NSW GOVERNMENT

NSW Resources Regulator

TECHNICAL REFERENCE GUIDE

POWERED WINDING SYSTEMS

Part 1: General requirements

NSW Resources Regulator

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AMENDMENT SCHEDULE		
Date	Version	Amendment
January 2020	1	Original version Supersedes MDG 33 (1998), MDG 12 (1992), MDG 26 (1999) and MDG 2005 (2003). Reflects 2020 NSW WHS legislative framework. Developed in consideration of current Australian standards, international standards, the EES008 series and industry feedback from the 2011 consultation process for draft MDG 33 (1-7) series.

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Foreword

Powered winding systems (PWS) are important items of infrastructure in underground mines. They are considered high risk plant, and if they fail, they have the potential for multiple fatalities.

There are many installations operating in NSW ranging from those designed for personnel transport, both personnel and materials transport and solely for materials haulage. Some PWS have the potential to carry more than 150 people in a single lift.

The safe design of PWS plays a critical role in eliminating hazards and risks before the PWS is introduced to a mine. Safe design applies to every phase in the PWS life cycle from conception to disposal.

The types of winders include drift winders, vertical shaft drum winders, vertical shaft friction winders, shaft sinking winders (used for relatively short-term projects) and emergency winders (used for emergency egress for permanent installations).

The *Technical reference guide: Powered winding systems* series provides an industry benchmark for engineering standards associated with the safe design, commissioning and use of PWS. The series consists of five parts:

- *Part 1: General requirements*
- *Part 2: Drift winders*
- *Part 3: Vertical shaft winders (drum, friction, shaft sinking and emergency winders)*
- *Part 4: Ropes*
- *Part 5: Control systems*

The series represents acceptable industry practice for reducing lifecycle risks and refers to the suite of Australian Standards that have been developed for PWS. Adoption of this technical information and the appropriate use of risk assessment techniques should foster safe winding practices.

Conformance with this series does not guarantee safety and will not address all risks related to a PWS. Therefore, appropriate risk management and lifecycle management processes must be carried out.

The series collates all winder types and includes information previously provided in the original:

- MDG 33 *Guideline for design, commissioning and maintenance of drum winders* (1998)
- MDG 12 *Guideline for the construction of friction winders* (1992)
- MDG 26 *Guidelines for the examination, testing and discard of mine winder ropes* (1999).

- MDG 2005 *Electrical technical reference for the approval of powered winding systems* (2003)
- EES008 Series – Technical reference – electrical engineering safety – *Design of powered winding systems.*

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1. Introduction

1.1. Scope and application

This document covers the general requirements applicable for the design, commissioning and use of all winding system types:

- ***Drift winding system*** means a drum winding system used in a drift.
- ***Vertical shaft drum winding system*** means a drum winding system that operates in a vertical shaft.
- ***Friction (Koepe) winding system*** means a vertical shaft winding system in which conveyances are raised and lowered by means of multiple ropes passing over a driving sheave, such that the driving force is transmitted from the sheave to the ropes by friction.
- ***Shaft sinking winding system*** means a drum winding system that is used on a short term basis for the development, equipping or refurbishment of vertical shafts. A shaft sinking winding system is relocatable and is not a permanent fixture.
- ***Emergency egress winding systems*** means a winding system that is used solely for emergency egress.

The following definitions are provided for further clarification of the above terms:

- ***Winding system*** has the same meaning as it has in clause 3 of the Work Health and Safety (Mines and Petroleum Sites) Regulation 2014.
- ***Drum winding system*** means a winding system in which a conveyance is raised and lowered by means of a single rope attached directly to the conveyance and the rope is wound onto a cylindrical drum. A drum winding system includes a winder with two drums (double drum), each raising and lowering a conveyance.
- ***Vertical shaft winding system*** means a winding system that operates in a vertical shaft and includes vertical shaft drum winding systems; friction (Koepe) winding systems; shaft sinking winding systems; and emergency egress winding systems.
- ***Drift*** means a mine adit or shaft, on slopes of 10 to 30 degrees, for the transport of persons and materials. This term is commonly used in coal mines.

- ***Shaft***, in underground workings, means a mine heading. A shaft may be orientated from 0 to 90 degrees.

As outlined in the table below, Part 1 does not cover:

- specific requirements applicable only to drift winding systems (refer to Part 2)
- specific requirements applicable only to vertical shaft winding systems (drum, friction, shaft sinking and emergency winding systems) (refer to Part 3)
- ropes (refer to Part 4)
- control systems (refer to Part 5).

WINDER TYPE	APPLICATION OF TRG: POWERED WINDING SYSTEMS				
	Part 1: General requirements	**Part 2**: Drift winders	**Part 3**: Vertical shaft winders (drum, friction, shaft sinking and emergency winders)	**Part 4**: Ropes	**Part 5**: Control systems
Drift	☑	☑		☑	☑
Vertical shaft drum	☑		☑	☑	☑
Friction (Koepe)	☑		☑	☑	☑
Shaft sinking	☑		☑	☑	☑
Emergency	☑		☑	☑	☑

Part 1 should be used by designers, manufacturers, owners and end users with consideration to:

- designing new PWS
- verifying new PWS
- applying for design registration of PWS
- altering existing PWS

- carrying out five yearly audits of PWS
- reviewing PWS designs following an incident
- altering, maintaining or repairing PWS.

1.2. Out of scope

This series does not cover person-riding hoists. Refer to:

- MDG 42.1 *Person-riding hoists (winding systems) in small gemstone mines (Design)*
- MDG 42.2 *Person riding hoists in gem mines (maintenance).*

Note: Person riding hoists means a winding system used in an underground mine, that is a small gemstone mine, where the winding system lifts no more than 40 metres from the surface of the small gemstone mine to the underground workings and carries no more than two people.

1.3. References

Refer to the Appendix for a list of Australian and International Standards noted in this series

Note: All Standards referred to in this series relate to the 2019 revision of the Standard, as amended from time-to-time.

2. Work health and safety management

2.1. Work health and safety legislative framework

The *Work Health and Safety Act 2011* and Work Health and Safety Regulation 2017 apply to all workplaces in NSW, including mines and petroleum sites. They impose a general obligation to ensure the work health and safety (WHS) of people at work through a process of identifying hazards, assessing risks and eliminating or controlling risks.

The *Work Health and Safety (Mines and Petroleum Sites) Act 2013* and the Work Health and Safety (Mines and Petroleum Sites) Regulation 2014 apply to all mines and petroleum sites in NSW. These support the WHS Act and WHS Regulation and provide additional provisions for WHS issues unique to mines and petroleum sites.

2.1.1. NSW code of practice: Mine shafts and winding systems

The NSW code of practice: *Mine shafts and winding systems* (February 2019) (the code) provides guidance for mine operators in developing and implementing a principal hazard management plan (PHMP) for PWS, as required under the WHS laws. The PHMP provides the means by which the mine operator will manage any risks associated with PWS.

The code may also be used by other duty holders such as contractors and businesses involved in the various stages of a PWS lifecycle including design, manufacture, installation, commissioning, operation, maintenance and decommissioning.

Refer to the code for further information about the requirements in relation to:

- **duties** relating to PWS
    - a person conducting a business or undertaking (PCBU) with the management or control of the PWS (this includes the mine operator)
    - designers, manufacturers, importers and suppliers of PWS.
- **management of risks** associated with PWS
    - hazard identification
    - assessment of risks
    - specific risk control measures including but not limited to:
      ropes and devices (slack rope, rope slip, unsafe balance rope conditions, unsafe

coiling of rope), overwind, braking systems, warning systems, signalling and communication, devices for attaching ropes to conveyances, testing and monitoring, isolation and energy dissipation, inspections, testing and discard criteria for ropes and shaft conveyances

  - maintenance of control measures
  - review of control measures.
- **principal hazard management plan (PHMP)** for PWS
  - content of the PHMP
  - consultation
  - interaction of PHMP with principal control plans (mechanical and electrical).
- **registration of PWS**
  - design registration

Note: The gazetted design order specifying design standards for winding systems (other than exempt hoists) is available on the NSW Resources Regulator's website.

  - item registration.
- **life cycle management**
  - design
  - manufacture
  - installation
  - commissioning
  - operation
  - testing and maintenance
  - documentation – **plant safety file.**
- **monitoring**
  - inspections

   - assessments.
- **performance standards and audit**
- **functional safety management.**

2.1.2. Five-yearly safety audits

A safety audit on the PWS must be carried out a maximum of five-yearly intervals from the date of the design registration notice.

Note: This is a condition placed on the design registration in accordance with section 271 of the WHS Act.

The safety audit must:

- be carried out by an independent person(s) with competence in winding system design and safety integrity assessments of winding systems, and
- confirm the winding system remains in compliance with the registered plant design, and
- confirm safety aspects of the winding system are being adequately maintained and are in a safe condition.

Any recommendations resulting from the safety audit must be complied with in the timeframe specified by the independent competent person(s) who conducted the safety audit.

Refer to **Appendix B** for items that should be covered in the five-yearly safety audit.

3. Design

3.1. Design documentation

The designer must outline all the design-dependent requirements to ensure safe outcomes over the life of the PWS. This documentation must be provided and must include, as a minimum, the following:

- The functional specification of the PWS.
- Functional safety evaluations and analysis.
- Operational, inspection, testing and maintenance requirements necessary to ensure safe outcomes.
- Relevant technical standards.
- Design risk assessment identifying the design risk controls necessary to ensure the safe use of the PWS (see clause 3.2 '*Design risk assessment*').
- Training and competency standards.
- A detailed description of the PWS including the following:
  - purpose and description of use
  - make and model
  - manufacturer
  - installed power and ratings
  - breaking strength of ropes
  - description of braking system
  - description of control system
  - designed, winding loads and speeds for both personnel and materials.
  - a functional specification on the controls of the PWS including all design controls, their limits and set points.
  - identification of each component that constitutes the PWS

- any other information pertinent to the safe operation of the PWS.

- representational documents of the PWS including:
  - general arrangement drawings
  - winding plant and conveyance drawings
  - drawings or identification of the wire rope and associated attachments
  - all hydraulic and pneumatic control system drawings
  - electrical schematics
  - any other drawings or documents as required to clearly identify the PWS including foundations and headframe.

Note: Refer to clause 5.7 of the code for information about the design documentation that should be kept in the plant safety file.

3.2. Design risk assessment

A design risk assessment must be carried out to assess all risks to the safety of people from the intended lifecycle requirements of the PWS. The design risk assessment must recognise the design intention and any lifecycle management controls necessary to maintain this design intent. These design intentions must be nominated in the form that nominates the relevant risks and controls using the hierarchy of controls.

The design risk assessment should be reviewed and an operational risk assessment carried out whenever alterations are carried out to the PWS or whenever a significant incident occurs.

Note: The design risk assessment should be in a form that systematically analyses the failure of all components of the PWS. For example, but not limited to, failure modes effect analysis (FMEA), fault tree analysis (FTA), event tree analysis (ETA), quantitative risk assessment (QRA) or similar (see IEC 31010).

3.3. Design safety audit

A design safety audit on the PWS must be carried out before the PWS begins operation. The safety audit must:

- be carried out by an independent person(s) with competence in winding system design and safety integrity assessments of winding systems, and
- validate that all the design-dependent requirements (detailed in clause 3.1 '*Design documentation*') have been provided and implemented.

Note: For shaft sinking winders, where design and construction takes place following shaft development, a design safety audit must be carried out before handover and operation by the end user.

3.4. General design requirements

PWS must be designed using good engineering principles and engineering standards to ensure the system is fit-for-purpose for the required duty.

Materials used in PWS must be appropriate for the intended application and the environment likely to be encountered in service.

All machinery and systems should comply with the relevant parts of the AS 4024.1 series of Standards.

Any fire suppression or protection equipment installed must meet requirements of relevant Australian Standards and legislation.

3.4.1. Australian standards

PWS must be designed in accordance with the design criteria contained in the following Standards (as amended from time to time) as is relevant to the type of PWS:

- AS 1554.1
- AS 3600
- AS 3637.1
- AS 3637.2
- AS 3637.3
- AS 3637.4

- AS 3637.5
- AS 3637.6
- AS 3751
- AS 3785.1
- AS 3785.2
- AS 3785.3
- AS/NZS 3785.4
- AS 3785.5
- AS/NZS 3785.6
- AS 3785.7
- AS/NZS 3785.8
- AS 3990
- AS 4100.

3.4.2. Ladders, stairs, platforms and walkways

The design of the PWS must include ladders, stairs, platforms and walkways to provide safe and convenient access to all parts and devices of the PWS that require inspection, examination and testing, adjustment cleaning or service. These components must comply with AS 1657.

3.4.3. Hydraulic fluid systems

Hydraulic fluid systems should be designed, manufactured and installed in accordance with ISO 4413.

3.4.4. Pneumatic fluid systems

Pneumatic fluid systems should be designed, manufactured and installed in accordance with ISO 4414 and consideration given to MDG 41 *Fluid power safety systems at mines*.

3.4.5. Steel structures

Steel structures must be:

- manufactured from materials specified in AS 3990 or AS 4100. Steels, which do not comply with AS 3990 or AS 4100, may be used when the mechanical properties, chemical composition and weldability (if applicable) are verified by test to be suitable for the application.
- assembled according to the designs and match markings specified on the detail drawings.
- plumb and bolted connections must be tightened to the specified torque for the size and type of bolt in the connection.

3.4.6. Welding

All welding and testing should be carried out in accordance with the following, as applicable:

- AS 1554.1
- AS 1554.4, or
- AS 1554.5.

3.4.7. Manual and automatic winders

3.4.7.1. General

PWS may be designated as either:

- manual (driven from the winder house by a winder driver), or
- automatic (press button operated like an automatic lift).

Winder houses must be provided with two paths of escape from any fire in the control room or winder room. Winder rooms must have adequate fire detection and suppression equipment including alarms located as required by AS 1670.1. and any relevant statutory bodies.

3.4.7.2. Manual winders

For manual winders, a driver control station is situated in the winder house. The driver responds to signals, and controls the winder as required. The driver controls normal service winding and braking with proportional control of the motor. Service braking is also controlled by the driver via a brake lever that proportionally controls the braking effort.

Control rooms must have adequate means of escape in the event of fire or incident.

3.4.7.3. Automatic winders

Most modern PWS operate fully automatically. The winder must be capable of being operated from the control conveyance permanently attached to the rope or from call stations. Call stations may be located in the winder house, and at the portal or inset for drifts or at the shaft top, plats and bottom loading stations.

There must be adequate means of escape from the winder room in the event of fire or incident. A minimum of two escape routes must be provided.

Winder rooms must have adequate fire equipment and alarms located as required by the outcomes from the risk management process.

3.5. Loads

3.5.1. Loads and powers

When designing components for the PWS, the winder loads must be established first. The method of determining the loads and torques will vary depending on the type of winder.

The designer must comply to the relevant Standards for design (refer Appendix A) for all components under load during operation, not limited to winding ropes, conveyances, attachments, brakes, winding drum, shaft and bearings, drive motors and gearboxes, headsheaves, structures and foundations.

3.5.2. Load and torque

Some loads, such as the material mass, or the skip/conveyance mass, remain constant. Other loads will vary depending on the depth of wind, deceleration rates, or acceleration rates. Frictional and windage forces must also be considered.

The PWS design must also take into account the shaft configuration requirements such as the depth of the shaft and the conveyance mass.

3.5.3. Load cycles

The decision on the winder capacity for production winding will depend on the mine's requirements and will normally be selected on the basis of a required 'tonnes per hour' of operating time. Once the tonnes per hour are calculated, the engineer can design the winder to output this quantity of product.

For personnel riding winding, the design of the winder will be governed by the number of personnel the winder will be required to transport, the size of the shaft and the time requirements for transportation. Personnel riding winders vary greatly in capacity, from just a few personnel to up to more than 100 in single or multideck cages.

For drift winding of personnel and/or materials, the size of the winder will be governed by the maximum materials load required to be transported to the drift bottom. The advantage and usual purpose of drift winding is to transport large machinery to underground seams without having to dismantle it. Winders can be designed to have an 'end of rope' capacity of from 40 to 100 plus tonnes. The drift winder is also designed to transport personnel to and from the surface. It is not unusual to transport up to 140 people at a time in rail mounted conveyances.

Winder duty cycles must be determined in all cases. The duty cycles will relate the speed and torque at specific stages of the wind, to time. This exercise must be carried out for all variations of the winding requirements including heavy and light loads.

3.6. System torque

The power and torque for all PWS can be developed from the following requirements. The torque must be able to:

- lift/lower the load at constant speed
- accelerate the load and system at a nominated acceleration rate
- decelerate the load and system at a nominated deceleration rate
- overcome frictional resistances including ropes guides, sheaves and shafts as applicable.

3.7. System inertia

3.7.1. General

Component and system inertia calculations must be provided by the designer to calculate acceleration and deceleration for the various loads of the PWS.

Inertia is the resistance of a body to being moved. Rotational inertia is the resistance of rotating bodies such as drums, gears, head sheaves to being accelerated or decelerated (braked). Rotational inertia, also known as the polar moment of inertia, J_m, has the dimensional units Kg m^2 and the general equation:

$$J_m = \Sigma\, m_j r_j^2$$

To accelerate the PWS, a portion of the supplied torque will be needed to overcome the components' resistance to movement.

The polar moments of inertia are related to the mass and shape of the moving parts. To calculate the inertia for a component, such as the winder drum, the component is broken down into smaller parts, or segments and the segment inertia calculated. The summation of the individual segments becomes the inertia for the component.

In PWS design, the inertia must be referred to the drum shaft in order to establish the torque at the driving shaft.

The values for the various shapes required to establish component inertia can be found in standard texts or *Machinery's Handbook*[1]. Some values will be taken directly from manufacturers' catalogues (such as for gearboxes, couplings, motors). The designer should ensure that the units being used are the same.

Components not directly associated with the drum axis should have the inertia referred to the drum shaft. Inertias of linear moving masses will have an equivalent inertia referred to the drum shaft.

Other methods providing an equivalent level of safety may be used for addressing inertia in the design of a PWS.

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[1] *Published by Industrial Press, Authors: Franklin D. Jones, Holbrook Horton, Henry H. Ryffel and Erik Oberg*

3.7.2. Winder drum shaft loads

Winder drum shaft loads include ropes, skips, cage, attachments and similar.

To convert linear inertia of shaft loads to rotational inertia seen by the drum:

Inertia at drum shaft = mass x drum radius^2

3.7.3. Head sheaves

inertia at drum shaft = head sheave inertia x ((drum dia)/(sheave dia))^2

3.7.4. Motor armature

inertia at drum = motor inertia x gear ratio^2

3.7.5. Gearbox

Gearbox inertia is normally given by the gearbox manufacturer as the inertia at the input shaft.

inertia at drum shaft = inertia gearbox (input) x gear ratio^2

3.8. Accelerating and decelerating torque

3.8.1. General

Having calculated or otherwise obtained the system inertia at the drum shaft, the following formula must be used to find the torque required to overcome the rotational inertias:

$T = J_m\alpha$

where:
- T is torque in Nm
- J_m is rotational inertia in Kg.m^2
- α is angular acceleration in radians/second^2

Where the required acceleration for the winder is given at the conveyance in units of metres/second^2, the units must be converted to angular acceleration or deceleration at the drum rope PCD.

$$\alpha\ (\text{Radians/sec}^2) = \frac{\text{linear acceleration x 2 (metres/sec}^2)}{\text{rope PCD}}$$

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3.8.2. Static torque

Static torque is that torque required to hold the load stationary at a nominated depth, ignoring frictional resistances.

3.8.3. For vertical shafts

$$T = \frac{\text{mass (Kg)} \times 9.81}{1000} \times \text{drum radius (m)}$$

where T is torque in kN.m.

3.8.4. For inclined shafts (drifts)

$$T = \frac{\text{mass (in Kg)} \times 9.81}{1000} \times \text{Sin(gradient angle)} \times \text{drum radius (in m)}$$

where T is torque in kN.m.

3.8.5. Accelerating and decelerating torque - calculations

The torque required at the drum shaft to accelerate or decelerate the PWS will be the summation of the various torques created by inertias, frictional resistances, and static torques.

Total torque = static torque + inertial torque + torque from friction

To keep calculations conservative regarding braking requirements of winders, frictional resistances should be ignored, because frictional resistances vary and therefore cannot be relied upon.

Example 1: Calculate torque to accelerate system

A vertical shaft winder has components with the following calculated moments of inertia and masses. Find the system inertia and the torque required to accelerate the system when the conveyance is at the bottom on the shaft. Assume a gearbox ratio of 40.16:1 and a maximum acceleration rate of 1.5 m/s^2.

Component	Component Inertia Kg m^2	Component Mass Kg	Inertia to Drum Shaft Kg m^2	
Drum	10017.5			= 10017.5
Drum shaft	1.6			= 1.6
LS coupling	9.3			= 9.3
Gearbox	0.15		0.15 x 40.16^2	= 241.92
HS coupling	3.5		3.5 x 40.16^2	= 5644.89
HS brake	5.2		5.2 x 40.16^2	= 8386.7
Motor	35.0		35 x 40.16^2	= 56449
Headsheave	2500.0		2500 x (2520/2000)^2	= 3969
Cage		4200	2278 x (2.52/2)^2	= 3616.6
Rope		2278	4200 x (2.52/2)^2	= 6667.9
Payload		1760	1760 x (2.52/2)^2	= 2794.17
			$J = \Sigma mk^2$ = 97789.6 Kg m^2	

Angular acceleration at drum	=	$\frac{\text{linear acceleration x 2}}{\text{Drum diameter}}$
	=	$\frac{1.5 \text{ x } 2}{2.52}$
	=	1.1905 Radians/second^2
Additional torque to accelerate	=	$J\,\alpha$
	=	97789.6 × 1.1905
	=	116429.2 Nm
	=	116.43 kNm
Static torque at shaft bottom	=	Static load x drum radius
	=	80.82 x 2.52/2
	=	101.84 kNm
Torque to overcome friction	=	Static torque x friction coeff.
	=	101.84 x .18
	=	18.33 kNm
∴ Total torque to accelerate	=	116.43 + 101.84 + 18.33
	=	236.6 kNm

3.9. Winder drums

3.9.1. Function

For drum winders, the purpose of the winder drum is to accommodate the winding rope, together with any excess or testing lengths. It also provides a secure anchor for the rope and allows the rope to scroll correctly on the drum.

For friction winders (also known as Koepe winders), the winder drum is a driving sheave that accommodates driving elements, wedged and bolted to the periphery to drive the winding rope(s) by frictional force from contact with the driving elements. Both conveyances, or conveyance and counterweight, are connected to the same rope, which pass over the drive sheave in a groove of friction material. The friction winder may be ground-mounted adjacent to the headgear or in a tower over the shaft.

3.9.2. General construction of winder drums

Winder drums are often fabricated using rolled steel plates. Such drums have flexible end connections while older-type drum constructions use rigid end connections (with much stiffening).

Fabricated drums are normally in mild steel plate. Plates must be certified by the manufacturer as free from laminations and inclusions. Any inclusions present at the time of rolling are likely to become laminations during rolling, and the plate could be rejected after much of the work has been done.

Before any machining commences, the fabricated drum should be stress relieved and all major welds ultrasonically proved.

The brake disc material should be suitable for the purpose and should be in accordance with the disc calliper supplier recommendation. Typically, Grade 350 steel has been used. Other steels of equivalent or greater hardness may be used, depending on the brake forces and thermal requirements of the braking system.

Give special attention to the shell-to-endplate connection and the method used for welding. The connection must be flexible enough to avoid weld cracking.

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

A harmonic analysis should be carried out to ensure that fundamental vibrations do not coincide with the rope/drum crossover frequency.

Note: Many winders in operation in NSW have exceeded their expected design and operating life. Particular maintenance and monitoring detail should be carried out to ensure crack mitigation and migration does not occur.

3.9.3. Design method for drums

An acceptable and equivalent stress analysis method, such as the Atkinson and Taylor method, must be used to calculate drum design stresses.

Note: The Atkinson and Taylor method is not applicable to friction (Koepe) winder driving sheaves.

Where finite element analysis (FEA) software is used, additional verification and detail in the modelling must be applied using the process detailed in Appendix C Finite element analysis.

Alternate designs must be supported with supportive calculations that show the maximum stress and fatigue values as being acceptable.

Stress values must be calculated and assessed with referenced authoritative data and standards. This includes both calculative and derivations where FEA analysis is used.

For Grade 250 steel:

- a maximum shell compressive stress of 150 MPa must not be exceeded
- bending stresses in the shell must not exceed 40 MPa, and bending stresses in the end plates 60 MPa.

Note: Where a stress concentration occurs (e.g. high stress areas surrounding bolt holes and welds and high frequency reverse bending occurs), other fatigue-related, stress limitations may apply. Guidance on allowable stresses adjacent to welds is available in various Standards, including:

- AS 3990
- AS 4100
- BS 7608.

3.9.4. Rope flanges

Note: This clause does not apply to driving sheaves on friction (Koepe) winders.

The rope flange height should be a minimum of the fully wound rope depth plus two-and-a-half (2.5) full rope diameters. This is to ensure that, should two coils pile up on the drum flange, they will not run off the flange. Associated stress values in the final flange arrangement must be shown as acceptable.

3.9.5. Winding drum construction

Note: This clause does not apply to driving sheaves on friction (Koepe) winders.

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

3.9.5.1. Drum-to-rope ratio

The correct drum-to-rope ratio (D/d Ratio) will depend on the rope speed, winding loads and duty, wire tensile strength and rope construction. For rope speeds (v) up to six metres/second, a minimum D/d ratio of 80:1 is a good guide for typical winding drums using triangular or flattened strand ropes. As combinations of these duties increase, so too, will the selection to higher drum diameters to rope diameters. For locked coil rope, a D/d ratio of 100:1 should be used.

Alternatively, the following may be used:

- for stranded ropes:
  - $D/d \geq 56 + 4V$ where $V \leq 6$
  - $D/d \geq 80$ where $V \geq 6$; and
- for locked coil ropes $D/d \geq 100$.

Note: The lower the D/d ratio, the lower the rope life achieved. Final design ratio, together with the rope specifications, must be supported with confirmation from the rope manufacturer that the specific design regarding loads, speeds and cycles of use are acceptable.

3.9.5.2. Fleet angle

The correct fleet angle from the winding drum to the head sheave should be maintained. See clause 3.9.7 '*Rope fleet angles*'.

Note: The fleet angle is the angle formed between 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.

3.9.5.3. Grooving

For permanent drum winders, the drum shell must be grooved to suit the rope, unless designed and used for low frequency use, e.g. emergency winder. For winders with a single rope layer, spiral or parallel grooving may be used. For multiple layers, parallel grooving with one or two cross-over sections must be used. Harmonic analysis must be used to decide whether symmetrical or asymmetrical cross-overs are needed.

The following guidance may be used:

- for winding speed <2 m/sec **AND** frequency of use <1000 hrs per year, plain drums are acceptable
- for winding speed between 2m/sec and 6m/sec **OR** frequency of use >1000 hours per year, parallel grooving is acceptable
- for winding speed >6.0 m/sec, 'Lebus' or similar grooving is acceptable.

Parallel rope grooves should have a:

- nominal pitch spacing of Nominal Rope Diameter + 5% to 8%
- nominal groove radius of Nominal Radius of Rope + 5% to 10%
- groove depth of 30% to 31% of the rope diameter.

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

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

3.9.6. Rope overcoiling protection for drum winders

Drum winders must include an over-coil protection system to prevent excessive layers of rope developing following from potential miscoiling.

Note: For shaft sinking and emergency winders, an overcoiling protection system must be provided on the winding drum in the event of the rope miscoiling on the drum. Where the system may not be effective as a result of many lays of rope operating on the drum, additional controls must be provided to manage the foreseeable risks of miscoiling.

Figure 1 Rope over coiling device

Figure 2 Older spoked, stiff winder drum design

Figure 3 Flexible fabricated drum design

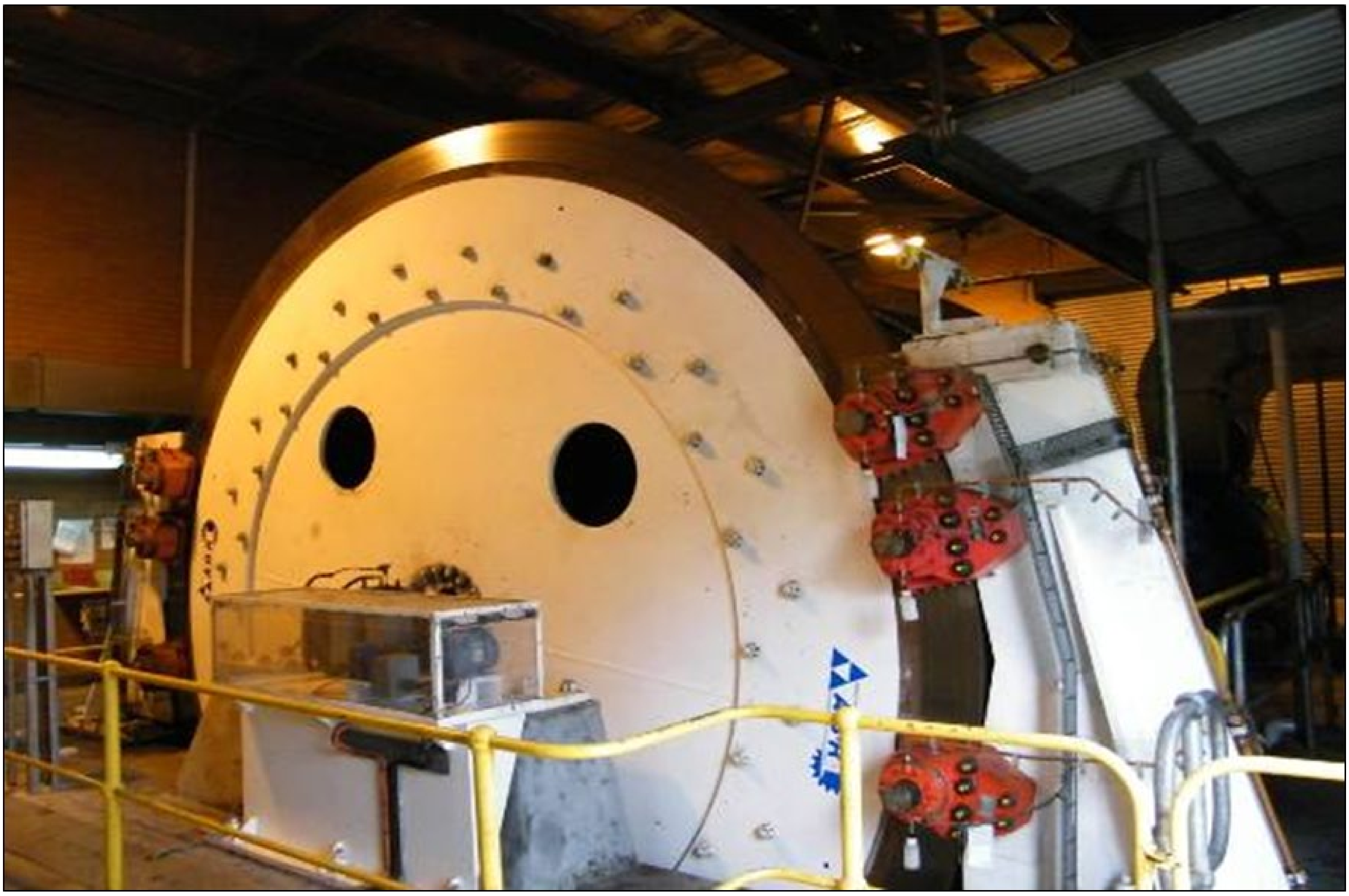
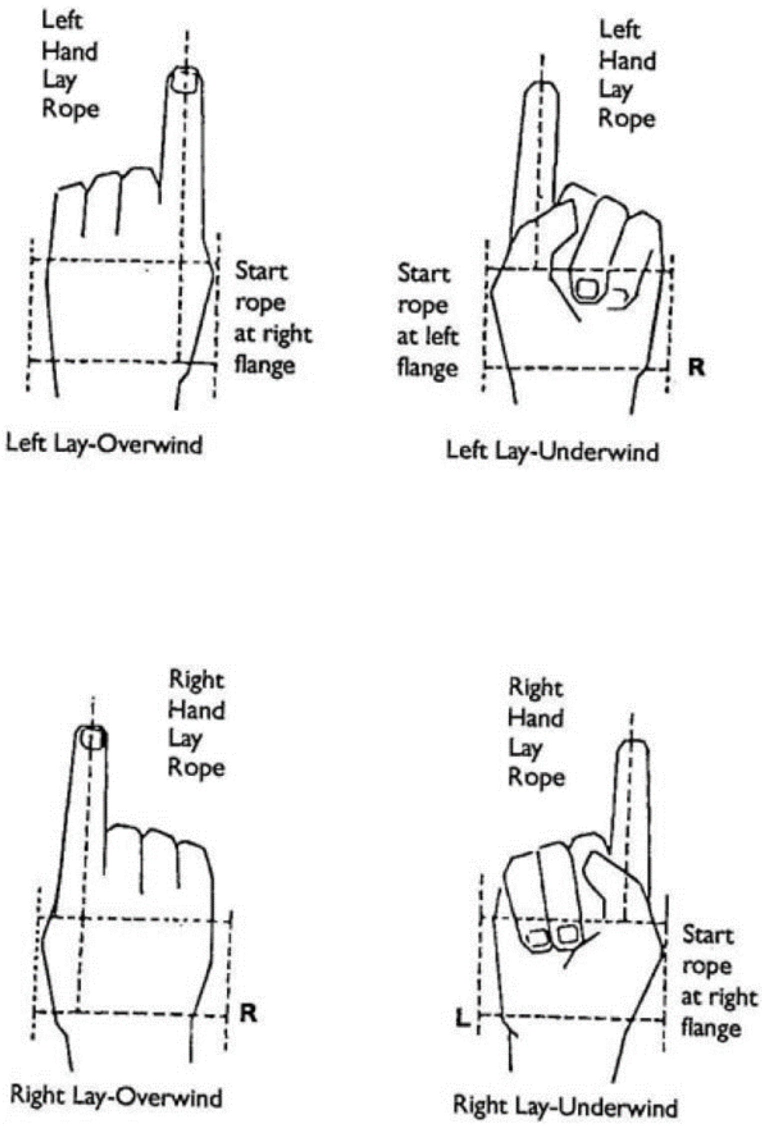


Figure 4 Method of determining direction of coiling



3.9.7. Rope fleet angles

Note: This clause does not apply to driving sheaves on friction (Koepe) winders.

The width of the drum between the rope flanges will be governed by the required fleet angle to give correct scrolling of the rope away from the drum flange. Excessive fleet angle results in abrasion of the rope and of the rope grooves. Insufficient angle may lead to the rope over-coiling against the rope flanges.

For grooved drums and triangular or flattened strand or non-spin ropes, the fleet angle must not exceed 2.0 degrees. An angle of 1.5 degrees is a good working angle.

For ungrooved drums, the maximum fleet angle must be 1.5 degrees.

In the case of locked coil ropes, the fleet angle should not exceed 1 degree 20 minutes (1.33 degrees).

3.9.8. Brake disc attachment to drum

The brake disc path may be welded or bolted to the drum. Both methods are successfully used.

The static design capacity must be shown to provide the design rope break load (rope break load × 1.2).

3.9.9. Rope attachment to drum

When attaching the winding rope to the winder drum, a minimum of three complete dead coils must be retained on the drum at all times.

The winder rope must be anchored to the winder drum with a suitable clamping device or system. The factor of safety of the clamping device or system must be not less than the rope factor of safety.

Note: Rope factors of safety are covered in Part 4 *Ropes* of this series.

Spare rope stored on the drum must not be considered as reducing the load on the anchorage.

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

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

3.9.10. Hawse holes

Note: This clause does not apply to driving sheaves on friction (Koepe) winding drums.

Hawse holes must be designed so that the rope enters the drum without sharp turns. Corners and sharp edges must be removed to avoid damage to the rope by nicking or crushing.

The rope is passed from the rope anchorage position, usually inside the drum endplate, to the first coil through a hole formed in the drum shell and known as the hawse hole. It is important that the correct position and side of the drum be determined for the hawse hole.

Where the centre of the sheave falls to one side of the drum rather than on the centreline of it, the hawse hole on that side should be used, irrespective of what hand of lay the rope is.

The arrangement should be such that the number of unused turns of rope on the drum is sufficient to cause the live turns of rope to always be on the side of the drum beyond the sheave centreline with respect to the hawse hole in use.

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3.9.11. Wedges and risers

Note: This clause does not apply to friction (Koepe) winders.

To avoid abrasion of the rope on its first turn, a steel rope wedge must be fitted against the flange in front of the hawse hole. When the rope fills the first layer and starts to return on the second layer, the rope will be lifted. At this point, severe crushing can occur. To prevent this, a steel riser must be fitted to the flange and drum shell to lift the rope.

Wedges and risers should be approximately 20 rope diameters long.

3.9.12. Rope vibrations

Note: This clause does not apply to friction (Koepe) winder driving sheaves.

Transverse vibrations or oscillation of the rope between the headsheave and the drum is a problem sometimes encountered on drum winders when operating with multi-layers of rope. These oscillations may occur during some part of the winding cycle. These oscillations should be checked in the design stage, since they are difficult to overcome once the winder is in place.

The frequency of the fundamental vibrations may be measured from:

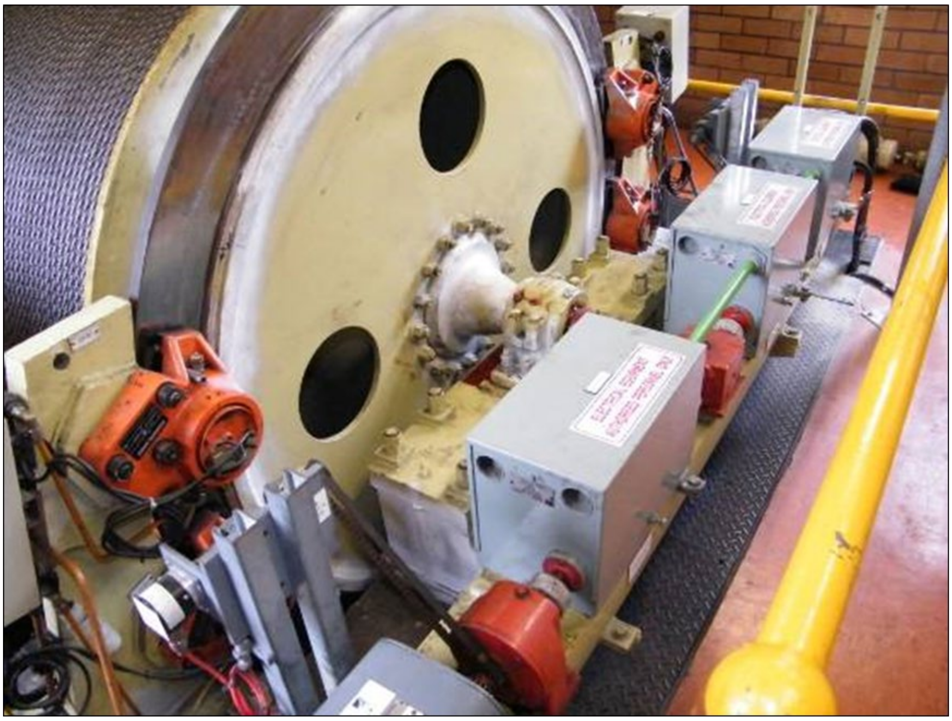
$$\omega = \frac{1}{2Lc} \times \frac{\sqrt{F}}{\sqrt{m}}$$

Where	ω	=	fundamental frequency in cycles/sec
	Lc	=	distance from headsheave to drum in metres
	F	=	tension in rope in kN
	m	=	mass per unit length of rope in kilograms/metre

Ensure that the impulses from the turn cross-over on the drum do not coincide with the fundamental frequency of the rope. Second and third harmonics should also be checked where higher rope speeds are being used.

Figure 5 Drum shaft attachment – keyed arrangement

Figure 6 Drum shaft attachment - Bolted arrangement



3.10. Shaft design

Shafts for winder drums must be designed in accordance with AS 1403.

The maximum acceleration or braking loads must be used.

In shaft design, torque, bending moments, and axial loads, and any combination of loads must be examined. All loads must be considered, including normal working, accelerating, braking, heavy materials, erection, and special heavy lift loads.

3.10.1. Fatigue

A fatigue reserve factor of not less than 1.6 must be used when designing the shaft.

The shaft material should be 1040 or 1045 grade steel. This provides an economical shaft with good fatigue and machining properties. Steels having higher tensile properties may be used, however, unless designing for strength, there is little economic or engineering gain.

The shaft must be designed on the maximum peak loads calculated from acceleration and braking loads, as defined by AS 1403. Consideration must be given to using a cumulative fatigue damage calculation to determine the effects of a small number of heavy loads on the fatigue life of the shaft.

Shafts must be checked for deflections to confirm that bearing selection is within deflection tolerances. High speed shafts must be designed to ensure vibrations are kept within limits.

3.10.2. Strength

Check shafts for strength. The winder shaft must resist the breaking force of the rope plus 20% without permanent deformation.

3.10.3. Bearings

Bearing selection must be shown to service and provide for the calculated loads.

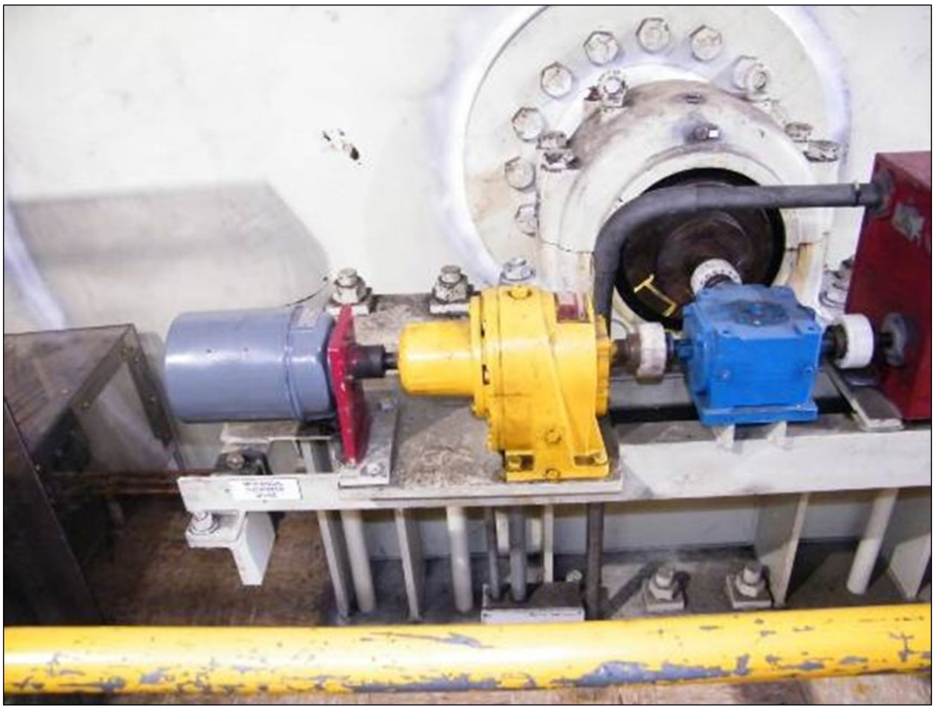
Calculate bearing life based on the life of the winder using a safety factor that ensures overall system reliability.

Bearing housings, housing caps and housing hold down bolts must provide minimum capacities for rope break strength plus 20% without failure.

Housing bolts and caps must be specified and shown applied.

Figure 7 Coupling end shaft connection for 80 tonne drift haulage

Figure 8 Non-coupling end of drum shaft for 80 tonne drift haulage



3.10.4. Shaft drum connection

Bolted connections should be used to connect shafts to drums.

If keys are used, they must be shown to comply for both fatigue and strength. Keys fitted to winder shafts must be a tight side fit to avoid fretting caused by any inertial movements of masses.

3.11. Gears, gearboxes and couplings

Using gears and/or gearboxes in the winder drive system is a common method of speed reduction/torque increase for the winder drum. Some large winder designs, however, eliminate the gearbox or gears and couple the motor armature directly to the drum shaft. Technological advances also allow the armature to be built inside the drum.

Braking paths must not rely on transfer of their application torque via gears, gearboxes and couplings.

The designer and manufacturer recommendations for such components must consider failure mode and factors of safety within those additional components. These have generally lower factors of safety and may be acting as single line safety critical braking systems.

Emergency stop conditions exposing inertial forces both to and from the gearbox and drive components may cause overloading.

Peripheral speeds may cause excessive heat and brake capacity limitations.

Gearboxes and related connections to the winder drum shaft should have the same design criteria applied as the winder drive shaft.

Designers and manufacturers should provide maintenance recommendations for the winder drive system to the mine operator. The mine operator should consider these recommendations.

Continuous monitoring for excessive temperature and vibration should also be provided for all rotating elements in the drive system. This includes shaft bearings, gearboxes, motors, drive sheaves etc.

3.11.1. Selection of gearboxes

Ratings of gearboxes for use with drum winders must be based on both fatigue and strength.

The fatigue and strength ratings selected for gearboxes or gears must be based on both the cumulative fatigue damage analysis that takes into account all load cycles, including any heavy lift, abnormal load conditions such as emergency braking and power loss, and maximum peak loads due to acceleration or braking.

The service factor for:

- durability for winder gears and gearboxes must be a minimum of 1.5.
- strength for winder gears and gearboxes must be a minimum of 1.75.

Where modern dynamic design models are used, service factors for strength and for durability should be shown to provide equal to or better than the conventional values detailed above.

Select a service life of 40 years as a minimum for winder gears and gearboxes.

Give special consideration to the thermal rating of hardened and ground gearboxes. Where possible, gearboxes should be sized to avoid using external cooling systems.

Gearboxes that effectively form part of the drum main shaft must be capable of withstanding the 120% rope break case and any repeated moment or offset operational loading.

3.11.2. Gearbox monitoring

Real time gearbox monitoring is recommended for automatic winders. Sensors should be used to monitor:

- high lubricating oil temperature
- low lubricating oil level
- high bearing temperature
- vibration.

3.11.3. Bull gears and pinions

When bull gears and pinions are used as the final reduction drive gears, service factors for:

- fatigue must be 1.5 minimum

- strength must be a minimum of 1.75.

Gears and pinions must be adequately sealed to prevent lubrication splash and contamination of brake discs.

Shaft sections of the gear pinions must have sufficient strength to resist rope break plus 20% without failure.

Bearing housings, caps and bolts must resist rope break load plus 20% without failure.

3.11.4. Gearboxes with manual change ratios

Manual change ratios within winder drive gearboxes must not be used.

3.11.5. Duty cycles determine winder drive requirements

The winder duty serves to determine driveline specifications, in turn to detail motor and driveline including gearbox.

Example 2 - Selection of gearbox for specified winder duty

Calculate the values for the torque-speed-time duty cycle for a single drum winder winding to a seam depth of 400 metres with a load of 20 people. Assume 40 cycles per day for a 7 day per week operation over a period of 40 years. Assume an acceleration and deceleration rate of 1.5 metres/second^2 and a maximum speed of 4 metres/sec. The conveyance will creep out of and into the fixed guides at 1 metre/second for a distance of 5 metres.

Values for each section of the cycle will be calculated and presented in a table as follows (see over page):

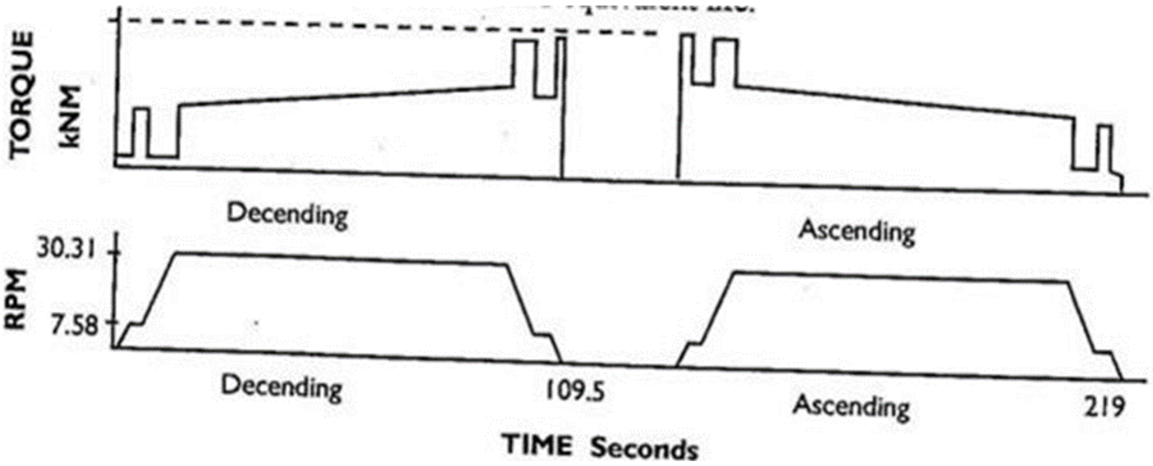
	Drum RPM	Time (Sec)	Distance (m)	Torque (kNm)	Total Hours
Descending					
Section 1	0	0		41.75	
Acceleration	7.58	0.667	0.33	41.72	108.20
Section 2	7.58			93.04	
Const. Speed	7.58	5.667	5.33	93.38	811.12
Section 3	7.58			41.38	
Acceleration	30.31	7.667	10.33	41.04	324.45
Section 4	30.31			93.72	
Const. Speed	30.31	101.835	389.67	119.46	15276.28
Section 5	30.31			235.89	
Deceleration	7.58	103.835	394.67	236.23	324.45
Section 6	7.58			119.80	
Const. Speed	7.58	108.835	399.67	120.14	811.12
Section 7	7.58			236.56	
Deceleration	0	109.502	400.00	236.60	108.20
Ascending					
Section 8	0	0		236.60	
Acceleration	7.58		0.35	236.56	108.20
Section 9	7.58			120.14	
Const. Speed	7.58	5.667	5.33	119.79	811.12
Section 10	7.58			236.23	
Acceleration	30.31	7.667	10.33	235.89	324.45
Section 11	30.31			119.46	
Const. Speed	30.31	101.835	389.67	93.72	15276.28
Section 12	30.31			41.04	
Deceleration	7.58	103.835	394.67	41.38	324.45
Section 13	7.58			93.38	
Const. Speed	7.58	108.835	399.67	93.04	811.12
Section 14	7.58			41.72	
Deceleration	0	109.502	400.00	41.75	108.20
		Σ = 219 Sec			Σ = 35527 Hrs

Total hours @ 40 cycles/day for 40 years $= \dfrac{40 \times 219 \times 40 \times 365}{3600}$

= 35527 hours (continuous life)

The duty cycle for the winder may be presented with the torque-speed-time graphs taken from the previous table. Selection of the gearbox can now be based on a cumulative fatigue damage calculation. For a commercial gearbox, the gearbox rating is normally given with a life rating of 20000 hours with a service factor of 1. An equivalent torque rating can be obtained from for 20000 hours equivalent life.

Figure 1 Torque and speed duty



Equivalent life design torque and speed analysis component reference: Selection of gearbox

Data for cumulative fatigue analysis

Step no	Total time (hours)	Speed in (RPM)	Speed out (RPM)	Torque in (kNm)	Torque out (kNm)
1	108.2	0	7.58	41.75	41.725
2	811.12	7.58	7.58	93.04	93.38
3	324.45	7.58	30.31	41.38	41.04
4	15276.28	30.31	30.31	93.72	119.46
5	324.45	30.31	7.58	235.89	236.23
6	811.12	7.58	7.58	119.8	120.14
7	108.2	7.58	0	236.56	236.6
8	108.2	0	7.58	236.6	236.56
9	811.12	7.58	7.58	120.14	119.79
10	324.45	7.58	30.31	236.23	235.89
11	15276.28	30.31	30.31	119.46	93.72
12	324.45	30.31	7.58	41.04	41.38
13	811.12	7.58	7.58	93.38	93.04
14	108.2	7.58	0	41.72	41.75

S-N slope index P for component material 3.5

Analysis output

Design torque	=	129.307 kNm
Design speed	=	30.31 RPM
Design hours	=	20000
Design KW	=	410.397

(Cumulative fatigue calculation courtesy **MECH-PAK**™ software)

Gearbox rating	Durability	=	410.4 x 1.5
		=	615.6 kW with service factor 1.5
	Strength	=	410.4 x 1.75
		=	718.2 kW with service factor 1.75
	Peak torque	=	236.6 x 2
		=	473.2 kNm with safety factor 2

3.12. Rope attachments

3.12.1. General

When selecting the attachments, expert guidance should be sought from a reputable, competent and specialised manufacturer.

Attachments must be designed in accordance with the relevant parts of AS 3637 and AS 3751.

Note: (1) For shaft sinking and emergency winders, due to the work and physical environment where kibble chains must be often manually removed, these attachments may not fully comply with AS 3637 and AS 3751. In this case, alternate equivalent design controls for safe use must be provided.

(2) The type of rope attachments such as wedge capels, thimbles and rope sockets inclusive with the arresting and crash/catching systems proposed by the designer must be risk assessed and shown to provide safe outcome under all operating conditions.

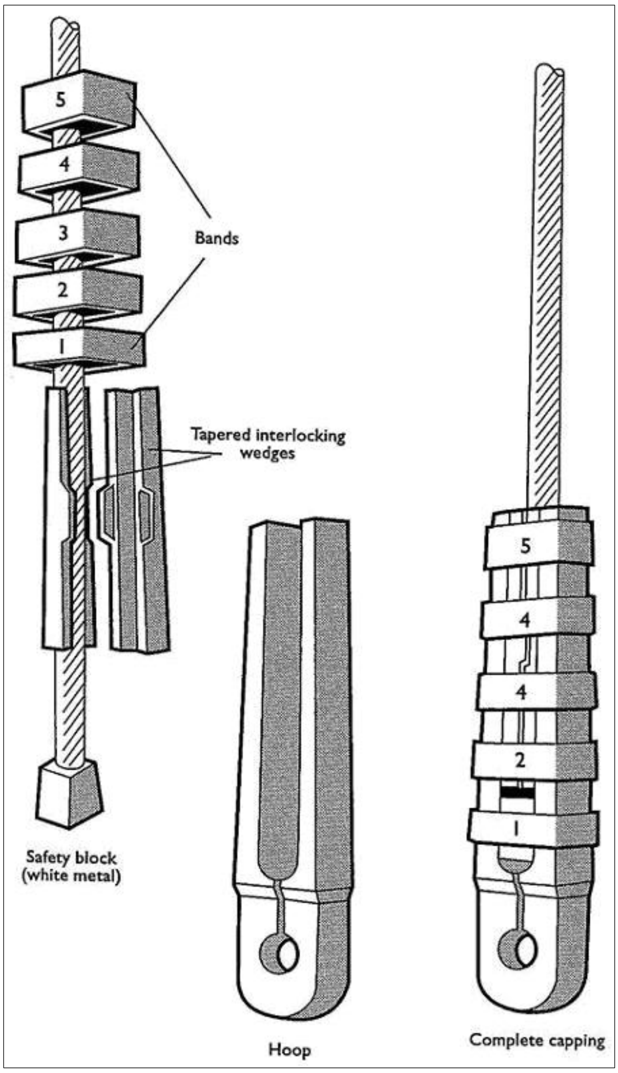
(3) Detaching hooks must not be used on friction (Koepe) winders.

3.12.2. Wedge-type capels

Wedge-type capels, rope sockets and thimble type capels are commonly used for attaching the rope to the conveyance or guide weights used in vertical shafts (refer to Figure 10 below).

Wedge-type capels have an advantage to provide a means for monitoring deterioration and slippage etc. during their service life.

Figure 2 Wedge type rope capel

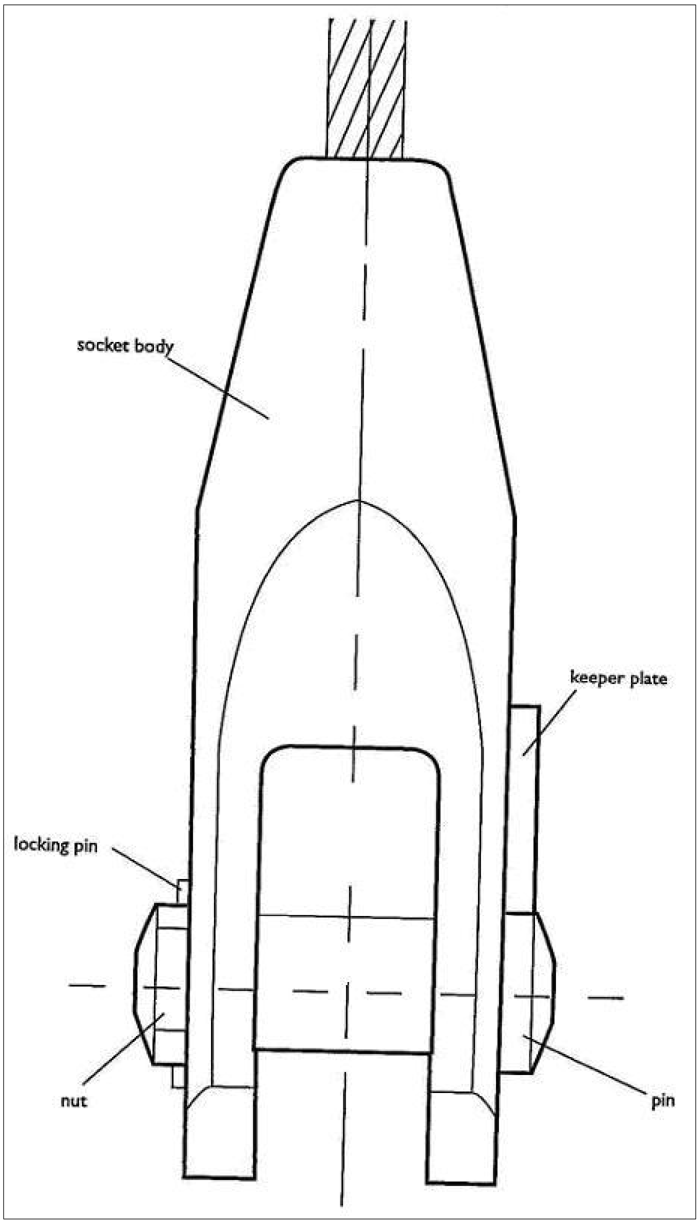


3.12.3. Rope sockets

Rope sockets may be used to attach the conveyance to the rope.

Traditionally, fluted plug and tail, white metal and approved resin-filled-type rope sockets have been used for attaching the rope to the attachments. The use of epoxy resin type fillers may be used provided the system complies with AS 3637.3.

Figure 3 White metal or resin filled rope socket



3.12.4. Rope attachment suspension arrangement

Typical arrangements of rope attachment suspension systems are shown in Figures 14 - 18.

Rope attachments include the cross links and various clevis arrangements attaching to the structure of the conveyance.

Suspension arrangements should include the ability to easily adjust individual rope lengths. There are various design arrangements to do this including both coarse and finer adjusting links.

Pin-type, coarse adjusting linkage (see Figure 12) and compensating chaseblocks are the most common types of coarse adjustment, while threaded components can provide additional fine tension adjustments (see Figure 13).

It is important that head rope tensions on multi-rope installations for friction winders have the design and maintenance capability to provide equal tension to all ropes. This allows not only for extended rope and drum liner life, but also reduces the net torque imbalance back onto the conveyances. This imbalance has been shown to provide rotation forces on conveyances that can lead to reduced operating clearances in the shaft.

Figure 4 Pin-type, coarse adjusting linkage

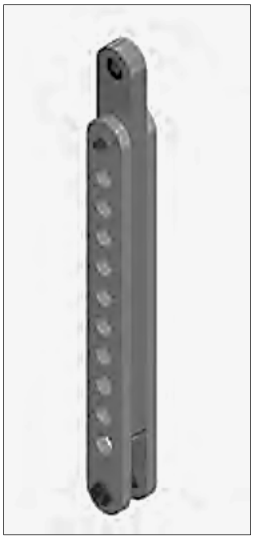


Figure 13 Multi-rope fine tension adjustment attachment set

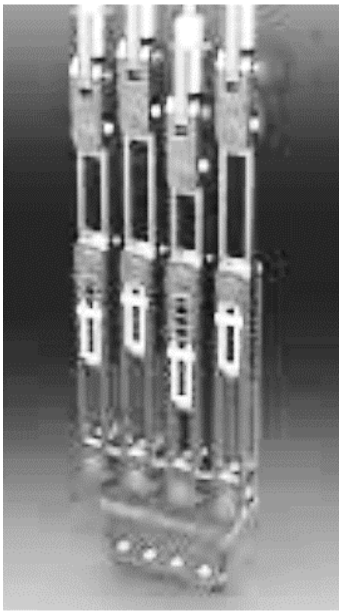
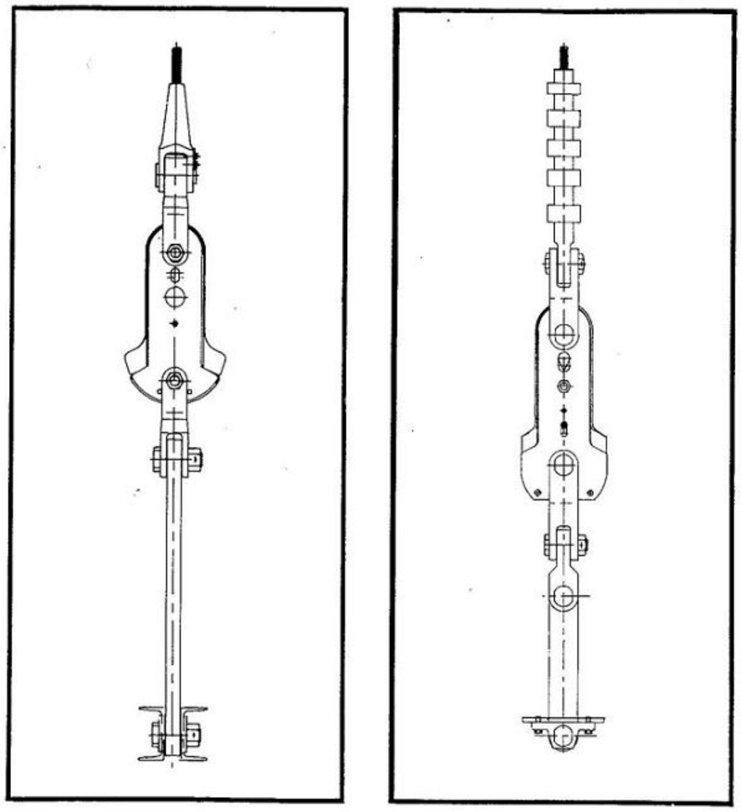


Figure 5 Examples of single rope suspension systems

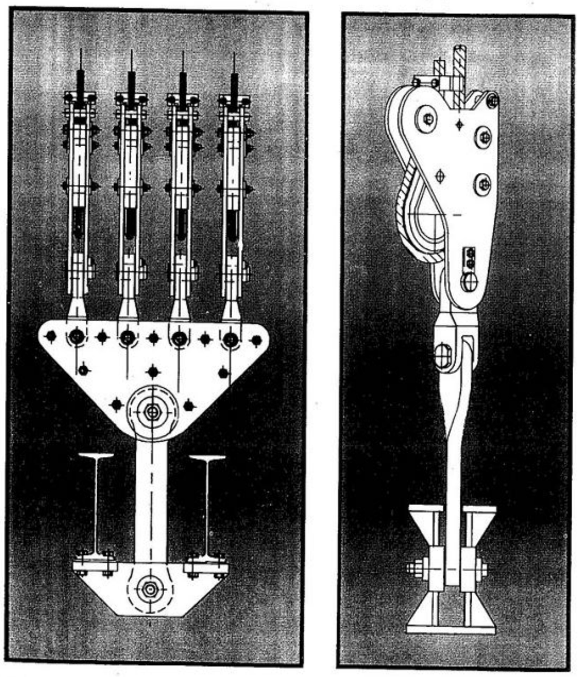


Head Rope Suspension arrangement consisting of Inserted Cone and Tail Socket, Humble Type Detaching Hook, Drawbar and Transom Support.

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

Figure 6 Thimble-type attachments on a conveyance

Figure 7 Examples of multi-rope suspension systems



A four rope suspension system showing the thimble capel connection to an equalizing 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.

3.12.5. Lubrication

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

Particular attention and effective control should be given to areas of the rope and attachments where additional corrosion is expected. These areas include, but are not limited to:

- areas, including the rope and attachments, susceptible to the gravitational effects of moisture and water
- static areas of the rope that are untested and often not monitored via the regular maintenance inspections
- areas of the rope and attachments that are often difficult to access.

Guide and tail ropes should be regularly lubricated. The type of lubricant should be investigated and the results of the life and wear conditions of the rope, environmental conditions etc. should be recorded for ongoing improvement.

Particular attention should be paid to excess lubricant around brake paths and local environment where excess rope lubricant or grease may present additional risk.

There are some special purpose lubricants for friction winder head ropes. These should not have regular grades of rope lubricant applied because of the reduction of friction around the drum and subsequent potential rope slip. Other ropes should be regularly lubricated to extend their life. Lubrication will limit both internal and external corrosion and wear and maintain higher rope strength value.

3.12.6. Non-destructive testing

Non-destructive testing on attachments should be carried out in accordance with the AS 3637 and 3751 series of Standards.

Any attachments, including detaching gear, sockets, capels, couplings and other attachment components should be thoroughly stripped and examined, in conjunction with the NATA test authority or manufacturer, following any incident that results from such components becoming loaded in their otherwise unloaded state. Such incidents include overwind and underwind situations. A formal report outlining cause, effect and prevention strategies should accompany such incidents.

3.13. Brakes

Note: Under clause 47(1)(c) of the WHS(MPS) Regulation, every PWS used or that may be put into use at an underground mine (other than an opal mine) must include at least two braking (or equivalent) systems that ensure the winder remains under control in the event of a failure in any one of the systems. Braking systems that conform to the requirements of AS 4730.2 section 3 *Essential safety outcomes* using a minimum of two independent brake channels and two independent brake paths and can demonstrate compliance to the braking requirements of TRG: PWS Part 1: General Requirements are deemed to meet the equivalence requirements of clause 47(1)(c) of the WHS(MPS) Regulation.

3.13.1. General

Note: Refer to clause 4.8 '*Brake testing and examinations'* for requirements in relation to brake testing and examinations.

The design principle to be applied to all PWS is such that the mechanical brakes must be the ultimate means of retarding the PWS. The objective is that this principle should apply even in the event of the failure of any one component.

Lifecycle management of winder braking control and systems used to transport people and equipment is critical to ensure the high energies involved are controlled and managed to achieve safe outcomes when called upon.

Most new drum winders use disc brake calipers in single or multiple units acting on a brake disc, which is attached directly to the drum by a bolted or welded connection. Older winders have various configurations of braking paths, posts, and brake components. In all cases the brake must apply a braking torque to the drum, and hence the rope, to stop the conveyance and PWS in a controlled manner within the requirements of this guide.

Under all circumstances, deceleration in power loss situations while under the control of brakes is to be shown acceptable for both equipment and people.

Design information must provide and show expected fatigue life with the nominated air gaps between element and disc is acceptable.

Braking systems with multiple braking paths direct on the drum may be controlled with channel logic and hydraulic proportioning control to achieve the required deceleration.

Brakes must act in both directions.

Winder drive systems must be designed to allow the brakes to be easily and accurately tested and recorded.

The braking system comprising the brake components must fail to safety.

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

Any single-line components must be identified and have the necessary controls to manage their safety provided by the designer.

The braking system must be designed so there are no common cause or mode failures between the braking paths.

A common cause failure is where two or more portions of the system fail at the same time from a single common cause. A common mode failure is where two components or portions of the system fail in the same way, at the same time.

The two braking paths must be arranged so that they contain no common single-line components.

All critical connecting pins must be secured using split pins or fastening systems. Grub screws must not be used.

3.13.2. Braking paths

The braking system must be comprised of two independent braking paths applying directly to the winding drum that are both capable of providing 200% maximum static out-of-balance capacity.

There must be two braking paths applied directly to the winding drum for all PWS.

A single brake disc, with associated brake elements, represents a single braking path. There must be no singular or common fault on either braking path that prevents the winder from stopping safely under all possible conditions. For further guidance refer to AS 4730.2.

One disc with a brake element per side is not considered to provide for a braking system (the system must provide for two braking paths).

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

Irrespective of this, all mechanical braking paths should not contain any single-line components.

The failure of any brake component within a braking path must not provide an unsafe condition or exposure to hazards to any people.

Each braking path must be designed (and should be adjusted and maintained) to safely stop and hold the conveyance under all conditions of loading, direction of travel and speed and emergency stop.

Note: A braking path installed on the high speed shaft, does not satisfy the requirement for two braking paths being directly installed on the drum.

3.13.3. Double drum winder brakes

Where a double drum winder is used, and people are to be transported at any time in the conveyance attached to one drum when the other drum is de-clutched, the drum for winding the personnel conveyance must have two independent mechanical braking paths attached directly to it.

Any singular drum in a double drum winding arrangement that is used only for materials must have at least one braking path attached directly to it.

3.13.3.1. Drum de-clutching

Where the drums of a double drum winder are clutched, each braking path must be capable of providing 200% of the maximum out-of-balance load when used for personnel riding. With the drums stationary and loads balanced, each braking path must be capable of holding the maximum torque that may be applied in either direction by the winding motor. In the declutched condition, each drum brake should continue to be capable of stopping and holding at least 200% of the personnel riding out-of-balance torque.

The maximum out-of-balance torque applied to each braking path must be stated and shown acceptable by the designer.

The 200% maximum personnel riding and maximum material out of balance torque capable of being applied to each braking path must be nominated, such that the capacities of each braking path can be routinely tested. These tests should be carried out weekly or otherwise specified by the designer.

Exceptions to this must be nominated and shown acceptable and safe for people under all operating conditions by the designer.

At all times, maximum personnel riding loads must be provided with at least 200% static brake capacity on each braking path.

The braking paths on all double drum winders must be capable of testing each individual braking path prior to the clutch being withdrawn.

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

3.13.4. Parking and emergency braking

PWS mechanical braking systems must perform two prime functions:

- **park braking:** must hold the load safely when the wind is completed, or when power is disconnected for servicing or standing.

- **emergency braking:** must be designed to bring the winder to a stop from an overspeed in the shortest practicable time without causing injury to personnel. It must be activated when:
  - the controls malfunction or control is lost
  - power is lost
  - an emergency stop is instigated by a person
  - a protective device signals an operating fault.

The braking system should be designed with a margin of safety that allows for possible deterioration of performance.

Note: Modern PWS almost exclusively use electrical motor control for service braking. Service braking involves the retarding or the restraining of the speed of the PWS as required by the operator or by the automatic controls.

3.13.5. Brake operation

Mechanical brakes must automatically apply on:

- power failure
- overspeed on ramp control
- overspeed of haulage drum
- overspeed of conveyance
- overwind through limits
- reduced head, tail or other conveyance rope tension that may indicate incorrect and potentially unsafe conveyance travel condition
- rope overcoiling on drum (excluding Koepe)
- conveyance dump brake pressure loss (drift application)
- derailment of conveyance (drift application)
- lost motion on gear drive train
- loss of system pressure in the brake control system
- high level drum pit flood alarm

- emergency stop buttons at any station
- initiation by a normal control stop by driver or the control system.
- failure to detect 'brakes off'
- braking path over temperature (automatic winders)
- other safety functions designed to stop the winder in the event of an unexpected movement or operating condition.

The brake control system must be designed to ensure that, in the event of a control failure or malfunction, the brake system will fail to safety.

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

To maximise safe transport of personnel, consideration should be provided regarding alarms and stop conditions (completion or wind or otherwise) required for defects as follows:

- brake wear indications
- faulty or stuck valve indication
- low hydraulic oil levels
- low system and brake pressures
- earth leakage alarm
- high temperature alarms including fire alarms
- low level drum pit flood alarm.

Any pit required to house the winding drum and braking path must 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.

Winder and braking foundations should be constructed in a way that prevents environmental exposure and degradation of components.

3.13.6. Brake performance

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

The brake application time, from initiation of the emergency stop signal to the initiation of the brakes applying on the drum must be less than one second. Brake application times with the worst case stop distances, (including load and speed conditions), under emergency control, present no risk to or equipment.

Calculated stop times must be demonstrated and proven as specified by the designer to ensure reliable service life. Critical areas such as end of travel for conveyances must be shown acceptable with test protocols provided for ongoing safety checks.

The brakes must not overheat or fade during an emergency stop under worse case highest load conditions.

The brakes must be able to retard to rest at least twice in succession, the worst case load conditions that would compromise safe operation. This may include the descending conveyance, approaching the lower limits of travel, carrying full rated load, and travelling at the maximum speed permitted by the overspeed device. Worst case conditions are to be provided and used for the brake testing.

The application of brakes should not cause slack rope or problems associated with loss of tension in the ropes. Calculations for worse case in both directions of travel must be shown by the designer to be acceptable.

The minimum and maximum air gap values that provide for the required compliant brake capacity must be specified by the designer. Hardware provisions must be provided that prevent use of the winder in the event the air gap varies outside these parameters.

The total braking torque applied by the braking system must ensure there is no multiplication of brake effort that could cause damage or injury.

3.13.6.1. Brake capacity and calculations

3.13.6.1.1. Documentation

The brake torque calculations must be supported by technical literature on the frictional and thermal properties of the brake lining material being used.

Operating speeds must be shown considered in braking calculations.

Brake capacity calculations must be provided for all PWS. These calculations must include:

- capacity as a percentage of maximum static load applied for both personnel and materials
- deceleration rates under maximum and minimum load cases to show compliance to this guide

- deceleration times, specifying maximum range values resultant from most adverse conditions including personnel riding
- stopping distances specifying maximum range values resultant from most adverse conditions including personnel riding
- thermal efficiencies including static and dynamic values with respect to the winding speeds
- brake components factors of safety
- methods for recording brake test results.

The following documentation must be retained in the plant safety file and available for design registration purposes:

- brake control circuit specifications and drawings
- brake arrangement and type
- brake friction material and characteristics for both static and dynamic conditions during operation
- methods for recording brake test results.

3.13.6.1.2. Static design capacity

Each braking path should be designed to achieve a minimum static capacity of 200% of the maximum static torque generated as a function of the suspended loads (net torque) as applied to the winding drum.

Where a braking path is not able to achieve 200% net braking torque, the designer must document how this braking path will achieve effective braking during all foreseeable load conditions, including overload, during successive winding cycles, over the full lifecycle of the PWS. These considerations must be shown to take into account the secondary braking path being failed.

At all times, for personnel riding loads, or exposures to hazards to people are presented, each braking path must achieve a minimum 200% static net torque braking capacity.

Where theoretical design capacities of braking system are less than 200% for material related loads only, then assessment including decelerating conditions and stopping distances with maximum load conditions is required to be shown to be safe for each singular braking path including related channels.

If one mechanical braking path fails, the other must be designed to retard and stop the PWS safely in all operating conditions. In the case where two conveyances operate in a friction winder, the descending conveyance also, in worse case load condition, must be stopped safely and without collision.

Each single braking path must have design calculations to support safe stopping for both equipment and persons from the overspeed condition or power loss situation. Analysis showing heat absorption/generation and acceptable dynamic friction values for the braking elements under these conditions must be provided in the design calculations.

3.13.6.1.3. Brake deceleration rates

When considering the application of braking effort, the protection of personnel being transported is a prime concern. For emergency braking, the deceleration rate must not be greater than 0.5g ($4.9 m/s^2$) and not less than $1.0 m/s^2$. Deviations must be shown safe under all operating and emergency conditions.

Note: Where single drum winders with ascending conveyances are subject to an emergency stop, deceleration rates of higher than $5.0 m/s^2$ may be recorded due to the action of gravity alone without any braking effort at all. The designer must demonstrate that the PWS can be brought safely to rest under these conditions.

When PWS are used to transport both personnel and heavy loads, brakes must be designed to maintain deceleration rates within the minimum to maximum load range.

Note: 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 where decelerations are limited to $5 m/s^2$. At low speeds (less than 2.5 m/s) individuals can withstand higher decelerations. Necessary restraint systems should be employed to minimise injury to personnel.

3.13.6.1.4. Drift brake– retardation and stopping

Note: This clause is only applicable to drift winders.

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

If the surface of the drum is retarded at greater than $g*\sin\alpha$ in a shaft inclined at α to the horizontal, the ascending conveyance will over-run the rope and the rope can become kinked or broken.

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.

3.13.6.1.5. Brake – multiple testing requirements

The brakes must 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.

3.13.7. Factor of safety for brake components

Single line components should not be used for brake linkages.

Any brake component on any braking path, which if it fails may present a potentially unsafe situation to persons, must have a minimum factor of safety of 10 based on worse maximum applied load case. This includes post design and mounting bolt or foundation bolt design. In all cases, multiple mounting bolts should be used. Screwed threads require a minimum factor of safety of 15 applied on the root diameter of the thread.

The failure of any one component within the braking system must not affect the ability of the braking system to perform the braking functions and be capable to bring the conveyance to a safe stop under worse case conditions.

The design specification must demonstrate this through calculation and appropriate risk assessment of the braking system.

Braking system components must be selected and located to minimise and control hazards including those resulting in deterioration by heat, corrosion, wear and contamination.

The static design factor for critical components must be:

- for components other than axially loaded threaded components, not less than 10
- for axially loaded threaded components, not less than 15, and
- for pins in combined bending and shear, not less than 10.

The fatigue reserve factor for critical components must be not less than 1.3 for infinite fatigue life.

The allowable design stresses in non-critical components must comply with AS 3990 or AS 4100, or other applicable standards where other materials have been used.

Any material used in non-critical components must be deemed to be suitable, provided the material can be demonstrated to have the strength and serviceability required for the application. The strength and fatigue capacity of structural elements supporting mechanical components must be able to withstand the design’s static and dynamic loads arising from the operation of the brakes for the design service life of the winder. Deflection limits for functionality of the braking system must be taken into account in the design of the structural supporting elements.

Note: The deflection limit requirements of AS 4100 may be inappropriate for this application.

3.13.8. Brake linings

Static and dynamic friction factors for the brake linings must be provided and shown to meet the operating and design criteria for the PWS.

Linings fitted to brake shoes must be of asbestos free material and should have a static coefficient of friction within the range of 0.30 to 0.43.

Thermal and peripheral speed limitations for the friction values are to be provided by the supplier and shown acceptable during braking application.

Note: Each braking path must be shown to provide the necessary safe deceleration rates under the design overspeed values.

Calculations are required that show with the maximum brake forces applied on a singular braking path, the PWS will safely stop with two consecutive normal stops and one emergency overspeed stop. The calculations must consider heat accumulation, application forces and peripheral speeds during the stopping period.

These calculations will be provided with supportive evidence from the lining supplier that the necessary friction values are provided to achieve the required deceleration rates.

Linings must be a type shown acceptable under the operating and design conditions of the braking system.

Braking element wear should be monitored including shutdown provisions when there may be insufficient braking torque as a result of such wear. A 10% safety margin is required.

Brake lift monitoring should be provided to prevent winder operation in the event that elements have not lifted during required operation.

Fastening bolts relating elements, callipers, mounts and stands must be used in groups such there is no point of single line component failure within the attachment. Factors of safety for such groups should exceed 10.

3.13.9. Brake discs

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

Discs that are bolted to the drum may be split into segments to assist mounting and reduce heat distortion problems. Split discs should be keyed at the joint to maintain surface accuracy.

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

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

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

Note: A braking path installed on the high speed shaft, does not satisfy requirement for two braking paths being directly installed on the drum.

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

Brake disc design should ensure that heating or expansion of the disc caused by brake applications does not reduce the braking capacity.

3.13.10. Brake control system

Brake controls for all PWS types must comply with *TRG: Powered winding systems* – Part 5: Control systems.

The brake control system is designed to provide a system to monitor and control the mechanical braking system to ensure it operates as required.

Hydraulic control systems for the brake may be incorporated into an integrated drive control unit.

The brake control system must be designed to ensure that, in the event of a control failure or malfunction, the system will fail to safety with the braking system being applied.

To maximise safe transport of personnel, consideration must be given to alarms and stop conditions (completion or wind or otherwise) required to monitor for defects as follows:

- brake wear indications
- faulty or stuck valve indication
- low hydraulic oil levels

- low system and brake pressures
- earth leakage alarm
- high hydraulic oil temperature alarms
- fire monitoring and alarms associated with the brakes
- low level drum pit flood alarm.

3.13.11. Brake safety indicators

Brake engines or cylinders that may be used in post caliper arrangements must 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. Electronic devices should be used in conjunction with the visual indicators to provide alarm, run and stop conditions for the PWS.

Brake calipers must be fitted with indicating and alarm devices to detect brake lift, pad wear and brake pad lift failure. These devices must be incorporated into the alarm, run and stop conditions for the winder.

3.13.12. Braking path contamination

Braking system failures, shown by the static brake tests failures are typically caused by brake element contamination. Early recognition and prevention is the only way to prevent such failure before the winder brakes become ineffective.

Braking paths must be protected from contamination of any product or material including:

- debris
- water
- hydraulic fluid leaks
- solvents
- airborne contaminants such as moisture, coal and motor brush wear materials etc.

Protection is required to ensure the frictional braking capacity between the brake drum and the braking elements is maintained as the design requires. This contamination can occur rapidly or accumulate slowly.

If a hydraulic unit is used to control the braking system, it should be located and constructed so as to avoid contaminating the braking paths in the event a spillage, leakage, burst pipe, or oil spray occurs. Oil spray from any hydraulic leak on any one braking path must not be able to contaminate a braking path.

All hydraulic lines and connection points should be shielded to provide maximum protection to the braking path and disc from contamination in the event of a component failure.

The braking path and disc must be protected from contamination if flooding or water ingress is at all possible. Natural drainage systems should be utilised where possible, otherwise the pit should be fitted with an automatic pump-out system.

Alarms and shutdown systems must be installed to indicate if flooding has occurred that may affect the braking system. The PWS must be stopped prior to braking path contamination. If any braking path (disc) is in a pit that could flood, then the second braking path should not be in that same pit.

Winder and braking foundations should be constructed in a way that prevents environmental exposure and degradation of components.

Where climatic conditions are likely or shown to cause condensation on the braking path and subsequent loss of braking capacity, provision must be made to prevent such contamination. Changes to the operating environment including insulation, heating, fans etc. should be considered.

3.13.13. Hydraulic power units

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

3.13.13.1. Power unit design

The hydraulic brake unit must include:

- duplicated main control valves including actuation to brake actuators
- duplicated exhaust lines from control valves to reservoir for brake actuators
- faulty control valve operation alarm
- low level hydraulic fluid alarm
- low oil pressure alarm
- high oil temperature alarm

- full flow filters of a size to ensure contaminates do not lead to seizure of valves and back pressure monitoring
- monitoring the power supply and operation of the individual brake actuating solenoids
- other monitoring devices and systems to ensure the brakes have applied when required.

3.13.13.2. Use of spool valves

Spool type main control valves should not be used in the design of hydraulic power units. Hydraulic valves must be designed to minimise the potential for seizure.

3.13.13.3. Bunding the oil reservoir

The hydraulic unit should be designed to confine within the unit, any oil spill, leak, or spray, due to pipes, seals or joints rupturing. Any collecting tray or container used for this purpose should be easily removable or emptied appropriately. The hydraulic bund should be capable of holding at least 100% of the reservoir capacity. The design of the system should be to minimise any potential for any leakage or spray to contaminate a brake path, refer to clause 3.13.12 '*Braking path contamination*'.

3.13.13.4. Oil reservoir capacity

The oil reservoir should be large enough to allow the completion of a cycle after a low oil level alarm has been activated (refer to clause 3.13.13.8 '*Brake unit control circuit*').

3.13.13.5. Dual systems

Dual oil supply systems should allow either pump to be isolated for removal and servicing.

3.13.13.6. Control valve identification and locking

Flow valves or other application components must 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.

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.

3.13.13.7. Power pack and hydraulic adjustment security

To maintain security of the hydraulic unit, the control system should be designed to be enclosed in a lockable cabinet.

Only those authorised, trained and assessed should have access to be able to make the adjustments.

Consider advantages of transparent cabinets or doors that provide some visual indication regarding relevant safety inspections.

3.13.13.8. Brake unit control circuit

The brake control circuit should allow the winder to complete its cycle (return to ramp or docking position) but not commence a new cycle, where any of the following events occurs during a cycle:

- faulty or stuck valve indication
- low hydraulic oil level
- low hydraulic oil pressure
- high oil temperature.

3.13.14. Air control of brakes

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

3.13.15. Band brakes

Band brakes are unacceptable for winders and must not be used. This is due to their inability to dissipate heat during dynamic braking conditions.

3.14. Clutches

The normal method of changing levels for double drum winding is to de-clutch one drum and turn the de-clutched drum to relocate the conveyance to a different level. This is achieved with a toothed clutch. The clutch housing is attached to the winder drum. The clutch body slides on the shaft. When considering clutches associated with winders, this is the main purpose of the clutch; however other component areas such as gearbox clutches may also be required. The standard clutch design principles apply to all toothed clutches.

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3.14.1. Clutch design

The clutch must be designed to good engineering design principles. Winder clutches are normally designed using involute or straight splines. Where involute splines are used, the standard DP (Inch) or Module (Metric) system must be adopted.

3.14.1.1. Interlocking of clutches and brakes

Before the winder drums can be declutched, the drum brakes on the declutched drum must be interlocked in the engaged position.

3.14.1.2. Clutch factors of safety

If a winder drum clutch fails, the winder drum brake must be the means of arresting the conveyance. In this case, the respective drum brakes must be activated by the drum overspeed and broken shaft control system which must be independent of a clutch failure. Therefore, the factors of safety required for the clutch should be regarded as being the same as those required for the shaft, i.e. 1.3 on fatigue rating and a minimum of 2 on strength.

3.14.1.3. Commercial clutches

Where a commercial clutch unit is to be used, the clutch must use a service factor of 2.0 for vertical winders and 1.75 for drift winders. In all cases the strength of the clutch must be verified against the worst possible load.

Figure 8 A double drum shaft winder

Figure 9 Alternate view of a double drum shaft winder

3.15. Handrails, guards, ladders and stairways

3.15.1. General

During the design of a PWS, access and guarding should be considered and an engineering design undertaken. This should consider access for operation, inspection and maintenance throughout the lifecycle of the PWS. The ergonomics of the access system should be considered and should facilitate the correct method of carrying out inspection and maintenance tasks. Guarding is required to protect workers from hazards such as rotating or hot components, moving machinery and falls from heights.

The design of the ladders, stairs, platforms and walkways should comply with the relevant components of AS 1657.

Guarding should be designed in accordance with the AS 4024 safety of machinery series of standards.

3.15.2. Design principles

The following principles must be observed in the design of all guards and fences:

- Guards must be designed and positioned, so far as is reasonably practicable, to protect people from hazards.
- Guards must be designed to take into account the practical considerations that will arise in service.
- To maintain observation and ventilation, guards should be made of a mesh material, suitably protected at the edges. However, in some cases a solid guard may be preferable.
- Guards must be provided with sufficient joints or other features to facilitate initial installation and subsequent maintenance operations.
- Where practicable the design must enable safe lubrication without removing the guard. Where this is impracticable, arrangements must be made to ensure that lubrication can be achieved without danger (e.g. for the machinery to be stopped and isolated).
- Where it is necessary to carry out routine adjustments with machinery in motion, the design must allow for this without the need to remove the guard.
- Guards must be designed so that individual sections have adequate strength and stiffness for transporting and installing, and when in use are sufficiently robust to retain their shape and designed clearance from moving parts. This may be achieved either by using mesh or plate of

adequate inherent stiffness, or by using lighter mesh or plate with suitable additional stiffening.

- All metallic guards should be protected against corrosion to a standard appropriate for the application.
- Where sheet metal is used it must be a minimum thickness of 1.5mm.

3.16. Foundations

3.16.1. Foundations for winder design

Foundation design for winder drums, associated machinery, headframes and head sheave supports, and rope roller supports including crest and side guide or turnout roller support structures should be undertaken, and/or checked by a competent civil design engineer.

Design foundations for the winder house and headframes must be designed to the loading conditions specified in AS 3785.5 and to the rope break tension plus 20% of the rope break load.

A complete set of foundation calculations and drawings, certified by a person accredited to do so, must be provided in the plant safety file.

The foundation design must be carried out to the current relevant Australian Standard civil and structural codes, including those relating and referenced in AS 3600.

For all winders, foundation bolts must be capable of resisting all fatigue loading cycles, and must consider the maximum rope break condition plus 20% without failure.

For single rope winders, the foundations for drums and head sheaves must allow for the maximum rope break condition plus 20% without failure of either the concrete or steel support structure. For this condition failure means ‘no longer able to be used to support the winder working loads’.

3.16.2. Foundation bolts

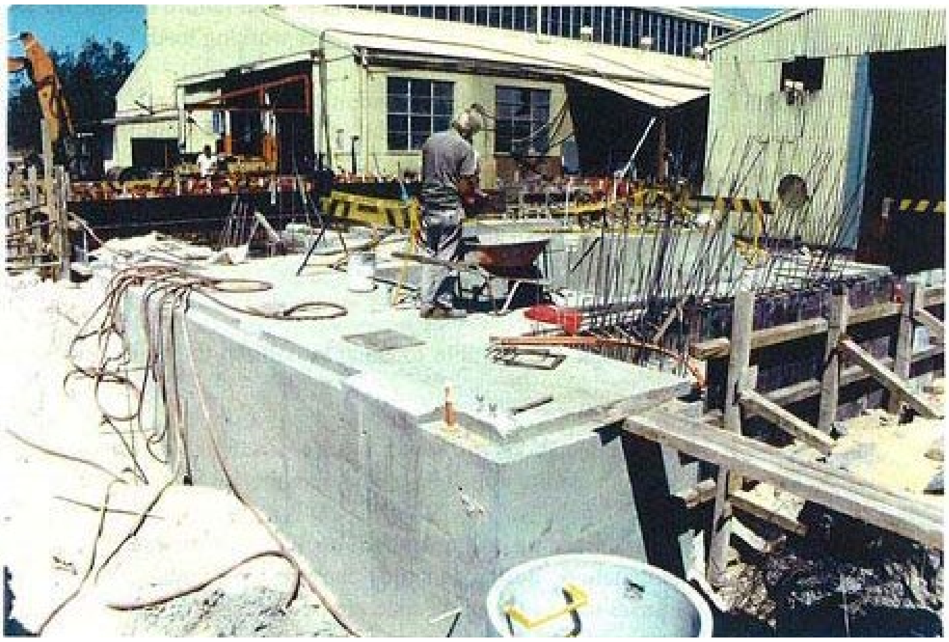
All foundations must use multiple foundation bolts to transmit loads to mass concrete.

Bolt calculations for both fatigue loadings and rope break or strength loadings must be included in the foundation calculations.

Bolt tightening torques must be included in the calculations. Foundation design should consider maximum bolt loadings transmitted to the mass concrete by bolt tightening to a maximum torque of 0.65 × proof stress of bolt material.

Figure 19 Winder foundations showing pit and footings

Figure 10 Winder foundations showing pit and footings



3.17. Headsheaves and deflection sheaves

Headsheaves, deflecting sheaves, shafts and bearings used for drum winders must comply with AS 3785.7.

3.17.1. Calculations

Appendix A of AS 3785.7 gives constructional proportions for rim sections for both plain rims and rims with inserts. Calculations should substantiate the use of these dimensions.

Design calculations must be provided for both fatigue and strength considerations. Strength calculations must assess the rope break condition and must evaluate the rope forces at rope break condition plus 20% without failure of any sheave assembly component. For this condition failure means 'no longer able to support the winder working loads'.

3.17.2. Headsheave support bolts and structure

Headsheave support bolts and the support structure design must encompass the fatigue loads and the rope breaking loads.

When calculating stresses in the sheave components, stresses must be based on the maximum worn condition for the headsheave rim.

3.17.3. Wheel diameter to rope ratio

Final design ratios, together with the rope specifications, are to be supported with confirmation from the rope manufacturer that the specific design regarding loads, speeds and cycles of use are acceptable.

In general, sheave wheel diameter to rope diameter ratio is the same as that required for the drum.

In the case of sheaves for vertical shaft drum winders, using triangular strand ropes, usual D/d ratios range from 70:1 to 100:1. Further guidance is given in respect to friction winders in *TRG: Powered winding systems – Part 3: Vertical shaft winders (drum, friction, shaft sinking and emergency winders).*

In drift winders where the angle of wrap is low, that is the lesser of:

- 15 degrees; or
- the angle subtended by 1 rope lay length in contact with the sheave

the wheel to rope diameter ratio may be as low as 50:1 for triangular or flattened strand ropes.

Figure 11 Older-style spoked headsheave

Figure 12 Fabricated and machined headsheave

Figure 13 Headsheave installation - shaft winder

Figure 14 Headsheave installation - drift winder

Figure 15 Headsheave installation - ground mounted friction winder

3.17.4. Sheave wheel materials

Materials for the wheel construction will depend on the type of manufacture. Sheave wheels may be cast in either steel or meehanite (or SG iron) or be fabricated from rolled steel and flat plate. Grey cast iron is not considered suitable for sheave wheels and must be avoided.

See AS 3785.7 for the testing of sheave materials.

The most appropriate material for sheave wheel shafts is grade 1040 or 1045 steel. Little economical or engineering advantage is gained by using higher tensile grades of steel.

3.17.5. Headsheave wheel construction

The headsheave wheel construction may vary with the type of duty required.

Flat plate construction consists of a profiled circular steel plate with the rope groove machined in the outer circumference. The wheel may be lightened to reduce inertia by profile cutting the web area to form spokes or lightening holes. Bosses are added to build up the hub to provide stability and reduce shaft stresses. Where welding processes are used, the sheave should be stress relieved. These sheaves are used for slow speed, non-production requirements such as stage winders.

Cycle spoke type headsheaves consist of a cast rim and hub with steel bars integrally cast into the hub and rim to form spokes. This type of wheel has been popular for production winding for many years due to its low inertia.

Cast meehanite or cast steel construction wheels may be either single piece or split halves which are machined, keyed and bolted together. Split type sheaves are used when large diameter sheave size becomes a transport problem.

Fabricated sheave wheels using a combination of a cast rim and hub and cold rolled steel section for the spokes are common.

3.17.6. Headsheave design

The design of headsheaves, shafts, and covers and bearings must comply with AS 3785.7.

The static design load must be the design rope break load (the rope break load × 1.2). This should include the effects of the fleet angle.

For static design the combined:

- stress should not exceed 0.9 × yield stress
- buckling stress should not exceed 0.9 times the Euler buckling stress for components in compression.

Limit shaft deflection to 1 in 2000 at the maximum working load.

For fatigue design, assess the effects of the fleet angle and groove misalignment, along with any dynamic or vibrational loadings.

Calculate the maximum allowable fatigue stress using a rational analysis method (e.g. Goodman diagram) and allowing a fatigue reserve factor of 1.3.

The bearing stress between the rope and the rim groove at the maximum working load should not be greater than 3.1 MPa. A general figure of 2 MPa is often used.

Headsheave assemblies should be designed such that one sheave is fixed to the common shaft and the other sheaves are provided with bearings to enable them to freely rotate at different speeds depending on their actual (worn down) groove diameters.

Rope guides must be used if there is likelihood of the rope becoming slack and unguided from the sheave groove.

3.18. Environmental design considerations

3.18.1. Oil spillage

Pits should be fitted with alarms to indicate flooding, and to stop the winder. Where drain pipes are fitted, the pipes should be duplicated to reduce the risk of fouling. If gravity drainage is unavailable the pit should be fitted with an automatic pump out systems.

Pumps should not pump pit water into the stormwater drainage system without adequate treatment.

3.18.2. Winder house

The winder house must provide protection from external sources of contamination that may affect the safe operation of the winder. Potential contamination sources include heavy rain, local flooding, condensation, dust, insects and vermin etc. Provision must be made to drain water away from any pit including any pits associated with the winding drum and brakes.

Where the winder is located in dusty or dirty environments, e.g. coal conveyors, consideration should be given to installing a ventilation system that pressurises the winder house with clean air.

Component parts of the PWS within the winder house should be separated or protected from potential sources of contamination such as hydraulic leaks.

Provision must be made for cable tray channels to be well drained.

Winder houses must have a security system which prevents unauthorised persons from entering without permission.

Transformers and other electrical equipment outside the winder house must be protected at all times to prevent access by unauthorised persons.

Winder and braking foundations must be designed and constructed in a way that prevents degradation of the foundations from environmental factors such as erosion.

3.18.3. Rope lubricant

Use trays or other means to gather and control rope lubricant spray or drips from ropes in use within the winding system. Treat any water runoff in the area before disposing in the storm water drainage system.

3.19. Design validation

3.19.1. Manufacture and factory testing to validate design

Manufacture and factory testing must include all manufacturing and factory tests necessary to satisfy compliance.

Where items are required to be subjected to testing, the manufacturer must advise the testing criteria, provide access for witnessing the test procedure, obtain a proof test certificate for the item and include the documentation in the Plant Safety File for use as required including for registration purposes.

3.19.2. Commissioning to validate design

Every new, relocated, upgraded or altered PWS must be subjected to thorough testing and commissioning including:

- all components comprising the PWS
- static and dynamic brake capacities and performance testing (refer to clause 4.8.1.2 *'Static and dynamic brake testing')*
- rope design and the necessary tests to satisfy compliance (refer to *TRG: Powered winding systems Part 4: Ropes)*
- winder control system design: testing of the control functions, safety functions, safety function settings, operating times of safety functions, over speed settings, and any other relevant tests (refer to *TRG: Powered winding systems Part 5: Control systems*).

The commissioning and testing procedures must be developed by the designer and must be prepared and assessed for adequacy by both the manufacturer and design verifier prior to commissioning.

The commissioning process must:

- validate the design and be confirmed by both the designer and design verifier
- validate the design drawings
- include and verify all inspections, examinations and testing of the installation necessary for safe use
- be verified by an independent competent person
- be carried out by competent people.

The designer and verifier must both sign off that the commissioning process is complete and to an acceptable standard prior to the PCBU handover.

3.19.2.1. Commissioning records

Commissioning and test records must be retained in the plant safety file (refer to clause 5.7 of the code).

Test records must define all testing and record the results of such testing of safety equipment, safety equipment settings, brake settings and performance, conveyance stopping distances, deceleration rates, test loads and certification, and any other tests relevant to the PWS, or as required by the appropriate Standards and guidelines.

4. Operation, maintenance and testing

4.1. General

When designing a PWS, all aspects of the lifecycle of the plant must be considered. Inspection and maintenance considerations should extend to extended frequency tasks, not only frequent inspections and maintenance. This should include considering major component replacement and decommissioning.

In conjunction with the supplier, the owner/operator of the PWS should document the procedures and standards applicable to the operation and maintenance of the PWS in the principal hazard management plan (PHMP). The requirements of a PHMP are detailed in the code.

A change management process should be utilised when any changes are made to the PWS, the operating parameters or the operating environment.

4.2. Operational risk assessment

Users of PWS should carry out an operational risk assessment(s) to identify all hazards, assess the risks arising from those hazards and implement appropriate risk controls from the use of the PWS. This operational risk assessment should be carried out before the PWS is used on a mine site. The WHS(MPS) Regulation and the code detail specific requirements related to risk management.

4.3. Users of powered winding systems

The following matters should be considered regarding the use of a PWS:

- the PWS is used in accordance with its intended operational envelope (rated speeds, loadings, accelerations etc. specified by the designer) and the designer’s recommendations
- the PWS is not operated unless the operator receives adequate information and training
- the PWS is only used for the purpose for which it was designed
- a change management process is in place to manage any changes
- safety features are used as intended by the designer of the PWS
- people do not work in the immediate area of remotely or automatically energised parts of the PWS without appropriate controls and systems of work in place
- measures are provided to prevent unauthorised alterations or use of PWS

- PWS are subject to appropriate checks, tests and inspections necessary for safety
- the PWS is withdrawn from operation if there is an immediate risk to safety, and
- only competent people make adjustments.

4.4. Competencies

The PHMP, in conjunction with the supplier, should address the minimum acceptable competencies for particular types of work. Such competencies should be:

- for workers operating the PWS
- for workers conducting inspection and maintenance tasks. The frequency of reassessment should also be identified and implemented in the mine's management systems.
- be re-assessed at regular intervals.

4.5. Operation procedures

Mines should have written procedures in place to manage the operations involved in the transport of personnel and materials using PWS.

Operating procedures relating to risks associated with use of the PWS should be developed and implemented and should include:

- appointment of drivers
- inspections of the system
- carriage of personnel
- carriage of materials
- securing of loads
- haulage capacity limits
- speed restrictions for loads
- persons working in the drift
- emergency response involving the PWS.

These operational procedures should make reference to job instructions, standard operating procedures and recording sheets that define the details relating to individual processes.

4.6. Documented procedures

Where a detailed written instruction is required to manage the tasks and associated risks involved with performing a specific job, a documented procedure should be developed.

These procedures are job specific and provide step-by-step instructions to enable a trained and competent person to perform a specified task.

Suitable detail should be provided in the standard operating procedure or can be referenced in supporting documents.

4.7. Maintenance

An appropriate maintenance, inspection and testing system must be developed and implemented to ensure the PWS is fit for purpose and without risks to health and safety when properly used. Section 5.6 of the code details matters that should be included for maintenance and Appendix E of the code provides information regarding the maintenance of components deemed to impact on functional safety.

When developing the maintenance strategy for a PWS, the following should be considered:

- using a structured approach incorporating good engineering practice (such as FMEA)
- recommendations of the designer
- site based operational and environmental conditions
- site or company history with similar plant
- use of specialists related to the PWS such as rope suppliers and functional safety professionals.

The following matters regarding repair and maintenance of the PWS should be considered:

- necessary facilities, equipment, tooling and systems of work are provided and maintained
- inspections, maintenance and cleaning is carried out in accordance with designer and manufacturer recommendations or otherwise developed by a competent person
- all safety features and warning devices on the PWS are tested and maintained
- competent people assess any damage to the PWS

- repair, inspection and testing is carried out by a competent person
- repairs keep the PWS within its design limits
- if access to the PWS is required, the PWS is stopped and appropriate isolation methods or other control measures are used.
- sufficient commissioning tests are carried out following replacement or repair of critical components such as brakes, drive system, ropes, and ropes attachments
- non-destructive testing of the PWS components is carried out annually or as deemed by the designer or standards requirements with respect to the cycles of operation.
- testing is carried out by a competent person.

4.8. Brake testing and examinations

4.8.1. Testing – general

For every PWS, the following testing and examination should be undertaken to a predetermine schedule:

- Brake performance testing (refer clause 4.8.1.1 '*Brake performance testing*').
- Brake capacity testing (static and dynamic) (refer clause 4.8.1.2 *'Static and dynamic brake testing').*

Note: Brake performance testing and brake capacity testing must also be carried out as part of the commissioning process in order to validate the design.

- Examination and non-destructive testing of critical brake components (refer clause 4.8.1.5 *'Examination and testing of critical brake components'*).

The above testing and examinations should be recorded in the plant safety file. Brake test results must be shown to meet the minimum required value for each path and channel capacities as outlined by the design.

Each braking system of every PWS, including conveyances must also be subjected to testing to the required design limits at the time of commissioning together with periodic testing.

4.8.1.1. Brake performance testing

Brake performance testing should include, but is not limited to, the following areas:

- hydraulic power supply, brake control tests, components and their settings
- arresting equipment and other braking interfaces associated with conveyance and PWS brakes
- caliper and spring tests
- brake elements
- static and dynamic capacity tests
- routine dynamic drag testing on winder braking systems (or part thereof) or other methods to confirm actual braking force or torque being applied for that system. Monitoring such test results provides valuable life cycle management information prior to static brake test failures with subsequent reliability improvements.

All components affecting brake performance must be identified by the designer and have service and test frequencies carried out during the life of the winder.

Note: Conveyance arresting systems are retardation devices and as such should also be included in the designer's maintenance recommendations to ensure the required performance at any time required during their life.

4.8.1.2. Static and dynamic brake testing

Note: This includes both testing to validate the design as part of commissioning as well as ongoing operational testing.

Brake testing should consist of both static and dynamic tests of all braking systems including other control channels as applicable.

Static and dynamic brake testing should also:

- monitor and be capable of trending the maximum capacities being achieved.
- provide the ability to monitor deterioration of the capacity to enable troubleshooting and rectification prior to any test failures.

PWS should not operate when test results are less than that related to the required capacities and loads for safe operation.

4.8.1.3. Static testing

Static brake tests should be carried out at least once each week where personnel riding is performed. For production winders, this may be required once each day.

For emergency egress winders or winders used for shaft sinking, static brake tests should be carried out each day before their required use.

The purpose of the static brake test is to indicate the holding capacity of each braking system. Each brake in the system should be tested to a minimum of 200% of the maximum static unbalanced torque required by design.

Any lesser test requirement values are to be nominated and supported by the designer. In this case, the designer is to show provision of an equivalent level of safety by the braking system.

The results of the all brake tests should be recorded.

The normal method will be to locate the conveyance at a safe position and attempt to drive through the brakes by applying motor torque to each braking path, in turn, until the required torque is reached or the brakes pull through.

An established method for conducting the static tests and training operators should be documented.

Static tests should only be carried out with all management safety requirements and rules in place.

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

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.

4.8.1.4. Dynamic testing

Dynamic brake tests should be conducted at least every six months and should only be carried out:

- after overspeed tests have been performed
- after static tests have been performed and the results are acceptable
- after brake timing (all brake units) has been checked and verified
- with all management safety requirements and rules in place
- to written and approved procedures
- under the direction and supervision of a person authorised by the mine to conduct such tests.

The dynamic brake tests should provide evidence of the design capacities, deceleration and stopping distances being met. In the case of vertical shaft friction (Koepe) winders, the maximum out of balance conditions for both directions are to be tested together with the lowest out of balance condition where deceleration rates should be shown safe for personnel riding.

Dynamic tests (or false landing tests) should not only test the brake performance, but should also check the speed/distance envelope at the end of the wind. As such they should be conducted at the upper and lower limits for each conveyance.

These tests should be carried out annually and be nominated and detailed by the designer. They should be carried out in a way that considers the worst case likely speeds to critical areas such as all end of travel limits, their protection points, crash beams, arrestors etc. as applicable

Note: These tests may be carried out in positions of the travel way that minimise risk.

In the case of modern friction (Koepe) winders, there are two, and often three levels of overwind and overspeed protection. Setting a false bank in midshaft to test the overspeed protection normally requires a series of overspeed tests. Engineering design consideration and procedures should be provided such that the testing itself cannot invoke an unnecessarily harsh sequence of emergency brake applications or potentially unsafe situations.

A risk assessment and subsequent procedure should be carried out to ensure any risks are mitigated during the testing. An example procedure is provided below:

STEP	ACTION
Step 1	Provide the dynamic winder brake test procedure to those involved with testing. This should be developed. Ensure static brake testing and brake timing checks have been completed before proceeding to dynamic testing. Ensure all emergency stop buttons are operating, overspeed devices and conveyance braking systems have been tested and other safety devices are operational. Ensure documented procedures are in place to confirm these tests are completed prior to dynamic tests.
Step 2	Load the system to the maximum person load or maximum out-of-balance person load. Ensure any electrical retardation will not occur during tests
Step 3	Position the conveyance at a point towards the bottom of the drift or shaft, with ample margin to stop under brakes. The location for carrying out the test should be considered in the risk assessment.

Step 4	Connect the required deceleration rate test recording equipment, where applicable, or mark the rope with suitable tape to measure the stopping distances.
Step 5	With the braking system in the operating state, allow the winder to run to half speed, then apply the brakes by activating the emergency stop planned for use during the tests.
Step 6	With the braking system in the operating state, allow the winder to run to full speed, then apply the brakes by activating the emergency stop.
Step 8	Record loads and stopping distances. Calculate average deceleration rates. Sign and file the brake test sheets.
Step 9	Check manufacturer requirements for any brake tests required for material loads. Include in test procedure.

4.8.1.5. Examination and testing of critical brake components

The examination and testing requirements of all critical brake components should be identified by the designer.

When considering the significance of failure in a braking system, critical components are defined as any component, the failure of which will result in the loss of at least 50% of design brake capacity for that system.

As such, any critical brake component or assembly, on any braking path, which if it fails will present a potentially unsafe situation to persons, must have a minimum factor of safety of 10, except in the case of screwed threads. In this case, a minimum factor of safety of 15 must be applied, based on the root diameter of the thread.

4.8.1.6. Examinations of critical components

Intervals between critical component examinations are influenced by a number of factors including:

- operational duty of the installation
- the stressing of a particular component
- the significance of the failure
- the size of the designer’s stated acceptable imperfections.

Pinned connections and other components that are subject to movement, wear and tear, during brake operation, should be thoroughly examined. This requires strip down and formal assessment against the 'as new' condition and carried out, as a minimum, every five years or as specified by the designer

Records should be kept and used to justify any replacements or existing maintenance provisions and reliability of these components.

4.8.1.7. Non-destructive testing of critical components

For brake components classified as critical, the frequency of non-destructive testing should be not less than as follows:

- heavy duty - one year between examinations
- medium duty - two years between examinations
- light duty – three to five 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.

Non-destructive testing is one of the means of ensuring integrity of some braking system components. . These procedures include magnetic inspection, ultrasonic testing and dye-penetrant methods.

Note: Non-destructive testing does not always provide absolute assurance regarding a components' original capacity and performance. In this case, additional examinations are required.

4.9. Plant safety file

PWS documentation should be retained throughout the life of the PWS in a plant safety file. Section 5.7 of the code details what is required to be maintained as part of the safety file.

Appendices

Appendix A – References

Definitions

For the purpose of the *TRG: PWS* series, the following definitions apply:

Actual diameter	The measured diameter as per clause 13.4 of AS 2759
Arrester system	An assembly, incorporating one or more arrestors, for decelerating and stopping the conveyance(s) within a winding system.
Attachments	Components used to connect the conveyance to the end of rope. The components may include rope sockets, capels, pins, couplers, chains bars, detaching hook, rope swivels and swivel hooks and similar (refer AS 3637:1-6 and AS 3751).
Balance rope	One or more ropes connecting the undersides of a pair of conveyances or conveyance and counterweight.
Base line diameter	The actual diameter of the rope measured at the respective the datum or reference locations.
Brake application / brake proving protection	A function designed to detect the application of the winder brakes.
Brake lift monitoring	A function designed to detect the lifting of the winder brakes.
Brake oil level monitoring	A function designed to monitor the level of oil in the oil storage tank(s) of hydraulically operated braking systems.
Brake oil / air pressure monitoring	A function designed to monitor the brake oil/air pressure of oil/air operated braking systems.
Brake oil / air temperature monitoring	A function designed to monitor the brake oil/air temperature of oil/air operated braking systems.
Brake path contamination	The deposition of water, condensation, oil, other fluids, or other material or fluids on brake paths, such that the brake performance can be compromised.
Brake temperature monitoring	A function designed to monitor the operating temperature of brake materials.
Brake wear monitoring	A function designed to monitor the degree of wear of brake materials.

Cage	Refer to conveyance
Chairing	Supporting of a conveyance at some point in its normal vertical path by means other than the winding ropes or gripper system.
Chairing beam	Beams used to secure conveyances of drift winders and conveyances or counterweights of shaft winders for the purposes of maintenance and/or repair.
Code	NSW Code of practice: *Mine shafts and winding systems* (February 2019).
Common cause failure	Where two or more portions of the system fail at the same time from a single common cause.
Common mode failure	Where two components or portions of the system fail in the same way, at the same time.

Competent person	A person who has acquired through training, qualification or experience the knowledge and skills to carry out the task.
	In the following circumstances, a competent person means:
	• for design verification under clause 252 of the WHS Regulation, a person who has the skills, qualifications, competence and experience to design the plant or verify the design (Source: clause 5(1) of the WHS Regulation).
	• for inspection of plant for item registration purposes, a person who has:
	  ○ educational or vocational qualifications in an engineering discipline relevant to the plant being inspected, or
	  ○ knowledge of the technical standards relevant to the plant being inspected
	(Source: clause 267 of the WHS Regulation) (Source: GNC-005 Guidance Note – Registration of Plant Designs and GNC-006 Guidance Note – Plant Item Registration)

Control conveyance	A control conveyance is any primary conveyance directly attached to the winder rope (s) and is designed to control the operation of the winder from within the conveyance. **Note**: For drift winders, the conveyance may have the ability to mechanically attach other conveyances for transport purposes, however, the control

	conveyance is always attached to the rope(s) during normal operation of the winder.
Control system	A system, which responds to input signals from the process and/or from an operator and generates output signals, causing the winder to operate in the desired manner.
Conveyance	Refers to any car, carriage, cage, skip, kibble, counterweight, or stage in which people, minerals or materials are wound through a shaft or drift.
Crash beam	Structural beams in a winder headframe designed to resist impact forces following overwind.
Critical brake component	When considering the significance of failure in a braking system, critical components are defined as any component, the failure of which will result in the loss of at least 50% of design brake capacity for any one braking path.
Dead load	The load due to the mass of the permanent components of a conveyance.
Dead man control	A control switch (or other similar device) either hand or foot operated, when upon release, automatically returns to the off position and causes the conveyance to be brought safely to rest by application of the winder service brakes.
Defect management system	Is a system that outlines the actions to be taken how and when a defect is identified. A defect management system documents instructions to be taken when a defect is identified and how the details of the defect and actions taken are recorded and managed to ensure a safe condition at all times.
Depth indicator	A device showing the position of the conveyance in a drift or shaft.
Derail switch	A device fitted to the conveyance of drift winders to detect a derailing of the conveyance.
Diameter of rope	The transverse measurement through the centre of the smallest enclosing circle around the cross-section of the rope.
Door / gate monitoring	Mechanical and electrical interlocking of any door or gate fitted to conveyances and / or personnel cars of drift winders and all conveyances of shaft winders
Double drum clutch protection device	A device that verifies that a double drum winder clutch is either positively engaged or positively disengaged.

Drift	Means a mine adit or shaft, on slopes of 10 to 30 degrees, for the transport of persons and materials. This term is commonly used in coal mines.
Drift winding system	Means a drum winding system used in a drift.
Drum pit flood alarm	A function designed to monitor the level of water or other fluids in winder drum pits and raise an alarm before brake paths are contaminated.
Drum pit flood protection	A function designed to monitor the level of water or other fluids in winder drum pits and causes the conveyance to be brought safely to rest after a drum pit flood alarm and before brake path contamination.
Drum winding system	Means a winding system in which a conveyance is raised and lowered by means of a single rope attached directly to the conveyance and the rope is wound onto a cylindrical drum. A drum winding system includes a winder with two drums (double drum), each raising and lowering a conveyance.
Dump brakes	Hydraulic lift, spring applied pad type dump brakes fitted to the conveyance of drift winders. In an emergency situation, the brake pads engage the rail track and bring the conveyance to a safe stop.
Emergency egress winding system	Means a winding system that is used solely for emergency egress.
Engineering standards	A set of engineering standards that is applied to the mine to ensure equipment is safe to operate and maintain. This includes competency of persons, design, installation, commissioning, operation, maintenance and decommissioning.
Emergency stop	An emergency operation intended to stop a process or a movement that has become hazardous.
Emergency stop function	A function intended to stop all hazardous motion in an emergency situation.
Emergency stop device	Manually actuated control device used to initiate an emergency stop function (AS/NZS 4024.1204)
Fleet angle	The angle formed between the line of the rope and the normal line at its point of incidence on the drum or sheave, measured in the plane of the rope.

Friction (Koepe) winding system	Means a vertical shaft winding system in which conveyances are raised and lowered by means of multiple ropes passing over a driving sheave, such that the driving force is transmitted from the sheave to the ropes by friction.
Functional safety	Is that part of overall safety that depends on a system (or equipment) operating correctly in response to its inputs.
Gear loss / broken shaft protection	A function designed to monitor for a break in the gear train, by detecting a differential in speed between the opposite drive end the winder drive motor and the extremity of any device driven by the winder drum.
Guides	Stiff structural members or suspended steel wire ropes located in a mine shaft or sky shaft or both, to limit lateral movement of a conveyance.
Head rope	One or more ropes connected to the top side of a conveyance or pair of conveyances.
Headframe	The structure, including its footings, that supports the rope loads in a winding installation (see AS 3785.5 *Underground mining – Shaft equipment - Headframes*).
Keps	Devices used to support the conveyance while loading and unloading operations are carried out to prevent movement of the conveyance. These may also be referred to as chairs, catches, dogs or keeps.
Kibble	Refer to conveyance
Lay length	The distance measured axially along the rope, between the crown (highest point) of one strand and the next crown of the same strand.
Live load	The load resulting from the operation of a conveyance.
Load sensing	A system to detect the weight of the conveyance and its load prior to movement in the drift or shaft. The system generally determines the speed of the winder based on the load measured and prevents the winder from operating where an excessive load is detected.
Main load bearing members	A main load bearing component that lies in the load transfer path to attachments, the failure of which puts at risk the integrity of the conveyance suspension.
Materials winder	A winding system that transports mine product, either coal or ore, from the underground parts of a mine. These may be either friction or drum winders.

	Note: These are often referred to as a bulk winder in coal mines or a skip winder in mines other than coal mines.
May	Indicates an optional course of action that this guideline is indicating the duty holder should consider. However, an alternative method of achieving a safe system of work may be chosen.
Mechanical brakes	Includes all brakes, other than the electrical regenerative braking by the motor, that is used to decelerate, stop and hold a drum winder. (The brakes may be hydraulic, pneumatic or electrically operated.)
Mechanical braking system	Includes all braking paths, channels and components used for holding and controlling the winder loads, but does not include the arrester system. The braking system is separate from normal electrical drive and control energy. The brakes may be hydraulic, pneumatic or electrically operated.
Minimum breaking force	The minimum tensile force in kilo newtons as guaranteed by the manufacturer's original test certificate. **Note**: Verification of this value is obtained from reference to the value recorded for actual breaking force.
Monkey	A device used on shaft sinking winders that assists in stabilising the kibble during ascent and descent. The monkey sits (by gravity) above the kibble and is secured by the 'staging' guide ropes. On modern shaft sinking winders, signalling and communication devices are attached to the monkey and a switch is provided to monitor the separation distance between the monkey and the kibble.
Motion detection device	A device fitted to all drift winder conveyance capable of personnel-riding, to detect motion of the conveyance.
Multiple redundancy	Redundancy that relies on multiple independent systems to provide a higher level of integrity than could otherwise be achieved. This is important where the maximum reasonable consequence of an incorrect operation or failure to operate is multiple fatalities.
Must	Indicates that legal requirements exist and must be complied with.
Nominal diameter of the rope	The diameter used for size classification for purposes of description.
Non-destructive examination (NDE)	An examination using non-destructive testing equipment and visual examination.

Non-destructive testing (NDT)	An examination using magnetic detecting and recording instruments, unless otherwise stated.
Over-speed device	A device intended to monitor the speed of the winder drum or conveyance and initiate operation of the associated safety circuit.
Over travel limit	A safety device or limit switch located in the headgear for a shaft winder and end of track at the gantry of a drift winder, to activate and protect the conveyance (and counterweight where applicable) from passing a predetermined point of travel.
Overwind	Unintentional travel of an ascending conveyance beyond its normal operating limits.
Overwind safety catch system	A system of devices mounted in the headframe and on the conveyance to prevent the conveyance from falling an excessive distance after the conveyance has been brought to rest.
Personnel transport	Any conveyance that is used for the transport of one or more people at any time within the duty-cycle or life-cycle of the powered winding system. The term also refers to purpose designed, personal transport carriers which are attached to the conveyance of drift winders.
Person-riding hoist	means a winding system used in an underground mine, that is a small gemstone mine, where the winding system lifts no more than 40 metres from the surface of the small gemstone mine to the underground workings and carries no more than two people.
Plat	A term used for a shaft entry.
Plat gate	A device used to bridge a gap that exists between the conveyance and a shaft entry to provide safe access for personnel to enter and leave the conveyance. The gate is designed in such a manner that personnel are protected from the danger of exposure to open sections of the shaft.
Plat gate monitoring	Electrical interlocking to monitor the opening or closing of any mine winder plat gate. This also includes mechanical interlocking monitored by the electrical control system through separate electrical interlocks to ensure that the mechanical interlocks are engaged.
Powered winding system	Means a ‘winding system’ but excluding ‘person-riding hoists’.

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Primary safety circuit	A safety circuit containing all the safety critical devices that require the powered winding system to be brought to a quick stop.
Radio control	A method whereby control signals to and from the conveyance and associated control stations are connected via any form of radio frequency link.
Radio frequency (R/F)	A method of transferring voice, data and video information from a transmitting device to a receiving device via a medium that requires no mechanical or electrical connections.
Radio frequency control file	Information identifying all radio frequencies used at the winder location, complete with supporting documentation as to the possible effects of R/F transmission conflict.
Rated load	The maximum load a conveyance is designed to carry during normal use.
Rope area	Metallic cross-sectional area of a wire rope (excludes the area of any non-metallic core).
Rubbing ropes	Suspended steel wire ropes installed between closely spaced rope guide conveyances.
Safe coiling protection	A function designed to ensure that the winder rope coils safely on the winder drum and does not “climb up “ the rope flange or pile up on the winder drum. **Note:** The device also assists in monitoring slack rope and is fitted to all winder drums with the exception of friction (Koepe) winders. A device required on drum friction winders to detect slippage of the rope(s) on the winder drum and to assist to detect slack rope in the event of a ‘hang up’ of the conveyance in a shaft.
Safety circuit	A circuit that detects abnormal conditions and causes the winding apparatus to be brought to rest, prevents it from being moved and/or indicates the nature of the abnormal occurrence.
Safety integrity level (SIL)	A discrete level (range is from 1 to 4) for specifying the safety integrity requirements of the safety functions to be allocated to the E/E/PE SRS, where SIL 4 has the highest level and SIL1 the lowest. **Note**: This concept is focused on achieving a level of risk reduction that provides tolerable risk in terms of a corporate risk matrix.
Secondary safety circuit	A safety circuit designed to operate the service braking system and bring the conveyance safely to rest.

Shaft	, in underground workings, means a mine heading. A shaft may be orientated from 0 to 90 degrees.
Shaft / drift obstruction monitoring	A function designed to monitor for obstructions in the shaft or drift that may affect the safe movement of the conveyance.
Shaft / drift profile monitoring	A sub-system installed at all entrances to a shaft or drift to monitor the maximum permissible dimensions of any load taken in or out of a shaft or drift.
Shaft entry door / gate monitoring	Monitoring of the status of any mine winder shaft entry gate or door for closed and locked. This also includes mechanical interlocking monitored by the electrical control system through separate electrical interlocks to ensure that the mechanical interlocks are engaged.
Shaft sinking winding system	Means a drum winding system that is used on a short term basis for the development, equipping or refurbishment of vertical shafts. A shaft sinking winding system is relocatable and is not a permanent fixture.
Should	Indicates a recommended course of action. **Note**: Deviations from recommendations should be provided with a respective management control, shown to provide the same level of safety outcome.
Sky shaft	A structure including, its footings, that is primarily designed to support conveyance guides above a shaft collar and to withstand impact loads resulting from an overwind.
Slack rope device	A device installed on drift and shaft winders to detect the occurrence of a slack rope condition.
Stage tilt device	A device to detect the tilting of any staging located in a shaft. The tilting is detected before it reaches a hazardous angle of inclination.
Tail / balance rope wander switches	Switches installed to detect any horizontal (sideways) or vertical (up or down) movement of a tail rope
Torque sensing device	A device to detect drive motor torque is being developed and is available to move the conveyance.
Ultimate safety circuit	A safety circuit designed to operate as a “back up” stopping system to that of the primary safety circuit.
Under travel limit	A safety device or limit switch located at the shaft bottom of a shaft winder and at drift bottom of a drift winder, to activate and protect the

	conveyance (and counterweight where applicable) from passing a predetermined point of travel.
Underwind	Unintentional travel of a descending conveyance beyond its normal operating limits.
Visual examination	The physical examination of a rope by a competent person or by a person nominated as detailed in section 4 '*Examination*' of Part 4 'Ropes'.
Vertical shaft drum winding system	Means a drum winding system that operates in a vertical shaft.
Vertical shaft winding system	Means a winding system that operates in a vertical shaft and includes vertical shaft drum winding systems; friction (Koepe) winding systems; shaft sinking winding systems; and emergency egress winding systems.
Winder drum over speed device	A device driven by the winder drum to detect an over speed of the winder drum.
Winder motor / motive force (hydraulic / pneumatic) over speed device	A device driven by the winder motor shaft to detect an over speed of the winder motor.
Winder speed profile monitoring	A monitoring system to detect an over speed of the winder during periods of acceleration, constant speed and deceleration.
Winding system	has the same meaning as it has in clause 3 of the Work Health and Safety (Mines and Petroleum Sites) Regulation 2014 which is as follows: ***winding system*** means any plant (other than a portable winch or plant that is manually operated) that is used in a shaft to lift a person to or from an underground mine or between levels at an underground mine (regardless of whether it is used exclusively for that purpose).
Wire rope	A group of strands laid helically and symmetrically with uniform pitch and direction around a central core of natural or synthetic fibre or wire.
Wire rope lay length	The distance measured parallel to the centre line of a wire rope in which a strand makes one complete spiral or turn around the rope. **Note**: The length of a strand lay is the distance measured parallel to the centre line of the strand in which one wire makes one complete spiral or turnaround the strand. The rope lay length is measured at the respective datum or reference locations.

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Abbreviations

AS	Australian Standards
AS/NZS	Australian / New Zealand Standard
FMECA	failure modes and critically analysis
PWS	powered winding system
ISO	International Organisation for Standardisation
LMA	loss of metallic cross sectional area
MDG	mining design guideline
PPE	personnel protection equipment
SIL	safety integrity level
TRG	technical reference guide
WHS	work, health and safety

Relevant Australian Standards

AS 1065	AS 1065 Non-destructive testing - Ultrasonic testing of carbon and low alloy steel forgings
AS 1085.1	AS 1085.1 Railway track material – Steel rails
AS 1085.2	AS 1085.2 Railway track material - Fishplates
AS 1085.3	AS 1085.3 Railway track material - Sleeper plates
AS 1085.4	AS 1085.4 Railway track material - Fishbolts and nuts
AS 1085.7	AS 1085.7 Railway track material - Spring washers
AS 1085.8	AS 1085.8 Railway track material - Dogspikes
AS 1085.10	AS 1085.10 Railway track material - Rail anchors
AS 1085.12	AS 1085.12 Railway track material - Insulated joint assemblies
AS 1085.13	AS 1085.13 Railway track material - Spring fastening spikes for sleeper plates
AS 1085.14	AS 1085.14 Railway track material - Prestressed concrete sleepers
AS 1085.17	AS 1085.17 Railway track material - Steel sleepers
AS 1085.18	AS 1085.18 Railway track material - Screw spikes and threaded inserts
AS 1085.19	AS 1085.19 Railway track material - Resilient fastening assemblies
AS 1085.20	AS 1085.20 Railway track material - Welding of steel rail
AS 1085.21	AS 1085.21 Railway track material - Turnouts, switches and crossings
AS/NZS 1170.0	AS/NZS 1170.0 Structural design actions - General principles
AS 1171-1998	AS 1171 Non-destructive testing - Magnetic particle testing of ferromagnetic products, components and structures
AS 1210-2010	AS 1210 Pressure vessels
AS 1403	AS 1403 Design of rotating steel shafts
AS 1554.1	AS 1554.1 Structural steel welding –Welding of steel structures

AS/NZS 1554.4	AS/NZS 1554.4 Structural steel welding - Welding of high strength quenched and tempered steels
AS/NZS 1554.5	AS/NZS 1554.5 Structural steel welding - Welding of steel structures subject to high levels of fatigue loading
AS 1657	AS 1657 Fixed platforms, walkways, stairways and ladders - Design, construction and installation
AS 1670.1	AS 1670.1 Fire detection, warning, control and intercom systems - System design, installation and commissioning - Fire
AS 1710	AS 1710 Non-destructive testing - Ultrasonic testing of carbon and low alloy steel plate and universal sections - Test methods and quality classification
AS 1735.2	AS 1735.2 Lifts, escalators and moving walks - Passenger and goods lifts – Electric
AS 2574	AS 2574 Non-destructive testing - Ultrasonic testing of ferritic steel castings
AS 2671	AS 2671 Hydraulic fluid power - General requirements for systems (ISO 4413, MOD)
AS 2759	AS 2759 Steel wire rope - Use, operation and maintenance
AS 2788	AS 2788 Pneumatic fluid power - General requirements for systems (ISO 4414, MOD)
AS 3507.2	AS 3507.2 Non-destructive testing - Radiographic determination of quality of ferrous castings
AS 3569	AS 3569 Steel wire ropes - Product specification
AS 3600	AS 3600 Concrete structures
AS 3637.1	AS 3637.1 Underground mining - Winding suspension equipment - General requirements

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AS 3637.2	AS 3637.2 Underground mining - Winding suspension equipment - Detaching hooks
AS 3637.3	AS 3637.3 Underground mining - Winding suspension equipment - Rope cappings
AS 3637.4	AS 3637.4 Underground mining - Winding suspension equipment - Drawbars and connecting links
AS 3637.5	AS 3637.5 Underground mining - Winding suspension equipment - Rope swivels and swivel hooks
AS 3637.6	AS 3637.6 Underground mining - Winding suspension equipment - Shackles and chains
AS 3751	AS 3751 Underground mining - Slope haulage - Couplings, drawbars, and safety chains
AS 3785.1	AS 3785.1 Underground mining - Shaft equipment - Shaft overwind safety catch system
AS 3785.2	AS 3785.2 Underground mining - Shaft equipment - Shaft winding arresting systems
AS 3785.3	AS 3785.3 Underground mining - Shaft equipment - Drum winding gripper systems
AS/NZS 3785.4	AS/NZS 3785.4 Underground mining - Shaft equipment - Conveyances for vertical shafts
AS 3785.5	AS 3785.5 Underground mining - Shaft equipment - Headframes
AS/NZS 3785.6	AS/NZS 3785.6 Underground mining - Shaft equipment - Fixed guides, rope guides and rubbing ropes for conveyances
AS 3785.7	AS 3785.7 Underground mining - Shaft equipment - Sheaves
AS/NZS 3785.8	AS/NZS 3785.8 Underground mining - Shaft equipment - Conveyances for inclined shafts

AS 3990	AS 3990 Mechanical equipment - Steelwork
AS 4024	AS 4024 safety of machinery series of standards
AS 4024.1	AS 4024.1 Series Safety of Machinery (all sub-Parts as applicable)
AS/NZS 4024.1204	Safety of machinery – Electrical equipment of machines - General requirements (IEC 60204-1:2016 (ED. 6.0) MOD)
AS 4024.1503	Safety of machinery- Safety-related parts of control systems—General principles for design'
AS 4024.1604	Safety of machinery - Design of controls, interlocks and guarding—Emergency stop—Principles for design
AS 4100	AS 4100 Steel structures
AS 4730.2	AS 4730.2 Mining - Winding equipment - Braking systems
AS/NZS 4812	AS/NZS 4812 Non-destructive examination and discard criteria for wire ropes in mine winding systems
AS 60529	Degrees of protection provided by enclosures (IP Code)
AS 61508 Series	Functional safety of electrical/electronic/programmable electronic safety-related systems
AS 61511	AS 61511 series of standards 'Functional safety – Safety instrumented systems for the process industry sector'
AS 62061	Safety of machinery ‐ Functional safety of safety-related electrical, electronic and programmable electronic control systems
AS/NZS ISO 9001	AS/NZS ISO 9001 Quality Management Systems - Requirements
AS ISO 31000	AS ISO 31000 Risk management - Guidelines

International standards

ISO 286-1	ISO 286-1 : Geometrical product specifications (GPS) - ISO code system for tolerances on linear sizes - Part 1: Basis of tolerances, deviations and fits
BS 7608	BS 7608 Guide to fatigue design and assessment of steel products
ISO Guide 73	ISO Guide 73 Risk management - Vocabulary
ISO 4309	ISO 4309 Cranes - Wire ropes - Care and maintenance, inspection and discard
ISO 4413	ISO 4413 Hydraulic fluid power - General rules and safety requirements for systems and their components
ISO 4414	ISO 4414 Pneumatic fluid power - General rules and safety requirements for systems and their components
IEC 31010	IEC 31010 Ed. 2.0 (Bilingual 2009) Risk management - Risk assessment techniques
ISO 12100	ISO 12100 Safety of machinery – General principles for design – Risk assessment and risk reduction
Other Reference	Safe man riding in Mines parts 1A and 1B, parts 2A and 2B, being the first and second report of the National Committee for Safety of man riding in shafts and unwalkable Outlets.
SABS 0293	Condition assessment of steel wire ropes on mine winders code of practice
ASTM E1571 – 11(2016)e1	Standard Practice for Electromagnetic Examination of Ferromagnetic Steel Wire Rope

Appendix B – Items which should be covered in the five yearly safety audit

The five-yearly safety audit (refer clause 2.1.2 *'Five yearly safety audit'*) should assess the safety condition of the PWS, address and review all safety aspects of design, operation, servicing, testing and maintenance of the PWS, and review the management systems that govern the use of the PWS.

The five-yearly safety audit should include, but not be restricted to, the following:

- Review PWS certification and registration documents.
- Review design calculations, drawings, and specifications.

Note: For ongoing audits, these documents may require only sighting where a previous audit indicates that the documents have been examined and are acceptable.

- Review associated risk assessments.
- Review the PWS principal hazard management plan.
- Review the PWS maintenance management system.
- Review the structural integrity inspection reports, their frequency and check that all components of the system are covered.
- Review all associated condition monitoring reports for the various components.
- Verify that all safety and control devices are in place and functioning per design and that a testing program for these devices is in place and being carried out on the schedule. Verify that the records of these test results are acceptable.
- Verify that a brake testing program is in place and is up-to-date. Verify that static and dynamic brake testing records are being kept and acceptable.
- Witness PWS static and dynamic brake testing of the winder and conveyances as appropriate. Check that the capacities and deceleration rates comply with the requirements within this document series. Ensure that persons authorised to conduct these tests are fully conversant with the purpose and method of safely carrying out this testing and have been assessed accordingly.
- Review brake maintenance servicing records for both winder and conveyance as appropriate. Check the performance, including the application times and capacities of the PWS and conveyance brakes comply to design requirements.

- Inspect vertical shaft conveyances, attachments, arresting devices, safety catches and all other safety components, and verify the acceptability of all safety features including associated reports. Verify that the certification and testing frequencies conforms to the appropriate Australian Standard.
- Inspect drift conveyances, attachments, conveyance braking systems, safety chains, and all other safety components including control systems. Verify the acceptability of all safety and control features. Verify that the certification and testing frequencies conform to the appropriate Australian Standard.
- Examine all current rope ‘destructive’ and ‘non-destructive test’ reports for compliance to AS 4812Non-destructive examination and discard criteria for wire ropes in mine winding systems and TRG: Powered winding systems – Part 4: Ropes. Examine all visual examination reports. Check the factors of safety for the strength of the rope at new and at the present strength, comply to requirements. Visually examine the rope for any defects or anomalies including areas that may cause such damage.
- Examine the winder and braking systems. Verify the condition of these components and that all related service and condition reports are consistent with requirements outlined in this series of documents.
- Examine all load bearing components within the PWS. Areas include structures, hold down and fastening systems, headframes, headsheaves, support rollers, guides, etc. Verify the required testing and inspections are included in the maintenance schedule and are being carried out effectively.

Note: Additional conveyances such as flat tops, rolling stock, personnel riding and other service and maintenance platforms are to be included.

- Review all training and competency related documentation, with respect to the PWS for winding drivers, operators and maintenance personnel.

Appendix C – Finite element analysis

General

This appendix provides guidance for the use of FEA in support of winder related design. Modelling suggested is consistent with Appendix I 'Finite Element Analysis' of AS 1210 ' *Pressure vessels'*.

Verification of FEA results

Where FEA results are used to support the design of components which have a catastrophic consequence of failure or the risk of a life threatening situation, e.g. winder main shafts, winding drums etc., the results must be verified using an alternative methodology. However, complete and exact verification using alternative methodology is often not possible due to complex geometry, loading and restraint. In these cases, a degree of structural idealisation or stress/deflection results remote from complex geometry areas and discontinuities should be used in order to verify the FEA results.

Alternative methodologies that may be used include:

a. structural testing in which measured results (e.g. deflection, stress) are compared with the FEA results
b. classical calculation.

Where verification is performed by method b) the calculations should be based and stated from the associated references and standards

Documentation

Any FEA should be documented with the following information provided as a minimum in that documentation:

1. A description of the model stating the type of elements used, applied loading, boundary conditions and restraints and the type of solution (e.g. static elastic, nonlinear material and/or geometry).
2. A description of any assumptions, together with the derivation of loading where this is not self-evident (e.g. the number of rope layers, conveyance position, whether and how dynamic effects such as braking and friction are included).
3. Images showing the mesh configuration at critical areas.
4. Stress (or other variable, e.g. temperature) contour plots for the critical areas for each critical load and restraint case considered. The basis for stress plots should be stated, i.e.

a) are reported stresses from element centroids, nodes or gauss points

b) what averaging has been applied

c) what type of stress is plotted or reported (e.g. Von Mises, maximum/minimum principal, maximum shear etc.).

5. Deflected shape images for each critical load case (or buckling mode) considered.
6. Identification of all software (with version status) used for the analysis.
7. A description of the alternative method(s) used to verify the FEA with all applicable references identified, e.g. technical references and data sources for calculations, structural test reports. Where calculations are used to verify the FEA, those calculations must be documented in full such that they can be checked by an independent peer.

Fatigue

Weldments are common in winder related structures and require special consideration with respect to fatigue. Stresses derived using FEA (or other means) at or in the vicinity of welds must be assessed for the expected number of cycles, against the requirements of an authoritative and stated weld fatigue code.

Similarly, it is recommended that other winder components subject to fatigue loading e.g. shafts , hold down bolts and brake components be assessed with referenced authoritative data and standards. It is important that stress results from FEA or other calculations are not simply compared with unsubstantiated ‘endurance strength’ values without accounting for surface roughness, corrosion, size, fretting, interference fits and other relevant issues.

FEA practice

Elements

Element shape

Element aspect ratios (longest edge length / shortest edge length), internal angles (angle between edges), plate warping (due to non-planar plate element nodes) for any PWS components must be within the FE program recommendations and demonstrated to apply with the specific sections being modelled. Maximum stress concentrations must be shown acceptable.

Element size

Sizes of the adjacent elements must be shown gradual throughout the model with a fine mesh in regions where the stress result is critical and courser mesh elsewhere. The size ratio between adjacent elements should never exceed two.

The mesh in the vicinity of structural discontinuities must have sufficient elements justified that capture the local behavior.

Small element size (i.e. less than the material thickness) must be used where stress distribution and magnitude adjacent to discontinuities are examined, e.g. near fillet weld toes to determine a geometric or 'hot spot'. In all cases, the analyst must ensure that the element size is sufficiently small to capture the true stresses. Progressive mesh refinement in critical areas may be used to ensure convergence of the result (h-code methodology) or alternatively p-code elements (if available) can be used to progressively increase the element order to obtain result convergence, or a mixture of the two methods can be used.

Element selection

Linear or constant strain triangular and tetrahedral elements should not be used except where stress gradients are very low.

Further information on element limitations is usually provided in the documentation accompanying the finite element software used. Various publications issued by the National Agency for Finite Element Methods and Standards (NAFEMS) also provide advice on best practice with respect to element selection (together with other FEA guidance).

In all cases, it is the responsibility of the analyst to ensure that the element selection is appropriate for the model geometry, loading and restraint.

Meshing

Degrees of freedom compatibility

Check and confirm that the number of degrees of freedom (DOF) on elements connected to one another is compatible. For example, do not connect a beam normal to a four node plate where the plate nodes do not accept z axis rotation.

Consistency

Check that there are no 'almost coincident' nodes that are meant to be one node and that edges are joined with consistent mesh where the structure is continuous, i.e. no free edges. This is especially important where geometry has been imported to the FEA software.

Plate offset

Where doublers (or 'compensation' plates) are added such that plate bending occurs due to the reinforcement offset, that offset should be represented in the FEA.

In all cases the meshing technique should ensure the following:

- Large elements are not adjacent to small elements. Element size should vary through the structure smoothly. The ratio of adjacent element sizes in regions of interest should not exceed 2:1.
- The aspect ratio of elements is in the range 0.33 to 3.
- Four-sided elements are used in preference to three sided elements, and higher order elements are used in preference to lower order elements.
- Structural discontinuities have sufficient elements to capture the local behaviour (e.g. a cylindrical shell has a characteristic length $L + 0.55\sqrt{Dt}$ and a hole in a plate has a characteristic length equal to its radius). In such cases at least two quadratic elements or six linear elements within this characteristic length are required to capture local behaviour, where this is important.
- Benchmark standard results or established analytical methods are used to help verify the output. For example, membrane stresses and bending stresses can often be calculated at locations remote from discontinuities.
- A mesh/grid having an element spacing that varies smoothly throughout the structure is selected.
- Boundary conditions (e.g. planes of symmetry and imposed loads) can be readily verified.

Review of results

<u>Contour plots</u>

Contour plots (e.g. stress) should show smooth contours with no abruptly changing patterns that cannot be attributed to the physical structure.

Deflected shape

Deflected shape plots should be reviewed, in particular to verify that restraints have worked as expected and that the deflection shape and magnitude seem reasonable for the applied loading and restraint conditions.

Stress

The maximum variation in stress across any element, excluding those adjacent to singularities, as a proportion of the total variation in Tresca stress should not exceed the following:

ELEMENT ORDER	MAXIMUM STRESS VARIATION
0	10%
1	20%
2	30%
>2	40%

Force balance

Check to ensure that global equilibrium is achieved between applied loads and reactions at specified boundary conditions.

FEA analysis must only be undertaken by shown competent and experienced persons. All results should be reported in such a way as to facilitate their verification and include the following:

- plot(s) of the deflected shape(s) of the structure under all relevant loading conditions
- type of mesh used
- loads used
- boundary conditions used
- sufficient data to show that away from structural discontinuities the stresses are those of simple shell or strut models
- a description of the model and the assumptions used
- software package and version used.

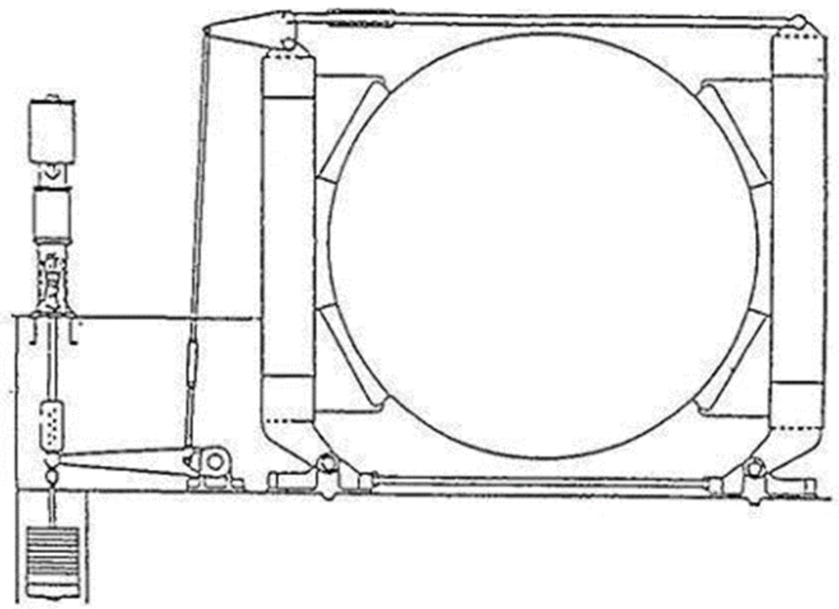
Appendix D - Typical brake configurations

Drift winders – typical brake configurations

Drum shoe caliper brakes

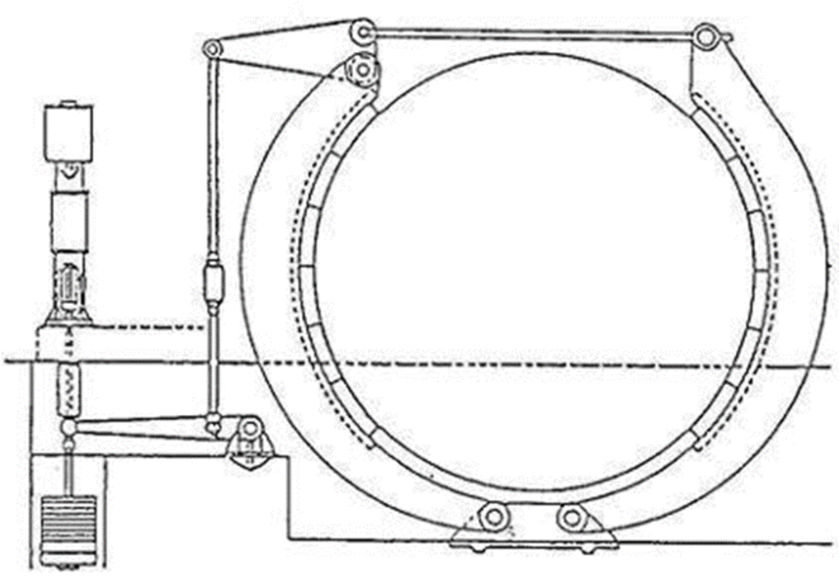
Traditionally, drum winders have drum shoe caliper brakes of various configurations (refer to Figures 26 - 31), operating on a cylindrical brake drum, and incorporating a dead weight or spring applied system of brake force.

Figure 16 Typical drum winder brake configurations



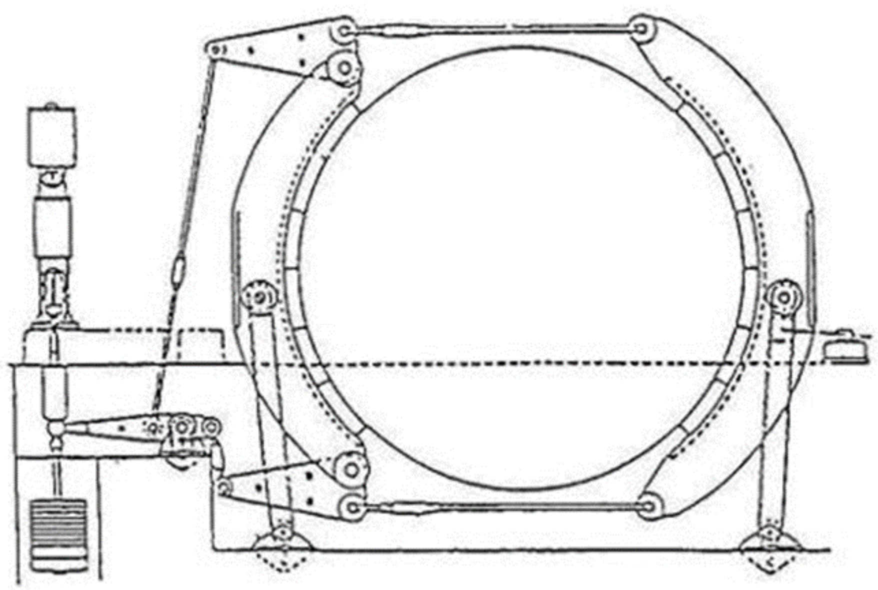
Post Brake

Figure 17 Typical drum winder brake configurations (cont'd)



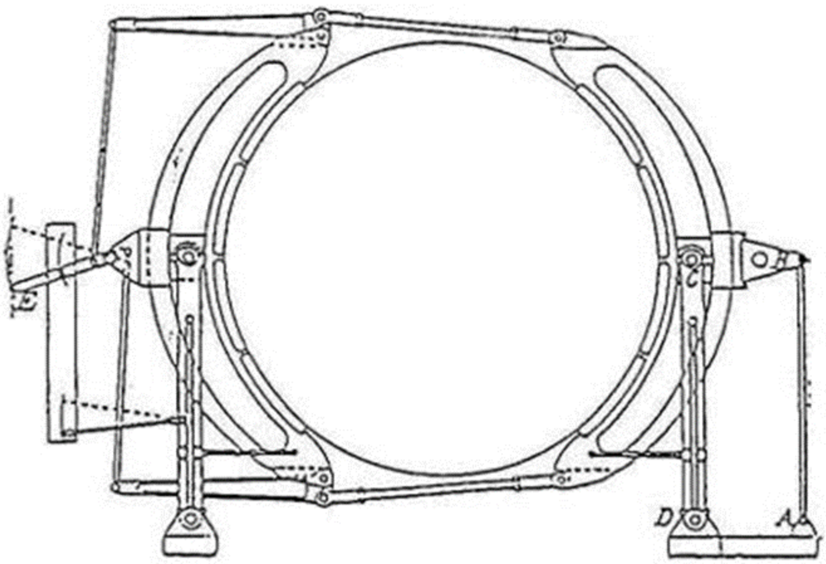
CALIPER BRAKE

Figure 18 Typical drum winder brake configurations (cont'd)



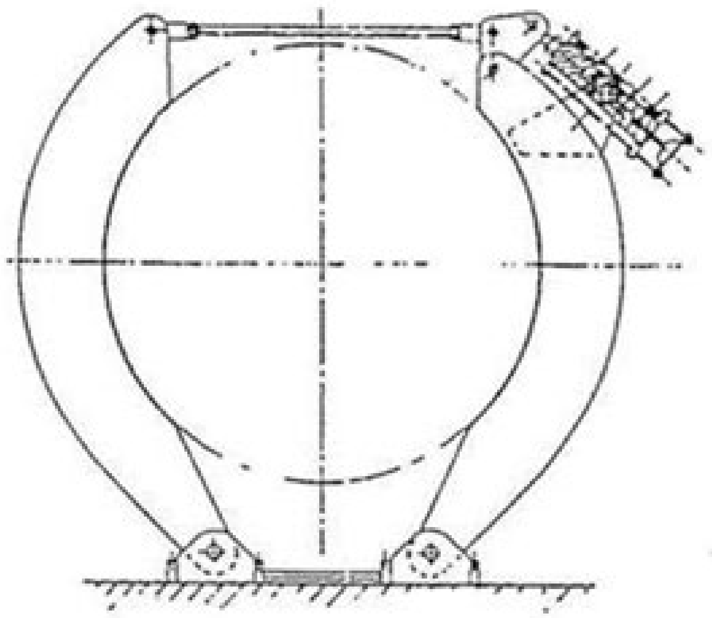
SUSPENDED POST BRAKE

Figure 29 Typical drum winder brake configurations (cont'd)



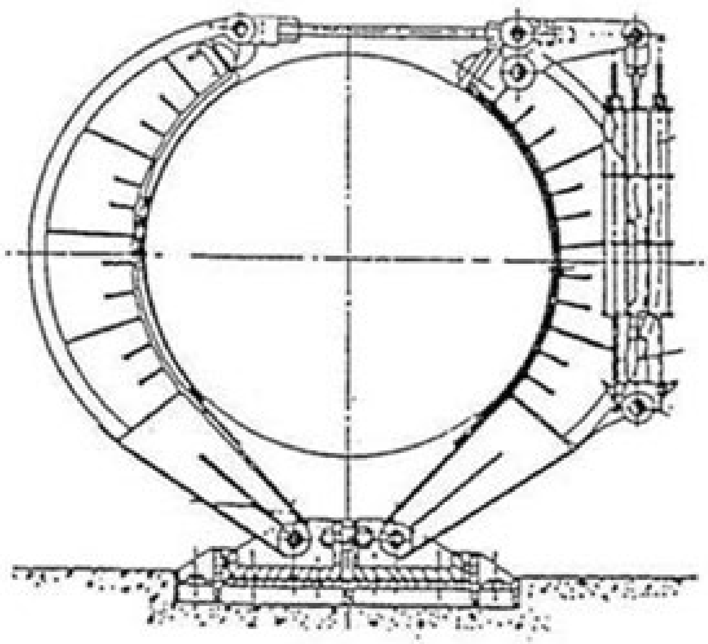
PARALLEL MOTION BRAKE

Figure 19 Typical drum winder brake configurations (cont'd)



High pressure, pressure applied spring backup Caliper Brake

Figure 20 Typical drum winder brake configurations (cont'd)



High pressure spring applied Caliper Brake

Multi-caliper disc brakes

Newer drum winders employ one or more disc calipers operating on a disc which incorporates hydraulic pressure to lift the brakes and spring force to apply the brakes (refer to figure 32 for drift winders).

Multi disc calipers are preferred as they provide some redundancy of these critical components.

Braking discs with multiple calipers are the preferred mechanical braking arrangements given their inherent heat dissipation, reliability and control capabilities.

Figure 21 Example of a multiple caliper drift winder braking path

Figure 22 Drift haulage winder low speed brake, disc and caliper arrangement

Vertical shaft winders – typical brake configurations

Figure 23 Ground mounted friction winder showing one brake path

Figure 24 Tower mounted friction winder showing two brake paths