt or foundation bolt design. In all cases, multiple mounting bolts should be used.

3.1.19 Drum Brake Disks

3.1.19.1 Brake disks mounted directly on the winder drum may be welded directly to the drum, or bolted to a drum flange.

3.1.19.2 Disks which are bolted to the drum may be split into segments to assist mounting and reduce heat distortion problems. Split disks should be keyed at the joint to maintain surface accuracy.

3.1.19.3 Straightness, flatness and runout tolerances on the brake disk should be to caliper supplier recommendations.

3.1.19.4 Material used for the disk manufacture must be suitable for the purpose and to the disk caliper supplier recommendations.

3.1.19.5 Where high speed disks are provided for emergency high speed brakes, the disks should be dynamically balanced to the maximum overspeed RPM.

3.1.19.6 Brake disks should be aligned and fixed to prevent side movement in order to maintain the nominated air gaps and limit switch settings.

3.1.20 Effect of Drive Trains

Winder drive systems must be designed to allow the brakes to be easily and accurately tested. Because of this requirement, the use of worm reduction gearboxes in the main drive system should be avoided. If they are to be used, documented information on reverse drive efficiencies and the effect on the brake efficiency and testing will be required. (Refer Section 4.4 for further details on drive train information).

3.2 Operations & Maintenance

3.2.1 Non-Destructive Testing of Brake Components

Ref: Safe Manriding in Mines, Parts 1A and 1B, 2A and 2B.

All critical brake components shall be examined at pre-determined intervals.

3.2.1.1 Non-destructive testing is one of the means of ensuring the quality of some brake system components prior to service, by detecting defects. These procedures include magnetic inspection, ultrasonic testing and dye-penetrant methods.

3.2.1.2 Intervals between examinations can be influenced by a number of factors:

- operational duty of the installation
- the stressing of a particular component
- the significance of the failure
- and the size of the acceptable imperfections.

3.2.1.3 When considering the significance of failure, it is possible to identify, in a braking system, critical components, which may be defined as **any** component, the failure of which will result in the loss of at least 50% of braking area or force for any one brake system.

3.2.1.4 Intervals between examinations can be determined from the number of winds per year. A wind is defined as a single journey in a shaft or drift.

- (a) Heavy Duty - more than 200,000 winds per year.
- (b) Medium Duty - 10,000 to 200,000 winds per year.
- (c) Light Duty - less than 10,000 winds per year.

- 3.2.1.5** For brake components classified as critical, the frequency of non-destructive testing should be not less than as follows:
- (a) Heavy duty - 1 year between examinations
 - (b) Medium duty - 2 years between examinations
 - (c) Light duty - 3 to 5 years between examinations

Visual examination of non-critical components should be made at the time when full non-destructive tests are made on critical components.

- 3.2.1.6** At the examination all areas comprising pinned connections should be checked for freedom of movement. All pins should be removed and checked for wear and damage.

3.2.2 Brake Testing

- 3.2.2.1** Each brake of every winder shall be subjected to testing at the time of installation.

- 3.2.2.2** Brake capacity testing and recording to a pre-determined schedule shall thereafter be undertaken for every winder transporting personnel, or being used where personnel are working in the vicinity of operation.

- 3.2.2.3** The testing shall consist of both static and dynamic tests of all brake systems. The records must be available to an Inspector upon request.

- 3.2.2.4** **Static brake** tests shall be carried out at least once per week. For production winders this may be required once per day.

- (a) The purpose of the static brake test is to indicate the holding capacity of the brakes. Each brake system should be tested and the results recorded.
- (b) The normal method will be to locate the conveyance at a safe position, for example, on a surface turnout, and pull the brake path through the brakes by applying motor torque to each brake system in turn, until the required torque is reached or the brakes pull through.
- (c) An established method for conducting the static tests and training operators should be documented.
- (d) Static tests should only be carried out with all management safety requirements and rules in place.

- (e) Static tests should only be carried out under the direction and supervision of a person authorised by the mine to conduct such tests.

3.2.2.5 All winders should be equipped with facilities to record the results of all brake tests.

3.2.2.6 A system of reporting loss of brake efficiency should be part of the management plan in order to detect and correct any deterioration indicated by the recorded results.

3.2.2.7 Dynamic brake tests shall be conducted at least every six months.

3.2.2.8 **Dynamic brake** tests should only be carried out:

- (a) after static tests have been performed and the results are acceptable
- (b) with all management safety requirements and rules in place
- (c) under the direction and supervision of a person authorised by the mine to conduct such tests.

3.2.2.9 To carry out a normal dynamic brake test the following procedure should be adopted:

Step	Action
Step 1	Load the conveyance with a dead load equivalent to the maximum person load or maximum out-of-balance person load. (For drifts, disconnect the conveyance overspeed device). Ensure any electrical retardation will not occur during test.
Step 2	Position the conveyance at a point towards the bottom of the drift or shaft, with ample margin to stop under brakes.
Step 3	Check the brake systems application timing is correct. Adjust timings if necessary.
Step 4	With all brake systems in the operating state allow the winder to free run to half speed, then apply the brakes by activating an emergency stop (press button).
Step 5	With all brake systems in the operating state allow the winder to free run to full speed, then apply the brakes by activating an emergency stop (press button).
Step 6	With all brake systems in the operating state, allow the winder to free fall to overspeed, letting the drum overspeed device trip and activate an emergency stop.
Step 7	Sign and file the brake test sheets.
Step 8	Return the winder to its "ready" condition

3.3 Brake Calculations

3.3.1 Brake Capacity Calculations

Brake capacity calculations shall be required for all winders before approval is given.

3.3.1.1 These calculations should include:

- (a) percentage of static load
- (b) deceleration rates
- (c) deceleration times
- (d) stopping distances
- (e) thermal efficiencies
- (f) brake component factors of safety

3.3.1.2 Information presented for system approvals should include:

- (a) brake control circuit
- (b) brake arrangement and type
- (c) brake friction material and characteristics
- (d) methods for recording brake test results.

3.4 Brake Dynamic Performance - General Comments

3.4.1 Retardation and Stopping

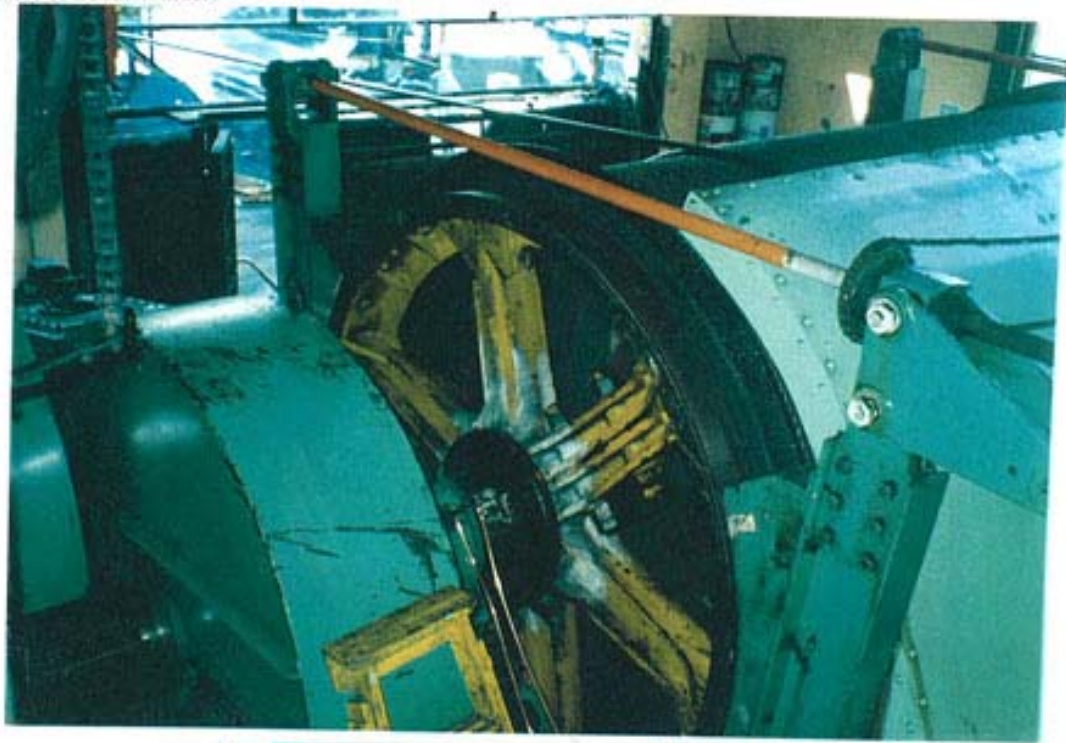
Each brake must be capable of retarding and stopping the winder safely before the descending conveyance carrying the rated load reaches any obstruction.

3.4.1.1 In general the conveyance should be retarded at a minimum of 1 m/s^2 .

3.4.1.2 If the surface of the drum is retarded at greater than g (9.81 m/s^2) in a vertical shaft, or $g \cdot \sin \alpha$ in a shaft inclined at α to the horizontal, the ascending conveyance will over-run the rope and the rope may be kinked or broken.

3.4.1.3 The ropes act as an elastic link between the drum and the conveyance. If the braking effort builds up smoothly over an appropriate period of time, deceleration at the conveyance will be only slightly greater than the deceleration of the drum. If full braking effort is suddenly applied, the conveyance will bounce significantly and the maximum deceleration can be up to twice as great as at the drum, especially in deep shafts.

3.4.1.4 Personnel cannot withstand as high an acceleration rate as materials. A healthy, attentive person can tolerate deceleration rates of around 6 m/s^2 either up or down. Personnel are not likely to be injured if decelerations are limited to 5 m/s^2 . At low speeds (less than 2.5 m/s) individuals can withstand higher decelerations.



Whitmore overwinding mechanism associated with post brake



Modern drum winder drive and brake arrangement showing high and low speed brakes, hydraulic power pack and cycle meter